Exelon Nuclear
200 Exelon Way
Kennett Square, PA 19348

www.exeloncorp.com

Exelon Nuclear

PROPRIETARY INFORMATION – WITHHOLD UNDER 10 CFR 2.390

10 CFR 50.55a

TMI-11-062
April 6, 2011

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Three Mile Island Nuclear Station, Unit 1
Renewed Facility Operating License No. DPR-50
NRC Docket No. 50-289

Subject: Response to Request for Additional Information - Submittal of Relief Request RR-10-02 Concerning the Weld Overlay of the Pressurizer Spray Nozzle to Safe-End and Safe-End to Elbow Dissimilar Metal Welds

References:

1) Letter from P. B. Cowan (Exelon Generation Company, LLC) to U.S. Nuclear Regulatory Commission, "Submittal of Relief Request RR-10-02 Concerning the Weld Overlay of the Pressurizer Spray Nozzle to Safe-End and Safe-End to Elbow Dissimilar Metal Welds," dated September 30, 2010

2) Letter from P. Bamford (U.S. Nuclear Regulatory Commission) to M. J. Pacilio, "Three Mile Island Nuclear Station, Unit 1 – Request for Additional Information Regarding Relief Request RR-10-02, Weld Overlay of the Pressurizer Spray Nozzle to Safe-End and Safe-End to Elbow Dissimilar Metal Welds (TAC NO. ME4795)," dated February 28, 2011

3) Letter from D. P. Helker (Exelon Generation Company, LLC) to U.S. Nuclear Regulatory Commission, "Response to Request for Additional Information - Submittal of Relief Request RR-10-02 Concerning the Weld Overlay of the Pressurizer Spray Nozzle to Safe-End and Safe-End to Elbow Dissimilar Metal Welds," dated March 9, 2011

In the Reference 1 letter, Exelon Generation Company, LLC (Exelon) requested relief to perform a weld overlay of pressurizer spray nozzle to safe-end and safe-end to elbow dissimilar metal welds at Three Mile Island Nuclear Station (TMI), Unit 1. In the Reference 2 letter, the U.S. Nuclear Regulatory Commission requested additional information. Reference 3 contained our response to questions 2, 3 and 4. As discussed in Reference 2, the response to question 1 would be provided by April 28, 2011.

Attachment 4 transmitted herewith contains Proprietary Information.
When separated from attachments, this document is decontrolled.

Attachment 1 is our response to question 1. Attachments 2 and 3 contain copies of Calculation No. 1000320.315, Revision 0 and Calculation No. 1000320.316, Revision 0, respectively. Attachment 4 contains information proprietary to AREVA NP Inc. (AREVA) and Structural Integrity Associates (SI), Inc. AREVA and SI request that Calculation No. 1000320.310, Revision 0 and Calculation No. 1000320.314, Revision 0 be withheld from public disclosure in accordance with 10 CFR 2.390(b)(4). Attachment 5 contains non-proprietary versions of these two calculations (i.e., Calculations 1000320.310, Revision 0 and Calculation 1000320.314, Revision 0). Affidavits supporting AREVA and SI's request are contained in Attachment 6.

There are no regulatory commitments contained in this submittal.

If you have any questions concerning this letter, please contact Tom Loomis at (610) 765-5510.

Respectfully,

D. P. Helker

David P. Helker
Manager - Licensing & Regulatory Affairs
Exelon Generation Company, LLC

Attachments:
1) Response to Request for Additional Information - Submittal of Relief Request RR-10-02 Concerning the Weld Overlay of the Pressurizer Spray Nozzle to Safe-End and Safe-End to Elbow Dissimilar Metal Welds
2) Calculation No. 1000320.315
3) Calculation No. 1000320.316
4) Proprietary Version - Calculation No. 1000320.310 and Calculation No. 1000320.314
5) Non-Proprietary Version - Calculation No. 1000320.310 and Calculation No. 1000320.314
6) Affidavits

cc: Regional Administrator, Region I, USNRC
USNRC Senior Resident Inspector, TMI
USNRC Project Manager, [TMI] USNRC

ATTACHMENT 1

Response to Request for Additional Information - Submittal of Relief Request RR-10-02 Concerning the Weld Overlay of the Pressurizer Spray Nozzle to Safe-End and Safe-End to Elbow Dissimilar Metal Welds

Question:

1. Section 5 of relief request (RR)-10-02 (page 4, third paragraph) states that the overlay design is currently in development. Please submit the weld overlay design information, including analyses, to demonstrate that the weld overlay design will mitigate the potential for primary water stress-corrosion cracking in the Alloy 82/182 dissimilar metal welds.

Response:

The following calculations are attached:

1. Calculation No. 1000320.315, "ASME Code, Section III Qualification of Pressurizer Spray Nozzle with Weld Overlay Repair," Revision 0 (Attachment 2)
2. Calculation No. 1000320.316, "Crack Growth Evaluation of Pressurizer Spray Nozzle with Weld Overlay," Revision 0 (Attachment 3)
3. Calculation No. 1000320.310, "Pressurizer Spray Nozzle Weld Overlay Sizing Calculation," Revision 0 (Attachment 4 – Proprietary Version, Attachment 5 – Non-Proprietary Version)
4. Calculation No. 1000320.314, "Residual Stress Analysis of Pressurizer Spray Nozzle with Weld Overlay Repair," Revision 0 (Attachment 4 – Proprietary Version, Attachment 5 – Non-Proprietary Version)

ATTACHMENT 2

Calculation No. 1000320.315

Structural Integrity Associates, Inc.®

CALCULATION PACKAGE

File No.: 1000320.315

Project No.: 1000320

Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
TMI-1 Pressurizer Spray Nozzle WOL

CONTRACT NO.:
59091

CLIENT:
Welding Services, Inc. (WSI)

PLANT:
Three Mile Island Nuclear Generating Station, Unit 1

CALCULATION TITLE:
ASME Code, Section III Qualification of Pressurizer Spray Nozzle with Weld Overlay Repair

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 27 A-1 - A-2 B-1 - B-18 Computer Files	Initial Issue	Norman Eng Norman Eng NE 03/21/11	Aparna Aparna Alleshwaram AA 03/21/11 Charles Fourcade Charles Fourcade CJF 03/21/11

Table of Contents

List of Tables

List of Figures

1.0 OBJECTIVE

The objective of this calculation package is to determine if the ASME Code, Section III design requirements are satisfied for a weld overlay repair of the pressurizer spray nozzle-to-safe end dissimilar metal weld (DMW1) and the safe end-to-elbow dissimilar metal weld (DMW2) with weld overlay repair at Three Mile Island Nuclear Generating Station, Unit 1 (TMI-1). A design drawing of the weld overlay repair is provided in Reference 1.

Two finite element models used to determine structural and thermal operational stresses are developed in Reference 2. The two finite element models are constructed as 3-dimensional (3-D) "half-symmetry" (180 degrees) models. One of the 3-D models is constructed with the maximum weld overlay dimensions; whereas the other is constructed using minimum weld overlay dimensions. The model with the minimum overlay dimension is used for mechanical load evaluations. The model with the maximum overlay dimension is used for thermal stress evaluations. Further discussion of these finite element models can be found in Reference 2.

Several finite element stress and thermal analyses have been performed [3] to support the ASME Code evaluations. These analyses, together with the design requirements of the ASME Code [4], are used to determine the adequacy of the repair.

2.0 DESIGN CRITERIA

The weld overlay repair is designed to the requirements of the ASME Code, Section III, for Class 1 components. Thus, the rules of Article NB-3000 of Section III of the ASME Code, 2004 Edition [4] are used.

The weld overlay repair region affects the pressurizer spray nozzle, the safe end, and the attached spray piping. As a result, the nozzle portion of the repair at the pressurizer end will be evaluated using the rules of Subarticle NB-3200 of the ASME Code. For the attached safe end and piping, guidance from the rules of Subarticle NB-3600 of the ASME Code will be taken to satisfy NB-3200 acceptance criteria.

3.0 LOADS

This evaluation only considers Service Level A and Service Level B operating conditions in regards to meeting ASME Code, Section III Service Level A/B allowables and fatigue. As such, thermal stresses resulting from Service Level C and Service Level D thermal transients are not considered [4, NB-3224.4 and Appendix F-1310 (c)].

Primary stresses (such as mechanical loads due to deadweight, and seismic effects) resulting from Service Levels A, B, C and D operating conditions were previously evaluated in Reference 7, and are discussed in Section 4.0.

Pressure

Per Table 9 of Reference 6, the operating pressure loads range from 15 psia (0 psig) to 2,807 psia (2,792 psig) throughout the various thermal transients, whose temperatures range from 70°F to 682°F. The Hydro Test pressure ranges from 15 psia (0 psig) to 3,140 psia (3,125 psig) and the corresponding temperatures are 70°F. The pressures for various transients are summarized in Table 2. The gauge pressure (psig) is used in all calculations.

Thermal Transients

Based on Table 9 of Reference 6, six bounding thermal transients (Plant Heatup (1A), Plant Cooldown (1B), Step Load Reduction/ Reactor Trip Due to High Reactor Pressure/ Rod Withdrawal Accident (7/8C/11), Reactor Trip with Loss of Flow/Loss of Station Power (8A/15), Reactor Trip Due to High Reactor Temperature (8B), Rapid Depressurization (9)), Stratification Moment, and one test condition (Hydro Test) are considered. These thermal transients were evaluated in Reference 3. Details of the various transients are shown in Table 2.

The number of cycles shown in Table 2 are for the 60-year design operating period [6] for which the repair configuration will be evaluated.

Details of the thermal stress analyses are provided in Reference 3.

Mechanical Piping Loads

The pressurizer spray nozzle is subjected to mechanical piping loads. These are defined in Table 3 of Reference 6. See Table 3 in this calculation for details. Note that Table 3 of Reference 6 also shows piping loads for the deadweight condition. However, deadweight loads are constant loads which occur for all load conditions. Therefore, deadweight loads do not contribute to the stress ranges for Service Levels A and B load combinations and fatigue evaluations (per NB-3222.2 and NB-3222.4 (for vessels) and NB-3653.1, NB-3653.2, and NB-3653.5 (for piping)) and are excluded for those evaluations.

4.0 LOAD COMBINATIONS

The load combinations used in the repair design are:

1. Level A Load Combination
2. Level B Load Combination
3. Level C Load Combination
4. Level D Load Combination
5. Test Load Combination

The weld overlay sizing evaluation [7] considered general primary membrane, P_m, and primary membrane-plus-bending, P_m+P_b, stress intensities resulting from Service Levels A and B operating conditions and Service Levels C and D conditions. The local primary membrane, P_L, stress intensities are not specifically evaluated because the acceptability of P_m and P_L+P_b stress intensities indicate that P_L stress intensities will be equally acceptable (local stress effects due to the WOL are expected to be minimal).

The sizing calculation does not specifically evaluate loads resulting from the Test Load Combination (Hydro Test). However, the Test Load Combination considers only primary stresses, which only result from pressure and mechanical loads. The added thickness of the weld overlay will only serve to reduce the general primary membrane, P_m, and primary membrane-plus-bending, P_L+P_b, stress intensities (and as previously indicated, local primary membrane, P_L, stress intensity) when compared to the original configuration. Therefore, the only stress category needed to be evaluated for stress acceptance is P_L+P_b+Q criteria for all load combinations for Service Levels A and B. The specific load combinations are shown in Table 4. The allowable stress intensities for the primary + secondary stress category for these load combinations are shown in Table 5 [4]. Also, as indicated in Table 5, for Service Levels A and B, peak stresses and cyclic operation criterion must also be met.

Thus, this calculation, together with Reference 7, contains the ASME Code qualification for the weld overlay repair.

It should be noted that in using the ASME Code, Section III, Class 1 rules in NB-3200 (and NB-3600 rules for piping) [4], the bounding load combinations are used for evaluation of Service Levels A/B.

5.0 ASME CODE STRESS LIMITS EVALUATION

Stress intensities are calculated for the various load combinations shown in Table 4 and compared to the allowable limits shown in Table 5. Linearized through-wall stresses are extracted through nine paths (Paths 1 through 9; see Figures 1 and 2) throughout the transient time histories and from the pressure and mechanical load analyses [3]. These calculated stress intensities are evaluated in accordance with ASME Code, Section III, Subarticle NB-3200 [4] for Paths 1, 4, and 7, with guidance from Subarticle NB-3600 [4] for Paths 2, 3, 5, 6, 8 and 9.

Selection of the nine indicated paths was based on re-qualifying the components impacted by the repair. For this nozzle, the components in question are the spray nozzle, the safe end, and a portion of the spray piping. For the nozzle and piping, the critical locations are at the extreme ends of the weld overlay repair. Both locations, as a result of the repair, now have discontinuities, which impact the primary-plus-secondary-plus-peak stresses, and the corresponding fatigue usage. In addition, the pipe location will see the greatest impact in primary-plus-secondary stress ranges due to the thickness change resulting from the overlay and its impact on the thermal stresses per NB-3653.1.

The safe end was also selected as a separate component, though strictly speaking, the safe end is also a piping component per NB-1131(a). However, the safe end tends to have the greatest overlay thickness, which impacts the thermal secondary stresses, and is fabricated from a material weaker than the adjacent nozzle. In order to guarantee ASME Code compliance, the safe end was therefore included.

5.1 Service Level A/B Load Combination

Examination of the membrane-plus-bending stresses from Reference 3 does not provide an obvious pairing of stresses resulting from the various thermal transients for determination of the worst operating ranges. Thus, the VESLFAT program [8], developed by Structural Integrity, is used to calculate primary-plus-secondary membrane-plus-bending (P+Q) and total (P+Q+F) stress intensity ranges. The same program is used to perform the fatigue usage analysis described in Section 6.0.

The VESLFAT program computes stress intensity ranges based on component stress differences for all event pairs per NB-3216.2. It evaluates the stress ranges for primary-plus-secondary and primary-plus-secondary-plus-peak based on six component stresses (3 direct and 3 shear stresses). When more than one load set is defined for either of the event pair loading, the stress differences are determined for all of the potential loads, saving the maximum for the event pair. The principal stresses for the stress differences are determined by solving for the roots of the cubic stress equation per NB-3215.

The primary-plus-secondary membrane-plus-bending (P+Q) and total (P+Q+F) component stress values for thermal, pressure, and mechanical loads are combined prior to use in the VESLFAT program. The thermal component stresses resulting at each time increment from the various thermal transients are added to the component stresses resulting from corresponding pressure, and to the component stresses resulting from mechanical loading. The combination is performed in a series of Excel spreadsheets (file names are listed in Appendix A). Within the spreadsheet, the various component results are manipulated to produce the combined transient stress conditions, including:

- The primary-plus-secondary membrane-plus-bending (P+Q) and total (P+Q+F) stress components due to pressure are scaled from the 1,000 psi unit pressure evaluation performed in Reference 3. The actual pressure at specific time points for a given transient is defined in Reference 6 and shown in Table 2 of this calculation. The pressure between any two specified time points is assumed to vary linearly throughout each of the thermal transients.

- The primary-plus-secondary membrane-plus-bending (P+Q) and total (P+Q+F) stress components due to mechanical force and moment loads (resulting from thermal expansion) are calculated using the component stress results for a unit axial force (1,000 lb) and a unit moment (1,000 in-lb) developed in Reference 3.

    - Per Subparagraph NB-3653.1 [4], piping force components (axial and shear) need not be included in the stress range determination and are, therefore, excluded for Paths 2, 3, 5, 6, 8, and 9 (safe end and piping).

    - Equation 10 of Subparagraph NB-3653.1 provides a closed form solution to determine stress intensity range contributions for pressure and mechanical loads for Paths 2, 3, 5, 6, 8, and 9. However, this closed form solution is not used; rather, the actual stresses resulting from the finite element evaluations [3] are used.

- Per Reference 6, Section 4.3, the thermal expansion loads are applicable for a base fluid temperature of 555°F, and are scaled to other temperatures using a thermal load factor calculated as $(T_{fluid}-70)/(555-70)$, where T_{fluid} is the spray fluid temperature (T_{spray}) in °F as listed in Table 2.

- All forces related to piping mechanical loads are evaluated in the same manner for each event. The component forces are added together where appropriate and the resulting forces are then combined by SRSS to create a single bounding force load.

- All moments related to piping mechanical loads are evaluated in the same manner for each event. The component moments are added together where appropriate and the resulting moments are then combined by SRSS to create a single bounding moment load.

- Because it is not obvious which direction of applied moment loading produces the worst stress range, the evaluation considers both positive (Base case) and negative (Reverse case) loading directions for the thermal expansion loads and seismic loads in order to determine the worst range.

- The thermal stratification loads are treated as separate event as shown in Table 8 with 7200 cycles. Depending on the resultant stresses, OBE is applied to this event as shown in Table 1.

- The OBE piping loads are defined in Section 3.0 of Reference 6 as having a total of 660 cycles. Therefore 660 cycles of OBE loading are applied to the thermal range loads with no self cycling. The OBE loads are added to the piping loads to one of the thermal transient pair events that produce the highest stress intensity range, as determined on a per path basis. The transient load pairs on which OBE is being applied are shown in Table 1.

- Full range OBE is used for all paths to calculate the stress intensity range. Whereas half range OBE is considered while calculating fatigue.

Cyclic information, as well as material property data, are also needed to complete the VESLFAT input, though they do not play a direct role in the determination of membrane-plus-bending stress intensity ranges. This data is needed to support the fatigue evaluations, and is discussed in detail in Section 6.0.

Table 6 presents the evaluation of the primary-plus-secondary stress intensity ranges for Service Level A/B operating conditions. The stress ranges extracted from VESLFAT files, with the extension *.FAT, are the stress intensity ranges that produce the greatest ratio of stress intensity range versus allowable stress.

5.1.1 Simplified Elastic-Plastic Analysis

Paths 6 (outside) and 9 (outside) have stress intensity ranges which exceed the allowable stress intensity range. A simplified elastic-plastic analysis is conducted per Subparagraph NB-3653.6 [4], since the $3S_m$ limit is exceeded.

- NB-3653.6, Part (a), requires that "Equation (12) shall be met." Equation (12) is defined as:

$$S_e = C_2 \frac{D_o}{2I} M_i^* \leq 3S_m$$

  In Equation (12), M_i^* is identified as the moment range that includes only the thermal expansion. The largest thermal moment range is 173,263 in-lbs at a fluid temperature range of 70°F to 636°F (extracted from Excel Spreadsheet *" SectionIII_v120-TMI-SPRAY-no-obe.xls" tab "Eq-12"*) for Path 6 Outside. The largest thermal moment range for Path 9 outside is 7604 in-lbs at a fluid temperature range of 70°F to 636°F. These values are used to calculate the membrane-plus-bending stress intensity results from the 1,000 in-lb unit moment results in Reference 3. For Path 6 outside, the unit out-of-plane moment results are used, since stratification is present. According to the isometric drawing in Figure 4 for spray piping, it can be seen that the Stratification is being applied in the Out-of-plane direction on the nozzle. The resulting stress intensities are shown in Table 7 with comparison to the allowable values.

- NB-3653.6, Part (b), requires that "primary plus secondary membrane plus bending stress intensity, excluding thermal bending and thermal expansion stresses, shall be < $3S_m$."

  Equation (13) of NB-3653.6, Part (b) is essentially identical to Equation (10) of NB-3653.1. To bound the various load combinations, the membrane-plus-bending stress intensities for the worst thermal transient pressure (2792 psig for the 7/8C/11 transient) were conservatively added to the maximum membrane stress intensity range that occurs for any two thermal transients (for Equation (13), the thermal piping moment loads are excluded). The results are listed in Table 7.

5.2 Thermal Ratcheting

The thermal stress ratchet is required to be evaluated to prevent cyclic growth in the component. The thermal stress ratchet effect is driven by internal pressure, as the component is subject to cyclic thermal stress. Paths 3, 6, 9 at the attached pipe location, are not protected by a thermal sleeve and have the thinnest cross-section, which produces the most conservative ΔT_1 allowable. These paths are selected for thermal ratcheting evaluation per Subparagraph NB-3653.7 [4]. Therefore, the limiting range of through-wall temperature gradient is calculated as:

$$x = \frac{P \cdot D_o}{2 \cdot t}\left(\frac{1}{Sy}\right) = \frac{2792 \cdot 4.5}{2 \cdot 0.438}\left(\frac{1}{29869}\right) = 0.48 \qquad \text{(bounding Path 3)}$$

where,

P = Maximum pressure for the set of conditions under consideration= 2,792 psig (see Table 2)
D_o = Outside diameter, 4.5 inches for the pressurizer spray pipe [2].
t = Wall thickness, 0.438 inches for the pressurizer spray pipe [2].
S_y = Per Note 11 of Subparagraph NB-3222.5, $1.5S_m$ can be substituted for S_y, if greater. The value of $1.5S_m$ is 29,869 psi [5] for SA-403, WP 316 (Path 3) at an average fluid temperature of 313°F.* (Note: * The pair with the maximum ΔT_1 range is the Plant Heatup transient. The average fluid temperature is 313°F (i.e., (555+70)/2). 313°F is used to calculate the value of $1.5S_m$)

Therefore, the limiting range of ΔT_1 can be calculated as:

$$\Delta T_1 \leq \frac{y' S_y}{0.7 \cdot E\alpha}(C_4) = \frac{2.08 \cdot 29869}{0.7 \cdot 28.3 \cdot 8.5}(1.3) = 479.65°F \text{ (bounding Path 3)}$$

where,

y' = 2.08 (Per NB-3222.5 [4]; y' = 1/x = 2.08, for x = 0.48).
C_4 = 1.3 for stainless steel material
E = Modulus of elasticity, 28.3e6 psi, for SA-403, WP 316 at room temperature [5].
α = Mean coefficient of thermal expansion, 8.5e-6 in/in/°F, for SA-403, WP 316 at room temperature [5].

The inside and outside surface temperatures are extracted from the thermal transients evaluated in Reference 3. The through-wall temperature difference (ΔT) is calculated for each time point of the transients. The maximum positive through-wall ΔT is subtracted from the minimum through-wall ΔT for the two limiting transients, and the resulting range conservatively considered the ΔT_1 range (see Excel Spreadsheet " *SectionIII_v120-TMI-SPRAY-no-obe.xls* ", Tab "ThermalRatchet"). ΔT_1 is defined in Subparagraph NB-3653.2 as the range of the temperature difference between the temperature of the outside surface and the temperature of the inside surface assuming moment generating equivalent linear temperature distribution. The maximum ΔT for Paths 1 through 9 is 112°F, which is below the allowable temperature range of 480°F. Therefore, the thermal ratcheting criterion is met for all paths.

6.0 FATIGUE EVALUATION

The fatigue evaluations are performed for Paths 1 through 9 for the weld overlay repair (see Figures 1 and 2). Both the inside and outside locations of the indicated paths are evaluated. The evaluations are performed in accordance with ASME Code, Section III, Subparagraph NB-3222.4(e) [4] (with guidance from NB-3600), using the Structural Integrity developed VESLFAT program [8].

6.1 VESLFAT Program

The VESLFAT program requires three input files. The first is the *.CYC file, which includes the number of cycles for each load combination. The data used in the *.CYC file is discussed in detail in Section 6.1.1. The second file is the *.FDT file, which includes the fatigue curve data, appropriate temperature dependent material properties, and simplified elastic-plastic limits and factors. These values are discussed in Section 6.1.2. The final input file is the *.STR file, which contains the component membrane-plus-bending and membrane-plus-bending-plus-peak (i.e., total) stresses for the various load conditions to be evaluated. Additional details are provided in Section 6.1.3. As several load conditions occur within each load case, these load conditions will be identified by a number, which matches the load condition to the load case. This number is defined in the *.CYC file. Each of these three files must be identically named, with the exception of the file extension.

A number of intermediate files are generated, which can be used to check the final results. The *.ST1 file is an echo output of the *.STR file but includes transformations to output the results in terms of psi. The *.ALL file reflects all of the stress range pairs that are calculated. The *.PR file is a shortened version of the *.ALL file and lists only the significant (i.e., fatigue causing) pairs. The *.ORD file re-sequences the *.PR file such that the ordered pairs are arrayed in order of reducing alternating stress.

The actual final output file is labeled *.FAT. It echoes the input data, shows the significant cycle pairings, the cycle elimination, individual cycle pair fatigue contributions, and the final overall fatigue usage. See Section 6.1.4 for fatigue results.

6.1.1 Cyclic Data (.CYC)*

Reference 6 assigned a total number of cycles for each bounding event, which are tabulated in Table 8 of this calculation. See Appendix B for an example of a *.CYC file.

6.1.2 Fatigue Data Input File (.FDT)*

The materials at the surfaces of the stress paths indicated in Figures 1 and 2 are tabulated in Table 9.

The fatigue curve for the stainless steel and Alloy 52M components is per Reference 4, Section III Appendices, Table I-9.2.

The fatigue curve for the SA-508 Class 1 material is also per Reference 4, Section III, Appendices, Table I-9.1.

The modulus of elasticity correction factor from the fatigue curves are based on Reference 5 temperature dependent modulus of elasticity values with a fatigue curve elastic modulus of 28.3e6 psi for the austenitic and Alloy 52M materials, and 30.0e6 psi for the SA-508 Class 1 material.

See Appendix B for an example *.FDT file.

6.1.3 Stress Data Input File (*.STR)

Linearized membrane-plus-bending (P+Q) and membrane-plus-bending-plus-peak (P+Q+F) component stresses from the finite element stress analyses [3] were extracted for pressure, mechanical, and thermal transient loads. Stresses are scaled in cases (pressure and mechanical) where the applied load magnitude is not the same as that analyzed.

The resulting component stresses are then added to create the load combination for each thermal transient throughout the length of the event. Thus, thermal stresses are added to the scaled pressure stresses and to the scaled mechanical load stresses to create each membrane-plus-bending and membrane-plus-bending-plus-peak component stress entry.

Paths 1, 4, 7, 3, 6, and 9 terminate on the outside at locations with geometric discontinuities. For these locations, the magnitude of the P+Q+F stress is determined by applying a fatigue strength reduction factor to the P+Q stress obtained from the finite element analysis (Reference 3). This is allowed per NB-3222.4(e)(2) [4] which allows for the use of theoretical techniques for the determination of a stress concentration factor. For only the inside locations (in contact with the fluid) with a fatigue strength reduction factor, the peak thermal stress components are added back into the total stress to capture the peak stress due to non-linear temperature gradients. The use of the fatigue strength reduction factor is shown as follows.

P+Q+F = (ANSYS membrane + bending)*FSRF + ANSYS thermal peak (Inside Locations)
P+Q+F = (ANSYS membrane + bending)*FSRF (Outside Locations)

For those paths that do not occur at a geometric discontinuity, no fatigue strength reduction factor is used. Instead, the membrane-plus-bending-plus-peak (P+Q+F) component stresses from the finite element stress analyses [3] will be used directly.

Similarly, a fatigue strength reduction factor is applied to Paths 2, 5 and 8, inside which are located at areas of tapered transition. Note that Paths 2 and 5 are located at areas of tapered transition on the outside surface for the maximum weld overlay case only.

Fatigue strength reduction factors as shown in the following table are calculated and applied to the affected path locations as detailed in Section 6.2 of Reference 9. A pictorial representation of the tapered transition section is provided in Figure 3.

The fatigue stress reduction factor is calculated as follows:

$$\text{Fatigue Stress Reduction Factor} = \frac{2\tan\alpha}{\left(\alpha + \frac{1}{2}\sin 2\alpha\right)}$$

where α is the tapered transition angle in radian.

Path No.	Surface	Tapered transition angle (α) in degrees	Fatigue Strength Reduction Factor
1	Inside	0	1.00
	Outside	30	1.21
2	Inside	18.4	1.07
	Outside	18.5	1.07
3	Inside	0	1.00
	Outside	24.7	1.13
4	Inside	0	1.00
	Outside	30	1.21
5	Inside	18.4	1.07
	Outside	14	1.04
6	Inside	0	1.00
	Outside	29.8	1.20
7	Inside	0	1.00
	Outside	30	1.21
8	Inside	18.44	1.07
	Outside	0	1.00
9	Inside	0	1.00
	Outside	49.1	1.41

The *.STR file includes the temperature of the location as it varies throughout the events and the pressure. The pressures vary as indicated in Table 2. The temperature at the stress path location is based on the actual metal temperature of the material rather than the fluid temperature. These metal temperatures were extracted from the prior stress evaluations in Reference 3 via the linearized stress results files which include the temperature data in the last field under "Total" stress.

Because it is not obvious as to which direction of applied force and moment loading produces the worst stress ranges, the fatigue evaluations will be considered in both positive (Base Case) and negative (Reverse Case) mechanical load directions, in order to capture the worst ranges and, therefore, the greatest fatigue usage.

The load combinations and the development of the *.STR file entries were performed in Excel spreadsheets named which are listed in Appendix A.

An example of the *.STR file is shown in Appendix B.

6.1.4 Fatigue Usage (.FAT)*

The fatigue evaluation automatically selects the load pairs that create the greatest stress intensity range, performs a K_e calculation, corrects for the modulus of elasticity, and performs the fatigue evaluation. It repeats this process selecting the next highest stress range until the available cycles are used up or the remaining stress ranges fall below the endurance limit. An example *.FAT file is included in Appendix B. The intermediate solution files *.ST1, *.ALL, *.PR, and *.ORD are included with computer files.

Table 10 tabulates the total fatigue usage for each location. In addition, the table includes information on the load pairing which produces the greatest alternating stress for each location, including the membrane-plus-bending stress intensity range, the calculated K_e elastic-plastic factor, and the alternating stress, S_a, for the specific load pair.

7.0 CONCLUSIONS

An evaluation of the pressurizer spray nozzle weld overlay repairs for the Three Mile Island Nuclear Generating Station, Unit 1 (TMI-1) has been performed in accordance with the requirements the ASME Boiler and Pressure Vessel Code, Section III, for Class 1 components [4]. Stress intensities were conservatively determined for pressure, piping loads and bounding thermal transients provided in Reference 6, and compared to ASME Code allowable values for primary-plus-secondary stress effects. In all cases, except for Path 6 outside and Path 9 outside, the reported values of stress intensity ranges are less than their corresponding allowable values (see Table 6). A simplified elastic-plastic analysis is conducted on Paths 6 outside and 9 outside, per Subparagraph NB-3653.6 [4], since the $3S_m$ limit is exceeded. The resulting stress intensities are shown in Table 7 with comparison to the allowable values and it can be seen that the stress intensity values are less than their corresponding allowable values.

A detailed fatigue analysis was also performed. For the given number of expected cycles (see Table 8), the total usage at all locations are less than the allowable of 1.0 (see Table 10).

In conclusion, the pressurizer spray nozzle weld overlay repair design shown on the design drawing [1] satisfies the requirements of the ASME Code, and is qualified for the 60 years of cyclic operation.

8.0 REFERENCES

1. SI Drawing No. 1000320.510 "Pressurizer Spray Nozzle Full Structural (FSWOL) Weld Overlay Design Drawing," (for revision number refer to SI Project Revision Log, latest revision).

2. SI Calculation No. 1000320.312, "Material Properties and Finite Element Models for Pressurizer Spray Nozzle with Weld Overlay Repair," (for revision number refer to SI Project Revision Log, latest revision).

3. SI Calculation No. 1000320.313, "Pressurizer Spray Nozzle Thermal and Mechanical Stress Analysis Calculation," (for revision number refer to SI Project Revision Log, latest revision).

4. ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Facility Components, 2004 Edition.

5. ASME Boiler and Pressure Vessel Code, Section II, Part D, Material Properties, 2004 Edition.

6. SI Calculation No. 1000320.311, "Design Loads for Pressurizer Spray Nozzle with Weld Overlay Repair," (for revision number refer to SI Project Revision Log, latest revision).

7. SI Calculation No. 1000320.310, "Pressurizer Spray Nozzle Weld Overlay Sizing Calculation," (for revision number refer to SI Project Revision Log, latest revision).

8. VESLFAT, Version 1.42, Structural Integrity Associates, Inc., February 6, 2007.

9. J. F. Harvey, "Theory and Design of Modern Pressure Vessels," 2nd Edition, Van Nostrand Reinhold Company, 1974.

10. GPU Nuclear Drawing No. ID-212-23-028, Sheet 2 of 6, Rev. 1, "LPSI/DECAY HEAT REMOVAL PIPING ANALYSIS," SI File Number 1000320.204.

Table 1: Transient Load Pairs that Consider OBE

Location	Primary-Plus-Secondary		Fatigue	
	Base	Reverse	Base	Reverse
Path 1 Inside	10	6	10	10
Path 1 Outside	6	2	6	6
Path 2 Inside	9	9	9	9
Path 2 Outside	3	6	3	6
Path 3 Inside	10	6	10	6
Path 3 Outside	6	3	6	3
Path 4 Inside	10	9	10	10
Path 4 Outside	9	2	9	6
Path 5 Inside	9	9	6	6
Path 5 Outside	9	9	9	9
Path 6 Inside	6	10	10	6
Path 6 Outside	9	9	9	9
Path 7 Inside	8	10	10	10
Path 7 Outside	2	6	6	6
Path 8 Inside	9	1	6	3
Path 8 Outside	3	6	3	6
Path 9 Inside	9	9	9	9
Path 9 Outside	3	6	3	6

Note:

1) The event ID # is identified in Table 8.

Table 2: Bounding Transients for Analysis

Transient	Time, sec	T_{PZR}, °F	T_{spray}, °F	h, Btu/hr-ft^2-°F Under TS[(3)]	h, Btu/hr-ft^2-°F Elsewhere[(4)]	P_{spray}, psig	Cycles	Factor
1A	0	70	70	173	1378	0	240	N/A
	10800	370	370	173	1378	159		1.000
	10800	370	70	22	21	216		1.000
	12240	410	110	26	26	319		0.082
	12240	410	110	141	427	319		0.082
	27432	650	532	160	739	2242		0.953
	27432	650	532	183	2149	2242		0.953
	28092	650	555	182	2123	2242		1.000
1B	0	650	555	179	1663	2242	240	1.000
	10800	430	300	177	1540	216		0.474
	21600	400	280	177	1484	216		0.433
	21600	400	210	152	578	159		0.289
	25920	330	150	147	494	15		0.165
	36000	200	125	141	427	0		0.113
7/8C/11	0	650	544	41	44	2242	65938	0.977
(bounds	0	650	566	182	2111	2242		1.023
2A, 3, 4,	4	682	586	182	2088	2792		1.064
6, 7, 8C,	12	682	590	182	2084	2792		1.072
10, 11,	144	682	590	182	2084	2792		1.072
14, and	144	639	575	182	2101	2092		1.041
20B)	192	633	562	182	2116	1997		1.014
	282	625	546	183	2134	1897		0.981
	372	616	540	183	2140	1777		0.969
8A/15	0	650	555	182	2123	2242	80	1.000
	8	662	570	174	1261	2442		1.031
	12	662	570	174	1261	2442		1.031
	20	650	555	164	844	2242		1.000
	30	632	550	154	612	1992		0.990
	720	643	550	154	612	1992		0.990
	720	643	636	173	1405	2142		1.167
		643	636	173	1405	2142		1.167
8B	0	650	544	183	2136	2242	180	0.977
(also	1	651	544	183	2136	2260		0.977
bounds	4	654	562	182	2116	2312		1.014
17A)	6	657	564	182	2113	2348		1.019
	10	661	560	182	2118	2419		1.010
	15	666	576	182	2100	2507		1.043
	22	653	568	182	2109	2297		1.027
	22	653	568	41	44	2297		1.027
	600	616	558	41	44	1757		1.006
	612	616	535	41	45	1757		0.959
9	0	650	580	182	2006	2242	1480	1.052
(also	900	519	500	182	2093	842		0.887
bounds 2B)	1200	515	490	182	2088	822		0.866
12			70			0	20	N/A
			70			3125		**N/A**

Notes: (1) Table is reproduced from Table 1 of Reference 3.
(2) Temperatures are assumed to vary linearly with time between indicated time points.
(3) At the region covered by the thermal sleeve.
(4) At all regions, including pressurizer shell, except thermal sleeve.

Table 3: Bounding Piping Interface Loads

Load Case	Forces, lb Fx	Fy	Fz	Moments, lb-in Mx	My	Mz
Deadweight	3	14	13	252	1222	781
OBE	422	629	493	10932	20102	15723
Thermal	6	4	11	6468	704	348
Maximum Stratification Moment (2)				Range = 173,263 lb-in		

Note: (1) The above table is reproduced from Table 3 of Reference 6.
(1) The Stratification occurs at 555°F and at a pressure of 2242 psig [6].

Table 4: Load Combinations

LOADS	Load Combinations Level A	Level B
Pressure	Note 1	Note 1
Temperature	Note 2	Note 2
Mechanical Piping Loads	X	X
Thermal Transients		
Plant Heatup	X	
Plant Cooldown	X	
Step Load Reduction/ Reactor Trip Due to High Reactor Pressure/ Rod Withdrawal Accident		X
Reactor Trip with Loss of Flow/Loss of Station Power		X
Reactor Trip Due to High Reactor Temperature		X
Rapid Depressurization		X
Stratification Moment	X	
Hydro test	Note 3	Note 3

Notes:

1. Varies between 15 psia and 3140 psia depending on transient conditions [6], summarized in Table 2.
2. Varies between 70°F and 682°F depending on transient conditions [6], summarized in Table 2.
3. Hydro Test pressure varies between 15 psia and 3140 psia. Hydro test is covered under NB 3226, but included here conservatively.

Table 5: Allowable Stress Intensities

Load Combination	P_m	P_L	$P_L + P_b$	$P_L + P_b + Q$	Note
Level A/B	(3)	(3)	(3)	3.0 S_m	1

Notes:

1. The requirements of ASME Code, Section III, Subparagraph NB-3222.4(e) [4] (and NB-3653.5 for piping) for peak stresses and cyclic operation must be met.
2. P_e is not specifically listed and is included with Q. P_e is defined in Figure NB-3222-1 [4] as stresses which result from the constraint of free end displacement. The piping loads provided in Reference 6 do not specifically detail the source of the loading (thermal expansion or thermal anchor movements for the thermal loads). Therefore, the loads are all classified as secondary, Q.
3. Not evaluated as explained in Section 4.0.

Table 6: Service Level A/B Load Combination, Primary-Plus-Secondary Stress Intensity Evaluation

Path Number(7)	Surface	Maximum Stress Intensity Range (S_n) (psi) – Base(8)(10)	Maximum Stress Intensity Range (S_n) (psi) – Reverse(9)(10)	Allowable $3S_m$ (psi)(6)(11)	Accept
1	Inside(1)	17502	17838	49066	Yes
	Outside(2)	20145	19443	53872	Yes
2	Inside(3)	19256	19028	69900	Yes
	Outside(4)	20935	21278	69900	Yes
3	Inside(5)	33832	34953	50614	Yes
	Outside(5)	36914	35839	51618	Yes
4	Inside(1)	17213	17937	49066	Yes
	Outside(2)	26722	19613	53872	Yes
5	Inside(3)	23697	21822	69900	Yes
	Outside(4)	21225	24480	69900	Yes
6	Inside(5)	32143	31601	50407	Yes
	Outside(5)	77277	67004	51642	No
7	Inside(1)	16896	16751	49066	Yes
	Outside(2)	19662	20334	53872	Yes
8	Inside(3)	19835	20681	69900	Yes
	Outside(4)	20577	20943	69900	Yes
9	Inside(5)	35982	37707	52350	Yes
	Outside(5)	48853	52459	51615	No

Notes:

1. Material at location is SA-240 TP 304 [3].
2. Material at location is SA-508 Class 1 [3].
3. Material at location is SB-166, treated as Alloy 600 [3].
4. Material at location is Alloy 52M [3].
5. Material at location is SA-403 WP-316 [3].
6. All material stress allowables [4] are based on the maximum $S_n/3S_m$ ratio from VESLFAT output files ending in *.FAT (see Appendix B for example).
7. See Figures 1 and 2 for illustration of indicated locations.
8. Mechanical loads are applied in the positive direction (Base Case).
9. Mechanical loads are reverse from the Base Case (Reverse Case).
10. S_n are based on the maximum $S_n/3S_m$ ratio from VESLFAT output files ending in *.FAT (see Appendix B for example).
11. The calculation of $3S_m$ is performed by VESLFAT using the element temperatures along the selected path and interpolating between the ASME Code, Section II values.

Table 7: Simplified Elastic-Plastic Evaluation Results

Path [3]	Surface	Equation (12)			Equation (13)		
		Moment Stress (ksi) [4]	Allowable $3S_m$, (ksi) [2][5]	Accept	Maximum Stress Intensity Range (S_n), (ksi) [6]	Allowable $3S_m$, (ksi) [5][7]	Accept
6	Outside [1]	51.165 [8]	51.642	Yes	41.794	51.642	Yes
9	Outside [1]	3.073 [9]	51.615	Yes	44.978	51.615	Yes

Notes:

1. Material at location is SA-403 WP316 [1].
2. Material stress allowables evaluated are based on those generated in Table 6.
3. See Figures 1 and 2 for illustration of indicated locations.
4. Equation 12 evaluation can be found in Excel Spreadsheet " *SectionIII_v120-TMI-SPRAY-no-obe.xls*" in the tab "Eq-12." Stress intensity results were conservatively used.
5. The calculation of $3S_m$ is performed by VESLFAT using the element temperatures along the selected Path and interpolating between the ASME Code, Section II values [5].
6. Equation 13 evaluation can be found in Excel Spreadsheet " *SectionIII_v120-TMI-SPRAY-no-obe.xls*" in the tab "Eq-13."
7. The calculation of $3S_m$ is performed by VESLFAT using the element temperatures along the selected path and interpolating between the ASME Code, Section II values.
8. Moment stress from out of plane moment (Mx) is used to calculate Equation 12, since stratification load is responsible for the Service level A/B failure.
9. Moment range used to calculate this stress is taken from events 1 through 8, excluding stratification event, as this is not the event which contributes to maximum stress intensity range in Table 6.

Table 8: Event Cycles

Transient	Event(1)	Cycles(2)
Plant Heatup	1	240
Plant Heatup	2	240
Plant Cooldown	3	240
Step Load Reduction/ Reactor Trip Due to High Reactor Pressure/ Rod Withdrawal Accident	4	65938
Reactor Trip with Loss of Flow/Loss of Station Power	5	80
Reactor Trip with Loss of Flow/Loss of Station Power	6	80
Reactor Trip Due to High Reactor Temperature	7	180
Rapid Depressurization	8	1480
Stratification Moment	9	7200
Hydro Test	10	20
OBE	-	660

Notes:
1. Used by VESLFAT to identify event groupings.
2. The cycles provided in Table 9 of Reference 6 are for 60 years of operation.

Table 9: Materials for Fatigue Evaluation

Path(1)	Surface	Material(2)
1, 4, 7	Inside	SA-240 TP304
	Outside	SA-508 Class 1
2, 5, 8	Inside	SB-166 (Treated as Alloy 600)
	Outside	Alloy 52M
3, 6, 9	Inside	SA-403 WP-316
	Outside	SA-403 WP-316

Notes:
1. See Figures 1 and 2 for illustration of indicated locations.
2. Identified in Reference 3.

Table 10: Fatigue Usage Results

Path No.[1]	Surface	Maximum Alternating Stress Load Pair: Event Pair[4]	S_n (psi)	K_e	Alternating Stress (psi)	Total Fatigue Usage[3]
1	Inside	6&10	16008	1	24472	0.0004334 [2]
	Outside	2&6	20233	1	14077	0.0010798
2	Inside	1&9	19256	1	---	0
	Outside	3&6	21278	1	---	0 [2]
3	Inside	6&10	34953	1	20109	0.000079 [2]
	Outside	3&6	37082	1	23263	0.0003368
4	Inside	6&10	15911	1	24398	0.0004795 [2]
	Outside	2&9	26722	1	18155	0.0041867
5	Inside	6&9	16862	1	15103	0.00003
	Outside	6&9	24480	1	---	0.0000000 [2]
6	Inside	1&6	30584	1	16873	0.0000766 [2]
	Outside	3&9	72648	2.293	110595	0.6640993
7	Inside	6&10	16704	1	24613	0.0004269 [2]
	Outside	2&6	20864	1	14259	0.0011338 [2]
8	Inside	3&6	9050	1	14935	0.0000092
	Outside	3&6	20943	1	---	0 [2]
9	Inside	1&9	37707	1	20661	0.0005513 [2]
	Outside	3&6	52459	1.055	43411	0.0080245 [2]

Notes:
1. See Figures 1 and 2 for illustration of indicated locations.
2. Reversed Piping Load Case.
3. Cumulative fatigue usage from all contributing load pairs.
4. Refer to Table 8 for event identification.

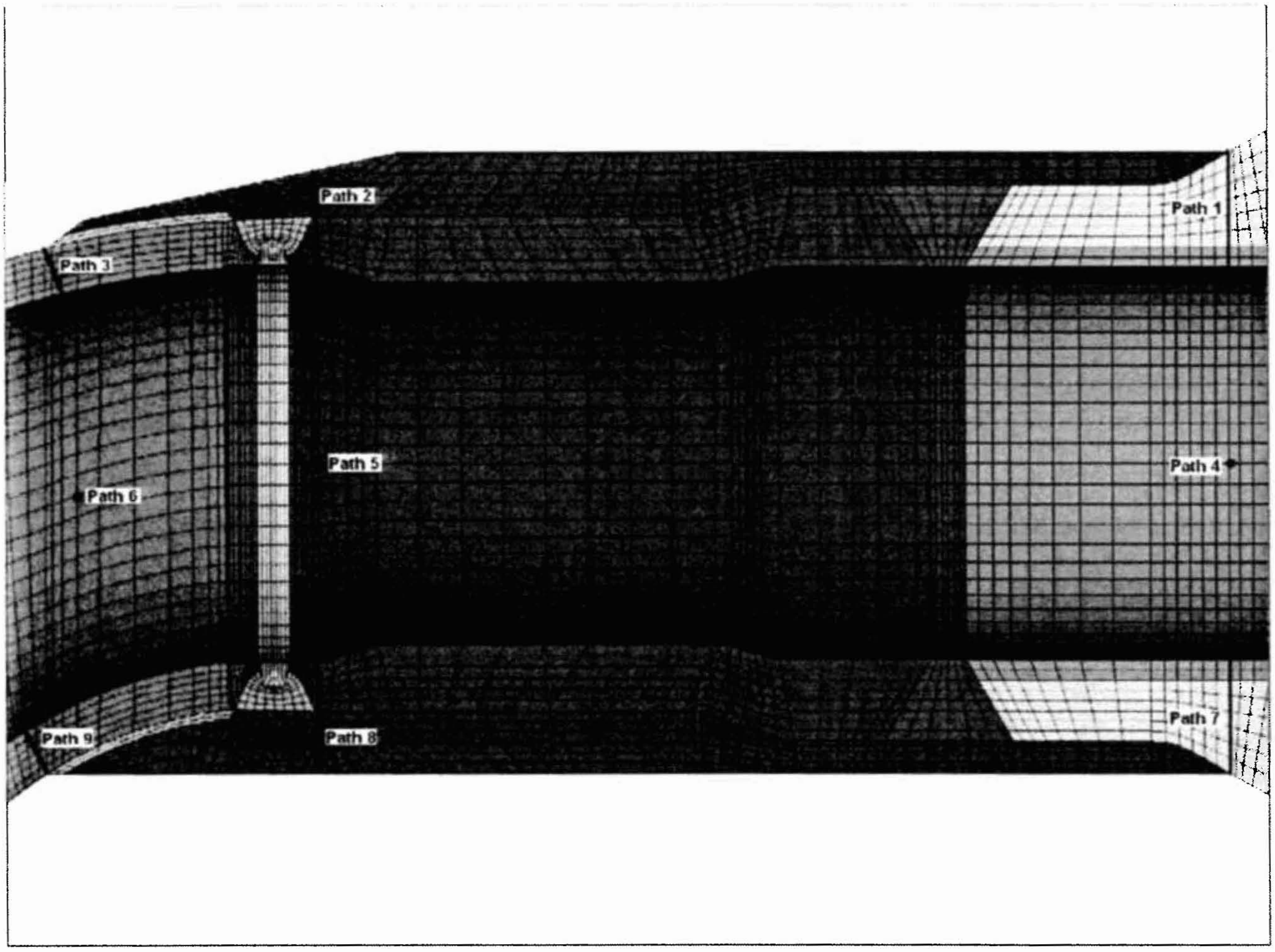


Figure 1. Stress Path Definitions of Minimum Weld Overlay for ASME Code, Section III Evaluations

(Figure is from Reference 3)

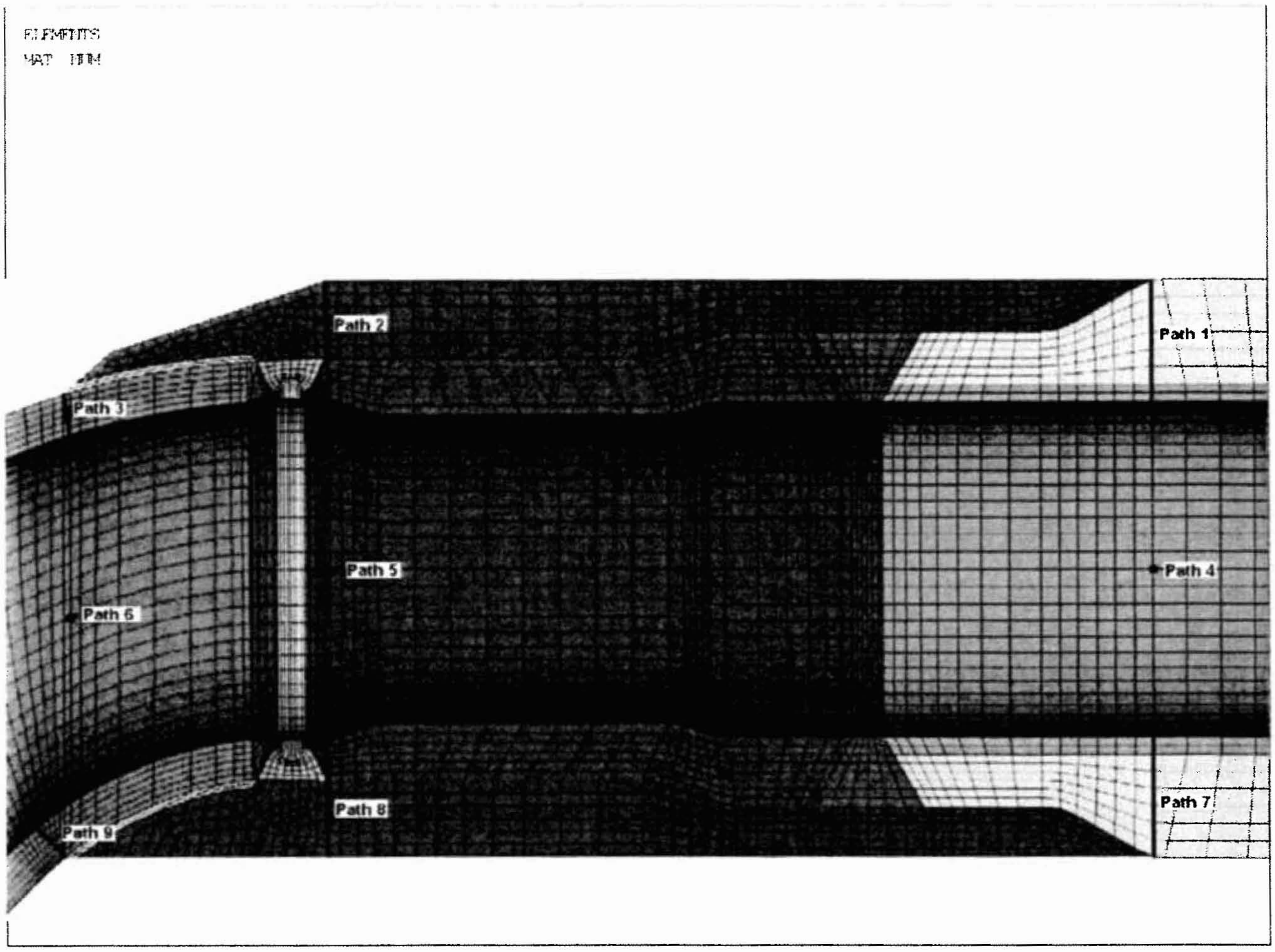


Figure 2. Stress Path Definitions of Maximum Weld Overlay for ASME Code, Section III Evaluations

(Figure is from Reference 3)

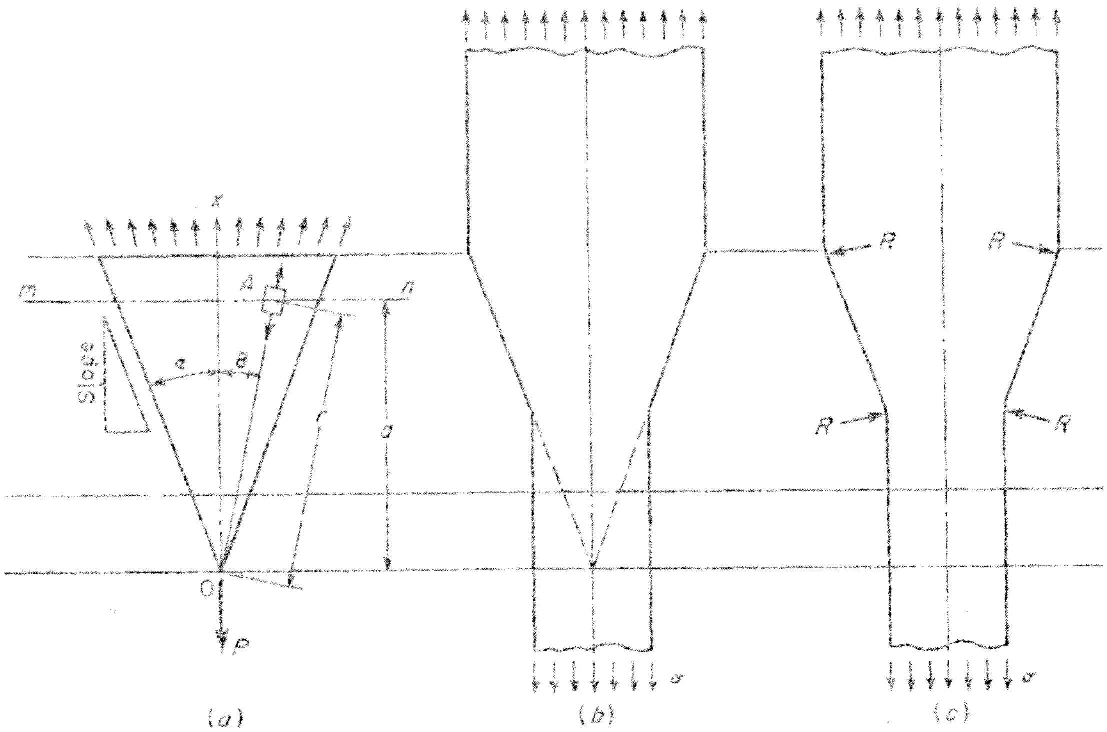


Figure 3. Tapered Transition Section

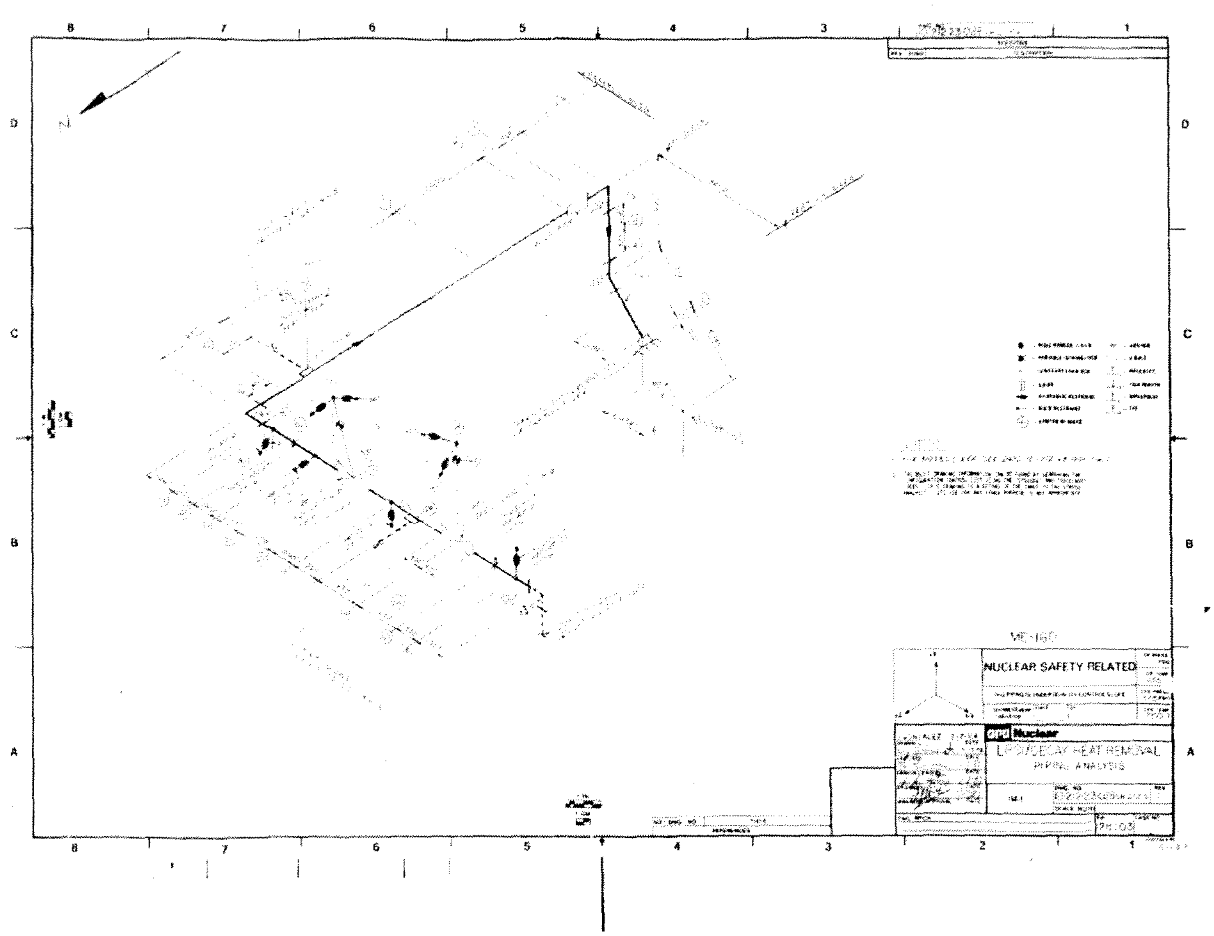


Figure 4. Isometric Drawing of the Spray Piping

(Note: Figure is obtained from Reference 10)

APPENDIX A

SUPPORT FILES

File Name	Description
SectionIII_v120-TMI-SPRAY-$$.xls	Excel Spreadsheet used to Create *.STR Files for use in VESLFAT Fatigue Program. ($$ = no-obe, Pair-1, Pair-2, Fatigue-Pair-1, Fatigue-Pair-2)
P*-I.CYC	Cycle Data Input File for Inside Surface Locations for VESLFAT Program where, * = Paths 1 through 9. 'r' in file name indicates Reverse Piping Load Case.
P*-O.CYC	Cycle Data Input File for Outside Surface Locations for VESLFAT Program where, * = Paths 1 through 9. 'r' in file name indicates Reverse Piping Load Case.
P*-I.FDT	Material Data Input File for Inside Surface Locations for VESLFAT Program where, * = Paths 1 through 9. 'r' in file name indicates Reverse Piping Load Case.
P*-O.FDT	Material Data Input File for Outside Surface Locations for VESLFAT Program where, * = Paths 1 through 9. 'r' in file name indicates Reverse Piping Load Case.
P*-I.STR	Stress Data Input File for Inside Surface Locations for VESLFAT Program Created by Excel Spreadsheets Listed Above, where, * = Paths 1 through 9. 'r' in file name indicates Reverse Piping Load Case.
P*-O.STR	Stress Data Input File for Outside Surface Locations for VESLFAT Program Created by Excel Spreadsheets Listed Above, where, * = Paths 1 through 9. 'r' in file name indicates Reverse Piping Load Case.
P*-I.ALL P*-I.ORD P*-I.PR P*-I.ST1	Intermediate Result File for Inside Surface Locations Created by VESLFAT Program where, * = Paths 1 through 9. 'r' in file name indicates Reverse Piping Load Case.
P*-O.ALL P*-O.ORD P*-O.PR P*-O.ST1	Intermediate Result File for Outside Surface Locations Created by VESLFAT Program where, * = Paths 1 through 9. 'r' in file name indicates Reverse Piping Load Case.
P*-I.FAT	Fatigue Result File for Inside Surface Locations Created by VESLFAT Program where, * = Paths 1 through 9. 'r' in file name indicates Reverse Piping Load Case.
P*-O.FAT	Fatigue Result File for Outside Surface Locations Created by VESLFAT Program where, * = Paths 1 through 9. 'r' in file name indicates Reverse Piping Load Case.

APPENDIX B

EXAMPLE VESLFAT FILES

VESLFAT INPUT FILE P3-O.CYC:

```
N     Name    N
          -------------------------
1 TMI_1-       240
2 TMI_2-    240
3 TMI_3-    660
4 TMI_4-    65938
5 TMI_5-    80
6 TMI_6-    80
7 TMI_7-    180
8 TMI_8-    1480
9 TMI_9-    7200
10 TMI_10-    20
```

VESLFAT INPUT FILE P3-O.FDT:

```
Fatigue Analysis Properties - Note: All text must remain in the file - ksi
        1.7         .3     m and n for elastic plastic analysis
        28300              E fatigue Curve,ksi
        1                  Multiplying factor to convert *.STR file data to psi
        0.010              Max Membrane Stress (ksi) per psi applied pressure
        40                 NB-3222.5 (b) limit on Sy if large number of cycles
        25                 Number of Points on Fatigue Curve
        9                  Number of points on Material Property Curve
Fatigue Curve with Cycles (ascending) and Salt, ksi
          10      708
          20      512
          50      345
         100      261
         200      201
         500      148
        1000      119
        2000      97
        5000      76
       10000      64
       20000      55.5
       50000      46.3
      100000      40.8
      200000      35.9
      500000      31
     1000000      28.2
     2000000      22.8
     5000000      18.4
    10000000      16.4
    20000000      15.2
    50000000      14.3
   100000000      14.1
  1000000000      13.9
 10000000000      13.7
100000000000      13.6
Material Property Curve  (SA-403, WP 316 ASME 2004)
 Temp    E,ksi   Sm, ksi    Sy, ksi
   70    28300    20.0      30.0
  200    27500    20.0      25.9
  300    27000    20.0      23.4
  400    26400    19.3      21.4
  500    25900    18.0      20.0
  600    25300    17.0      18.9
  650    25050    16.6      18.5
  700    24800    16.3      18.2
  750    24450    16.1      17.9
```

VESLFAT INPUT FILE P3-O.STR:

N	Name	Sxx	Syy	Szz	Sxy	Sxz	Syz	Sxx	Syy	Szz	Sxy	Sxz	Syz	Tmax	Pmax
1	TMI_1-0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70	0.0
1	TMI_1-360	181.2	355.9	380.3	-5.3	-182.0	-18.4	204.7	402.2	429.8	-6.0	-205.7	-20.8	79	5.3
1	TMI_1-720	298.1	525.8	598.1	-7.2	-292.2	-29.7	336.9	594.2	675.9	-8.1	-330.1	-33.6	89	10.6
1	TMI_1-1080	398.6	654.7	783.6	-8.4	-384.9	-39.4	450.4	739.9	885.5	-9.5	-434.9	-44.6	99	15.9
1	TMI_1-1440	504.5	784.7	977.5	-9.5	-481.4	-49.8	570.1	886.7	1104.6	-10.8	-544.0	-56.2	109	21.2
1	TMI_1-1800	618.8	923.8	1183.2	-10.7	-584.6	-60.6	699.2	1043.9	1337.1	-12.0	-660.6	-68.5	119	26.5
1	TMI_1-2160	739.5	1070.8	1398.9	-11.8	-693.3	-71.9	835.7	1210.0	1580.7	-13.3	-783.4	-81.3	129	31.8
1	TMI_1-2520	867.2	1226.3	1625.5	-12.9	-807.8	-83.8	980.0	1385.8	1836.9	-14.6	-912.8	-94.7	139	37.1
1	TMI_1-2880	1001.9	1390.4	1862.2	-14.1	-928.2	-96.2	1132.1	1571.1	2104.3	-15.9	-1048.9	-108.7	149	42.4
1	TMI_1-3240	1117.0	1529.4	2066.8	-15.0	-1032.0	-106.7	1262.2	1728.3	2335.5	-17.0	-1166.2	-120.6	159	47.7

1	TMI_1-3600	1225.7	1661.5	2263.5	-16.1	-1130.3	-117.0	1385.1	1877.5	2557.7	-18.1	-1277.2	-132.2	169	53.0
1	TMI_1-3960	1334.5	1792.5	2460.1	-17.1	-1228.5	-127.4	1508.0	2025.6	2780.0	-19.3	-1388.2	-144.0	179	58.3
1	TMI_1-4320	1442.3	1922.6	2654.8	-18.1	-1326.7	-137.6	1629.8	2172.5	2999.9	-20.5	-1499.2	-155.5	189	63.6
1	TMI_1-4680	1550.1	2052.6	2849.4	-19.2	-1423.9	-147.9	1751.6	2319.5	3219.9	-21.7	-1609.1	-167.2	199	68.9
1	TMI_1-5040	1698.8	2236.7	3112.1	-20.6	-1556.2	-161.9	1919.7	2527.4	3516.7	-23.2	-1758.5	-183.0	209	74.2
1	TMI_1-5400	1865.6	2440.7	3396.7	-21.8	-1703.4	-176.6	2108.2	2758.0	3838.3	-24.7	-1924.8	-199.6	219	79.5
1	TMI_1-5760	2038.4	2654.8	3692.4	-23.1	-1856.6	-191.9	2303.4	2999.9	4172.4	-26.1	-2098.0	-216.9	229	84.8
1	TMI_1-6120	2219.2	2876.8	3998.0	-24.4	-2015.8	-207.6	2507.7	3250.8	4517.8	-27.6	-2277.9	-234.6	239	90.1
1	TMI_1-6480	2405.9	3107.9	4314.7	-25.7	-2180.1	-224.0	2718.7	3511.9	4875.6	-29.1	-2463.5	-253.1	249	95.4
1	TMI_1-6840	2566.7	3302.9	4585.3	-26.6	-2322.3	-237.6	2900.4	3732.3	5181.4	-30.1	-2624.2	-268.4	259	100.7
1	TMI_1-7200	2726.5	3500.0	4856.0	-27.8	-2462.5	-251.4	3080.9	3955.0	5487.3	-31.4	-2782.7	-284.0	269	106.0
1	TMI_1-7560	2889.3	3701.0	5131.6	-28.9	-2606.7	-265.4	3264.9	4182.2	5798.7	-32.6	-2945.6	-299.9	279	111.3
1	TMI_1-7920	3055.0	3906.1	5411.3	-30.0	-2752.0	-279.5	3452.2	4413.9	6114.7	-33.9	-3109.7	-315.8	289	116.6
1	TMI_1-8280	3222.8	4114.1	5694.9	-31.1	-2900.2	-293.8	3641.8	4649.0	6435.3	-35.2	-3277.2	-332.0	299	121.9
1	TMI_1-8640	3404.6	4346.2	6007.6	-32.7	-3061.4	-310.0	3847.2	4911.2	6788.6	-37.0	-3459.4	-350.3	309	127.2
1	TMI_1-9000	3584.4	4565.2	6313.2	-34.1	-3219.7	-326.1	4050.3	5158.7	7133.9	-38.5	-3638.2	-368.5	319	132.5
1	TMI_1-9360	3767.1	4788.3	6624.9	-35.4	-3379.9	-342.4	4256.9	5410.7	7486.1	-40.0	-3819.3	-386.9	329	137.8
1	TMI_1-9720	3952.9	5015.3	6940.5	-36.8	-3544.1	-359.0	4466.8	5667.3	7842.8	-41.6	-4004.8	-405.6	339	143.1
1	TMI_1-10080	4141.7	5245.4	7262.2	-38.3	-3710.3	-375.9	4680.1	5927.3	8206.2	-43.2	-4192.7	-424.7	349	148.4
1	TMI_1-10440	4321.5	5457.4	7557.8	-39.1	-3865.6	-391.0	4883.3	6166.9	8540.3	-44.2	-4368.1	-441.8	359	153.7
1	TMI_1-10800	4510.2	5692.5	7872.5	-40.3	-4030.8	-406.8	5096.6	6432.5	8895.9	-45.6	-4554.8	-459.7	369	159.0
1	TMI_1-10800	4409.3	6036.8	7550.0	-43.0	-3885.0	-409.9	4982.5	6821.5	8531.5	-48.5	-4390.1	-463.2	369	216.0
1	TMI_1-10800	4409.3	6036.8	7550.0	-43.0	-3885.0	-409.9	4982.5	6821.5	8531.5	-48.5	-4390.1	-463.2	369	216.0
1	TMI_1-10818	3459.1	3308.7	4953.4	4.2	-2849.3	-318.9	3908.8	3738.9	5597.4	4.8	-3219.7	-360.4	362	217.3
1	TMI_1-10836	3170.9	2561.7	4229.8	21.3	-2548.6	-259.2	3583.2	2894.8	4779.7	24.1	-2879.9	-292.9	353	218.6
1	TMI_1-10860	3054.0	2241.9	3932.4	39.9	-2440.3	-190.2	3451.1	2533.4	4443.6	45.1	-2757.5	-214.9	343	220.3
1	TMI_1-10884	2999.1	2081.2	3810.8	58.1	-2411.9	-132.6	3389.0	2351.7	4306.2	65.6	-2725.5	-149.8	333	222.0
1	TMI_1-10908	2971.2	1976.4	3759.4	75.3	-2413.7	-82.7	3357.5	2233.3	4248.1	85.1	-2727.4	-93.4	323	223.7
1	TMI_1-10932	2947.3	1900.6	3728.9	90.8	-2418.4	-38.7	3330.5	2147.6	4213.7	102.6	-2732.7	-43.7	314	225.4
1	TMI_1-10956	2921.4	1870.1	3705.5	103.1	-2415.1	-0.9	3301.2	2113.2	4187.2	116.6	-2729.0	-1.0	306	227.2
1	TMI_1-10980	2870.5	1825.3	3689.1	113.9	-2406.8	30.0	3243.7	2062.6	4168.6	128.7	-2719.7	33.9	298	228.9
1	TMI_1-11004	2846.6	1748.0	3679.6	125.1	-2406.5	57.5	3216.7	1975.2	4158.0	141.4	-2719.3	64.9	291	230.6
1	TMI_1-11028	2825.7	1691.8	3679.0	134.7	-2407.1	82.4	3193.0	1911.7	4157.3	152.2	-2720.1	93.1	283	232.3
1	TMI_1-11052	2806.8	1651.4	3687.6	143.2	-2411.8	104.9	3171.7	1866.1	4167.0	161.9	-2725.4	118.6	277	234.0
1	TMI_1-11076	2789.9	1619.0	3701.1	151.1	-2417.5	125.7	3152.6	1829.5	4182.3	170.7	-2731.8	142.1	270	235.7
1	TMI_1-11100	2773.0	1586.2	3712.7	158.2	-2420.3	144.9	3133.5	1792.4	4195.4	178.7	-2734.9	163.8	264	237.5
1	TMI_1-11124	2752.1	1544.9	3714.3	164.5	-2418.0	162.7	3109.9	1745.7	4197.1	185.9	-2732.3	183.9	259	239.2
1	TMI_1-11148	2720.2	1473.8	3684.8	170.7	-2420.7	179.1	3073.8	1665.4	4163.9	192.9	-2735.4	202.4	253	240.9
1	TMI_1-11172	2712.3	1459.6	3678.2	175.0	-2408.3	194.3	3064.9	1649.4	4156.4	197.8	-2721.4	219.6	248	242.6
1	TMI_1-11196	2680.4	1447.7	3653.8	177.7	-2390.0	207.6	3028.8	1635.9	4128.8	200.7	-2700.7	234.6	243	244.3
1	TMI_1-11220	2637.5	1426.1	3616.4	179.4	-2366.7	218.9	2980.3	1611.5	4086.5	202.7	-2674.4	247.4	238	246.0
1	TMI_1-11244	2591.6	1400.2	3572.0	180.5	-2338.5	228.6	2928.5	1582.2	4036.3	204.0	-2642.5	258.4	233	247.8
1	TMI_1-11268	2542.7	1370.1	3520.5	181.0	-2305.2	236.7	2873.2	1548.2	3978.2	204.5	-2604.8	267.5	229	249.5
1	TMI_1-11292	2491.8	1338.5	3466.1	180.9	-2268.9	243.5	2815.7	1512.5	3916.7	204.5	-2563.8	275.2	225	251.2
1	TMI_1-11316	2438.8	1306.4	3407.5	180.4	-2229.5	248.9	2755.9	1476.3	3850.4	203.8	-2519.3	281.3	221	252.9
1	TMI_1-11340	2384.0	1275.5	3349.0	179.3	-2188.2	253.3	2693.9	1441.3	3784.4	202.6	-2472.7	286.2	217	254.6
1	TMI_1-11364	2330.1	1246.4	3289.6	177.8	-2146.9	256.4	2633.0	1408.4	3717.2	200.9	-2426.0	289.7	213	256.3
1	TMI_1-11388	2275.2	1220.0	3232.2	176.0	-2105.6	258.6	2570.9	1378.6	3652.4	198.9	-2379.4	292.2	210	258.1
1	TMI_1-11412	2224.3	1200.3	3177.7	173.7	-2063.3	259.7	2513.4	1356.3	3590.8	196.3	-2331.6	293.4	206	259.8
1	TMI_1-11436	2177.4	1193.9	3138.3	171.1	-2018.1	260.1	2460.4	1349.1	3546.3	193.3	-2280.4	293.9	203	261.5
1	TMI_1-11460	2120.4	1168.7	3085.7	168.6	-1976.7	259.6	2396.1	1320.6	3486.8	190.5	-2233.7	293.3	200	263.2
1	TMI_1-11484	2061.5	1130.3	3028.2	166.2	-1939.4	258.6	2329.5	1277.2	3421.9	187.8	-2191.5	292.2	197	264.9
1	TMI_1-11508	2014.6	1102.7	2981.8	163.8	-1902.1	257.2	2276.5	1246.0	3369.4	185.1	-2149.4	290.6	194	266.6
1	TMI_1-11532	1972.7	1080.4	2937.4	161.3	-1865.8	255.5	2229.2	1220.8	3319.3	182.3	-2108.4	288.7	191	268.4
1	TMI_1-11556	1931.8	1061.5	2895.0	158.7	-1831.5	253.3	2183.0	1199.4	3271.3	179.3	-2069.6	286.2	189	270.1
1	TMI_1-11580	1893.0	1045.8	2855.5	155.9	-1798.2	250.8	2139.0	1181.8	3226.7	176.1	-2032.0	283.4	186	271.8
2	TMI_2-11604	1856.0	1033.7	2817.9	153.0	-1765.9	247.9	2097.3	1168.1	3184.3	172.9	-1995.5	280.1	184	273.5
2	TMI_2-11628	1820.1	1024.6	2782.5	150.0	-1735.6	244.7	2056.7	1157.8	3144.2	169.5	-1961.2	276.5	181	275.2
2	TMI_2-11652	1786.2	1018.2	2749.0	146.9	-1707.3	241.2	2018.4	1150.5	3106.4	166.0	-1929.2	272.5	179	276.9
2	TMI_2-11676	1754.3	1014.8	2718.6	143.9	-1679.0	237.4	1982.4	1146.8	3072.1	162.6	-1897.3	268.2	177	278.7
2	TMI_2-11700	1723.4	1013.7	2689.2	140.6	-1653.7	233.4	1947.5	1145.5	3038.8	158.9	-1868.7	263.7	175	280.4
2	TMI_2-11724	1693.5	1014.6	2661.7	137.4	-1628.4	229.2	1913.7	1146.5	3007.8	155.3	-1840.1	259.0	173	282.1
2	TMI_2-11748	1665.6	1017.7	2635.1	134.1	-1604.1	224.8	1882.1	1150.0	2977.7	151.6	-1812.6	254.0	171	283.8
2	TMI_2-11772	1638.7	1022.3	2610.7	130.7	-1580.8	220.3	1851.7	1155.2	2950.1	147.7	-1786.3	248.9	169	285.5
2	TMI_2-11796	1612.8	1028.3	2586.3	127.5	-1558.5	215.6	1822.5	1161.9	2922.5	144.0	-1761.1	243.6	168	287.2
2	TMI_2-11820	1586.9	1036.0	2563.9	124.1	-1537.2	210.9	1793.2	1170.7	2897.2	140.2	-1737.0	238.3	166	289.0
2	TMI_2-11844	1563.0	1044.5	2541.4	120.8	-1515.9	206.0	1766.2	1180.3	2871.8	136.5	-1713.0	232.8	164	290.7
2	TMI_2-11868	1540.1	1054.0	2520.0	117.4	-1495.6	201.1	1740.3	1191.0	2847.6	132.7	-1690.1	227.2	163	292.4
2	TMI_2-11892	1517.2	1064.3	2499.4	114.0	-1476.3	196.1	1714.4	1202.6	2824.3	128.9	-1668.2	221.6	161	294.1
2	TMI_2-11916	1495.3	1074.9	2479.9	110.8	-1457.0	191.0	1689.7	1214.7	2802.3	125.2	-1646.4	215.8	160	295.8
2	TMI_2-11940	1474.4	1086.3	2460.5	107.5	-1438.7	185.9	1666.1	1227.6	2780.3	121.5	-1625.7	210.1	159	297.5
2	TMI_2-11964	1453.5	1098.5	2442.1	104.2	-1420.4	180.8	1642.4	1241.3	2759.6	117.7	-1605.0	204.3	157	299.3
2	TMI_2-11988	1433.6	1110.6	2423.6	100.9	-1403.1	175.7	1620.0	1255.0	2738.7	114.0	-1585.5	198.5	156	301.0
2	TMI_2-12012	1413.7	1123.3	2406.2	97.7	-1385.8	170.5	1597.5	1269.3	2719.0	110.4	-1566.0	192.7	155	302.7
2	TMI_2-12036	1394.8	1135.3	2388.6	94.7	-1370.5	165.4	1576.1	1282.9	2699.1	107.0	-1548.6	186.9	154	304.4
2	TMI_2-12060	1374.9	1145.9	2369.1	91.6	-1355.2	160.2	1553.6	1294.9	2677.1	103.5	-1531.3	181.0	153	306.1
2	TMI_2-12084	1356.0	1156.6	2349.7	88.5	-1339.9	155.0	1532.2	1307.0	2655.2	100.0	-1514.0	175.2	152	307.8
2	TMI_2-12108	1340.1	1171.7	2334.3	85.5	-1325.6	149.9	1514.3	1324.0	2637.8	96.6	-1497.9	169.4	151	309.6
2	TMI_2-12132	1326.2	1189.7	2321.9	82.5	-1310.3	144.9	1498.6	1344.3	2623.7	93.2	-1480.6	163.8	150	311.3
2	TMI_2-12156	1312.3	1208.8	2309.4	79.4	-1296.0	139.8	1482.9	1365.9	2609.6	89.8	-1464.5	158.0	149	313.0
2	TMI_2-12180	1298.3	1227.4	2296.8	76.5	-1281.6	134.7	1467.1	1387.0	2595.4	86.4	-1448.3	152.2	148	314.7
2	TMI_2-12204	1282.5	1244.9	2283.4	73.5	-1268.3	129.7	1449.2	1406.8	2580.2	83.1	-1433.2	146.6	147	316.4
2	TMI_2-12222	1271.3	1257.9	2272.8	71.3	-1258.5	125.9	1436.5	1421.4	2568.3	80.6	-1422.1	142.3	147	317.7
2	TMI_2-12240	1260.1	1270.8	2263.2	69.2	-1248.7	122.3	1423.9	1436.0	2557.5	78.2	-1411.0	138.2	146	319.0
2	TMI_2-12240	1260.1	1270.8	2263.2	69.2	-1248.7	122.3	1423.9	1436.0	2557.5	78.2	-1411.0	138.2	146	319.0
2	TMI_2-12240	1260.1	1270.7	2263.2	69.2	-1248.7	122.3	1423.9	1435.9	2557.5	78.2	-1411.0	138.2	146	319.0
2	TMI_2-12430	75.5	1056.4	261.7	21.6	-86.8	39.8	85.3	-97.6	295.7	24.4	-75.5	45.0	124	343.1
2	TMI_2-12620	405.8	1688.7	1159.0	-8.4	-444.5	-33.0	458.6	1193.7	1309.7	-9.5	-502.3	-37.3	122	367.1
2	TMI_2-12810	648.0	1688.7	1688.1	-21.2	-700.7	-69.1	732.3	1599.2	1907.6	-23.9	-791.7	-78.1	125	391.2
2	TMI_2-13024	831.3	2110.2	2057.9	-27.9	-887.3	-90.3	939.3	2384.6	2325.5	-31.6	-1002.7	-102.0	131	418.2
2	TMI_2-13238	968.6	2404.1	2331.8	-31.8	-1024.6	-104.0	1094.5	2716.6	2634.9	-35.9	-1157.7	-117.5	136	445.3
2	TMI_2-13453	1083.8	2639.0	2563.0	-34.4	-1138.3	-114.8	1224.7	2982.1	2896.2	-38.9	-1286.3	-129.8	142	472.5
2	TMI_2-13667	1188.7	2846.6	2775.8	-36.6	-1241.4	-124.6	1343.2	3216.6	3136.7	-41.4	-1402.8	-140.7	148	499.6
2	TMI_2-13881	1281.3	3031.1	2965.8	-38.4	-1333.0	-132.9	1447.9	3425.1	3351.4	-43.4	-1506.3	-150.2	154	526.7
2	TMI_2-14096	1361.3	3196.9	3139.0	-40.2	-1413.4	-140.5	1538.3	3612.5	3547.1	-45.4	-1597.2	-158.8	160	553.9
2	TMI_2-14286	1431.0	3340.0	3289.6	-41.7	-1483.0	-147.3	1617.0	3774.2	3717.3	-47.2	-1675.8	-166.5	165	578.0
2	TMI_2-14476	1499.6	3480.7	3439.2	-43.3	-1551.9	-154.0	1694.5	3933.2	3886.3	-48.9	-1753.6	-174.0	171	602.0
2	TMI_2-14665	1567.2	3620.4	3587.7	-44.8	-1620.1	-160.7	1771.0	4091.1	4054.1	-50.6	-1830.7	-181.6	176	626.0
2	TMI_2-14855	1634.8	3760.2	3735.1	-46.3	-1688.2	-167.3	1847.3	4249.0	4220.7	-52.4	-1907.7	-189.1	181	650.0
2	TMI_2-15045	1702.5	3899.3	3882.9	-47.9	-1755.5	-173.9	1923.8	4406.2	4387.7	-54.1	-1983.7	-196.5	186	674.1
2	TMI_2-15235	1769.1	4037.0	4029.4	-49.4	-1822.7	-180.5	1999.1	4561.8	4553.3	-55.8	-2059.7	-204.0	192	698.1
2	TMI_2-15425	1835.8	4176.0	4177.2	-50.9	-1891.0	-187.2	2074.4	4718.9	4720.2	-57.5	-2136.9	-211.5	197	722.2
2	TMI_2-15615	1908.4	4322.7	4335.7	-52.6	-1962.3	-194.6	2156.5	4884.7	4899.4	-59.5	-2217.3	-219.9	202	746.2
2	TMI_2-15805	2002.0	4492.8	4523.3	-54.3	-2052.5	-203.4	2262.3	5076.9	5111.4	-61.4	-2319.3	-229.9	208	770.3
2	TMI_2-15995	2097.6	4668.6	4714.9	-55.9	-2144.7	-212.3	2370.3	5275.5	5327.8	-63.2	-2423.5	-239.9	213	794.3
2	TMI_2-16185	2196.3	4846.6	4910.6	-57.6	-2238.0	-221.3	2481.8	5476.7	5549.0	-65.1	-2528.9	-250.0	218	818.4
2	TMI_2-16375	2296.9	5026.3	5108.2	-59.2	-2334.2	-230.4	2595.5	5679.8	5772.2	-66.9	-2637.7	-260.4	223	842.4
2	TMI_2-16564	2398.5	5208.8	5308.4	-60.9	-2430.3	-239.7	2710.3	5885.9	5998.4	-68.8	-2746.2	-270.9	229	866.3
2	TMI_2-16754	2503.2	5394.8	5513.1	-62.5	-2529.6	-249.2	2828.6	6096.2	6229.8	-70.6	-2858.4	-281.6	234	890.4
2	TMI_2-16944	2608.8	5582.6	5719.7	-64.2	-2629.8	-258.7	2947.9	6308.3	6463.2	-72.5	-2971.7	-292.4	239	914.4
2	TMI_2-17134	2716.4	5773.7	5929.3	-65.8	-2732.0	-268.4	3069.5	6524.2	6700.1	-74.4	-3087.2	-303.3	244	938.5
2	TMI_2-17324	2827.0	5962.4	6139.8	-67.4	-2836.2	-278.2	3194.5	6737.5	6938.0	-76.1	-3205.0	-314.4	250	962.5
2	TMI_2-17514	2921.7	6136.4	6327.6	-68.8	-2926.5	-286.4	3301.5	6934.2	7150.1	-77.8	-3307.0	-323.6	255	986.6
2	TMI_2-17704	3015.3	6309.2	6513.1	-70.4	-3015.8	-294.7	3407.3	7129.4	7359.8	-79.5	-3407.8	-333.1	260	1010.6
2	TMI_2-17894	3110.0	6482.2	6699.8	-72.0	-3106.0	-303.2	3514.3	7324.9	7570.8	-81.3	-3509.8	-342.6	266	1034.7
2	TMI_2-18084	3204.6	6656.0	6887.2	-73.5	-3196.2	-311.7	3621.2	7521.3	7782.6	-83.1	-3611.7	-352.2	271	1058.7
2	TMI_2-18274	3300.3	6832.0	7077.0	-75.1	-3288.5	-320.3	3729.3	7720.2	7997.0	-84.8	-3716.0	-361.9	276	1082.8
2	TMI_2-18463	3396.8	7007.4	7267.3	-76.6	-3380.6	-328.8	3838.4	7918.4	8212.1	-86.6	-3820.1	-371.6	281	1106.7
2	TMI_2-18653	3494.5	7185.5	7458.9	-78.2	-3472.9	-337.5	3948.7	8119.7	8428.6	-88.4	-3924.3	-381.4	287	1130.8
2	TMI_2-18843	3593.1	7364.3	7651.5	-79.8	-3566.1	-346.2	4060.2	8321.6	8646.2	-90.2	-4029.7	-391.2	292	1154.8
2	TMI_2-19033	3691.8	7543.3	7845.2	-81.3	-3660.4	-355.0	4171.7	8523.9	8865.1	-91.9	-4136.2	-401.1	297	1178.9
2	TMI_2-19223	3797.4	7739.0	8055.8	-83.4	-3761.6	-364.9	4291.0	8745.1	9103.0	-94.2	-4250.6	-412.4	303	1202.9
2	TMI_2-19413	3902.0	7925.1	8260.4	-85.0	-3860.8	-374.3	4409.3	8955.4	9334.2	-96.0	-4362.7	-423.0	308	1227.0
2	TMI_2-19603	4006.6	8109.9	8464.9	-86.7	-3960.0	-383.9	4527.5	9164.1	9565.4	-97.9	-4474.9	-433.8	313	1251.0
2	TMI_2-19793	4111.3	8294.9	8670.7	-88.4	-4059.3	-393.6	4645.8	9373.2	9797.9	-99.8	-4587.1	-444.7	318	1275.1
2	TMI_2-19983	4216.9	8481.6	8878.2	-90.1	-4159.6	-403.3	4765.1	9584.2	10032.4	-101.8	-4700.3	-455.8	324	1299.1
2	TMI_2-20173	4324.6	8669.7	9087.0	-91.8	-4260.8	-413.2	4886.8	9796.7	10268.3	-103.7	-4814.8	-466.9	329	1323.2
2	TMI_2-20362	4432.1	8858.1	9297.2	-93.5	-4361.9	-423.1	5008.3	10009.7	10505.8	-105.6	-4929.0	-478.1	334	1347.1
2	TMI_2-20552	4540.8	9047.9	9508.7	-95.2	-4465.1	-433.0	5131.1	10224.1	10744.8	-107.5	-5045.6	-489.3	340	1371.1
2	TMI_2-20742	4650.4	9238.9	9721.5	-96.9	-4568.4	-443.1	5255.0	10440.0	10985.2	-109.5	-5162.3	-500.7	345	1395.2
2	TMI_2-20932	4760.0	9423.7	9930.9	-98.3	-4671.6	-452.9	5378.8	10648.8	11221.9	-111.1	-5278.9	-511.8	350	1419.2
2	TMI_2-21122	4861.7	9601.7	10127.6	-99.8	-4765.9	-462.0	5493.7	10850.0	11444.2	-112.8	-5385.5	-522.0	355	1443.3
2	TMI_2-21312	4970.3	9793.4	10336.2	-101.4	-4868.1	-471.4	5616.5	11066.6	11679.9	-114.6	-5501.0	-532.7	361	1467.3
2	TMI_2-21502	5080.0	9986.5	10545.9	-103.0	-4971.4	-480.9	5740.4	11284.7	11916.9	-116.4	-5617.7	-543.4	366	1491.4
2	TMI_2-21692	5190.6	10181.2	10756.4	-104.6	-5074.6	-490.5	5865.4	11504.8	12154.8	-118.2	-5734.3	-554.3	371	1515.4
2	TMI_2-21882	5302.2	10376.3	10968.1	-106.2	-5178.8	-500.1	5991.5	11725.2	12393.9	-120.0	-5852.1	-565.1	376	1539.5
2	TMI_2-22072	5413.9	10572.0	11180.6	-107.8	-5284.1	-509.7	6117.7	11946.4	12634.1	-121.8	-5971.0	-576.0	382	1563.5
2	TMI_2-22261	5526.5	10768.8	11394.1	-109.4	-5389.3	-519.4	6244.9	12168.7	12875.4	-123.6	-6089.9	-586.9	387	1587.5
2	TMI_2-22451	5640.1	10967.5	11609.5	-111.0	-5495.4	-529.1	6373.3	12393.3	13118.8	-125.4	-6209.8	-597.9	392	1611.5
2	TMI_2-22641	5754.7	11166.6	11825.3	-112.6	-5602.7	-539.0	6502.9	12618.3	13362.6	-127.2	-6331.1	-609.0	398	1635.6
2	TMI_2-22831	5864.4	11363.3	12035.8	-114.2	-5706.9	-548.2	6626.7	12840.6	13600.5	-129.0	-6448.8	-619.5	403	1659.6
2	TMI_2-23021	5952.0	11529.4	12211.6	-115.7	-5791.2	-555.9	6725.8	13028.2	13799.1	-130.7	-6544.1	-628.2	408	1683.7
2	TMI_2-23211	6038.7	11692.1	12387.1	-117.2	-5874.5	-563.9	6823.7	13212.1	13997.5	-132.5	-6638.1	-637.2	413	1707.7
2	TMI_2-23401	6124.3	11855.2	12562.7	-118.8	-5957.7	-571.8	6920.5	13396.4	14195.9	-134.2	-6732.2	-646.1	419	1731.8
2	TMI_2-23591	6209.9	12017.9	12737.3	-120.4	-6040.9	-579.7	7017.2	13580.2	14393.1	-136.0	-6826.2	-655.1	424	1755.8
2	TMI_2-23781	6296.6	12181.0	12913.0	-121.9	-6124.2	-587.7	7115.1	13764.5	14591.7	-137.8	-6920.3	-664.1	429	1779.9
2	TMI_2-23971	6382.2	12342.7	13087.6	-123.5	-6207.4	-595.6	7211.9	13947.2	14789.0	-139.6	-7014.4	-673.0	435	1803.9
2	TMI_2-24160	6467.7	12505.1	13261.8	-125.1	-6290.5	-603.4	7308.6	14130.8	14985.8	-141.3	-7108.3	-681.9	440	1827.8
2	TMI_2-24350	6553.4	12667.2	13435.5	-126.6	-6373.8	-611.3	7405.4	14313.9	15182.1	-143.1	-7202.4	-690.8	445	1851.9
2	TMI_2-24540	6638.0	12828.9	13610.1	-128.2	-6456.0	-619.2	7501.0	14496.7	15379.4	-144.9	-7295.3	-699.7	450	1875.9
2	TMI_2-24730	6747.7	13014.0	13823.7	-129.9	-6558.2	-629.9	7624.9	14705.8	15620.7	-146.8	-7410.8	-711.7	456	1900.0
2	TMI_2-24920	6869.3	13219.7	14055.2	-131.7	-6671.4	-640.8	7762.3	14938.3	15882.4	-148.8	-7538.7	-724.1	461	1924.0
2	TMI_2-25110	6992.0	13426.8	14288.0	-133.4	-6785.7	-651.8	7900.9	15172.3	16145.4	-150.8	-7667.9	-736.6	466	1948.1
2	TMI_2-25300	7114.6	13634.5	14521.5	-135.2	-6901.0	-662.9	8039.5	15407.0	16409.3	-152.7	-7798.1	-749.1	471	1972.1
2	TMI_2-25490	7239.3	13843.6	14758.3	-136.9	-7016.3	-674.1	8180.4	15643.2	16676.8	-154.7	-7928.4	-761.7	477	1996.2

2	TMI_2-25680	7363.8	14053.3	14995.6	-138.7	-7132.4	-685.2	8321.2	15080.3	16945.1	-156.7	-8059.6	-774.3	482	2020.2
2	TMI_2-25870	7488.5	14264.4	15233.4	-140.4	-7248.7	-696.5	8462.0	16118.8	17213.7	-158.7	-8191.0	-787.1	487	2044.3
2	TMI_2-26059	7615.1	14475.8	15470.7	-142.2	-7366.8	-707.9	8605.1	16357.6	17481.9	-160.7	-8324.5	-799.9	493	2068.2
2	TMI_2-26249	7741.7	14687.9	15708.3	-144.0	-7484.1	-719.3	8748.2	16597.3	17750.4	-162.7	-8457.0	-812.8	498	2092.3
2	TMI_2-26439	7869.4	14902.6	15945.8	-145.7	-7602.1	-730.4	8892.4	16839.9	18018.9	-164.6	-8590.6	-825.4	503	2116.3
2	TMI_2-26629	7996.0	15117.7	16183.6	-147.3	-7719.6	-741.1	9035.5	17083.0	18287.5	-166.4	-8723.1	-837.4	508	2140.4
2	TMI_2-26819	8124.6	15333.4	16421.2	-148.9	-7837.8	-751.9	9180.9	17326.7	18555.9	-168.3	-8856.7	-849.6	514	2164.4
2	TMI_2-27009	8252.3	15550.5	16648.8	-150.5	-7956.0	-762.7	9325.1	17572.0	18813.1	-170.1	-8990.3	-861.8	519	2188.5
2	TMI_2-27199	8381.9	15767.2	16886.3	-152.1	-8074.2	-773.4	9471.6	17816.9	19061.6	-171.9	-9123.9	-874.0	524	2212.5
2	TMI_2-27315	8461.3	15901.6	17041.7	-153.1	-8148.3	-780.1	9561.2	17968.8	19257.1	-173.0	-9207.6	-881.5	528	2227.2
2	TMI_2-27432	8541.6	16036.3	17187.0	-154.1	-8221.3	-786.8	9652.1	18121.0	19421.4	-174.2	-9290.1	-889.1	531	2242.0
2	TMI_2-27432	8541.6	16036.3	17187.0	-154.1	-8221.3	-786.8	9652.1	18121.0	19421.4	-174.2	-9290.1	-889.1	531	2242.0
2	TMI_2-27432	8541.6	16036.3	17187.0	-154.1	-8221.3	-786.8	9652.1	18121.0	19421.4	-174.2	-9290.1	-889.1	531	2242.0
2	TMI_2-27498	8626.6	16172.1	17340.4	-154.7	-8301.8	-791.8	9748.1	18274.4	19594.7	-174.8	-9381.0	-894.7	533	2242.0
2	TMI_2-27564	8680.6	16233.9	17413.8	-154.8	-8347.2	-795.8	9809.1	18344.3	19677.6	-174.9	-9432.3	-899.3	536	2242.0
2	TMI_2-27638	8739.7	16303.5	17507.6	-155.0	-8397.8	-800.5	9875.9	18422.9	19783.6	-175.2	-9489.6	-904.6	538	2242.0
2	TMI_2-27708	8795.7	16370.2	17601.1	-155.3	-8446.3	-804.9	9939.2	18498.3	19889.3	-175.5	-9544.4	-909.5	541	2242.0
2	TMI_2-27774	8848.7	16432.0	17684.5	-155.5	-8490.8	-809.1	9999.1	18568.1	19983.5	-175.7	-9594.6	-914.3	543	2242.0
2	TMI_2-27840	8900.7	16494.8	17767.9	-155.7	-8536.2	-813.3	10057.8	18639.1	20077.7	-176.0	-9645.9	-919.0	545	2242.0
2	TMI_2-27906	8953.7	16557.6	17851.2	-156.0	-8581.7	-817.5	10117.7	18710.0	20171.9	-176.2	-9697.3	-923.8	547	2242.0
2	TMI_2-27972	9005.7	16610.3	17924.6	-155.9	-8625.1	-821.5	10176.4	18769.7	20254.8	-176.2	-9746.4	-928.3	550	2242.0
2	TMI_2-28032	9037.6	16648.2	17977.7	-155.8	-8652.4	-822.9	10212.4	18812.5	20314.8	-176.0	-9777.2	-929.9	552	2242.0
2	TMI_2-28092	9055.5	16671.1	18000.7	-155.7	-8668.8	-823.9	10232.7	18838.4	20340.8	-176.0	-9795.7	-931.0	554	2242.0
2	TMI_2-28152	9002.5	16518.1	17860.7	-152.8	-8609.8	-818.0	10172.8	18665.5	20182.6	-172.7	-9729.0	-924.3	554.6	2242.0
2	TMI_2-28212	8971.5	16436.8	17790.0	-151.4	-8575.8	-814.3	10137.7	18572.8	20103.5	-171.1	-9690.6	-920.2	554.8	2242.0
2	TMI_2-28287	8949.5	16382.1	17750.7	-150.5	-8551.8	-812.0	10112.9	18511.8	20058.3	-170.0	-9663.5	-917.6	554.9	2242.0
2	TMI_2-28362	8935.5	16351.1	17720.7	-150.0	-8537.8	-810.8	10097.1	18476.6	20024.4	-169.5	-9647.7	-916.2	555.0	2242.0
2	TMI_2-28437	8926.5	16331.1	17710.7	-149.7	-8528.8	-810.2	10086.9	18454.2	20013.1	-169.2	-9637.5	-915.5	555.0	2242.0
2	TMI_2-28512	8921.5	16318.1	17700.7	-149.6	-8523.8	-809.9	10081.2	18439.5	20001.8	-169.1	-9631.8	-915.2	555.0	2242.0
2	TMI_2-28587	8917.5	16310.1	17700.7	-149.5	-8519.8	-809.7	10076.7	18430.4	20001.8	-169.0	-9627.3	-915.0	555.0	2242.0
2	TMI_2-28640	8915.5	16306.1	17690.7	-149.5	-8517.8	-809.7	10074.5	18425.9	19990.5	-168.9	-9625.1	-915.0	555.0	2242.0
2	TMI_2-28692	8914.5	16303.1	17690.7	-149.5	-8516.8	-809.6	10073.3	18422.5	19990.5	-168.9	-9623.9	-914.9	555.0	2242.0
2	TMI_2-31692	8910.5	16293.1	17690.7	-149.5	-8511.8	-809.6	10068.8	18411.2	19990.5	-168.9	-9619.4	-914.9	555.0	2242.0
3	TMI_3-0	10578.5	14224.2	23422.4	-149.5	-10967.7	-809.7	11953.7	16073.4	26467.3	-168.9	-12393.5	-915.0	555.0	2242.0
3	TMI_3-270	10442.9	13819.6	23072.0	-143.2	-10816.6	-794.8	11800.5	15616.2	26071.4	-161.8	-12222.8	-898.1	549.3	2191.4
3	TMI_3-540	10260.3	13442.7	22711.4	-139.3	-10640.5	-778.2	11594.2	15190.2	25663.9	-157.4	-12023.8	-879.4	543.0	2140.7
3	TMI_3-810	10086.8	13089.7	22370.9	-136.1	-10473.4	-763.2	11398.1	14791.4	25279.2	-153.8	-11835.0	-862.4	536.7	2090.0
3	TMI_3-1080	9917.2	12746.1	22030.6	-133.0	-10311.4	-748.6	11206.5	14403.1	24894.6	-150.3	-11651.9	-846.0	530.3	2039.4
3	TMI_3-1350	9749.7	12407.5	21700.2	-130.0	-10151.4	-734.1	11017.2	14020.5	24521.3	-146.9	-11471.0	-829.6	523.9	1988.8
3	TMI_3-1620	9583.2	12070.5	21379.8	-127.1	-9993.3	-719.8	10829.0	13639.7	24159.2	-143.6	-11292.4	-813.4	517.6	1938.1
3	TMI_3-1890	9418.6	11734.6	21049.3	-124.1	-9835.2	-705.5	10643.0	13260.1	23785.7	-140.2	-11113.8	-797.3	511.2	1887.4
3	TMI_3-2160	9255.1	11400.9	20718.9	-121.1	-9678.2	-691.4	10458.2	12883.1	23412.4	-136.8	-10936.3	-781.2	504.8	1836.8
3	TMI_3-2430	9093.5	11069.3	20398.6	-118.1	-9522.2	-677.1	10275.7	12508.3	23050.5	-133.4	-10760.0	-765.1	498.4	1786.2
3	TMI_3-2700	8930.0	10739.4	20068.1	-114.9	-9364.1	-662.0	10090.9	12135.5	22677.0	-129.9	-10581.4	-748.0	492.1	1735.5
3	TMI_3-2970	8768.4	10409.4	19734.7	-111.8	-9208.0	-647.0	9908.3	11762.6	22300.2	-126.3	-10405.1	-731.1	485.7	1684.8
3	TMI_3-3240	8606.9	10081.7	19406.4	-108.7	-9052.0	-632.2	9725.8	11392.4	21929.3	-122.8	-10228.8	-714.4	479.3	1634.2
3	TMI_3-3510	8447.4	9756.1	19080.2	-105.5	-8897.0	-617.4	9545.6	11024.4	21560.6	-119.3	-10053.6	-697.6	472.9	1583.6
3	TMI_3-3780	8287.9	9430.1	18754.8	-102.4	-8743.0	-602.7	9365.3	10656.0	21192.9	-115.7	-9879.6	-681.0	466.6	1532.9
3	TMI_3-4050	8130.3	9106.1	18432.3	-99.3	-8589.9	-588.1	9187.3	10289.9	20828.5	-112.2	-9706.6	-664.5	460.2	1482.2
3	TMI_3-4320	7973.8	8784.5	18111.1	-96.2	-8436.9	-573.6	9010.4	9926.5	20465.5	-108.7	-9533.7	-648.2	453.8	1431.6
3	TMI_3-4590	7825.3	8466.8	17802.8	-93.1	-8290.9	-560.2	8842.6	9567.5	20117.2	-105.2	-9368.7	-633.0	447.5	1381.0
3	TMI_3-4860	7713.8	8197.6	17552.4	-90.3	-8176.9	-549.7	8716.9	9263.6	19834.2	-102.0	-9239.9	-621.2	441.1	1330.3
3	TMI_3-5130	7601.3	7929.8	17301.1	-87.4	-8062.9	-538.9	8589.5	8960.7	19550.2	-98.8	-9111.0	-609.0	434.7	1279.6
3	TMI_3-5400	7488.8	7662.2	17049.9	-84.5	-7947.9	-528.1	8462.3	8658.2	19266.4	-95.5	-8981.1	-596.8	428.3	1229.0
3	TMI_3-5670	7376.3	7394.5	16798.7	-81.6	-7832.9	-517.3	8335.2	8355.8	18982.5	-92.2	-8851.2	-584.6	422.0	1178.4
3	TMI_3-5940	7263.8	7125.5	16546.4	-78.7	-7718.9	-506.5	8208.1	8051.8	18697.4	-89.0	-8722.4	-572.4	415.6	1127.7
3	TMI_3-6210	7150.3	6857.5	16294.0	-75.8	-7603.9	-495.7	8079.8	7748.9	18412.2	-85.7	-8592.4	-560.2	409.2	1077.0
3	TMI_3-6480	7037.8	6588.8	16041.8	-72.9	-7488.9	-484.8	7952.7	7445.3	18127.3	-82.4	-8462.5	-547.9	402.8	1026.4
3	TMI_3-6750	6913.3	6310.1	15773.7	-70.0	-7366.0	-473.0	7812.1	7130.4	17824.2	-79.1	-8323.5	-534.4	396.5	975.8
3	TMI_3-7020	6765.8	5995.1	15470.3	-67.1	-7220.9	-459.9	7645.4	6774.4	17481.5	-75.8	-8159.7	-519.6	390.1	925.1
3	TMI_3-7290	6619.3	5682.0	15169.1	-64.1	-7078.9	-446.8	7479.8	6420.7	17141.0	-72.4	-7999.2	-504.8	383.7	874.4
3	TMI_3-7560	6473.8	5371.3	14868.9	-61.2	-6936.0	-433.9	7315.4	6069.6	16801.9	-69.1	-7837.7	-490.3	377.3	823.8
3	TMI_3-7830	6329.4	5061.7	14571.8	-58.2	-6795.1	-421.0	7152.2	5719.7	16466.1	-65.8	-7678.4	-475.7	371.0	773.2
3	TMI_3-8100	6185.9	4753.6	14275.6	-55.3	-6655.1	-408.1	6990.1	5371.6	16131.4	-62.4	-7520.3	-461.1	364.6	722.5
3	TMI_3-8370	6044.4	4445.9	13980.5	-52.3	-6516.2	-395.4	6830.2	5023.9	15797.9	-59.1	-7363.3	-446.8	358.2	671.9
3	TMI_3-8640	5902.9	4140.9	13687.2	-49.4	-6377.2	-382.7	6670.3	4679.2	15466.5	-55.8	-7206.2	-432.4	351.8	621.2
3	TMI_3-8910	5754.5	3819.2	13376.1	-46.1	-6231.3	-368.9	6502.6	4315.6	15115.0	-52.1	-7041.3	-416.9	345.5	570.6
3	TMI_3-9180	5613.0	3517.1	13078.8	-43.0	-6092.3	-355.5	6342.7	3974.3	14779.1	-48.6	-6884.3	-401.7	339.1	519.9
3	TMI_3-9450	5473.5	3216.0	12782.6	-40.0	-5954.3	-342.3	6185.1	3634.1	14444.4	-45.2	-6728.4	-386.8	332.7	469.2
3	TMI_3-9720	5334.1	2916.3	12489.6	-36.9	-5817.4	-329.1	6027.5	3295.4	14113.2	-41.7	-6573.7	-371.9	326.4	418.6
3	TMI_3-9990	5196.6	2618.6	12197.6	-33.9	-5681.5	-316.1	5872.2	2959.0	13783.2	-38.3	-6420.1	-357.2	320.0	368.0
3	TMI_3-10260	5061.2	2322.5	11908.4	-30.9	-5546.6	-303.2	5719.1	2624.4	13455.5	-34.9	-6267.6	-342.7	313.6	317.3
3	TMI_3-10530	4925.7	2027.8	11621.4	-27.9	-5413.7	-290.4	5566.1	2291.4	13132.2	-31.5	-6117.4	-328.2	307.2	266.7
3	TMI_3-10800	4792.2	1734.7	11336.2	-24.8	-5280.7	-277.7	5415.2	1960.2	12809.9	-28.1	-5967.2	-313.8	300.9	216.0
3	TMI_3-11340	4844.0	1919.0	11477.4	-28.7	-5344.4	-284.2	5473.7	2168.5	12969.4	-32.5	-6039.1	-321.2	299.1	216.0
3	TMI_3-11880	4839.8	1931.3	11473.6	-29.2	-5343.0	-283.9	5469.0	2182.4	12965.1	-32.9	-6037.6	-320.9	298.1	216.0
3	TMI_3-12420	4826.5	1917.6	11450.8	-29.2	-5330.7	-282.7	5454.0	2166.9	12939.4	-32.9	-6023.7	-319.5	297.1	216.0
3	TMI_3-12960	4810.3	1899.9	11425.0	-29.1	-5317.3	-281.3	5435.7	2146.8	12910.3	-32.9	-6008.6	-317.9	296.1	216.0
3	TMI_3-13500	4794.1	1880.2	11398.2	-29.0	-5303.0	-279.9	5417.3	2124.6	12880.0	-32.8	-5992.4	-316.3	295.1	216.0
3	TMI_3-14040	4777.9	1861.4	11371.4	-28.9	-5289.7	-278.5	5399.0	2103.4	12849.7	-32.7	-5977.3	-314.8	294.1	216.0
3	TMI_3-14580	4760.6	1841.7	11344.6	-28.8	-5275.3	-277.1	5379.5	2081.1	12819.4	-32.6	-5961.1	-313.2	293.1	216.0
3	TMI_3-15120	4744.4	1822.0	11318.8	-28.7	-5261.0	-275.7	5361.2	2058.9	12790.3	-32.5	-5944.9	-311.6	292.1	216.0
3	TMI_3-15660	4728.2	1802.3	11292.1	-28.6	-5246.7	-274.3	5342.8	2036.6	12760.0	-32.4	-5928.7	-310.0	291.1	216.0
3	TMI_3-16200	4711.9	1783.6	11265.3	-28.6	-5232.3	-272.9	5324.5	2015.4	12729.8	-32.3	-5912.5	-308.4	290.1	216.0
3	TMI_3-16740	4695.7	1763.9	11238.5	-28.5	-5219.0	-271.5	5306.2	1993.2	12699.5	-32.2	-5897.4	-306.8	289.1	216.0
3	TMI_3-17280	4679.5	1744.1	11212.7	-28.4	-5204.6	-270.1	5287.8	1970.9	12670.3	-32.1	-5881.2	-305.3	288.1	216.0
3	TMI_3-17820	4663.3	1725.4	11185.9	-28.3	-5190.3	-268.7	5269.5	1949.7	12640.1	-32.0	-5865.0	-303.7	287.1	216.0
3	TMI_3-18360	4646.0	1705.7	11159.1	-28.2	-5176.0	-267.3	5250.0	1927.5	12609.8	-31.9	-5848.8	-302.1	286.1	216.0
3	TMI_3-18900	4629.8	1687.0	11133.3	-28.1	-5162.6	-265.9	5231.7	1906.3	12580.7	-31.8	-5833.8	-300.5	285.1	216.0
3	TMI_3-19440	4614.6	1668.3	11106.5	-28.0	-5148.3	-264.5	5214.5	1885.2	12550.4	-31.7	-5817.6	-298.9	284.1	216.0
3	TMI_3-19980	4598.3	1648.6	11080.8	-27.9	-5134.0	-263.2	5196.1	1862.9	12521.3	-31.6	-5801.4	-297.5	283.1	216.0
3	TMI_3-20520	4582.1	1629.8	11054.0	-27.9	-5120.6	-261.8	5177.8	1841.7	12491.0	-31.5	-5786.3	-295.9	282.1	216.0
3	TMI_3-21060	4565.9	1610.1	11028.2	-27.8	-5106.3	-260.4	5159.4	1819.4	12461.8	-31.4	-5770.1	-294.3	281.1	216.0
3	TMI_3-21600	4549.7	1591.4	11002.4	-27.7	-5092.9	-259.0	5141.1	1798.3	12432.7	-31.3	-5755.0	-292.7	280.1	216.0
3	TMI_3-21600	4506.8	1424.6	10828.8	-25.0	-5027.2	-255.8	5092.7	1609.7	12236.5	-28.3	-5680.7	-289.0	280.1	159.0
3	TMI_3-21600	4506.8	1424.6	10828.8	-25.0	-5027.2	-255.8	5092.7	1609.7	12236.5	-28.3	-5680.7	-289.0	280.1	159.0
3	TMI_3-21627	2172.7	-5014.3	4649.6	89.6	-2502.6	-18.5	2455.2	-5666.1	5254.1	101.3	-2827.9	-20.9	255.1	158.1
3	TMI_3-21654	2260.3	-4109.1	5433.4	75.8	-2665.8	21.5	2563.2	-4643.3	6139.8	85.7	-3012.3	24.3	237.6	157.2
3	TMI_3-21681	2476.0	-3124.0	6340.6	60.1	-2962.7	13.8	2797.9	-3530.1	7164.9	67.9	-3347.8	15.6	227.2	156.3
3	TMI_3-21714	2641.2	-2363.6	7034.2	45.4	-3200.1	-10.5	2984.5	-2670.9	7948.6	51.3	-3616.1	-11.9	220.0	155.2
3	TMI_3-21763	2780.4	-1723.7	7589.8	29.0	-3397.2	-46.0	3141.8	-1947.8	8576.5	32.8	-3838.8	-52.0	214.5	153.6
3	TMI_3-21817	2876.8	-1308.5	7929.6	16.2	-3526.2	-75.0	3250.7	-1478.6	8960.4	18.2	-3984.6	-84.7	211.2	151.8
3	TMI_3-21871	2946.7	-1038.8	8137.2	7.1	-3612.8	-95.0	3329.8	-1173.9	9195.0	8.0	-4082.5	-107.3	209.1	150.0
3	TMI_3-21925	2999.7	-854.1	8272.9	0.8	-3674.4	-108.3	3389.7	-965.2	9348.4	0.9	-4152.1	-122.3	207.6	148.2
3	TMI_3-21979	3038.7	-724.2	8364.6	-3.6	-3718.9	-117.0	3433.7	-818.4	9452.0	-4.0	-4202.4	-132.2	206.4	146.4
3	TMI_3-22033	3066.7	-631.9	8425.3	-6.5	-3750.5	-122.7	3465.3	-714.0	9520.6	-7.3	-4238.0	-138.6	205.4	144.6
3	TMI_3-22087	3085.6	-567.6	8465.0	-8.5	-3772.9	-126.2	3486.8	-641.4	9565.4	-9.6	-4263.3	-142.6	204.4	142.8
3	TMI_3-22141	3098.6	-522.3	8488.7	-9.9	-3787.3	-128.4	3501.5	-590.2	9592.2	-11.2	-4279.6	-145.0	203.6	141.0
3	TMI_3-22195	3106.6	-491.9	8501.4	-10.8	-3796.7	-129.5	3510.5	-555.9	9606.5	-12.2	-4290.2	-146.3	202.7	139.2
3	TMI_3-22249	3109.6	-473.6	8506.1	-11.4	-3801.1	-130.1	3513.8	-535.2	9611.9	-12.9	-4295.3	-147.0	201.9	137.4
3	TMI_3-22303	3109.6	-462.3	8504.7	-11.8	-3801.5	-130.0	3513.8	-522.4	9610.4	-13.3	-4295.7	-147.0	201.1	135.6
3	TMI_3-22357	3106.6	-458.0	8498.5	-12.1	-3799.9	-129.8	3510.4	-517.5	9603.3	-13.6	-4293.9	-146.7	200.3	133.8
3	TMI_3-22411	3102.5	-457.7	8490.1	-12.3	-3797.3	-129.5	3505.9	-517.2	9593.8	-13.9	-4291.0	-146.4	199.6	132.0
3	TMI_3-22465	3098.5	-460.4	8480.9	-12.3	-3793.8	-129.1	3501.3	-520.2	9583.4	-13.9	-4286.9	-145.9	198.8	130.2
3	TMI_3-22519	3093.5	-465.0	8470.5	-12.4	-3790.2	-128.6	3495.6	-525.5	9571.7	-14.0	-4282.9	-145.4	198.0	128.4
3	TMI_3-22573	3088.5	-470.7	8460.2	-12.3	-3785.6	-128.1	3490.0	-531.9	9560.1	-13.9	-4277.7	-144.8	197.3	126.6
3	TMI_3-22627	3083.5	-478.4	8447.9	-12.3	-3780.0	-127.4	3484.3	-540.6	9546.1	-13.9	-4271.4	-144.0	196.5	124.8
3	TMI_3-22681	3077.4	-487.1	8435.6	-12.2	-3774.4	-126.8	3477.5	-550.4	9532.3	-13.8	-4265.1	-143.3	195.8	123.0
3	TMI_3-22735	3071.4	-496.8	8421.3	-12.1	-3768.8	-126.0	3470.7	-561.3	9516.1	-13.7	-4258.7	-142.4	195.0	121.2
3	TMI_3-22789	3064.4	-507.5	8407.0	-12.0	-3762.2	-125.3	3462.8	-573.4	9499.9	-13.6	-4251.3	-141.6	194.2	119.4
3	TMI_3-22843	3057.4	-519.1	8391.7	-11.9	-3755.6	-124.5	3454.8	-586.6	9482.6	-13.4	-4243.9	-140.7	193.5	117.6
3	TMI_3-22897	3049.4	-530.8	8376.4	-11.8	-3748.1	-123.7	3445.8	-599.8	9465.3	-13.3	-4235.3	-139.8	192.7	115.8
3	TMI_3-22951	3041.3	-543.5	8361.1	-11.6	-3741.5	-122.9	3436.7	-614.1	9448.0	-13.2	-4227.8	-138.9	192.0	114.0
3	TMI_3-23005	3034.3	-556.2	8344.8	-11.5	-3733.9	-122.0	3428.8	-628.5	9429.6	-13.0	-4219.3	-137.9	191.2	112.2
3	TMI_3-23059	3026.3	-569.9	8328.5	-11.4	-3726.3	-121.2	3419.7	-643.9	9411.2	-12.9	-4210.7	-137.0	190.5	110.4
3	TMI_3-23113	3017.3	-583.5	8312.2	-11.2	-3718.7	-120.4	3409.5	-659.4	9392.8	-12.7	-4202.1	-136.1	189.7	108.6
3	TMI_3-23167	3009.3	-597.2	8295.8	-11.1	-3710.7	-119.6	3400.5	-674.9	9374.3	-12.5	-4193.1	-135.2	189.0	106.8
3	TMI_3-23221	3001.3	-610.9	8279.6	-11.0	-3702.9	-118.7	3391.4	-690.3	9355.9	-12.4	-4184.3	-134.1	188.2	105.0
3	TMI_3-23275	2993.2	-624.6	8262.2	-10.8	-3695.0	-117.9	3382.3	-705.8	9336.3	-12.2	-4175.4	-133.2	187.5	103.2
3	TMI_3-23329	2984.2	-639.3	8246.0	-10.7	-3687.1	-117.0	3372.2	-722.4	9317.9	-12.1	-4166.4	-132.2	186.7	101.4
3	TMI_3-23383	2976.2	-653.0	8228.6	-10.5	-3679.1	-116.2	3363.1	-737.8	9298.3	-11.9	-4157.3	-131.3	186.0	99.6
3	TMI_3-23437	2967.2	-667.6	8212.4	-10.4	-3671.1	-115.4	3352.9	-754.4	9280.0	-11.7	-4148.3	-130.4	185.2	97.8
3	TMI_3-23491	2959.1	-682.3	8195.0	-10.3	-3663.0	-114.5	3343.8	-771.0	9260.4	-11.6	-4139.2	-129.4	184.5	96.0
3	TMI_3-23545	2950.1	-696.0	8178.7	-10.1	-3655.0	-113.7	3333.7	-786.5	9242.0	-11.4	-4130.2	-128.5	183.7	94.2
3	TMI_3-23599	2942.1	-710.7	8161.4	-10.0	-3646.9	-112.8	3324.6	-803.1	9222.4	-11.3	-4121.0	-127.4	183.0	92.4
3	TMI_3-23653	2933.1	-725.4	8145.1	-9.8	-3638.8	-112.0	3314.4	-819.7	9204.0	-11.1	-4111.9	-126.5	182.2	90.6
3	TMI_3-23707	2925.1	-740.1	8127.8	-9.7	-3630.7	-111.1	3305.3	-836.3	9184.4	-10.9	-4102.7	-125.5	181.5	88.8
3	TMI_3-23761	2916.1	-753.7	8110.5	-9.5	-3622.6	-110.3	3295.2	-851.7	9164.9	-10.8	-4093.5	-124.6	180.7	87.0
3	TMI_3-23815	2908.0	-768.4	8093.2	-9.4	-3614.5	-109.4	3286.1	-868.3	9145.3	-10.6	-4084.4	-123.6	180.0	85.2
3	TMI_3-23869	2899.0	-783.1	8076.9	-9.2	-3606.4	-108.6	3275.9	-884.9	9126.9	-10.5	-4075.2	-122.7	179.2	83.4
3	TMI_3-23923	2891.0	-797.8	8059.6	-9.1	-3598.2	-107.7	3266.8	-901.5	9107.3	-10.3	-4066.0	-121.7	178.5	81.6
3	TMI_3-23977	2882.0	-812.5	8042.3	-9.0	-3590.0	-106.9	3256.7	-918.1	9087.8	-10.1	-4056.7	-120.8	177.7	79.8
3	TMI_3-24031	2873.0	-827.2	8026.0	-8.8	-3581.9	-106.0	3246.5	-934.7	9069.4	-10.0	-4047.6	-119.7	177.0	78.0
3	TMI_3-24085	2865.0	-841.9	8008.7	-8.7	-3573.8	-105.2	3237.4	-951.3	9049.8	-9.8	-4038.3	-118.8	176.3	76.2
3	TMI_3-24139	2855.9	-855.5	7991.4	-8.5	-3565.7	-104.3	3227.2	-966.7	9030.2	-9.6	-4029.2	-117.8	175.5	74.4
3	TMI_3-24193	2847.9	-870.2	7974.1	-8.4	-3557.5	-103.4	3218.2	-983.3	9010.7	-9.5	-4020.0	-116.9	174.8	72.6
3	TMI_3-24247	2838.9	-884.9	7957.8	-8.2	-3549.3	-102.6	3208.0	-999.9	8992.3	-9.3	-4010.7	-115.9	174.0	70.8
3	TMI_3-24301	2829.9	-899.6	7940.5	-8.1	-3541.1	-101.7	3197.8	-1016.5	8972.8	-9.1	-4001.5	-114.9	173.3	69.0
3	TMI_3-24355	2821.9	-914.3	7923.2	-8.0	-3532.9	-100.8	3188.7	-1033.1	8953.2	-9.0	-3992.2	-114.0	172.5	67.2
3	TMI_3-24409	2813.1	-929.0	7905.9	-7.8	-3524.8	-100.0	3178.7	-1049.7	8933.7	-8.8	-3983.1	-113.0	171.8	65.4
3	TMI_3-24463	2804.4	-943.6	7888.6	-7.7	-3516.6	-99.1	3169.0	-1066.3	8914.1	-8.7	-3973.8	-112.0	171.0	63.6
3	TMI_3-24517	2795.8	-958.3	7872.3	-7.5	-3508.5	-98.3	3159.3	-1082.9	8895.7	-8.5	-3964.6	-111.1	170.3	61.8
3	TMI_3-24571	2787.2	-973.0	7855.0	-7.4	-3500.3	-97.4	3149.5	-1099.5	8876.1	-8.3	-3955.3	-110.1	169.5	60.0
3	TMI_3-24625	2778.5	-987.7	7837.7	-7.2	-3492.1	-96.6	3139.7	-1116.1	8856.6	-8.2	-3946.1	-109.1	168.8	58.2
3	TMI_3-24679	2769.9	-1002.4	7820.4	-7.1	-3483.9	-95.7	3129.9	-1132.7	8837.0	-8.0	-3936.8	-108.2	168.0	56.4

3	THI_3-24733	2761.2	-1017.1	7803.1	-6.9	-3475.7	-94.9	3120.2	-1149.3	8817.5	-7.8	-3927.6	-107.2	167.3	54.6
3	THI_3-24787	2752.5	-1031.7	7786.7	-6.8	-3467.5	-94.0	3110.3	-1165.9	8799.0	-7.7	-3918.3	-106.2	166.5	52.8
3	THI_3-24841	2743.9	-1046.4	7769.5	-6.7	-3459.4	-93.1	3100.6	-1182.5	8779.5	-7.5	-3909.1	-105.3	165.8	51.0
3	THI_3-24895	2735.3	-1060.7	7752.1	-6.5	-3451.2	-92.3	3090.9	-1198.6	8759.9	-7.4	-3899.8	-104.3	165.0	49.2
3	THI_3-24949	2726.6	-1075.4	7734.9	-6.4	-3443.0	-91.4	3081.0	-1215.2	8740.4	-7.2	-3890.6	-103.3	164.3	47.4
3	THI_3-25003	2717.9	-1090.0	7717.5	-6.2	-3434.8	-90.6	3071.3	-1231.7	8720.8	-7.0	-3881.3	-102.4	163.5	45.6
3	THI_3-25057	2709.3	-1104.7	7700.3	-6.1	-3426.6	-89.7	3061.6	-1248.3	8701.3	-6.9	-3872.1	-101.4	162.8	43.8
3	THI_3-25111	2700.6	-1119.3	7683.9	-5.9	-3418.4	-88.9	3051.7	-1264.9	8682.9	-6.7	-3862.8	-100.4	162.0	42.0
3	THI_3-25165	2692.0	-1133.9	7666.7	-5.8	-3410.2	-88.0	3042.0	-1281.4	8663.4	-6.5	-3853.5	-99.4	161.3	40.2
3	THI_3-25219	2683.3	-1148.6	7649.3	-5.6	-3402.0	-87.1	3032.1	-1297.9	8643.8	-6.4	-3844.2	-98.5	160.5	38.4
3	THI_3-25273	2674.7	-1163.3	7632.1	-5.5	-3393.8	-86.3	3022.4	-1314.5	8624.3	-6.2	-3835.0	-97.5	159.8	36.6
3	THI_3-25327	2665.9	-1178.0	7614.7	-5.4	-3385.6	-85.4	3012.5	-1331.1	8604.7	-6.1	-3825.7	-96.5	159.0	34.8
3	THI_3-25381	2657.2	-1192.7	7597.5	-5.2	-3377.3	-84.6	3002.7	-1347.7	8585.2	-5.9	-3816.4	-95.5	158.3	33.0
3	THI_3-25435	2648.6	-1207.4	7580.1	-5.1	-3369.1	-83.7	2992.9	-1364.3	8565.6	-5.7	-3807.1	-94.6	157.5	31.2
3	THI_3-25489	2639.9	-1222.0	7563.9	-4.9	-3360.9	-82.8	2983.1	-1380.9	8547.2	-5.6	-3797.9	-93.6	156.8	29.4
3	THI_3-25543	2631.3	-1236.7	7546.6	-4.8	-3352.7	-82.0	2973.3	-1397.5	8527.6	-5.4	-3788.6	-92.6	156.0	27.6
3	THI_3-25597	2622.6	-1251.4	7529.3	-4.6	-3344.5	-81.1	2963.5	-1414.1	8508.1	-5.2	-3779.3	-91.7	155.3	25.8
3	THI_3-25651	2613.8	-1266.1	7512.0	-4.5	-3336.3	-80.3	2953.6	-1430.7	8488.5	-5.1	-3770.0	-90.7	154.5	24.0
3	THI_3-25705	2605.1	-1280.8	7494.7	-4.3	-3328.1	-79.4	2943.8	-1447.3	8469.0	-4.9	-3760.8	-89.7	153.8	22.2
3	THI_3-25759	2596.5	-1295.5	7477.4	-4.2	-3319.8	-78.5	2934.1	-1463.9	8449.4	-4.7	-3751.4	-88.7	153.0	20.4
3	THI_3-25813	2587.8	-1310.2	7460.1	-4.1	-3311.6	-77.7	2924.2	-1480.5	8429.9	-4.6	-3742.2	-87.8	152.3	18.6
3	THI_3-25867	2579.1	-1324.8	7442.8	-3.9	-3303.3	-76.8	2914.4	-1497.1	8410.3	-4.4	-3732.8	-86.8	151.5	16.8
3	THI_3-25920	2570.6	-1339.4	7426.5	-3.8	-3295.3	-76.0	2904.7	-1513.6	8391.9	-4.3	-3723.7	-85.8	150.8	15.0
3	THI_3-26928	2574.7	-1268.3	7459.5	-5.9	-3307.7	-78.0	2909.4	-1433.1	8429.2	-6.7	-3737.6	-88.1	147.7	13.5
3	THI_3-27936	2546.2	-1296.9	7411.5	-5.9	-3283.2	-75.5	2877.2	-1465.5	8375.0	-6.7	-3710.1	-85.4	145.2	12.0
3	THI_3-28944	2513.6	-1337.1	7355.5	-5.7	-3254.4	-72.5	2840.4	-1510.9	8311.7	-6.4	-3677.5	-81.9	142.6	10.5
3	THI_3-29952	2480.6	-1378.9	7297.5	-5.4	-3225.2	-69.4	2803.1	-1558.1	8246.2	-6.1	-3644.5	-78.5	140.1	9.0
3	THI_3-30960	2448.1	-1420.4	7241.6	-5.1	-3196.3	-66.4	2766.3	-1605.0	8183.0	-5.8	-3611.8	-75.0	137.6	7.5
3	THI_3-31968	2415.8	-1461.3	7184.6	-4.8	-3167.6	-63.4	2729.9	-1651.3	8118.6	-5.5	-3579.4	-71.6	135.1	6.0
3	THI_3-32976	2384.1	-1501.7	7129.6	-4.5	-3139.4	-60.4	2694.0	-1697.0	8056.4	-5.1	-3547.6	-68.2	132.7	4.5
3	THI_3-33984	2352.7	-1541.6	7074.6	-4.3	-3111.5	-57.4	2658.6	-1742.0	7994.3	-4.8	-3516.0	-64.9	130.2	3.0
3	THI_3-34992	2321.9	-1580.9	7020.4	-4.0	-3084.0	-54.5	2623.7	-1786.4	7933.1	-4.5	-3484.9	-61.6	127.7	1.5
3	THI_3-36000	2291.4	-1619.6	6966.9	-3.7	-3056.9	-51.6	2589.3	-1830.2	7872.7	-4.2	-3454.3	-58.3	125.2	0.0
3	THI_3-36060	2293.7	-1611.4	6973.9	-3.9	-3059.7	-51.9	2591.9	-1820.9	7880.6	-4.4	-3457.4	-58.6	125.1	0.0
3	THI_3-36120	2295.3	-1605.9	6978.4	-4.0	-3061.6	-52.2	2593.7	-1814.7	7885.6	-4.5	-3459.6	-59.0	125.0	0.0
3	THI_3-36300	2297.7	-1598.9	6983.8	-4.2	-3064.2	-52.6	2596.4	-1806.8	7891.7	-4.7	-3462.5	-59.4	125.0	0.0
3	THI_3-36600	2299.3	-1594.5	6986.9	-4.3	-3065.9	-52.8	2598.2	-1801.8	7895.3	-4.8	-3464.4	-59.7	125.0	0.0
3	THI_3-39600	2300.5	-1591.4	6988.9	-4.3	-3067.1	-52.9	2599.6	-1798.3	7897.5	-4.9	-3465.8	-59.8	125.0	0.0
4	THI_4-0	8749.8	16090.9	17424.6	-147.7	-8373.8	-793.4	9887.2	18182.8	19689.8	-167.0	-9462.4	-896.6	544.4	2242.0
4	THI_4-0	8759.1	16079.3	17456.9	-147.7	-8387.7	-793.4	9897.8	18169.6	19726.3	-167.0	-9478.0	-896.6	544.4	2242.0
4	THI_4-0	8760.1	16080.3	17456.9	-147.8	-8388.7	-793.4	9899.0	18170.7	19726.3	-167.0	-9479.2	-896.6	544.4	2242.0
4	THI_4-1	9556.4	18940.5	19989.4	-200.4	-9235.3	-842.3	10798.7	21402.8	22588.0	-226.4	-10435.9	-951.8	544.5	2379.5
4	THI_4-2	10058.6	20817.8	21611.9	-233.8	-9829.9	-880.3	11366.2	23524.1	24421.4	-264.2	-11107.8	-994.8	544.9	2517.0
4	THI_4-3	10478.9	22365.1	22924.4	-260.2	-10338.6	-915.3	11841.1	25272.5	25904.6	-294.0	-11682.6	-1034.3	545.5	2654.5
4	THI_4-4	10864.1	23752.3	24106.9	-282.9	-10801.2	-948.8	12276.4	26840.1	27240.8	-319.6	-12205.4	-1072.2	546.3	2792.0
4	THI_4-5	11042.3	24212.0	24547.6	-290.0	-11014.5	-967.6	12477.8	27359.6	27738.8	-327.7	-12446.4	-1093.4	547.4	2792.0
4	THI_4-6	11153.5	24441.8	24788.3	-292.7	-11151.9	-982.2	12603.5	27619.2	28010.8	-330.7	-12601.6	-1109.9	548.7	2792.0
4	THI_4-8	11272.0	24581.2	24949.8	-292.3	-11282.5	-1001.8	12737.3	27776.8	28193.3	-330.3	-12749.2	-1132.1	551.5	2792.0
4	THI_4-10	11319.4	24550.7	24961.3	-289.9	-11340.1	-1016.8	12790.9	27742.3	28206.2	-327.5	-12814.3	-1149.0	554.4	2792.0
4	THI_4-12	11332.8	24450.2	24892.7	-286.8	-11356.7	-1028.5	12806.1	27628.7	28128.8	-324.0	-12833.1	-1162.2	557.1	2792.0
4	THI_4-15	11252.8	24030.2	24522.7	-278.3	-11267.7	-1038.0	12715.7	27154.1	27710.7	-314.4	-12732.5	-1173.0	561.2	2792.0
4	THI_4-19	11143.8	23580.2	24112.7	-270.0	-11141.7	-1041.9	12592.5	26645.6	27247.4	-305.1	-12590.2	-1177.4	564.7	2792.0
4	THI_4-25	10927.8	22810.2	23372.7	-257.0	-10888.7	-1039.2	12348.4	25775.5	26411.2	-290.4	-12304.3	-1174.3	570.0	2792.0
4	THI_4-32	10741.8	22180.2	22762.7	-246.9	-10666.7	-1031.5	12138.2	25063.6	25721.9	-279.0	-12053.4	-1165.6	574.0	2792.0
4	THI_4-38	10588.8	21680.2	22272.7	-239.1	-10482.7	-1021.4	11965.4	24498.6	25168.2	-270.1	-11845.5	-1154.2	577.1	2792.0
4	THI_4-45	10464.8	21280.2	21872.7	-232.9	-10331.7	-1010.3	11825.2	24046.6	24716.2	-263.1	-11674.9	-1141.7	579.4	2792.0
4	THI_4-52	10363.8	20950.2	21552.7	-227.7	-10208.7	-999.1	11711.1	23673.7	24354.6	-257.3	-11535.9	-1129.0	581.3	2792.0
4	THI_4-58	10279.8	20690.2	21292.7	-223.2	-10106.7	-988.0	11616.2	23379.9	24060.8	-252.3	-11420.6	-1116.5	582.7	2792.0
4	THI_4-65	10209.8	20470.2	21072.7	-219.3	-10020.7	-977.4	11537.1	23131.3	23812.2	-247.9	-11323.4	-1104.5	583.9	2792.0
4	THI_4-71	10149.8	20280.2	20892.7	-215.9	-9947.7	-967.5	11469.3	22916.6	23608.8	-243.9	-11240.9	-1093.3	584.8	2792.0
4	THI_4-78	10097.8	20120.2	20732.7	-212.7	-9884.7	-958.2	11410.5	22735.8	23428.0	-240.4	-11169.8	-1082.8	585.5	2792.0
4	THI_4-85	10051.8	19980.2	20602.7	-209.9	-9829.7	-949.6	11358.5	22577.6	23281.1	-237.2	-11107.6	-1073.1	586.2	2792.0
4	THI_4-91	10009.8	19860.2	20482.7	-207.3	-9780.7	-941.7	11311.1	22442.0	23145.5	-234.2	-11052.2	-1064.2	586.7	2792.0
4	THI_4-98	9972.8	19760.2	20382.7	-204.9	-9737.7	-934.5	11269.3	22329.0	23032.5	-231.5	-11003.6	-1056.0	587.1	2792.0
4	THI_4-104	9938.8	19660.2	20292.7	-202.7	-9697.7	-927.9	11230.9	22216.0	22930.8	-229.0	-10958.4	-1048.6	587.4	2792.0
4	THI_4-111	9906.8	19570.2	20212.7	-200.6	-9661.7	-922.0	11194.7	22114.3	22840.4	-226.7	-10917.8	-1041.9	587.7	2792.0
4	THI_4-118	9877.8	19490.2	20142.7	-198.8	-9628.7	-916.5	11161.9	22023.9	22761.3	-224.6	-10880.5	-1035.7	588.0	2792.0
4	THI_4-124	9849.8	19420.2	20082.7	-197.1	-9597.7	-911.6	11130.3	21944.8	22693.5	-222.7	-10845.4	-1030.1	588.2	2792.0
4	THI_4-131	9824.8	19350.2	20022.7	-195.5	-9569.7	-907.1	11102.0	21865.7	22625.7	-220.9	-10813.8	-1025.1	588.4	2792.0
4	THI_4-137	9799.8	19290.2	19962.7	-194.0	-9543.7	-903.0	11073.8	21797.9	22557.9	-219.2	-10784.4	-1020.4	588.6	2792.0
4	THI_4-144	9777.8	19230.2	19912.7	-192.7	-9518.7	-899.3	11048.9	21730.1	22501.4	-217.7	-10756.2	-1016.2	588.7	2792.0
4	THI_4-144	9440.0	16947.7	18439.0	-160.2	-8987.5	-859.3	10667.2	19150.9	20836.0	-181.0	-10155.8	-971.1	588.7	2092.0
4	THI_4-144	9440.0	16947.7	18439.0	-160.2	-8987.5	-859.3	10667.2	19150.9	20836.0	-181.0	-10155.8	-971.1	588.7	2092.0
4	THI_4-146	8873.4	15113.3	16738.1	-125.8	-8386.5	-823.1	10027.0	17078.1	18914.1	-142.1	-9476.8	-930.1	588.2	2087.2
4	THI_4-149	8676.9	14543.3	16207.4	-116.1	-8151.6	-804.1	9804.9	16434.0	18314.3	-131.2	-9211.3	-908.6	587.3	2082.5
4	THI_4-151	8585.4	14333.3	16006.6	-113.3	-8040.6	-791.6	9701.5	16196.7	18087.4	-128.0	-9085.9	-894.5	586.1	2077.8
4	THI_4-156	8521.7	14242.1	15906.7	-112.7	-7963.4	-777.1	9629.6	16093.6	17974.6	-127.4	-8998.6	-878.1	583.9	2069.0
4	THI_4-160	8491.7	14223.7	15895.1	-112.8	-7928.5	-766.0	9595.6	16072.8	17961.5	-127.5	-8959.2	-865.6	581.6	2059.5
4	THI_4-165	8472.6	14213.3	15893.5	-112.7	-7907.6	-757.4	9574.1	16061.1	17959.7	-127.3	-8935.6	-855.9	579.6	2050.0
4	THI_4-170	8454.6	14193.9	15881.9	-112.1	-7890.7	-750.5	9553.7	16039.1	17946.5	-126.7	-8916.5	-848.1	577.7	2040.5
4	THI_4-175	8435.5	14162.5	15870.3	-111.3	-7871.8	-744.6	9532.2	16003.7	17933.4	-125.8	-8895.1	-841.3	576.0	2031.0
4	THI_4-180	8414.5	14120.1	15848.7	-110.3	-7849.9	-739.4	9508.4	15955.7	17909.0	-124.6	-8870.4	-835.5	574.4	2021.5
4	THI_4-184	8390.4	14067.7	15807.1	-109.1	-7827.0	-734.8	9481.2	15896.5	17862.0	-123.3	-8844.5	-830.3	572.8	2012.0
4	THI_4-189	8364.4	14009.3	15775.5	-107.9	-7801.1	-730.6	9451.7	15830.6	17826.3	-121.9	-8815.2	-825.6	571.3	2002.5
4	THI_4-192	8349.4	13972.8	15742.9	-107.1	-7785.5	-728.4	9434.9	15789.2	17789.5	-121.1	-8797.6	-823.1	570.5	1997.0
4	THI_4-197	8342.7	13977.8	15761.3	-107.1	-7780.3	-726.4	9427.3	15794.9	17810.3	-121.0	-8791.7	-820.9	569.2	1992.0
4	THI_4-201	8337.0	13985.9	15779.8	-107.2	-7778.0	-725.0	9420.8	15804.1	17831.2	-121.1	-8789.2	-819.3	568.0	1987.0
4	THI_4-210	8323.6	13979.0	15786.7	-107.0	-7769.6	-723.4	9405.7	15796.3	17839.0	-120.9	-8779.6	-817.4	565.8	1977.0
4	THI_4-219	8305.2	13952.1	15783.6	-106.6	-7754.1	-722.2	9384.9	15765.9	17835.5	-120.5	-8762.2	-816.1	563.8	1967.0
4	THI_4-228	8282.8	13912.3	15760.5	-106.2	-7734.7	-721.1	9359.5	15720.9	17809.4	-120.0	-8740.2	-814.9	561.9	1957.0
4	THI_4-237	8259.3	13863.4	15727.5	-105.6	-7713.2	-720.2	9333.1	15665.6	17772.0	-119.3	-8715.9	-813.8	560.1	1947.0
4	THI_4-246	8233.9	13808.5	15694.4	-105.1	-7688.7	-719.1	9304.3	15603.6	17734.6	-118.7	-8688.3	-812.6	558.4	1937.0
4	THI_4-255	8208.5	13750.7	15651.3	-104.5	-7663.3	-718.0	9275.6	15538.2	17686.0	-118.0	-8659.5	-811.3	556.7	1927.0
4	THI_4-264	8183.1	13689.8	15598.2	-103.9	-7637.8	-716.8	9246.9	15469.5	17626.0	-117.4	-8630.7	-810.0	555.0	1917.0
4	THI_4-273	8154.7	13617.9	15545.1	-103.0	-7610.4	-715.5	9214.8	15388.2	17566.0	-116.4	-8599.7	-808.5	553.3	1907.0
4	THI_4-282	8123.3	13522.0	15462.0	-101.4	-7578.9	-713.4	9179.3	15279.9	17472.1	-114.5	-8564.2	-806.1	551.7	1897.0
4	THI_4-287	8132.3	13540.6	15499.1	-101.7	-7588.2	-713.5	9189.5	15300.8	17514.0	-114.9	-8574.7	-806.2	550.9	1891.0
4	THI_4-291	8144.3	13572.1	15536.3	-102.2	-7601.6	-713.9	9203.1	15336.5	17556.0	-115.5	-8589.8	-806.7	550.2	1885.0
4	THI_4-300	8167.5	13630.1	15601.1	-103.7	-7620.5	-715.3	9229.3	15411.1	17629.3	-117.1	-8611.1	-808.3	549.0	1873.3
4	THI_4-308	8175.8	13675.8	15646.4	-104.8	-7634.5	-717.2	9238.7	15453.7	17680.4	-118.4	-8627.0	-810.4	548.1	1861.8
4	THI_4-317	8179.3	13694.4	15662.4	-105.7	-7641.9	-718.9	9242.6	15474.7	17698.5	-119.4	-8635.3	-812.4	547.2	1850.6
4	THI_4-325	8178.7	13699.8	15678.1	-106.3	-7645.1	-720.4	9241.9	15476.7	17716.3	-120.1	-8638.9	-814.0	546.4	1839.3
4	THI_4-334	8175.1	13696.1	15673.9	-106.9	-7644.3	-721.7	9237.9	15476.6	17711.6	-120.8	-8638.1	-815.5	545.6	1828.0
4	THI_4-342	8169.6	13684.7	15669.8	-107.3	-7640.6	-722.5	9231.6	15463.8	17706.9	-121.3	-8633.9	-816.4	544.9	1816.8
4	THI_4-351	8162.0	13666.1	15655.5	-107.6	-7633.8	-723.1	9223.0	15442.7	17690.7	-121.6	-8626.2	-817.1	544.2	1805.5
4	THI_4-359	8153.4	13644.4	15641.3	-107.8	-7626.1	-723.4	9213.3	15418.1	17674.7	-121.8	-8617.5	-817.5	543.6	1794.2
4	THI_4-366	8146.1	13624.5	15622.8	-107.9	-7619.3	-723.4	9205.1	15395.7	17653.7	-121.9	-8609.9	-817.5	543.1	1785.6
4	THI_4-372	8137.9	13602.6	15604.4	-107.9	-7611.7	-723.3	9195.8	15370.9	17632.9	-121.9	-8601.2	-817.4	542.6	1777.0
4	THI_4-432	8242.9	13965.6	15914.4	-115.9	-7738.7	-738.5	9314.5	15781.1	17983.2	-131.0	-8744.7	-834.5	541.0	1777.0
4	THI_4-492	8302.9	14148.6	16064.4	-120.4	-7808.7	-748.2	9382.3	15987.9	18152.7	-136.0	-8823.8	-845.5	540.5	1777.0
4	THI_4-567	8347.9	14270.6	16164.4	-123.3	-7857.7	-754.7	9433.1	16125.7	18265.7	-139.3	-8879.2	-852.9	540.2	1777.0
4	THI_4-642	8376.9	14342.6	16214.4	-124.8	-7887.7	-758.1	9465.9	16207.1	18322.2	-141.0	-8913.1	-856.7	540.1	1777.0
4	THI_4-717	8394.9	14386.6	16244.4	-125.6	-7906.7	-759.9	9486.2	16256.8	18356.1	-142.0	-8934.5	-858.7	540.1	1777.0
4	THI_4-792	8406.9	14414.6	16264.4	-126.1	-7918.7	-760.9	9499.8	16288.5	18378.7	-142.5	-8948.1	-859.9	540.0	1777.0
4	THI_4-867	8413.9	14432.6	16284.4	-126.3	-7926.7	-761.4	9507.7	16308.8	18401.3	-142.8	-8957.1	-860.4	540.0	1777.0
4	THI_4-920	8417.9	14442.6	16284.4	-126.5	-7930.7	-761.6	9512.2	16320.1	18401.3	-142.9	-8961.7	-860.7	540.0	1777.0
4	THI_4-972	8420.9	14449.6	16294.4	-126.5	-7933.7	-761.7	9515.6	16328.0	18412.6	-143.0	-8965.1	-860.8	540.0	1777.0
4	THI_4-3972	8429.9	14469.6	16304.4	-126.7	-7941.7	-761.9	9525.8	16350.6	18423.9	-143.2	-8974.1	-861.0	540.0	1777.0
5	THI_5-0	8910.5	16294.1	17690.7	-149.5	-8513.8	-809.7	10068.8	18412.3	19990.5	-168.9	-9620.5	-915.0	555.0	2242.0
5	THI_5-1	8971.1	16530.9	17885.4	-153.6	-8581.6	-813.7	10137.3	18679.9	20210.5	-173.6	-9697.2	-919.5	555.0	2267.0
5	THI_5-2	9049.7	16831.7	18150.0	-158.9	-8671.4	-819.2	10226.2	19019.8	20509.5	-179.6	-9798.7	-925.7	555.0	2292.0
5	THI_5-3	9138.4	17160.5	18424.5	-164.7	-8773.2	-825.5	10326.3	19391.4	20819.7	-186.1	-9913.7	-932.8	555.1	2317.0
5	THI_5-4	9232.0	17502.3	18719.1	-170.6	-8882.0	-832.4	10432.2	19777.6	21152.6	-192.8	-10036.7	-940.6	555.2	2342.0
5	THI_5-5	9326.7	17833.1	19013.8	-176.4	-8992.8	-839.8	10539.1	20151.4	21485.6	-199.3	-10161.9	-948.9	555.4	2367.0
5	THI_5-6	9420.3	18164.0	19298.3	-182.0	-9102.6	-847.3	10644.9	20525.3	21807.0	-205.6	-10285.9	-957.4	555.6	2392.0
5	THI_5-7	9510.9	18484.8	19582.9	-187.3	-9210.4	-854.9	10747.3	20887.8	22128.7	-211.6	-10407.8	-966.0	555.9	2417.0
5	THI_5-8	9599.6	18785.6	19847.5	-192.2	-9314.3	-862.6	10847.5	21227.7	22427.7	-217.2	-10525.1	-974.8	556.2	2442.0
5	THI_5-9	9642.6	18895.6	19947.5	-194.0	-9366.3	-867.2	10896.1	21352.0	22540.7	-219.2	-10583.9	-980.0	556.6	2442.0
5	THI_5-10	9668.6	18945.6	20007.5	-194.6	-9398.3	-870.9	10925.5	21408.5	22608.5	-219.9	-10620.0	-984.2	557.0	2442.0
5	THI_5-11	9683.6	18965.6	20027.5	-194.6	-9417.3	-873.8	10942.4	21431.1	22631.1	-219.9	-10641.5	-987.4	557.4	2442.0
5	THI_5-12	9691.6	18965.6	20037.5	-194.2	-9427.3	-876.2	10951.5	21431.1	22642.4	-219.5	-10652.8	-990.1	557.8	2442.0
5	THI_5-13	9641.9	18744.8	19842.9	-190.1	-9374.6	-874.6	10895.4	21181.6	22422.5	-214.8	-10590.8	-988.3	558.3	2417.0
5	THI_5-14	9570.3	18444.0	19598.3	-184.6	-9290.6	-871.4	10814.4	20841.7	22146.0	-208.6	-10498.4	-984.7	558.6	2392.0
5	THI_5-15	9486.7	18113.1	19313.8	-178.6	-9193.8	-866.9	10719.9	20467.8	21824.6	-201.8	-10389.0	-979.5	559.0	2367.0
5	THI_5-16	9394.0	17762.3	19009.1	-172.4	-9087.0	-861.6	10615.2	20071.4	21480.3	-194.8	-10268.3	-973.6	559.3	2342.0
5	THI_5-17	9298.4	17411.5	18704.5	-166.2	-8974.7	-855.7	10507.1	19675.1	21136.1	-187.8	-10140.8	-966.9	559.5	2317.0
5	THI_5-18	9200.7	17053.7	18390.0	-160.1	-8859.4	-849.3	10396.8	19270.7	20780.7	-180.9	-10011.1	-959.7	559.7	2292.0
5	THI_5-19	9103.1	16705.9	18085.4	-154.2	-8744.6	-842.5	10286.5	18877.7	20436.5	-174.2	-9881.4	-952.1	559.8	2267.0
5	THI_5-20	9006.5	16368.1	17790.7	-148.6	-8630.8	-835.6	10177.3	18496.0	20103.5	-167.9	-9752.7	-944.2	559.9	2242.0
5	THI_5-21	8931.4	16102.6	17568.2	-144.4	-8539.8	-829.7	10092.5	18195.9	19852.0	-163.2	-9650.0	-937.5	559.9	2217.0
5	THI_5-22	8868.4	15881.0	17375.6	-141.1	-8461.8	-824.2	10021.2	17945.6	19634.4	-159.5	-9561.9	-931.3	559.8	2192.0
5	THI_5-23	8814.3	15688.5	17213.0	-138.4	-8393.9	-819.2	9960.2	17728.0	19450.7	-156.3	-9485.1	-925.7	559.7	2167.0
5	THI_5-24	8766.1	15512.7	17069.6	-135.9	-8331.6	-814.5	9905.6	17529.3	19288.6	-153.6	-9414.8	-920.4	559.5	2141.6
5	THI_5-25	8714.9	15327.8	16917.7	-133.4	-8267.4	-809.3	9847.8	17320.4	19117.0	-150.8	-9342.1	-914.5	559.3	2112.2
5	THI_5-27	8663.3	15130.6	16765.4	-130.8	-8200.3	-803.6	9789.5	17097.6	18944.9	-147.8	-9266.3	-908.1	559.1	2077.8
5	THI_5-28	8607.6	14913.5	16589.6	-127.9	-8128.3	-797.3	9726.6	16852.3	18746.2	-144.5	-9185.0	-900.9	558.7	2037.0
5	THI_5-30	8551.9	14690.8	16424.9	-124.9	-8056.2	-790.7	9663.7	16600.6	18560.2	-141.2	-9103.5	-893.5	558.4	1992.0
5	THI_5-65	8589.9	14900.8	16604.9	-128.5	-8098.2	-777.2	9706.6	16837.9	18763.6	-145.2	-9151.0	-878.3	554.3	1992.0
5	THI_5-99	8645.9	15086.8	16794.9	-130.6	-8165.2	-776.4	9769.9	17048.0	18978.3	-147.6	-9226.7	-877.4	552.3	1992.0
5	THI_5-134	8678.9	15197.8	16904.9	-132.0	-8206.2	-778.7	9807.2	17173.5	19102.6	-149.2	-9273.0	-880.0	551.3	1992.0
5	THI_5-187	8704.9	15283.8	16984.9	-133.6	-8237.2	-782.7	9836.6	17270.6	19193.0	-151.0	-9308.1	-884.5	550.7	1992.0
5	THI_5-256	8721.9	15340.8	17034.9	-135.1	-8258.2	-786.4	9855.8	17335.1	19249.5	-152.6	-9331.8	-888.7	550.3	1992.0
5	THI_5-325	8733.9	15374.8	17064.9	-136.0	-8271.2	-788.7	9869.4	17373.5	19283.4	-153.7	-9346.5	-891.3	550.2	1992.0
6	THI_6-394	8741.9	15396.8	17074.9	-136.6	-8279.2	-790.2	9878.4	17398.3	19294.7	-154.4	-9355.5	-893.0	550.1	1992.0
6	THI_6-463	8746.9	15410.8	17084.9	-137.0	-8285.2	-791.1	9884.0	17414.2	19306.0	-154.8	-9362.3	-894.0	550.1	1992.0

6	TMI_6-532	8750.9	15420.8	17094.9	-137.2	-8289.2	-791.6	9888.6	17425.5	19317.3	-155.0	-9366.8	-894.5	550.0	1992.0
6	TMI_6-566	8752.9	15424.8	17104.9	-137.3	-8290.2	-791.8	9890.8	17430.0	19328.6	-155.2	-9368.0	-894.8	550.0	1992.0
6	TMI_6-601	8753.9	15427.8	17104.9	-137.4	-8292.2	-792.0	9892.0	17433.4	19328.6	-155.2	-9370.2	-895.0	550.0	1992.0
6	TMI_6-635	8754.9	15430.8	17104.9	-137.4	-8293.2	-792.1	9893.1	17436.8	19328.6	-155.3	-9371.4	-895.1	550.0	1992.0
6	TMI_6-670	8755.9	15432.8	17104.9	-137.5	-8294.2	-792.2	9894.2	17439.0	19328.6	-155.4	-9372.5	-895.2	550.0	1992.0
6	TMI_6-695	8756.9	15434.8	17104.9	-137.5	-8295.2	-792.3	9895.3	17441.3	19328.6	-155.4	-9373.6	-895.3	550.0	1992.0
6	TMI_6-720	8756.9	15435.8	17104.9	-137.5	-8295.2	-792.3	9895.3	17442.4	19328.6	-155.4	-9373.6	-895.3	550.0	1992.0
6	TMI_6-636	8828.0	15926.6	17416.0	-144.5	-8407.1	-800.9	9975.6	17997.0	19680.1	-163.3	-9500.0	-905.0	550.0	2142.0
6	TMI_6-636	8829.0	15927.6	17416.0	-144.5	-8407.1	-800.9	9976.7	17998.1	19680.1	-163.3	-9500.0	-905.0	550.0	2142.0
6	TMI_6-725	12045.7	25849.0	26842.1	-326.0	-11912.0	-1027.9	13611.6	29209.4	30331.5	-368.4	-13460.6	-1161.5	557.9	2142.0
6	TMI_6-730	12665.7	27199.0	28182.1	-344.0	-12652.0	-1115.5	14312.2	30734.9	31845.7	-388.7	-14296.8	-1260.5	568.8	2142.0
6	TMI_6-735	12655.7	26759.0	27842.1	-333.0	-12662.0	-1153.4	14300.9	30237.7	31461.5	-376.3	-14308.1	-1303.3	579.4	2142.0
6	TMI_6-743	12305.7	25439.0	26612.1	-311.9	-12262.0	-1170.4	13905.4	28746.1	30071.6	-352.4	-13856.1	-1322.5	592.8	2142.0
6	TMI_6-753	11825.7	23879.0	25092.1	-290.2	-11748.0	-1171.4	13363.0	26983.3	28354.0	-327.9	-13275.3	-1323.7	604.0	2142.0
6	TMI_6-763	11495.7	22639.0	23922.1	-271.1	-11321.0	-1156.4	12990.1	25582.1	27031.9	-306.3	-12792.8	-1306.7	611.8	2142.0
6	TMI_6-773	11248.7	21729.0	23052.1	-256.4	-10999.0	-1134.4	12711.0	24553.8	26048.8	-289.7	-12428.9	-1281.9	617.4	2142.0
6	TMI_6-783	11072.7	21039.0	22402.1	-244.0	-10758.0	-1110.4	12512.1	23774.1	25314.3	-275.7	-12156.6	-1254.7	621.5	2142.0
6	TMI_6-793	10941.7	20509.0	21912.1	-233.7	-10577.0	-1087.7	12364.1	23175.2	24760.6	-264.1	-11952.0	-1229.1	624.5	2142.0
6	TMI_6-803	10840.7	20099.0	21542.1	-224.9	-10437.0	-1066.8	12249.9	22711.9	24342.5	-254.1	-11793.8	-1205.5	626.7	2142.0
6	TMI_6-813	10761.7	19769.0	21252.1	-217.3	-10325.0	-1047.8	12160.7	22339.0	24014.8	-245.5	-11667.3	-1184.0	628.4	2142.0
6	TMI_6-820	10715.7	19579.0	21092.1	-212.7	-10262.0	-1036.2	12108.7	22124.3	23834.0	-240.3	-11596.1	-1170.9	629.4	2142.0
6	TMI_6-833	10644.7	19289.0	20842.1	-205.2	-10166.0	-1017.1	12028.5	21796.6	23551.5	-231.8	-11487.6	-1149.3	630.7	2142.0
6	TMI_6-845	10584.7	19049.0	20652.1	-198.7	-10086.0	-1000.7	11960.7	21525.4	23336.8	-224.5	-11397.2	-1130.8	631.7	2142.0
6	TMI_6-870	10487.7	18709.0	20372.1	-188.3	-9966.0	-975.8	11851.0	21141.2	23020.4	-212.8	-11261.6	-1102.6	632.9	2142.0
6	TMI_6-895	10408.7	18439.0	20162.1	-180.2	-9872.0	-957.0	11761.8	20836.1	22783.1	-203.6	-11155.4	-1081.4	633.8	2142.0
6	TMI_6-920	10341.7	18229.0	20002.1	-173.8	-9795.0	-942.4	11686.1	20598.8	22602.3	-196.4	-11068.4	-1064.9	634.3	2142.0
6	TMI_6-945	10283.7	18069.0	19872.1	-168.8	-9730.0	-931.2	11620.5	20418.0	22455.4	-190.7	-10994.9	-1052.2	634.7	2142.0
6	TMI_6-970	10233.7	17929.0	19762.1	-164.9	-9675.0	-922.6	11564.0	20259.8	22331.1	-186.3	-10932.8	-1042.5	635.0	2142.0
6	TMI_6-995	10190.7	17819.0	19672.1	-161.8	-9629.0	-915.9	11515.4	20135.5	22229.4	-182.8	-10880.8	-1035.0	635.2	2142.0
6	TMI_6-1020	10153.7	17719.0	19602.1	-159.4	-9590.0	-910.7	11473.6	20022.5	22150.3	-180.1	-10836.7	-1029.1	635.4	2142.0
6	TMI_6-1045	10121.7	17639.0	19542.1	-157.5	-9557.0	-906.7	11437.5	19932.1	22082.5	-178.0	-10799.4	-1024.6	635.5	2142.0
6	TMI_6-1070	10094.7	17569.0	19492.1	-156.0	-9529.0	-903.5	11407.0	19853.0	22026.0	-176.3	-10767.8	-1020.9	635.6	2142.0
6	TMI_6-1095	10072.7	17519.0	19452.1	-154.8	-9506.0	-901.0	11382.1	19796.5	21980.8	-175.0	-10741.8	-1018.1	635.7	2142.0
6	TMI_6-1120	10052.7	17469.0	19412.1	-153.9	-9486.0	-899.0	11359.5	19740.0	21935.6	-173.9	-10719.2	-1015.9	635.7	2142.0
6	TMI_6-1145	10036.7	17429.0	19382.1	-153.1	-9469.0	-897.4	11341.4	19694.8	21901.7	-173.0	-10700.0	-1014.1	635.8	2142.0
6	TMI_6-1170	10021.7	17399.0	19362.1	-152.5	-9454.0	-896.2	11324.5	19660.9	21879.1	-172.4	-10683.1	-1012.7	635.8	2142.0
6	TMI_6-1195	10009.7	17369.0	19342.1	-152.0	-9442.0	-895.2	11310.9	19627.0	21856.5	-171.8	-10669.5	-1011.6	635.9	2142.0
6	TMI_6-1220	9999.7	17339.0	19322.1	-151.6	-9432.0	-894.4	11299.6	19593.1	21833.9	-171.4	-10658.2	-1010.7	635.9	2142.0
6	TMI_6-1245	9990.7	17319.0	19312.1	-151.3	-9423.0	-893.7	11289.4	19570.5	21822.6	-171.0	-10648.0	-1009.9	635.9	2142.0
6	TMI_6-1270	9983.7	17299.0	19302.1	-151.1	-9415.0	-893.2	11281.5	19547.9	21811.3	-170.7	-10639.0	-1009.3	635.9	2142.0
6	TMI_6-1295	9976.7	17289.0	19292.1	-150.9	-9409.0	-892.8	11273.6	19536.6	21800.0	-170.5	-10632.2	-1008.9	635.9	2142.0
6	TMI_6-1320	9971.7	17279.0	19282.1	-150.7	-9403.0	-892.4	11268.0	19525.3	21788.7	-170.3	-10625.4	-1008.4	635.9	2142.0
6	TMI_6-4320	9935.7	17189.0	19222.1	-149.9	-9367.0	-891.1	11227.3	19423.6	21720.9	-169.4	-10584.7	-1006.9	636.0	2142.0
7	TMI_7-0	8741.8	16100.9	17414.6	-148.6	-8367.8	-795.9	9878.2	18194.1	19698.5	-168.0	-9455.7	-899.4	544.0	2242.0
7	TMI_7-1	8750.3	16159.8	17452.0	-149.5	-8381.3	-796.9	9887.8	18260.6	19720.7	-168.9	-9470.8	-900.5	544.0	2260.0
7	TMI_7-2	8933.0	16778.3	18026.6	-161.1	-8571.9	-807.4	10094.3	18959.4	20370.1	-182.0	-9686.3	-912.4	544.0	2277.3
7	TMI_7-3	9188.8	17641.0	18811.5	-177.2	-8847.7	-823.3	10383.4	19934.4	21257.0	-200.2	-9997.9	-930.4	544.1	2294.7
7	TMI_7-4	9472.6	18574.4	19686.2	-194.6	-9163.3	-842.3	10704.0	20989.1	22245.4	-220.0	-10354.6	-951.8	544.3	2312.0
7	TMI_7-5	9638.5	19122.8	20185.0	-204.2	-9363.4	-856.3	10891.5	21608.8	22809.0	-230.8	-10580.6	-967.7	544.7	2330.0
7	TMI_7-6	9763.5	19501.2	20523.8	-210.2	-9512.4	-868.1	11032.7	22036.3	23191.9	-237.6	-10749.0	-980.9	545.2	2348.0
7	TMI_7-7	9808.5	19610.0	20619.2	-211.2	-9575.1	-875.4	11083.6	22159.2	23299.7	-238.6	-10819.8	-989.2	545.7	2365.8
7	TMI_7-8	9813.4	19588.4	20584.5	-209.6	-9592.6	-880.1	11089.2	22134.9	23260.5	-236.8	-10839.7	-994.5	546.4	2383.5
7	TMI_7-9	9797.4	19496.8	20499.7	-206.8	-9580.2	-883.0	11071.1	22031.4	23164.7	-233.7	-10825.6	-997.8	547.0	2401.2
7	TMI_7-10	9764.4	19365.6	20365.2	-203.4	-9548.8	-884.4	11033.8	21883.1	23012.6	-229.8	-10790.2	-999.4	547.6	2419.0
7	TMI_7-11	9830.1	19561.5	20546.4	-206.5	-9618.0	-890.7	11108.0	22104.5	23217.4	-233.3	-10868.3	-1006.5	548.2	2436.6
7	TMI_7-12	9939.8	19907.4	20857.6	-212.4	-9733.1	-899.6	11232.0	22495.4	23569.0	-240.0	-10998.4	-1016.6	548.8	2454.2
7	TMI_7-13	10070.5	20323.3	21248.8	-219.8	-9877.2	-910.1	11379.7	22965.3	24011.1	-248.4	-11161.3	-1028.5	549.4	2471.8
7	TMI_7-14	10218.2	20789.2	21669.9	-228.0	-10036.4	-921.6	11546.6	23491.8	24487.0	-257.6	-11341.1	-1041.5	550.1	2489.4
7	TMI_7-15	10374.9	21285.1	22121.1	-236.5	-10206.5	-934.1	11723.6	24052.1	24996.9	-267.3	-11533.3	-1055.6	550.8	2507.0
7	TMI_7-16	10396.2	21257.5	22137.3	-236.0	-10232.4	-938.5	11747.7	24021.0	25015.2	-266.7	-11562.6	-1060.5	551.6	2477.0
7	TMI_7-17	10369.5	21070.0	21993.3	-232.4	-10204.3	-940.1	11717.5	23809.1	24852.5	-262.7	-11530.9	-1062.3	552.5	2447.0
7	TMI_7-18	10317.8	20802.4	21769.5	-227.2	-10145.3	-939.7	11659.1	23506.7	24599.5	-256.8	-11464.1	-1061.9	553.3	2417.0
7	TMI_7-19	10249.1	20474.9	21505.5	-221.3	-10064.1	-937.8	11581.5	23136.6	24301.2	-250.0	-11372.5	-1059.7	554.1	2387.0
7	TMI_7-20	10169.4	20127.3	21221.7	-215.0	-9969.1	-934.8	11491.5	22743.8	23980.5	-242.9	-11265.1	-1056.3	554.9	2357.0
7	TMI_7-21	10081.7	19769.8	20917.7	-208.5	-9866.0	-930.8	11392.3	22339.8	23637.0	-235.6	-11148.5	-1051.8	555.6	2327.0
7	TMI_7-22	9990.0	19402.2	20603.9	-202.0	-9756.9	-926.2	11288.7	21924.5	23282.4	-228.3	-11025.3	-1046.6	556.2	2297.0
7	TMI_7-22	9990.0	19402.2	20603.9	-202.0	-9756.9	-926.2	11288.7	21924.5	23282.4	-228.3	-11025.3	-1046.6	556.2	2297.0
7	TMI_7-22	9990.0	19402.2	20603.9	-202.0	-9756.9	-926.2	11288.7	21924.5	23282.4	-228.3	-11025.3	-1046.6	556.2	2297.0
7	TMI_7-34	9330.8	17547.0	18841.2	-176.7	-9009.7	-893.3	10543.9	19828.1	21290.5	-199.6	-10181.0	-1009.5	558.1	2286.2
7	TMI_7-45	9089.6	16984.7	18268.5	-173.5	-8731.6	-881.2	10271.3	19192.7	20643.4	-196.1	-9866.7	-995.8	558.5	2275.4
7	TMI_7-57	8987.4	16762.5	18045.8	-174.2	-8614.4	-876.1	10155.8	18941.6	20391.7	-196.8	-9734.2	-990.0	558.6	2264.6
7	TMI_7-71	8933.8	16631.8	17906.9	-175.2	-8550.0	-872.7	10095.2	18794.0	20234.8	-198.0	-9661.5	-986.2	558.6	2250.9
7	TMI_7-92	8904.8	16528.1	17817.3	-175.3	-8511.7	-869.2	10062.4	18676.8	20133.6	-198.1	-9618.2	-982.2	558.7	2232.0
7	TMI_7-120	8885.9	16416.0	17731.2	-173.9	-8481.5	-864.4	10041.1	18550.1	20036.3	-196.5	-9584.1	-976.8	558.9	2205.3
7	TMI_7-149	8871.9	16311.0	17654.5	-171.7	-8458.0	-859.7	10025.2	18431.4	19949.5	-194.0	-9557.6	-971.4	559.1	2178.3
7	TMI_7-178	8859.9	16207.9	17577.7	-169.1	-8437.6	-855.0	10011.7	18314.9	19862.8	-191.1	-9534.5	-966.2	559.3	2151.3
7	TMI_7-207	8848.9	16106.8	17521.0	-166.5	-8418.2	-850.6	9999.3	18200.7	19798.7	-188.1	-9512.5	-961.2	559.4	2124.3
7	TMI_7-236	8836.9	16005.7	17454.3	-163.7	-8398.7	-846.1	9985.7	18086.5	19723.3	-185.0	-9490.5	-956.1	559.6	2097.3
7	TMI_7-265	8825.9	15904.7	17387.5	-161.0	-8378.3	-841.9	9973.3	17972.3	19647.9	-182.0	-9467.4	-951.3	559.6	2070.3
7	TMI_7-294	8813.9	15804.6	17330.8	-158.4	-8358.8	-837.8	9959.7	17859.2	19583.8	-178.9	-9445.5	-946.7	559.7	2043.3
7	TMI_7-322	8802.9	15703.5	17264.1	-155.7	-8339.4	-833.6	9947.3	17744.9	19508.4	-176.0	-9423.5	-942.0	559.7	2016.3
7	TMI_7-351	8790.9	15603.4	17207.3	-153.2	-8319.9	-829.7	9933.7	17631.9	19444.3	-173.1	-9401.5	-937.5	559.7	1989.3
7	TMI_7-380	8778.9	15503.3	17140.6	-150.6	-8300.5	-825.7	9920.2	17518.8	19368.9	-170.2	-9379.6	-933.1	559.7	1962.3
7	TMI_7-409	8766.9	15404.3	17083.9	-148.1	-8281.1	-821.9	9906.6	17406.8	19304.8	-167.4	-9357.6	-928.7	559.6	1935.3
7	TMI_7-438	8753.9	15304.2	17027.2	-145.7	-8260.6	-818.0	9891.9	17293.7	19240.7	-164.7	-9334.5	-924.4	559.6	1908.3
7	TMI_7-467	8741.9	15205.1	16960.4	-143.3	-8241.2	-814.4	9878.4	17181.8	19165.3	-162.0	-9312.5	-920.3	559.5	1881.3
7	TMI_7-496	8728.9	15106.0	16903.7	-141.0	-8220.7	-810.7	9863.7	17069.8	19101.2	-159.3	-9289.4	-916.0	559.3	1854.3
7	TMI_7-525	8715.9	15006.9	16847.0	-138.7	-8200.3	-807.1	9849.0	16957.8	19037.1	-156.7	-9266.3	-912.0	559.2	1827.3
7	TMI_7-554	8702.9	14907.9	16780.2	-136.5	-8179.8	-803.6	9834.3	16845.9	18961.7	-154.2	-9243.2	-908.0	559.0	1800.3
7	TMI_7-583	8689.9	14809.8	16723.5	-134.3	-8159.4	-800.0	9819.6	16735.1	18897.6	-151.7	-9220.1	-904.0	558.9	1773.3
7	TMI_7-600	8682.1	14750.6	16689.3	-132.9	-8147.1	-798.0	9810.8	16668.2	18858.9	-150.2	-9206.2	-901.7	558.8	1757.0
7	TMI_7-606	8638.2	14632.7	16552.4	-130.6	-8096.8	-794.6	9761.1	16534.9	18704.2	-147.5	-9149.4	-897.9	558.6	1757.0
7	TMI_7-612	8575.3	14463.8	16375.5	-127.4	-8026.6	-789.3	9690.1	16344.1	18504.4	-143.9	-9070.1	-891.9	558.3	1757.0
7	TMI_7-622	8544.3	14378.8	16295.5	-125.6	-7991.6	-783.7	9655.0	16248.0	18414.0	-141.9	-9030.5	-885.6	557.5	1757.0
7	TMI_7-632	8535.3	14350.8	16265.5	-124.5	-7981.6	-779.3	9644.9	16216.4	18380.1	-140.6	-9019.2	-880.6	556.7	1757.0
7	TMI_7-652	8539.3	14342.8	16275.5	-122.4	-7986.6	-772.6	9649.4	16207.3	18391.4	-138.3	-9024.9	-873.0	555.3	1757.0
7	TMI_7-672	8548.3	14346.8	16285.5	-120.3	-7997.6	-766.9	9659.6	16211.9	18402.7	-136.0	-9037.3	-866.6	554.0	1757.0
7	TMI_7-692	8557.3	14352.8	16305.5	-118.4	-8008.6	-762.1	9669.7	16218.6	18425.3	-133.8	-9049.8	-861.2	552.9	1757.0
7	TMI_7-712	8566.3	14359.8	16325.5	-116.6	-8019.6	-757.9	9679.9	16226.6	18447.9	-131.8	-9062.2	-856.4	551.8	1757.0
7	TMI_7-732	8573.3	14360.8	16335.5	-114.8	-8028.6	-754.2	9687.8	16227.7	18459.2	-129.7	-9072.4	-852.2	550.8	1757.0
7	TMI_7-752	8583.3	14355.8	16345.5	-112.7	-8040.6	-750.4	9699.1	16222.0	18470.5	-127.4	-9085.9	-847.9	550.0	1757.0
7	TMI_7-772	8590.3	14366.8	16365.5	-111.4	-8047.6	-746.8	9707.0	16234.5	18493.1	-125.9	-9093.8	-843.9	549.1	1757.0
7	TMI_7-792	8590.3	14371.8	16375.5	-110.4	-8051.6	-744.0	9707.0	16240.1	18504.4	-124.7	-9098.3	-840.7	548.4	1757.0
7	TMI_7-812	8588.3	14372.8	16375.5	-109.6	-8053.6	-741.5	9704.8	16241.2	18504.4	-123.8	-9100.6	-837.9	547.7	1757.0
7	TMI_7-832	8585.3	14372.8	16375.5	-108.9	-8053.6	-739.3	9701.4	16241.2	18504.4	-123.1	-9100.6	-835.4	547.0	1757.0
7	TMI_7-852	8581.3	14370.8	16375.5	-108.4	-8052.6	-737.4	9696.8	16239.0	18504.4	-122.5	-9099.5	-833.3	546.4	1757.0
7	TMI_7-872	8576.3	14368.8	16375.5	-108.0	-8049.6	-735.8	9691.2	16236.7	18504.4	-122.0	-9096.1	-831.4	545.9	1757.0
7	TMI_7-892	8570.3	14365.8	16375.5	-107.7	-8046.6	-734.4	9684.4	16233.3	18504.4	-121.7	-9092.7	-829.9	545.4	1757.0
7	TMI_7-912	8564.3	14361.8	16365.5	-107.5	-8043.6	-733.2	9677.6	16228.8	18493.1	-121.4	-9089.3	-828.5	544.9	1757.0
7	TMI_7-932	8558.3	14358.8	16365.5	-107.4	-8039.6	-732.3	9670.9	16225.4	18493.1	-121.3	-9084.8	-827.5	544.4	1757.0
7	TMI_7-952	8552.3	14354.8	16355.5	-107.4	-8035.6	-731.5	9664.1	16220.9	18481.8	-121.3	-9080.3	-826.6	544.0	1757.0
7	TMI_7-972	8545.3	14350.8	16355.5	-107.4	-8030.6	-730.9	9656.2	16216.4	18481.8	-121.4	-9074.6	-825.9	543.6	1757.0
7	TMI_7-992	8539.3	14346.8	16345.5	-107.5	-8025.6	-730.4	9649.4	16211.9	18470.5	-121.5	-9069.0	-825.3	543.2	1757.0
7	TMI_7-1012	8532.3	14343.8	16335.5	-107.7	-8021.6	-730.0	9641.5	16208.5	18459.2	-121.7	-9064.4	-824.9	542.9	1757.0
7	TMI_7-1032	8526.3	14339.8	16335.5	-107.9	-8016.6	-729.8	9634.7	16204.0	18459.2	-121.9	-9058.8	-824.7	542.5	1757.0
7	TMI_7-1052	8520.3	14336.8	16325.5	-108.1	-8011.6	-729.6	9627.9	16200.6	18447.9	-122.2	-9053.1	-824.4	542.2	1757.0
7	TMI_7-1072	8514.3	14332.8	16325.5	-108.4	-8007.6	-729.6	9621.1	16196.0	18447.9	-122.5	-9048.6	-824.4	541.9	1757.0
7	TMI_7-1092	8508.3	14329.8	16315.5	-108.7	-8002.6	-729.6	9614.4	16192.7	18436.6	-122.8	-9043.0	-824.4	541.7	1757.0
7	TMI_7-1112	8502.3	14326.8	16305.5	-109.0	-7997.6	-729.6	9607.6	16189.3	18425.3	-123.2	-9037.3	-824.4	541.4	1757.0
7	TMI_7-1132	8496.3	14324.8	16305.5	-109.3	-7993.6	-729.7	9600.8	16187.0	18425.3	-123.5	-9032.8	-824.6	541.1	1757.0
7	TMI_7-1152	8491.3	14321.8	16295.5	-109.6	-7988.6	-729.9	9595.1	16183.6	18414.0	-123.9	-9027.2	-824.8	540.9	1757.0
7	TMI_7-1172	8485.3	14318.8	16295.5	-110.0	-7984.6	-730.0	9588.4	16180.2	18414.0	-124.3	-9022.6	-824.9	540.7	1757.0
7	TMI_7-1192	8480.3	14316.8	16285.5	-110.3	-7980.6	-730.2	9582.7	16178.0	18402.7	-124.7	-9018.1	-825.1	540.5	1757.0
7	TMI_7-1212	8475.3	14314.8	16285.5	-110.7	-7975.6	-730.5	9577.1	16175.7	18402.7	-125.1	-9012.5	-825.5	540.3	1757.0
7	TMI_7-4212	8312.3	14261.8	16085.5	-124.6	-7834.6	-749.9	9392.9	16115.8	18176.7	-140.8	-8853.1	-847.4	535.3	1757.0
8	TMI_8-0	9047.1	16422.9	17927.4	-150.5	-8635.4	-822.2	10223.2	18557.9	20258.0	-170.0	-9758.0	-929.1	580.0	2242.0
8	TMI_8-23	8951.7	16086.4	17641.9	-144.9	-8522.1	-812.7	10115.4	18177.7	19935.3	-163.7	-9630.0	-918.4	579.1	2207.0
8	TMI_8-45	8870.3	15808.0	17416.3	-140.4	-8424.7	-803.3	10023.4	17863.0	19680.5	-158.7	-9520.0	-907.7	577.8	2172.0
8	TMI_8-68	8801.8	15574.5	17230.8	-136.7	-8344.4	-795.2	9946.1	17599.2	19470.8	-154.4	-9429.2	-898.6	576.1	2137.0
8	TMI_8-90	8742.4	15367.0	17065.3	-133.4	-8274.0	-788.1	9878.9	17364.7	19283.8	-150.8	-9349.7	-890.6	574.4	2102.0
8	TMI_8-113	8689.0	15178.6	16919.8	-130.5	-8210.7	-782.0	9818.6	17151.8	19119.4	-147.5	-9278.1	-883.7	572.5	2067.0
8	TMI_8-135	8640.6	15001.1	16784.3	-127.9	-8152.4	-776.6	9763.8	16951.3	18966.2	-144.5	-9212.2	-877.6	570.6	2032.0
8	TMI_8-158	8595.1	14833.7	16658.7	-125.5	-8098.0	-771.8	9712.5	16762.0	18824.4	-141.8	-9150.7	-872.1	568.7	1997.0
8	TMI_8-180	8551.7	14673.2	16543.2	-123.2	-8045.7	-767.4	9663.4	16580.7	18693.8	-139.2	-9091.6	-867.2	566.7	1962.0
8	TMI_8-203	8511.3	14517.7	16427.7	-121.0	-7997.3	-763.3	9617.8	16405.0	18563.3	-136.8	-9037.0	-862.5	564.7	1927.0
8	TMI_8-225	8471.9	14367.3	16312.2	-119.0	-7949.0	-759.4	9573.2	16235.0	18432.8	-134.4	-8982.3	-858.1	562.8	1892.0
8	TMI_8-248	8434.4	14219.8	16206.7	-117.0	-7903.6	-755.7	9530.9	16068.4	18313.5	-132.2	-8931.1	-854.0	560.8	1857.0
8	TMI_8-270	8398.0	14075.3	16101.1	-115.0	-7859.3	-752.1	9489.8	15905.1	18194.3	-130.0	-8881.0	-849.9	558.8	1822.0
8	TMI_8-293	8362.6	13933.9	15995.6	-113.1	-7815.9	-748.6	9449.7	15745.3	18075.0	-127.8	-8832.0	-845.9	556.8	1787.0
8	TMI_8-315	8328.2	13794.4	15890.1	-111.3	-7772.6	-745.2	9410.8	15587.7	17955.8	-125.7	-8783.0	-842.1	554.8	1752.0
8	TMI_8-338	8294.7	13657.0	15794.6	-109.4	-7731.2	-741.8	9373.0	15432.4	17847.9	-123.7	-8736.3	-838.2	552.8	1717.0
8	TMI_8-360	8257.3	13498.5	15669.0	-107.0	-7685.9	-738.0	9330.8	15253.3	17706.0	-120.9	-8685.0	-834.0	550.8	1682.0
8	TMI_8-383	8219.9	13345.0	15553.5	-104.4	-7636.5	-732.3	9288.5	15079.9	17575.5	-118.0	-8629.3	-827.5	548.9	1647.0
8	TMI_8-405	8168.5	13192.6	15428.0	-102.5	-7582.2	-727.0	9230.4	14907.6	17433.6	-115.8	-8567.9	-821.5	546.9	1612.0
8	TMI_8-428	8113.0	13035.1	15292.5	-100.7	-7522.8	-721.5	9167.7	14729.7	17280.5	-113.8	-8500.8	-815.3	544.9	1577.0
8	TMI_8-450	8053.6	12872.7	15147.0	-98.7	-7460.5	-715.6	9100.6	14546.1	17116.1	-111.5	-8430.4	-808.6	542.9	1542.0
8	TMI_8-473	7992.2	12706.2	15001.4	-96.7	-7396.1	-709.6	9031.2	14358.0	16951.6	-109.3	-8357.6	-801.9	540.9	1507.0
8	TMI_8-495	7929.8	12536.7	14855.9	-94.7	-7329.8	-703.5	8960.6	14166.5	16787.2	-107.1	-8282.7	-795.0	538.9	1472.0
8	TMI_8-518	7865.3	12365.3	14700.4	-92.9	-7263.4	-697.6	8887.8	13972.8	16611.5	-104.9	-8207.7	-788.3	536.9	1437.0
8	TMI_8-540	7801.9	12192.8	14554.9	-91.0	-7196.1	-691.9	8816.2	13777.9	16447.0	-102.8	-8131.6	-781.9	534.9	1402.0
8	TMI_8-563	7737.5	12021.3	14409.4	-89.2	-7129.7	-686.2	8743.4	13584.1	16282.6	-100.7	-8056.6	-775.4	532.9	1367.0
8	TMI_8-585	7675.1	11849.9	14263.8	-87.3	-7063.4	-680.5	8672.8	13390.4	16118.1	-98.7	-7981.6	-769.0	530.9	1332.0
8	TMI_8-608	7611.6	11679.4	14118.3	-85.5	-6997.1	-674.9	8601.1	13197.7	15953.7	-96.6	-7906.7	-762.6	528.9	1297.0
8	TMI_8-630	7549.2	11509.0	13972.8	-83.7	-6931.7	-669.3	8530.6	13005.1	15789.3	-94.5	-7832.8	-756.3	526.9	1262.0
8	TMI_8-653	7486.8	11339.5	13827.3	-81.8	-6866.4	-663.6	8460.1	12813.6	15624.8	-92.5	-7759.0	-749.9	524.9	1227.0

8	TMI_8-675	7424.4	11170.0	13681.8	-80.0	-6800.0	-658.0	8389.5	12622.1	15460.4	-90.4	-7684.0	-743.6	522.9	1192.0
8	TMI_8-698	7361.9	11000.6	13536.2	-78.2	-6735.7	-652.4	8319.0	12430.7	15295.9	-88.3	-7611.3	-737.2	520.9	1157.0
8	TMI_8-720	7300.5	10831.1	13390.7	-76.3	-6670.3	-646.8	8249.6	12239.2	15131.5	-86.3	-7537.5	-730.9	518.9	1122.0
8	TMI_8-743	7238.1	10662.7	13245.2	-74.5	-6605.0	-641.2	8179.0	12048.8	14967.1	-84.2	-7463.6	-724.6	516.9	1087.0
8	TMI_8-765	7176.6	10494.2	13099.7	-72.7	-6540.6	-635.7	8109.6	11858.4	14802.6	-82.1	-7390.9	-718.4	514.9	1052.0
8	TMI_8-788	7115.2	10325.7	12954.1	-70.9	-6475.3	-630.1	8040.2	11668.1	14638.2	-80.1	-7317.1	-712.0	512.9	1017.0
8	TMI_8-810	7053.8	10156.3	12808.6	-69.0	-6410.9	-624.5	7970.8	11478.8	14473.7	-78.0	-7244.3	-705.7	510.9	982.0
8	TMI_8-833	6992.4	9989.8	12663.1	-67.2	-6346.6	-618.9	7901.4	11288.5	14309.3	-76.0	-7171.6	-699.4	508.9	947.0
8	TMI_8-855	6930.9	9822.3	12523.6	-65.4	-6282.2	-613.4	7832.0	11099.3	14151.6	-73.9	-7098.9	-693.2	506.9	912.0
8	TMI_8-878	6870.5	9654.9	12380.1	-63.6	-6217.9	-607.8	7763.7	10910.0	13989.5	-71.8	-7026.2	-686.8	504.9	877.0
8	TMI_8-900	6809.1	9487.4	12236.5	-61.8	-6153.5	-602.3	7694.3	10720.8	13827.3	-69.8	-6953.5	-680.6	502.9	842.0
8	TMI_8-915	6820.4	9563.4	12298.7	-63.6	-6171.5	-603.6	7707.1	10806.7	13897.6	-71.9	-6973.8	-682.0	501.8	841.0
8	TMI_8-930	6828.7	9621.4	12344.9	-65.1	-6187.4	-605.3	7716.5	10872.2	13949.8	-73.5	-6991.8	-684.0	501.0	840.0
8	TMI_8-960	6833.3	9679.4	12385.3	-66.9	-6200.3	-607.9	7721.7	10937.7	13995.4	-75.6	-7006.3	-686.9	499.6	838.0
8	TMI_8-990	6831.0	9708.4	12399.7	-68.1	-6203.2	-609.3	7719.0	10970.5	14011.7	-77.0	-7009.6	-688.5	498.4	836.0
8	TMI_8-1020	6823.6	9720.4	12394.1	-69.0	-6200.1	-609.8	7710.7	10984.0	14005.3	-77.9	-7006.1	-689.0	497.3	834.0
8	TMI_8-1050	6813.2	9722.4	12378.5	-69.5	-6193.9	-609.5	7698.9	10986.3	13987.7	-78.5	-6999.2	-688.8	496.2	832.0
8	TMI_8-1080	6800.9	9716.3	12352.9	-69.8	-6183.8	-608.7	7685.0	10979.5	13958.7	-78.9	-6987.7	-687.9	495.2	830.0
8	TMI_8-1110	6786.5	9705.3	12333.2	-70.0	-6172.7	-607.6	7668.7	10967.0	13936.6	-79.1	-6975.2	-686.6	494.2	828.0
8	TMI_8-1140	6770.1	9690.3	12304.6	-70.1	-6158.6	-606.2	7650.2	10950.0	13904.2	-79.2	-6959.2	-685.0	493.2	826.0
8	TMI_8-1170	6752.7	9671.3	12274.0	-70.1	-6144.5	-604.7	7630.6	10928.6	13869.6	-79.2	-6943.3	-683.3	492.1	824.0
8	TMI_8-1200	6734.4	9650.3	12240.4	-70.1	-6128.4	-603.0	7609.8	10904.8	13831.7	-79.2	-6925.0	-681.4	491.1	822.0
8	TMI_8-1260	6778.4	9803.3	12370.4	-73.2	-6181.4	-608.3	7659.5	11077.7	13978.6	-82.7	-6984.9	-687.3	490.4	822.0
8	TMI_8-1320	6805.4	9883.3	12430.4	-74.9	-6212.4	-611.9	7690.1	11168.1	14046.4	-84.6	-7020.0	-691.4	490.2	822.0
8	TMI_8-1395	6825.4	9938.3	12470.4	-75.9	-6234.4	-614.2	7712.7	11230.3	14091.6	-85.8	-7044.8	-694.0	490.1	822.0
8	TMI_8-1470	6838.4	9971.3	12500.4	-76.5	-6247.4	-615.4	7727.3	11267.5	14125.5	-86.4	-7059.5	-695.4	490.1	822.0
8	TMI_8-1545	6847.4	9991.3	12510.4	-76.8	-6256.4	-616.0	7737.5	11290.1	14136.8	-86.8	-7069.7	-696.0	490.0	822.0
8	TMI_8-1620	6852.4	10005.3	12520.4	-77.0	-6262.4	-616.4	7743.2	11306.0	14148.1	-87.0	-7076.5	-696.5	490.0	822.0
8	TMI_8-1695	6856.4	10014.3	12530.4	-77.1	-6265.4	-616.5	7747.7	11316.1	14159.4	-87.1	-7079.8	-696.6	490.0	822.0
8	TMI_8-1748	6858.4	10018.3	12530.4	-77.1	-6267.4	-616.6	7749.9	11320.7	14159.4	-87.1	-7082.1	-696.7	490.0	822.0
8	TMI_8-1800	6859.4	10022.3	12530.4	-77.1	-6269.4	-616.6	7751.1	11325.2	14159.4	-87.2	-7084.4	-696.7	490.0	822.0
8	TMI_8-4800	6864.4	10033.3	12540.4	-77.2	-6273.4	-616.6	7756.7	11337.6	14170.7	-87.2	-7088.9	-696.7	490.0	822.0
9	TMI_9-0	8703.6	16550.8	16979.9	-1126.7	-8209.4	-822.2	9835.1	18702.4	19187.3	-1273.1	-9276.6	-929.1	555.0	2242.0
10	TMI_10-0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0	0.0
10	TMI_10-1	1479.7	10225.0	6481.3	-145.1	-2329.7	-178.6	1672.0	11554.3	7323.8	-164.0	-2632.5	-201.8	70.0	3125.0

VESLFAT RESULT FILE P3-O.FAT:

```
VESLFAT Version 1.42 12/29/2006 (VeslFat1p42)
11-04-2010    12:19:39
Page 1


VESLFAT Load Set Pair Module Version 1.42 - 01/03/2007 (&VeslFatPair1p42)
Stress Pairing Analysis
Elastic Plastic Properties
    m =  1.7
    n =  0.3

Stresses Multiplied by  1  to convert to psi
Max General Membrane Stress(ksi) per unit Pressure (psi) =  0.01
Upper Limit on Sy for large number of cycles NB-5222.5(b) (ksi) =  40

Material Properties vs Temperature
 T,F   E, ksi  3Sm, ksi   Sy, ksi
   70  28300      20.0       30.0
  200  27500      20.0       25.9
  300  27000      20.0       23.4
  400  26400      19.3       21.4
  500  25900      18.0       20.0
  600  25300      17.0       18.9
  650  25050      16.6       18.5
  700  24800      16.3       18.2
  750  24450      16.1       17.9

Stress ranges <  13328  psi neglected

Files:
        Input Stress File =          p3-o.STR
        Converted Stress File =      p3-o.ST1
        All Stress Ranges File =     p3-o.ALL
        Significant Ranges File =    p3-o.PR
        Thermal Ratchet Case File  = p3-o.TRC
```

```
  Max Ratio of Sn/3Sm =  0.574371  for Trans Pair  1  and  6
              Max P+Q Stress, psi =  29647.86  <=  3Sm, psi =  51618

VESLFAT Load Pair Sort Module Version 1.42 - 12/29/2006 (&VeslFatSort1p42)
Sorting Stress Ranges from File =          p3-o.PR
Storing Output Ordered Ranges in File =    p3-o.ORD
```

```
Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006
(&VeslFatFat1p42)
Page  2                             11-04-2010        12:19:47

Input Echo:

Fatigue Properties:
    m =  1.7     n =  0.3
    E (Fatigue Curve), ksi =  28300
    E (Analysis) chosen at the highest of transient pair temperatures
    Sm chosen at the highest of transient pair temperatures

Fatigue Curve:      Cycles          Salt, ksi
                   1.0E+01            708.00
                   2.0E+01            512.00
                   5.0E+01            345.00
                   1.0E+02            261.00
                   2.0E+02            201.00
                   5.0E+02            148.00
                   1.0E+03            119.00
                   2.0E+03             97.00
                   5.0E+03             76.00
                   1.0E+04             64.00
                   2.0E+04             55.50
                   5.0E+04             46.30
                   1.0E+05             40.80
                   2.0E+05             35.90
                   5.0E+05             31.00
                   1.0E+06             28.20
                   2.0E+06             22.80
                   5.0E+06             18.40
                   1.0E+07             16.40
                   2.0E+07             15.20
                   5.0E+07             14.30
                   1.0E+08             14.10
                   1.0E+09             13.90
                   1.0E+10             13.70
                   1.0E+11             13.60

Events:Index   Name       Num. Cycles
          1 TMI_1-                        240
          2 TMI_2-              240
          3 TMI_3-              660
          4 TMI_4-            65938
          5 TMI_5-               80
          6 TMI_6-               80
          7 TMI_7-              180
          8 TMI_8-             1480
          9 TMI_9-             7200
         10 TMI_10-              20
```

Stress input file:

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fatigue Analysis using [illegible] Fatigue Module Version 1.42 - 12/29/2006 [illegible]
Page [illegible] 11-04-2010 12:19:47

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fatigue Analysis using [illegible] Fatigue Module Version 1.42 - 12/29/2006 [illegible]
Page 4 11-04-2010 12:19:47

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006 (&VesLFatFat(p42)
Page 5 11-04-2010 12:15:47

[illegible]

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006 (&VesLFatFat(p42)
Page 6 11-04-2010 12:15:47

[illegible]

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006 (&VeslFatFatip42)
Page 7 11-04-2010 12:19:47

[illegible]	TMI_1=19980	4598.7	1644.6	11080.8	-27.9	-3134.0	-263.2	5198.1
[illegible]	TMI_1=20520	4592.1	1629.8	11054.0	-27.9	-3120.6	-261.9	5177.8
[illegible]	TMI_1=21060	4565.9	1610.1	11028.2	-27.8	-3106.3	-260.4	5155.4
[illegible]	TMI_1=21400	4549.2	1591.4	11002.4	-27.3	-3092.9	-259.0	5141.1
[illegible]	TMI_1=21600	4506.6	1424.6	10528.8	-25.0	-3027.2	-255.8	5052.7
[illegible]	TMI_1=21600	4506.6	1424.6	10528.8	-25.0	-3027.2	-255.8	5052.7
[illegible]	TMI_1=21623	2512.1	-1314.3	8449.6	89.6	-2502.6	-18.5	2475.2
[illegible]	TMI_1=21654	2168.1	-4109.3	5431.4	34.9	-2665.9	21.5	2563.2

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006 (&VeslFatFatip42)
Page 8 11-04-2010 12:19:47

[illegible]	TMI_1=21681	2416.0	-3124.0	6140.6	60.1	-2562.7	13.8	2297.5
[illegible]	TMI_1=21734	2441.2	-2165.6	7044.2	45.4	-3200.1	-18.5	2444.5
[illegible]	TMI_1=21763	2788.4	-1723.7	[illegible]	29.0	-3457.2	-46.0	3141.6
[illegible]	TMI_1=21817	2836.9	-1308.5	7929.6	16.2	-3528.2	-75.0	3250.7
[illegible]	TMI_1=21871	2946.7	-1048.8	8137.2	7.1	-3612.8	-95.0	3329.8
[illegible]	TMI_1=21925	2999.7	-874.1	8252.9	0.9	-3674.4	-108.3	3369.7
[illegible]	TMI_1=21979	3036.7	-724.2	8344.6	-4.6	-3718.9	-117.0	3433.7
[illegible]	TMI_1=22033	3066.7	-631.9	8425.3	-6.5	-3750.5	-122.7	3445.3
[illegible]	TMI_1=22087	3085.6	-567.6	8465.0	-8.5	-3772.9	-126.2	3466.8
[illegible]	TMI_1=22141	3098.6	-522.3	8488.7	-9.9	-3787.3	-128.4	3501.5
[illegible]	TMI_1=22195	3106.6	-491.9	8501.4	-10.8	-3798.7	-129.3	3510.5
[illegible]	TMI_1=22249	3109.6	-477.6	8506.1	-11.4	-3801.3	-130.3	3513.6
[illegible]	TMI_1=22303	3109.6	-462.3	8504.7	-11.8	-3801.5	-130.0	3513.8
[illegible]	TMI_1=22357	3106.6	-454.0	8498.5	-12.1	-3799.9	-129.8	3510.4
[illegible]	TMI_1=22411	3102.5	-457.7	8490.1	-12.3	-3797.3	-129.5	3505.9
[illegible]	TMI_1=22465	3098.5	-460.4	8480.9	-12.3	-3793.8	-129.1	3501.3
[illegible]	TMI_1=22519	3091.5	-461.0	8470.1	-12.4	-3790.2	-128.6	3495.6
[illegible]	TMI_1=22573	3086.5	-470.7	8460.2	-12.3	-3785.6	-128.1	3490.0
[illegible]	TMI_1=22627	3083.5	-478.4	8447.9	-12.3	-3780.0	-127.4	3484.3
[illegible]	TMI_1=22681	3077.4	-487.1	8435.6	-12.2	-3774.4	-126.8	3477.5
[illegible]	TMI_1=22735	3071.4	-496.8	8421.3	-12.1	-3768.8	-126.0	3470.7
[illegible]	TMI_1=22789	3064.4	-507.5	8407.0	-12.0	-3762.2	-125.3	3462.9
[illegible]	TMI_1=22843	3057.4	-519.1	8391.7	-11.9	-3755.6	-124.5	3454.8

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006 (AVesIFatFatip42)
Page 9 11-04-2010 12:15:37

1	TMI_1=24463	2804.4	-564.6	2664.4	-3.3	-1116.4	-55.1	1169.0	-1044.1	5914.1	-3.3	-1553.8	-112.0	141.0	61.6
1	TMI_1=24513	2251.4	-584.4	3672.3	[illegible]	-1104.5	-55.1	1159.4	-1082.6	5905.7	-4.1	-1564.6	-111.1	150.1	61.8
1	TMI_1=24575	2347.2	-571.0	[illegible]	-1.4	-1089.1	-51.8	1145.5	-1098.5	5856.1	-4.3	-1577.3	-110.1	149.5	60.0
1	TMI_1=24625	2334.5	-541.7	5611.1	-1.2	-1062.1	-56.6	1116.2	-1116.1	5856.6	-4.2	-1584.1	-109.1	148.9	58.2
1	TMI_1=24675	2749.4	-1002.4	3520.4	-1.1	-1064.5	-57.7	1123.9	-1112.3	5853.8	-4.3	-1594.5	-109.2	148.0	56.4
1	TMI_1=24733	2761.2	-1017.1	3404.3	-4.9	-1427.7	-64.9	1120.2	-1149.3	5913.5	-3.8	-1627.6	-107.7	147.3	44.6
1	TMI_1=24787	2712.5	-1011.7	7266.5	-6.8	-1467.5	-64.7	1110.3	-1147.5	5749.0	-3.7	-1619.2	-106.2	146.5	52.4
1	TMI_1=24841	2747.9	-1046.4	1697.5	-6.7	-1414.8	-63.1	1160.6	-1142.5	5734.1	-3.5	-1644.1	-107.1	145.6	51.0
1	TMI_1=24895	2715.3	-1080.7	7712.1	-6.5	-1412.2	-62.3	1098.9	-1150.6	5758.9	-3.4	-1695.8	-104.3	145.0	45.2
1	TMI_1=24949	2754.6	-1095.6	7154.9	-6.4	-1446.0	-61.8	1061.0	-1215.2	5746.1	-3.2	-1690.6	-103.1	144.3	47.4
1	TMI_1=25003	2213.9	-1070.0	7113.5	-6.2	-1414.8	-60.6	1031.1	-1231.7	5738.8	-3.0	-1681.1	-102.4	143.5	45.6
1	TMI_1=25057	2709.3	-1184.7	7130.1	-6.1	-1426.6	-59.7	1061.6	-1248.3	5741.8	-6.9	-1832.1	-101.4	142.8	43.8
1	TMI_1=25111	2780.6	-1119.1	7663.9	-5.9	-1418.4	-58.9	1051.7	-1244.9	5682.9	-6.7	-1862.8	-100.8	142.0	42.0
1	TMI_1=25165	2692.0	-1124.9	7466.7	-5.8	-1410.2	-58.9	1042.0	-1251.8	5663.4	-6.5	-1853.5	-99.4	141.3	40.2
1	TMI_1=25219	2683.4	-1136.4	7449.1	-5.6	-1402.0	-57.3	1031.1	-1257.9	5644.8	-6.4	-1844.2	-98.5	140.5	38.4
1	TMI_1=25273	2674.2	-1163.1	7432.1	-5.5	-1393.8	-56.3	1022.4	-1314.5	5626.1	-6.2	-1834.0	-97.5	139.8	36.6
1	TMI_1=25327	2665.9	-1179.0	7414.7	-5.4	-1385.6	-55.4	1012.5	-1331.1	5606.7	-6.1	-1825.7	-96.5	139.0	34.8
1	TMI_1=25381	2657.2	-1192.7	7397.1	-5.2	-1377.3	-54.6	1002.1	-1342.3	5589.2	-6.0	-1816.4	-95.5	138.3	33.0
1	TMI_1=25435	2648.6	-1207.4	7380.2	-5.1	-1369.1	-53.7	2992.9	-1364.1	5565.6	-5.7	-1807.1	-94.6	137.5	31.2
1	TMI_1=25489	2639.9	-1222.0	7362.9	-4.9	-1360.9	-52.8	2983.1	-1390.9	5543.2	-5.6	-1797.8	-93.6	136.8	29.4
1	TMI_1=25543	2631.1	-1236.7	7346.6	-4.8	-1352.7	-52.0	2973.4	-1397.7	5527.6	-5.4	-1788.6	-92.6	136.0	27.6
1	TMI_1=25597	2622.6	-1251.4	7328.4	-4.6	-1344.5	-51.1	2963.5	-1414.1	5508.1	-5.2	-1779.3	-91.7	135.3	25.8
1	TMI_1=25651	2613.8	-1266.1	7312.0	-4.5	-1336.3	-50.3	2953.6	-1430.7	5484.7	-5.1	-1770.0	-90.7	134.5	24.0
1	TMI_1=25705	2605.1	-1280.8	7294.5	-4.3	-1328.1	-49.4	2943.9	-1447.5	5469.0	-4.9	-1760.8	-89.7	133.8	22.2
1	TMI_1=25759	2596.5	-1295.5	7277.4	-4.2	-1319.8	-48.5	2934.1	-1463.4	5449.4	-4.7	-1751.5	-88.7	133.0	20.4
1	TMI_1=25813	2587.8	-1310.2	7260.1	-4.1	-1311.6	-47.7	2924.2	-1480.5	5429.9	-4.6	-1742.2	-87.8	132.3	18.6
1	TMI_1=25867	2579.1	-1324.8	7242.8	-4.0	-1303.3	-46.8	2914.5	-1497.3	5410.3	-4.4	-1732.9	-86.8	131.5	16.8
1	TMI_1=25920	2570.6	-1339.4	7226.5	-3.8	-1295.1	-46.0	2904.7	-1513.6	5391.9	-4.3	-1723.7	-85.8	130.8	15.0
1	TMI_1=25928	2574.7	-1248.3	7529.5	-5.9	-1437.7	-18.0	2599.4	-1451.1	5429.2	-6.3	-1737.6	-94.2	147.7	14.5
1	TMI_1=25936	2566.2	-1256.9	7811.5	-5.5	-1265.2	-75.5	2877.2	-1465.5	5475.0	-6.3	-1720.1	-85.4	145.2	12.3
1	TMI_1=25944	2513.6	-1313.1	1554.1	-1.3	-1258.4	-12.5	2848.8	-1515.9	5311.7	-6.4	-1692.7	-81.9	142.6	10.5
1	TMI_1=25952	2483.6	-1315.5	7267.5	-5.4	-1225.2	-69.4	2803.1	-1558.1	5246.2	-6.1	-1644.5	-78.9	140.1	9.0
1	TMI_1=26060	2449.1	-1420.4	7241.6	-5.1	-1196.1	-66.4	2766.1	-1605.0	5183.0	-5.8	-1621.6	-75.0	137.6	7.2
1	TMI_1=26068	2415.8	-1441.1	7184.6	-4.8	-1167.6	-64.4	2729.9	-1651.1	5118.6	-5.5	-1574.4	-71.6	135.1	6.0
1	TMI_1=26076	2384.1	-1501.3	7129.4	-4.5	-1139.4	-60.4	2694.0	-1697.0	5058.6	-5.1	-1547.6	-68.2	132.3	3.7
1	TMI_1=26084	2352.2	-1541.6	7074.6	-4.3	-1111.5	-57.4	2658.6	-1742.0	5994.4	-4.8	-1514.0	-64.9	130.2	1.0
1	TMI_1=26092	2321.5	-1560.9	7020.4	-4.0	-1084.0	-54.5	2623.3	-1786.4	5931.1	-4.5	-1484.5	-61.6	127.7	0.0
1	TMI_1=46000	2291.4	-1619.6	6666.9	-3.7	-1056.9	-51.6	2594.1	-1830.2	5872.7	-4.2	-1454.1	-58.1	125.2	0.0
1	TMI_1=46060	2261.3	-1611.8	6571.9	-3.9	-1056.7	-51.9	2591.9	-1820.9	5860.6	-4.4	-1452.0	-58.6	125.1	0.0
1	TMI_1=46120	2235.1	-1605.9	6538.4	-4.0	-1061.6	-52.2	2593.7	-1814.7	5865.6	-4.5	-1459.6	-59.0	125.0	0.0
1	TMI_1=46300	2241.0	-1599.9	6463.8	-4.2	-1064.2	-52.6	2598.4	-1806.8	5891.7	-4.7	-1462.5	-59.4	125.0	0.0
1	TMI_1=46600	2250.3	-1594.5	6446.4	-4.3	-1066.9	-52.9	2598.2	-1801.8	5895.3	-4.8	-1464.4	-59.7	125.0	0.0
1	TMI_1=46600	2530.5	-1591.4	6449.5	-4.3	-1083.1	-52.9	2599.6	-1796.1	5931.5	-4.9	-1465.8	-59.8	125.0	0.0
4	TMI_4=0	5749.8	16098.5	13424.6	-143.1	-6033.8	-5855.8	5993.2	19352.8	19668.8	-147.0	-5462.4	-5996.6	544.4	2242.0
4	TMI_4=0	5753.1	16075.3	13556.9	-143.3	-6023.3	-5857.4	5993.7	19369.6	19726.5	-147.0	-5478.0	-5996.6	544.4	2242.0
4	TMI_4=0	5760.1	16060.3	13556.9	-143.8	-6388.7	-5855.4	5999.3	19378.1	19726.1	-147.0	-5479.2	-5996.6	544.4	2242.0
4	TMI_4=1	9556.4	19948.5	17165.4	-200.4	-9235.3	-8442.3	10764.7	21402.8	22366.0	-226.4	-13435.9	-8851.8	544.5	2379.5
4	TMI_4=2	10058.6	20817.6	21611.9	-233.6	-9929.9	-8880.3	11368.2	23524.1	24421.4	-244.2	-11107.8	-9394.4	544.5	2517.0
4	TMI_4=3	10478.9	22345.1	22924.8	-260.2	-10398.4	-9315.2	11541.1	25272.5	25988.6	-244.0	-11682.6	-10094.3	545.5	2654.5
4	TMI_4=4	10964.1	24152.3	24106.9	-282.9	-10801.2	-9468.6	12276.4	26440.1	25240.8	-159.6	-12205.4	-10372.2	546.3	2792.0
4	TMI_4=5	11042.5	24212.0	24547.6	-290.8	-11014.5	-9567.6	12517.8	27359.6	27378.8	-171.7	-12446.4	-10953.8	547.4	2792.0
4	TMI_4=6	11155.5	24441.8	24568.3	-292.5	-11151.9	-9962.2	12603.5	27619.2	28010.8	-170.7	-12601.6	-11109.9	548.7	2792.0

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006 (AVesIFatFatip42)
Page 10 11-04-2010 12:15:37

4	TMI_4=8	11272.0	24581.2	24649.8	-292.1	-11282.5	-10012.8	12737.1	27776.8	28193.3	-330.3	-12749.2	-11321.1	551.5	2792.0
4	TMI_4=10	11319.4	24550.2	24561.3	-289.9	-11180.1	-10016.8	12760.9	27742.5	28209.2	-327.1	-12818.1	-11350.0	554.4	2792.0
4	TMI_4=12	11332.8	24430.2	24492.1	-284.8	-11356.1	-10026.5	12804.1	27628.7	28128.8	-324.0	-12833.1	-11362.2	557.1	2792.0
4	TMI_4=17	11250.8	24350.2	24122.7	-276.5	-11247.7	-1038.0	12715.7	27154.1	27930.7	-314.4	-12732.5	-11313.0	561.2	2792.0
4	TMI_4=19	11143.8	24280.2	24112.7	-270.0	-11141.3	-1041.9	12592.5	26645.4	27477.4	-305.1	-11550.2	-11233.6	564.7	2792.0
4	TMI_4=25	10923.8	20810.2	23372.7	-257.0	-10868.7	-1039.2	12348.4	25735.5	26411.2	-290.4	-12304.5	-11741.7	570.0	2792.0
4	TMI_4=32	10741.6	21260.2	22942.7	-246.9	-10666.7	-1041.5	12158.2	25061.6	25721.9	-279.0	-12074.4	-11656.6	574.0	2792.0
4	TMI_4=38	10588.8	21060.2	22652.7	-239.1	-10482.7	-1021.4	11965.4	24468.6	25216.2	-270.1	-11945.5	-11542.2	577.1	2792.0
4	TMI_4=45	10466.8	21280.2	21472.7	-232.9	-10351.7	-1010.3	11835.2	24346.6	24716.2	-273.1	-11674.5	-11441.1	579.4	2792.0
4	TMI_4=52	10363.8	20950.2	21812.7	-227.7	-10286.7	-999.1	11711.1	24073.5	24456.6	-257.1	-11515.9	-11249.0	581.5	2792.0
4	TMI_4=58	10239.8	20890.2	21292.7	-223.2	-10106.7	-988.0	11616.2	23729.0	24060.8	-252.3	-11420.6	-11145.5	582.7	2792.0
4	TMI_4=65	10209.8	20470.2	21012.7	-219.5	-10020.7	-977.4	11537.1	23151.1	23812.2	-247.5	-11327.4	-11104.5	583.9	2792.0
4	TMI_4=71	10149.8	20280.2	20692.7	-215.9	-9947.7	-967.5	11469.3	22916.6	23608.8	-243.9	-11240.9	-11049.3	584.9	2792.0
4	TMI_4=78	10093.8	20120.2	20332.7	-212.7	-9884.7	-958.2	11410.5	22731.8	23428.0	-240.4	-11149.8	-11002.8	585.5	2792.0
4	TMI_4=85	10053.8	19990.2	20602.7	-209.9	-9829.7	-949.6	11359.5	22537.6	23281.1	-237.3	-11103.6	-11071.1	586.2	2792.0
4	TMI_4=91	10009.8	19860.2	20482.7	-207.1	-9780.7	-941.7	11311.1	22442.0	23145.5	-234.7	-11052.2	-11044.2	586.7	2792.0
4	TMI_4=98	9972.8	19760.2	20382.7	-204.9	-9737.7	-934.5	11266.9	22329.0	23025.5	-231.5	-11003.6	-11036.0	587.1	2792.0
4	TMI_4=104	9938.8	19660.2	20282.7	-202.7	-9697.7	-927.9	11230.9	22216.0	22908.8	-229.0	-10958.6	-11089.6	587.4	2792.0
4	TMI_4=111	9906.8	19570.2	20192.7	-200.6	-9661.7	-922.0	11194.3	22114.3	22804.4	-226.7	-10917.6	-11041.9	587.7	2792.0
4	TMI_4=118	9877.8	19490.2	20102.7	-198.8	-9628.7	-916.5	11161.9	22021.9	22761.3	-224.6	-10880.5	-11015.7	588.0	2792.0
4	TMI_4=124	9849.8	19420.2	20042.7	-197.1	-9597.7	-911.6	11130.3	21944.8	22693.5	-222.7	-10845.4	-10930.1	588.2	2792.0
4	TMI_4=131	9824.8	19350.2	20022.7	-195.5	-9569.7	-907.1	11102.0	21865.7	22625.7	-220.9	-10813.8	-10925.1	588.4	2792.0
4	TMI_4=137	9799.8	19290.2	19982.7	-194.0	-9543.7	-903.0	11073.8	21797.9	22557.9	-219.2	-10784.4	-10920.4	588.6	2792.0
4	TMI_4=144	9777.8	19230.2	19412.7	-192.7	-9518.7	-899.3	11048.9	21730.1	22501.4	-217.7	-10756.2	-10916.2	588.7	2792.0
4	TMI_4=144	9440.0	16547.7	16539.0	-180.2	-9087.5	-859.3	10567.2	19150.4	20036.0	-181.0	-10155.8	-9711.1	588.7	2092.0
4	TMI_4=144	9440.0	16547.7	16418.0	-180.2	-9087.5	-859.3	10667.2	19370.9	20036.0	-181.0	-10155.8	-9711.1	588.7	2092.0
4	TMI_4=146	9477.4	15119.5	16338.1	-125.5	-8979.8	-825.1	10027.0	17078.1	17914.1	-142.1	-9476.8	-9510.1	588.2	2087.2
4	TMI_4=149	8436.9	14543.3	16207.4	-116.1	-8151.6	-804.1	9808.9	16834.0	16914.3	-131.2	-9211.1	-9308.6	587.3	2082.5
4	TMI_4=151	8565.4	14355.3	16006.6	-113.1	-8040.6	-781.6	9701.5	16156.7	16087.4	-128.0	-9085.9	-8994.5	586.1	2077.8
4	TMI_4=156	8521.3	14242.1	15906.7	-112.3	-7963.4	-777.1	9629.6	16093.8	15974.6	-127.4	-9998.4	-8978.1	583.9	2069.0
4	TMI_4=160	8491.7	14221.7	15895.1	-112.8	-7925.5	-766.0	9545.6	16072.5	15961.5	-125.5	-9959.2	-8869.6	581.6	2059.5
4	TMI_4=165	8472.6	14217.3	15693.5	-112.7	-7887.6	-757.4	9574.1	16061.1	15959.7	-123.3	-9935.6	-8855.9	579.6	2050.0
4	TMI_4=170	8454.4	14193.9	15981.9	-112.1	-7849.7	-750.5	9553.3	16039.1	15946.5	-126.3	-8916.5	-8848.1	577.7	2040.5
4	TMI_4=175	8435.5	14162.5	15970.3	-111.1	-7811.8	-746.6	9572.2	16003.7	15715.4	-125.8	-8855.1	-8691.3	576.0	2031.0
4	TMI_4=180	8414.5	14120.1	15634.7	-110.2	-7769.9	-740.4	9506.4	15955.7	15689.0	-124.6	-8850.4	-8635.5	574.4	2021.5
4	TMI_4=184	8390.4	14063.7	15607.1	-109.1	-7827.0	-734.8	9481.2	15866.5	15662.0	-125.1	-8844.5	-8640.5	572.9	2012.0
4	TMI_4=188	8364.4	14007.3	15579.5	-107.9	-7801.1	-730.6	9451.3	15830.6	15626.3	-121.9	-8819.2	-8620.4	571.3	2002.5
4	TMI_4=192	8349.4	13952.8	15342.9	-105.3	-7765.5	-726.8	9434.9	15789.2	15599.5	-121.1	-8792.6	-8623.1	570.5	1943.0
4	TMI_4=197	8342.7	13977.8	15361.1	-103.1	-7780.3	-726.4	9427.3	15754.9	15410.5	-121.0	-8791.2	-8620.9	569.2	1942.0
4	TMI_4=201	8337.0	13085.9	15279.8	-105.2	-7778.0	-725.0	9420.8	15604.1	15831.2	-121.1	-8789.2	-8619.3	569.0	1967.0
4	TMI_4=210	8323.4	13939.0	15766.3	-107.0	-7769.6	-721.4	9405.2	15756.3	15619.0	-120.5	-8775.6	-8612.4	565.8	1977.0
4	TMI_4=219	8305.2	13952.1	15783.6	-106.6	-7714.1	-722.2	9384.9	15745.9	15635.5	-120.5	-8762.2	-8616.1	563.8	1967.0
4	TMI_4=228	8282.4	13912.5	15763.7	-106.2	-7714.7	-721.1	9359.5	15720.9	15609.4	-120.0	-8140.2	-8614.3	561.9	1957.0
4	TMI_4=237	8259.3	13863.8	15727.5	-105.6	-7713.2	-720.2	9333.1	15665.6	15572.4	-119.3	-8715.9	-8614.4	560.1	1947.0
4	TMI_4=246	8233.9	13808.5	15694.4	-105.1	-7688.7	-719.1	9304.3	15603.6	15536.6	-118.7	-8684.3	-8612.6	558.4	1937.0
4	TMI_4=255	8208.5	13760.7	15651.3	-104.5	-7663.1	-714.0	9275.6	15538.2	15484.0	-118.0	-8655.5	-8611.3	556.7	1927.0
4	TMI_4=264	8183.1	13664.8	15599.2	-103.9	-7637.8	-716.5	9246.9	15469.5	15426.0	-117.4	-8640.3	-8610.3	555.0	1917.0
4	TMI_4=273	8154.7	13617.9	15545.1	-103.0	-7610.4	-715.5	9214.8	15406.2	15566.0	-116.4	-8598.1	-8608.5	553.3	1907.0
4	TMI_4=282	8123.3	13522.0	15482.0	-101.8	-7515.9	-713.4	9179.3	15259.9	15432.1	-114.5	-8540.2	-8606.1	551.7	1897.0
4	TMI_4=287	8132.3	13540.6	15459.1	-101.3	-7586.2	-713.5	9169.7	15300.8	15414.0	-114.8	-8574.7	-8606.2	550.9	1891.0
4	TMI_4=291	8144.4	13572.1	15576.3	-102.2	-7601.4	-711.9	9203.1	15336.5	15556.0	-115.5	-8589.6	-8604.7	550.2	1885.0
4	TMI_4=300	8163.5	13638.1	15601.1	-103.7	-7620.5	-715.3	9224.3	15411.1	15629.4	-117.1	-8611.1	-8606.3	549.0	1873.3

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006 (<VeslFatFat[p42])
Page 11 11-04-2010 12:19:47

[illegible]

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006 (<VeslFatFat[p42])
Page 12 11-04-2010 12:19:47

[illegible]

Structural Integrity Associates, Inc.®

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006 (&VeslFatFatlp42)
Page 13 11-04-2010 12:19:47

2	TMI_7-5	[illegible]	15122.8	20185.0	-288.2	-10363.4	-516.3	10891.5	21608.8	22489.0	-240.8	-10983.6	[illegible]	744.7	2349.0
2	TMI_7-6	[illegible]	15031.2	20121.8	-218.2	-10312.4	-488.1	11052.7	22036.1	22391.9	-237.6	-10749.0	[illegible]	[illegible]	[illegible]
2	TMI_7-7	[illegible]	15310.0	20619.2	-211.2	-10229.1	-525.4	11083.6	22179.2	22299.7	-238.6	-10615.4	[illegible]	[illegible]	[illegible]
2	TMI_7-8	[illegible]	15198.4	20744.5	-209.6	-10142.6	-590.1	11089.2	22114.9	22260.5	-236.8	-10455.3	[illegible]	746.4	[illegible]
2	TMI_7-9	9292.4	15456.8	20649.7	-206.8	-10140.2	-449.0	11073.1	22014.4	22164.7	-233.1	-10527.6	[illegible]	747.0	2401.2
2	TMI_7-10	[illegible]	[illegible]	20465.2	-203.5	-10128.5	-464.4	11023.8	21994.1	22012.4	-229.8	-10390.2	[illegible]	747.6	2419.0
2	TMI_7-11	[illegible]	[illegible]	20746.8	-208.5	-10478.0	-490.7	11146.0	[illegible]	22217.4	-237.1	-10464.5	[illegible]	749.2	2436.6
2	TMI_7-12	[illegible]	15992.4	20857.6	-212.4	-10255.1	-499.8	11232.0	[illegible]	[illegible]	-240.0	-10594.4	-1016.6	748.8	2454.2
2	TMI_7-13	10310.5	20325.1	21244.8	-239.8	-9877.2	-410.3	11279.7	[illegible]	23011.3	-238.4	-11161.3	-1029.5	749.4	2471.8
2	TMI_7-14	10218.2	[illegible]	21669.9	-226.0	-10036.4	-421.6	11746.6	[illegible]	24447.0	-257.6	-11141.1	-1041.7	[illegible]	[illegible]
2	TMI_7-15	[illegible]	21299.1	21121.1	-236.5	-10036.5	-394.7	[illegible]	24852.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2501.8
2	TMI_7-16	14996.2	22151.5	21551.5	-234.0	-10202.4	[illegible]	11743.3	24821.0	[illegible]	[illegible]	-11162.6	-1060.5	[illegible]	[illegible]
2	TMI_7-17	14869.5	21010.0	21951.5	-232.4	-10208.1	-540.1	11317.5	[illegible]	[illegible]	[illegible]	[illegible]	-1062.1	[illegible]	2453.0
2	TMI_7-18	10917.8	20802.4	21169.5	-227.2	-10147.5	-565.7	11659.3	[illegible]	[illegible]	[illegible]	-11164.1	-1061.7	[illegible]	2423.0
2	TMI_7-19	10248.1	20834.9	22207.5	-221.3	-10064.1	-537.9	12081.5	[illegible]	24101.2	[illegible]	-11132.5	-1056.7	[illegible]	2453.0
2	TMI_7-20	10169.4	20127.3	22211.7	-215.0	-9569.1	[illegible]	11591.5	22783.8	[illegible]	-242.9	-11165.1	-1056.3	[illegible]	2357.0
2	TMI_7-21	13081.7	19769.8	20411.7	-204.5	-9466.8	-440.8	11492.3	[illegible]	[illegible]	[illegible]	-11148.5	-1051.8	[illegible]	2327.0
2	TMI_7-22	9990.0	19402.2	20603.9	-202.0	[illegible]	-526.2	11288.7	21426.5	[illegible]	[illegible]	[illegible]	-1046.4	[illegible]	[illegible]
2	TMI_7-23	[illegible]	19402.2	20603.9	-202.0	[illegible]	-526.2	11288.7	[illegible]	[illegible]	[illegible]	[illegible]	-1046.4	[illegible]	[illegible]
2	TMI_7-22	9990.0	19402.2	20635.9	-202.0	[illegible]	-526.2	11288.7	[illegible]	[illegible]	[illegible]	[illegible]	-1046.4	[illegible]	2293.0
2	TMI_7-4	[illegible]	19547.0	19441.2	-136.3	-9909.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-10181.0	-1060.5	[illegible]	2286.2
2	TMI_7-45	[illegible]	16984.3	[illegible]	[illegible]	-9561.6	-691.2	10271.3	19192.7	20647.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	TMI_7-65	[illegible]	16762.5	19047.9	-174.2	-9614.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2264.6
2	TMI_7-33	[illegible]	16641.8	[illegible]	[illegible]	[illegible]	-492.7	10095.2	18174.0	20214.8	-196.0	[illegible]	-566.2	[illegible]	[illegible]
2	TMI_7-92	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10062.4	[illegible]	[illegible]	[illegible]	[illegible]	-562.2	[illegible]	[illegible]
2	TMI_7-120	[illegible]	16414.0	[illegible]	[illegible]	[illegible]	-684.4	10071.1	[illegible]	20036.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	TMI_7-149	[illegible]	[illegible]	[illegible]	[illegible]	-9458.0	-659.3	10025.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	TMI_7-178	[illegible]	16203.9	[illegible]	-169.2	[illegible]	[illegible]	10011.7	[illegible]	19962.8	[illegible]	[illegible]	-566.2	[illegible]	2151.3
2	TMI_7-207	[illegible]	16108.8	17521.0	-166.5	-9418.2	[illegible]	[illegible]	19500.7	[illegible]	-198.3	-9512.5	[illegible]	[illegible]	2124.3
2	TMI_7-236	[illegible]	16005.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	TMI_7-265	[illegible]	[illegible]	[illegible]	-161.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	TMI_7-294	8813.9	15904.6	17330.8	[illegible]	[illegible]	-847.8	[illegible]	[illegible]	[illegible]	-178.9	-9445.5	-566.7	[illegible]	2043.3
2	TMI_7-322	[illegible]	15703.5	17264.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-176.0	[illegible]	[illegible]	[illegible]	2016.3
2	TMI_7-351	8790.9	15601.4	[illegible]	-153.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-9401.5	[illegible]	[illegible]	[illegible]
2	TMI_7-380	[illegible]	15503.3	17140.6	-150.4	[illegible]	-425.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1962.3
2	TMI_7-409	[illegible]	15404.1	[illegible]	[illegible]	-8281.1	[illegible]	[illegible]	17406.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	TMI_7-438	[illegible]	15304.2	[illegible]	-145.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	TMI_7-467	[illegible]	15205.1	16960.4	-143.7	-8241.2	-814.4	[illegible]	17181.8	[illegible]	-164.3	[illegible]	[illegible]	[illegible]	1881.3
2	TMI_7-496	[illegible]	15106.0	16903.7	-141.0	-8220.7	-810.7	[illegible]	[illegible]	19101.2	[illegible]	[illegible]	[illegible]	[illegible]	1854.3
2	TMI_7-525	[illegible]	15006.9	16847.0	[illegible]	-8200.3	-807.1	[illegible]	16957.8	[illegible]	[illegible]	[illegible]	-512.0	[illegible]	[illegible]
2	TMI_7-554	[illegible]	[illegible]	16790.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18961.7	-154.2	[illegible]	[illegible]	[illegible]	1800.3
2	TMI_7-583	[illegible]	14809.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18897.8	[illegible]	-9220.1	[illegible]	[illegible]	[illegible]
2	TMI_7-600	8662.1	14750.6	16669.3	-152.5	-8147.1	-798.0	[illegible]	16668.2	[illegible]	-150.2	-9206.2	-501.7	[illegible]	1757.0
2	TMI_7-606	[illegible]	14632.3	16802.8	[illegible]	[illegible]	[illegible]	[illegible]	16534.9	18708.2	-147.5	[illegible]	[illegible]	558.6	1757.0
2	TMI_7-612	[illegible]	14441.8	16335.5	-127.4	-8026.6	-299.1	9690.1	16744.1	18508.4	-143.9	-9020.1	-441.9	558.3	1757.0
2	TMI_7-622	8544.3	14534.8	16295.5	-125.6	-7991.6	-285.7	9655.0	16288.0	18416.0	-141.9	-9030.5	-485.6	557.5	1757.0
2	TMI_7-642	[illegible]	14510.8	16265.5	-124.5	-7941.6	-279.1	9644.9	16216.4	18380.1	-140.6	-9015.2	-480.6	556.7	1757.0
2	TMI_7-652	[illegible]	14442.8	16271.5	-122.4	-7866.6	-732.6	9649.4	16207.3	18391.4	-138.3	-9024.9	-487.0	555.1	1757.0
2	TMI_7-672	8568.3	14546.8	16285.5	-120.3	-7967.6	-766.9	9659.6	16211.9	18402.7	-136.0	-9033.3	-666.6	554.8	1757.0
2	TMI_7-692	8551.3	14452.8	16405.5	-118.4	-8008.6	-762.1	9669.7	16218.6	18425.3	-133.8	-9049.8	-441.2	552.9	1757.0
2	TMI_7-712	8566.3	14459.8	16325.5	-116.6	-8019.6	-752.9	9679.9	16226.6	18447.9	-131.8	-9062.2	-456.4	551.8	1757.0
2	TMI_7-732	8575.3	14460.8	16335.5	-114.8	-8028.6	-754.2	9687.8	16227.7	18459.2	-129.7	-9072.4	-462.2	550.8	1757.0

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29-2006 (&VeslFatFatlp42)
Page 14 11-04-2010 12:19:47

2	TMI_7-752	8593.3	14575.8	16485.5	-112.7	-8040.6	-750.4	9659.1	16222.0	18470.5	-127.4	-9085.9	-447.9	550.0	1757.0
2	TMI_7-772	8598.3	14566.8	16565.5	-111.4	-8047.6	-746.8	9707.0	16234.5	18493.1	-125.9	-9091.8	-441.9	549.1	1757.0
2	TMI_7-792	8590.3	14571.8	16475.5	-110.6	-8051.6	-744.0	9707.0	16240.1	18504.4	-124.7	-9098.1	-440.7	548.4	1757.0
2	TMI_7-812	8588.3	14432.8	16335.5	-109.6	-8053.6	-741.5	9504.8	16241.2	18504.4	-123.8	-9100.6	-433.7	547.7	1757.0
2	TMI_7-832	8565.3	14372.8	16375.5	-108.9	-8055.6	[illegible]	9701.4	16241.2	18504.4	[illegible]	-9100.6	[illegible]	547.0	1757.0
2	TMI_7-852	8583.3	14370.8	16375.5	-108.4	-8052.6	-737.4	9696.8	16239.0	18504.4	-122.5	-9099.5	[illegible]	546.4	1757.0
2	TMI_7-872	8576.3	14366.8	16375.5	-108.0	-8049.6	-735.8	9691.2	16236.7	18504.4	-122.0	-9096.1	-631.4	545.9	1757.0
2	TMI_7-892	8574.3	14365.8	16375.5	-107.7	-8046.6	-734.4	9684.4	16231.3	18504.4	-121.7	-9092.1	-626.9	545.4	1757.0
2	TMI_7-912	8564.3	14361.8	16365.5	-107.5	-8043.6	-733.2	9677.6	16226.8	18493.1	-121.4	-9089.3	-626.5	544.6	1757.0
2	TMI_7-932	8558.3	14358.8	16365.5	-107.4	-8039.6	-732.1	9670.9	16225.4	18493.1	-121.1	-9084.8	-627.5	544.4	1757.0
2	TMI_7-952	8552.3	14354.8	16355.5	-107.4	-8035.6	-731.5	9664.1	16220.9	18481.8	-121.1	-9080.3	-626.6	544.0	1757.0
2	TMI_7-972	8545.3	14350.8	16355.5	-107.4	-8030.6	-730.9	9656.2	16216.4	18481.8	-121.4	-9074.6	-625.9	543.6	1757.0
2	TMI_7-992	8539.3	14346.8	16345.5	-107.5	-8025.6	-730.4	9649.4	16211.9	18470.5	-121.5	-9069.0	-625.3	543.2	1757.0
2	TMI_7-1012	8532.3	14343.8	16335.5	-107.7	-8021.6	-730.0	9641.5	16206.5	18459.2	-121.7	-9064.4	-624.9	542.9	1757.0
2	TMI_7-1032	8526.3	14339.8	16335.5	-107.9	-8016.6	-729.8	9634.7	16204.8	18459.2	-121.9	-9058.8	-624.7	542.5	1757.0
2	TMI_7-1052	8520.3	14336.8	16325.5	-108.1	-8011.6	-729.6	9627.9	16200.6	18447.9	-122.2	-9053.1	-624.4	542.2	1757.0
2	TMI_7-1072	8514.3	14332.8	16325.5	-108.4	-8007.6	-729.6	9621.1	16198.0	18447.9	-122.5	-9048.6	-624.4	541.9	1757.0
2	TMI_7-1092	8508.3	14329.8	16315.5	-108.7	-8002.6	-729.6	9614.4	16192.7	18436.6	-122.8	-9043.0	-624.4	541.7	1757.0
2	TMI_7-1112	8502.3	14326.8	16305.5	-109.0	-7997.6	-729.6	9607.6	16189.3	18425.3	-123.2	-9037.3	-624.4	541.4	1757.0
2	TMI_7-1132	8496.3	14324.8	16305.5	-109.3	-7993.6	-729.7	9600.8	16187.0	18425.3	-123.5	-9032.8	-624.6	541.1	1757.0
2	TMI_7-1152	8491.3	14321.8	16295.5	-109.6	-7988.6	-729.9	9595.1	16183.6	18414.0	-123.9	-9027.2	-624.9	540.9	1757.0
2	TMI_7-1172	8485.3	14318.8	16295.5	-110.0	-7984.6	-730.0	9588.4	16180.2	18414.0	-124.3	-9022.6	-624.9	540.7	1757.0
2	TMI_7-1192	8480.3	14316.8	16285.5	-110.3	-7980.6	-730.2	9582.7	16178.0	18402.7	-124.7	-9018.1	-625.1	540.5	1757.0
2	TMI_7-1212	8475.3	14314.8	16285.5	-110.7	-7975.6	-730.5	9577.1	16175.7	18402.7	-125.1	-9012.5	-625.5	540.3	1757.0
2	TMI_7-4212	8312.3	14261.8	16085.5	-124.6	-7834.6	-749.9	9392.9	16115.8	18138.7	-140.6	-8853.1	-647.4	535.3	1757.0
6	TMI_8-0	9087.1	14622.9	17927.4	-150.5	-8635.4	-422.2	10223.2	18157.9	20258.0	-170.0	-9738.0	-526.1	580.0	2242.0
6	TMI_8-23	9051.7	16096.4	17441.9	-144.9	-8522.1	-412.7	10115.4	18037.7	19997.3	-163.7	-9620.0	-518.4	579.1	2207.0
6	TMI_8-45	8870.3	15908.0	17416.3	-140.4	-8424.7	-403.3	10023.4	17863.0	19800.5	-158.7	-9520.0	-503.7	577.8	2172.0
6	TMI_8-68	8801.8	15574.5	17230.8	-136.7	-8344.4	-395.2	9946.1	17599.2	19670.8	-154.4	-9429.2	-498.6	576.1	2137.0
6	TMI_8-90	8742.4	15367.0	17065.1	-133.4	-8274.0	-388.1	9878.9	17364.7	19293.8	-150.8	-9349.7	-490.6	574.8	2102.0
6	TMI_8-113	8698.0	15138.6	16919.8	-130.5	-8210.7	-382.0	9819.6	17151.8	19019.4	-147.5	-9279.1	-483.7	572.5	2067.0
6	TMI_8-135	8640.6	15001.1	16794.3	-127.9	-8152.4	-376.4	9765.6	16951.3	18866.2	-144.5	-9212.2	-477.6	570.6	2032.0
6	TMI_8-158	8590.1	14831.7	16658.7	-125.5	-8098.0	-371.9	9712.5	16762.0	18824.4	-141.8	-9150.7	-472.1	568.7	1997.0
6	TMI_8-180	8551.7	14673.2	16543.2	-123.2	-8045.7	-367.4	9661.4	16580.7	18693.8	-139.2	-9091.6	-467.2	566.7	1962.0
6	TMI_8-203	8511.3	14517.7	16427.7	-121.0	-7997.1	-363.3	9617.8	16405.3	18563.3	-136.8	-9037.0	-462.5	564.7	1927.0
6	TMI_8-225	8471.4	14367.3	16312.2	-119.0	-7949.0	-359.4	9573.2	16239.0	18429.9	-134.4	-8982.5	-458.1	562.8	1892.0
6	TMI_8-248	8434.4	14219.8	16196.7	-117.0	-7903.6	-355.7	9530.9	16086.4	18315.5	-132.2	-8931.1	-454.0	560.8	1857.0
6	TMI_8-270	8398.0	14075.3	16101.1	-115.0	-7859.3	-352.1	9489.9	15905.1	18162.3	-130.0	-8881.0	-449.9	558.8	1822.0
6	TMI_8-293	8362.6	13933.5	15995.6	-113.1	-7815.9	-348.6	9449.7	15745.3	18035.0	-127.8	-8832.0	-445.9	556.6	1787.0
6	TMI_8-315	8328.2	13794.4	15900.1	-111.3	-7772.6	-345.2	9410.4	15587.7	17959.9	-125.7	-8783.0	-442.1	554.9	1752.0
6	TMI_8-338	8294.7	13657.0	15774.6	-109.4	-7731.2	-341.9	9370.0	15432.4	17845.9	-123.7	-8736.3	-438.2	552.8	1717.0
6	TMI_8-360	8257.3	13498.5	15669.0	-107.3	-7685.9	-338.0	9330.8	15272.3	17706.0	-120.9	-8685.0	-434.0	550.8	1682.0
6	TMI_8-383	8219.5	13345.0	15553.5	-104.4	-7636.5	-332.3	9288.5	15070.5	17579.5	-118.3	-8629.5	-423.5	548.9	1647.0
6	TMI_8-405	8168.5	13192.6	15428.0	-102.5	-7582.2	-327.0	9230.4	14907.6	17433.6	-115.8	-8567.9	-421.5	546.5	1612.0
6	TMI_8-428	8117.0	13055.1	15292.5	-100.3	-7522.6	-321.5	9167.1	14729.7	17280.5	-113.6	-8500.6	-415.3	544.9	1577.0
6	TMI_8-450	8051.6	12832.7	15137.0	-98.3	-7460.5	-315.6	9100.6	14546.1	17114.1	-111.5	-8430.4	-408.6	542.9	1542.0
6	TMI_8-473	7992.2	12706.2	15001.4	-96.7	-7396.1	-305.6	9031.2	14358.0	16951.6	-109.3	-8357.6	-401.9	540.9	1507.0
6	TMI_8-495	7929.9	12538.7	14855.9	-94.7	-7329.6	-303.5	8960.6	14166.5	16787.2	-107.1	-8282.3	-395.0	538.9	1472.0
6	TMI_8-518	7865.3	12365.1	14500.4	-92.9	-7263.4	-697.6	8887.9	13972.8	16611.5	-104.9	-8207.3	-388.3	576.9	1437.0
6	TMI_8-540	7801.9	12192.8	14574.9	-91.0	-7196.1	-691.9	8816.2	13777.9	16447.0	-102.8	-8131.6	-381.5	534.9	1402.0
6	TMI_8-563	7737.5	12021.3	14404.4	-89.2	-7129.3	-686.2	8743.4	13584.1	16292.6	-100.7	-8056.6	-375.4	532.9	1367.0
6	TMI_8-585	7675.1	11849.5	14264.8	-87.3	-7063.4	-680.5	8672.8	13390.4	16118.1	-98.7	-7981.6	-369.0	530.9	1332.0

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006 (&VeslFatFat1p42)
Page [illegible] 11-04-2010 12:19:47

Ordered Input E-corrected Stress Intensities are from: p3-o.ORD
Stress Input (psi. - Salt w/E-modulus correction):

#	Event1		#	Event 2	Sn	Ke	Salt
1	TMI_1-	and	6	TMI_6-	29795	1.0000	18692
6	TMI_6-	and	10	TMI_10-	29795	1.0000	18692
2	TMI_2-	and	6	TMI_6-	29596	1.0000	18567
3	TMI_3-	and	6	TMI_6-	27494	1.0000	17249
4	TMI_4-	and	10	TMI_10-	26564	1.0000	16619
1	TMI_1-	and	4	TMI_4-	26564	1.0000	16619
2	TMI_2-	and	4	TMI_4-	26367	1.0000	16496
1	TMI_1-	and	3	TMI_3-	25473	1.0000	15929

Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006
(&VeslFatFat1p42)
Page 16 11-04-2010 12:19:47

Stress Input (psi. - Salt w/E-modulus correction):

#	Event1		#	Event 2	Sn	Ke	Salt
3	TMI_3-	and	10	TMI_10-	25473	1.0000	15929
3	TMI_3-	and	4	TMI_4-	25447	1.0000	15910
2	TMI_2-	and	3	TMI_3-	25270	1.0000	15802
1	TMI_1-	and	7	TMI_7-	23691	1.0000	14803
7	TMI_7-	and	10	TMI_10-	23691	1.0000	14803
2	TMI_2-	and	7	TMI_7-	23494	1.0000	14680
3	TMI_3-	and	7	TMI_7-	22589	1.0000	14112
5	TMI_5-	and	10	TMI_10-	21596	1.0000	13513
1	TMI_1-	and	5	TMI_5-	21596	1.0000	13513
2	TMI_2-	and	5	TMI_5-	21401	1.0000	13391

```
Fatigue Analysis using VESLFAT Fatigue Module Version 1.42 - 12/29/2006
(&VeslFatFat1p42)
Page  17                              11-04-2010        12:19:48
```

I	Load Sets	Cycles	Sn	Ke	Salt	Nallowed	Usage
1	1 TMI_1-	240	29795	1.000	18692	4.6743E+06	.0000171
	6 TMI_6-	80					
2	4 TMI_4-	65938	26564	1.000	16619	9.2310E+06	.0000022
	10 TMI_10-	20					
3	1 TMI_1-	160	26564	1.000	16619	9.2310E+06	.0000173
	4 TMI_4-	65918					
4	2 TMI_2-	240	26367	1.000	16496	9.6556E+06	.0000249
	4 TMI_4-	65758					
5	3 TMI_3-	660	25447	1.000	15910	1.3185E+07	.0000501
	4 TMI_4-	65518					

Total Usage = 0.0001115

<u>ATTACHMENT 3</u>

Calculation No. 1000320.316

Structural Integrity Associates, Inc.®

CALCULATION PACKAGE

File No.: 1000320.316

Project No.: 1000320

Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
TMI-1 Pressurizer Spray Nozzle WOL

CONTRACT NO.:
59091

CLIENT:
Aquilex WSI, Inc.

PLANT:
Three Mile Island Nuclear Generating Station, Unit 1

CALCULATION TITLE:
Crack Growth Evaluation of Pressurizer Spray Nozzle with Weld Overlay

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 34 A-1 - A-3	Initial Issue	Norman Eng Norman Eng NE 03/23/11	Aparna Aparna Alleshwaram AA 03/23/11 P. Ashwin. Ashwin Padmala AP 03/23/11

Table of Contents

List of Tables

List of Figures

1.0 PURPOSE

The purpose of this calculation package is to calculate crack growth in the susceptible material regions (SMRs), which include the nozzle-to-safe end weld (DMW1), safe end (SE) and safe end-to-pipe weld (DMW2), for the spray nozzle with weld overlay (WOL) repair. Loads considered are external piping loads, internal pressure, thermal transients, local effect of stratification, and residual stress. Both fatigue crack growth (FCG) and Primary Water Stress Corrosion Cracking (PWSCC) are considered. PWSCC is due to sustained loading at steady state normal operating conditions.

2.0 METHODOLOGY

Representative fracture mechanics models (Section 3.2) are used to determine stress intensity factors (K) within the susceptible material regions. The stress intensity factors for each type of load are computed as a function of assumed crack depth in the susceptible and superimposed for the various operating states. Stresses that contribute to fatigue crack growth and PWSCC are compiled from previous calculations (References 4 and 6). These stresses resulted from primary loads such as internal pressure and external piping loads, and secondary loads such thermal gradient stresses (due to thermal transient events), and residual stresses. The through-wall stresses are extracted and curve fitted to a third order polynomial. FCG (or combined FCG and PWSCC growth if PWSCC is active) is computed using linear elastic fracture mechanics (LEFM) techniques. Potential for PWSCC is determined by computing the stress intensity factor versus flaw depth curve (K-vs-a) at steady state normal operating conditions. A crack growth law for Alloy 600 weld metals (Alloy 82/Alloy 182) with a multiplier to account for crack growth in a pressurized water reactor (PWR) environment is used at the susceptible material regions. The time it takes for an initial flaw of 75% of the original base metal thickness to reach the overlay is reported.

3.0 DESIGN INPUTS

3.1 Geometry

Details of the spray nozzle geometry are provided in the finite element model calculation package [1]. The sections evaluated for crack growth, and considered representative for the susceptible material regions are shown in Figure 1. The three sections considered here are named DMW1, safe end and DMW2 as shown in Figure 1. Note that in the figure, the minimum and maximum dimensions of the sections (due to the use of minimum and maximum overlay designs in the finite element models [1]) are shown. The thinner (minimum weld overlay) section is used for pressure, piping interface loads and residual stresses. The thicker (maximum weld overlay) section is used for all local thermal gradient stresses. See Section 3.3 for descriptions of the different loads applied to the nozzle.

3.2 Fracture Mechanics Models

Three fracture mechanics models, two of which are from the EPRI Ductile Fracture Handbook [2] and one model for moment loading from Tada-Paris-Irwin [3], are shown in Figures 6 through 8. The three models are described below:

- Circumferential flaw, under arbitrary through-wall stress distribution (EPRI Ductile Fracture Handbook model): full 360° flaw in a cylinder with the actual R_i/t ratio is used, where $1 \leq R_i/t \leq 10$. The R_i/t ratios are calculated as follows (geometric dimensions obtained from Figure 1):
  - Minimum WOL (DMW1): $R_i/t = (1.8125)/(1.05) = 1.73$
  - Maximum WOL (DMW1): $R_i/t = (1.8125)/(1.3) = 1.40$
  - Minimum WOL (Safe End): $R_i/t = (1.7638)/(1.0986) = 1.61$
  - Maximum WOL (Safe End): $R_i/t = (1.7638)/(1.3486) = 1.31$
  - Minimum WOL (DMW2): $R_i/t = (1.846)/(0.7715) = 2.39$
  - Maximum WOL (DMW2): $R_i/t = (1.846)/(1.11309) = 1.66$

  It is determined in Reference 12 that the influence coefficients for calculating K must be computed using the plots provided in the reference as opposed to using the provided equation.

- Circumferential flaw, moment loading (Tada-Paris-Irwin model): full 360° flaw in a cylinder with the actual inside radius-to-outside radius ratio R_i/R_o is used. The R_i/R_o ratios are calculated as follows (geometric dimensions obtained from Figure 1):
  - Minimum WOL (DMW1): $R_i/R_o = (1.8125)/(2.8625) = 0.633$
  - Maximum WOL (DMW1): $R_i/R_o = (1.8125)/(3.1125) = 0.58$
  - Minimum WOL (Safe End): $R_i/R_o = (1.7638)/(2.8624) = 0.616$
  - Maximum WOL (Safe End): $R_i/R_o = (1.7638)/(3.1124) = 0.57$
  - Minimum WOL (DMW2): $R_i/R_o = (1.846)/(2.6175) = 0.71$
  - Maximum WOL (DMW2): $R_i/R_o = (1.846)/(2.9601) = 0.62$

- Axial flaw under arbitrary through-wall stress distribution (EPRI Ductile Fracture Handbook model): semi-elliptical inside surface flaw with an aspect (depth-to-length) ratio of 0.2 in a cylinder is used for FCG and 0.5 for PWSCC. The reason a 0.5 aspect ratio was used for PWSCC is that, assuming stresses are compressive at normal operating pressure and temperature (for which PWSCC is evaluated, see Section 5.0 under "PWSCC"), a *higher* aspect ratio for semi-elliptical flaws would produce more conservative (less compressive) values of K. Note that for tensile K distributions, it is the opposite: a *lower* aspect ratio produces more conservative (greater tensile) values for K. The same R_i/t ratios computed for the circumferential flaw non-moment loading are used, where $1 \leq R_i/t \leq 10$. Self-similar growth is assumed. The K at the deepest point is used.

  In addition, the same axial flaw model but with internal pressure loading is used for the pressure loading.

Stress intensity factors using the above flaw models for all loads (Section 3.3) are all calculated via a Microsoft Excel Visual Basic for Applications (VBA) macro in spreadsheet "StressIntensityFactors1.xls." for DMW1, "StressIntensityFactorsSE.xls." for safe end, and "StressIntensityFactors2.xls." for DMW2. The macro is verified to ensure the equations from the EPRI Ductile Fracture Handbook [2] and the Paris-Tada-Irwin solution [3] are correctly used.

3.3 Loads

Loads considered (described in detail in the following sub-sections) are internal pressure, interface piping loads, local thermal gradient stresses due to thermal transients, local effect of stratification, and residual stresses. Through-wall stresses are curve fitted with a third order polynomial in the form shown below:

$$\sigma(x) = C_0 + C_1 x + C_2 x^2 + C_3 x^3 \qquad (1)$$

where:

σ = stress (axial or hoop)
x = distance from the inside surface

Stresses were obtained for the above curve fits for through-wall paths in the susceptible material regions (Figure 2). These paths are defined in the thermal and mechanical stress analysis calculation package [4]. It is important to note that the critical paths selected within the SMR have different path lengths in addition to the fact that mechanical stresses and thermal stresses are extracted from models with the minimum and maximum overlays, respectively (Section 3.1). The intent for this approach is to characterize the stresses for each of the different loading conditions for three regions within the SMR. As long as the correct stresses are extracted from the correct model (minimum or maximum overlay model depending on the load type) and correct path, the resulting stress intensity factors are correct because crack growth is computed for only one representative section (Figure 1) using the most limiting path per each section (DMW1, safe end and DMW2 sections).

Curve fits for residual stresses are calculated in spreadsheets "1000320-314.xls" obtained from the residual stress analysis [6]. Linearized stresses and curve fits for local thermal gradient stresses (and stresses due to mechanical loads) are in spreadsheet "CG_SPRAY_DMW1.xls" for DMW1, "CG_SPRAY_DMWSE.xls" for safe end, and "CG_SPRAY_DMW2.xls" for DMW2. The curve fit coefficients are used to calculate the K-vs-a values using a K-solution from Paris-Tada-Irwin [3] for circumferential flaw moment loading (Figure 7) or input into the EPRI Ductile Fracture Handbook models [2] for the circumferential (non-moment loading) and axial flaws (Figures 6 and 8). These spreadsheets are included in the computer files. Table 1 shows the polynomial coefficients for all loads at the DMW1, safe end and DMW2 susceptible material regions. Details of how the Table 1 coefficients are obtained are explained in the following sub-sections.

Internal Pressure

In the thermal and mechanical stress analysis calculation package [4], a unit internal pressure load (1000 psig) was applied to the spray nozzle finite element model. The resulting through-wall stress distributions within the SMR were extracted and given a third order polynomial curve fit. Files "TMI_PR_P*_MAP.OUT" (* = 1 through 18), listed in Appendix A in the table labeled "Stress Output," contain the through-wall stress maps. These output files are obtained from [4]. The CSV file versions of these files contain the resulting stress coefficients for the unit pressure loading condition. The resulting stress coefficients are shown in Table 1 for DMW1, safe end and DMW2 regions. Stress intensity factors resulting from the stresses in Table 1 are scaled by actual pressure values during the transient. Note that a constant through-wall stress of 1000 psig is added to the C_0 coefficient of the "Unit Pressure" stresses to account for the internal pressure acting on the crack face.

Piping Interface Loads

The piping interface loads were determined in the design loads calculation package [5] and shown in Table 2. Finite element analyses for an applied unit axial force (1000 lbs) and unit moment (1000 in-lb) at the free end of the piping interface were performed in [4]. Through-wall stresses within the SMR were extracted from the analysis in [4] and included in this calculation package. See files "TMI_AXIAL_P*_MAP.OUT (*= 1 through 18), and "TMI_MOM$_P*_MAP.OUT" ($ = X and Z; * = 1 through 18) in Appendix A in the table labeled "Stress Output." These files are included in the computer files. For the axial stresses due to the unit moment load, only the maximum stress in the section is used because a constant stress is required in the fracture mechanics model that is used for moment loading (see Figure 7). Stress intensity factors using the fracture mechanics models described in Section 3.2 were determined from these stresses. Thermal piping interface loads are scaled to the actual temperatures during the transient. The resulting stress intensity factors are scaled in two ways: (1) by the axial force values (Fx) in Table 2 for the force Ks, (2) by the square root sum of the squares (SRSS) of the transverse moment values (Mx and Mz) in Table 2 for the moment Ks.

The resulting stress coefficients for the unit axial and unit moment cases are shown in Table 1.

Local Thermal Gradient Stresses

Bounding thermal transients for crack growth analysis are shown in Table 3, which were developed in the design loads calculation package [5]. Determining the thermal gradient stresses due to these transients is a two-step process. First, a bounding path in the SMR is selected by comparing the thermal gradient stresses at the six representative paths in the SMR (Paths 1, 2, 7, 8, 13 and 14 for DMW 1; Paths 3, 4, 9, 10, 15 and 16 for safe end; paths 5, 6, 11, 12, 17, and 18 for DMW2, in Figure 2) for the transients. Second, the times at which the maximum and minimum inside surface membrane-plus-bending axial and hoop stresses during each transient listed in Table 3 are determined so that the worst through-wall thermal gradient stresses may be extracted for the bounding path.

Thermal gradient stresses for Hydro Test will be similar to the thermal gradient stresses for Transient 1A at 0 seconds. Thermal gradient stresses for Stratification will be similar to the thermal gradient stresses for Transient 1B at 0 seconds, since from Reference 5, it can be seen that stratification occurs at 555°F and 2242 psig, which are the same conditions as Transient 1B at 0 seconds.

To select the bounding path in the SMR, the time histories of the inside surface linearized membrane-plus-bending stresses for each transient are plotted for axial and hoop stresses. A typical plot is shown in Figure 3 for axial and hoop stresses for the Heatup transient. The linearized membrane-plus-bending stresses and corresponding mapped stresses fitted with a third order polynomial are contained in files "TMI_STR_$$_P*_MAP.csv" (($$ = event IDs 1 through 6 in Table 4 and * = 1 through 18). Figure 3 shows, for example, that Path 1 is used for the maximum axial stress and Path 2 for the minimum axial stress for the Heatup transient. Table 1 shows the bounding paths used at the SMR.

Once the bounding path for the SMR is determined, the times at which the maximum and minimum membrane-plus-bending axial and hoop stresses during each transient may now be determined. Note that although the inside surface linearized membrane-plus-bending axial and hoop stresses were used in selecting the critical times, the stress coefficients resulting from the through-wall mapped stresses at the critical times are total stresses. The resulting bounding thermal gradient stress coefficients due to the thermal transients at the times of maximum and minimum inside surface linearized membrane-plus-bending stresses are shown in Table 1.

Residual Stresses

Residual axial and hoop stresses were extracted from the residual stress analysis [6] for six paths within the SMR. These paths from [6] are Paths 1 through 6, and correspond (approximately) to Paths 1 through 18 in Figure 2. Stresses were obtained from file "1000320-314.xls" of Reference 6. The resulting stresses were curve fit with a third order polynomial in this spreadsheet in worksheet "Path Data." The bounding (least compressive or most tensile stress) residual stress curve fits were determined for two paths of the SMR for DMW1, safe end and DMW2. These bounding residual stresses are used for the crack growth analysis. Residual stresses at 70°F are shown in Figure 4.

The bounding path for the axial and hoop stress for the six paths within the SMR can be determined either by calculating the K-vs-a curve via the "StressIntensityFactors1.xls", "StressIntensityFactorsSE.xls", and "StressIntensityFactors2.xls" spreadsheets for DMW1, safe end and DMW2 SMR's respectively. The residual stress coefficients (at 70°F) for all six paths are input into the spreadsheet and the K-vs-a plotted. This comparison is shown in Figure 5, which shows that at 75% of the original wall thickness, Path 2 gives the worst K distribution for the axial flaw and circumferential flaw for DMW1 region; Path 3 gives the worst K distribution for the axial flaw and circumferential flaw for safe end region; Path 5 gives the worst K distribution for the axial flaw and circumferential flaw for DMW2 region. The Ks for these selected paths that give the worst Ks are considered representative for the entire PWSCC susceptible material.

The resulting residual stress coefficients at 70°F and at steady state pressure (2155 psig) and temperature (650°F) are shown in Table 1.

3.4 Crack Growth Laws

3.4.1 Alloy 82/182 Fatigue Crack Growth Law

NUREG/CR-6907 [7] indicates that "The CGRs of Alloy 82/182 in the PWR environment are a factor ~ 5 higher than those of Alloy 600 in air under the same loading conditions." Thus the fatigue crack growth rate (FCGR) for the SMR used in this analysis is that for Alloy 600 in air (Equation (2) below) multiplied by 5. The FCGR for air obtained from NUREG/CR-6721 [8] is given by:

$$(da/dN)_{air} = C_{A600}\,(1\text{-}0.82R)^{-2.2}\,(\Delta K)^{4.1}\text{, units of m/cycle} \qquad (2)$$

where:

C_{A600} = $4.835\text{x}10^{-14} + 1.622\text{x}10^{-16}T - 1.49\text{ x}10^{-18}T^2 + 4.355\text{ x}10^{-21}T^3$
T = temperature inside pipe, °C (taken as the maximum during the transient)
R = R-ratio = (K_{min}/K_{max})
ΔK = $K_{max} - K_{min}$ = range of stress intensity factor, Mpa-m$^{0.5}$

Note that Equation (2) in accordance with NUREG/CR-6907 is independent of rise time.

3.4.2 Alloy 82/182 PWSCC Growth Law

When appropriate PWSCC growth is computed using Equation (3) below. This is for Alloy 182 weld metal and obtained from Eq. 4.5 of MRP-115 [11, pgs 4-4 to 4-5 for US customary units].

$$\dot{a} = \exp\left[-\frac{Q_g}{R}\left(\frac{1}{T}-\frac{1}{T_{ref}}\right)\right]\alpha(K)^{\beta} \qquad (3)$$

where:

$\dot{a}$ =	crack growth rate	in/hr
Q_g =	31	kcal/mole
R =	1.10E-03	kcal/mole-°R
T =	650	F
T_{ref} =	1076.67	R (617°F)
α =	2.47E-07	crack growth amplitude
K =	Stress intensity factor	ksi-in^0.5
β =	1.6	

3.4.3 Treatment of Negative Stress Intensity Factors

Because of the beneficial compressive residual stresses produced by the weld overlay, the stress intensity factors for many load cases are negative. This condition is handled as follows in the FCG analyses:

1. For Alloy 600 and its weld metals (Alloy 82/Alloy 182), the crack growth law in Equation (2) above includes an R-ratio correction $(1\text{-}0.82R)^{-2.2}$ that applies to both positive and negative R-ratios [7, 8]. For negative R-ratios, the factor is less than 1, yielding a corresponding decrease in crack growth rate when K_{min} is negative. Therefore, Equation (2) is used directly for crack growth in the SMR when K_{max} is greater than zero, for both positive and negative K_{min}. As noted, a factor of 5 [7] is applied for PWR environmental effects.

2. If both K_{max} and K_{min} in a load cycle are negative, zero fatigue crack growth is assumed. This is a reasonable assumption based on the work on compression fatigue crack growth (FCG for which K_{max} and K_{min} are negative) in Reference 10, in which it was shown that although FCG is present, the values of FCG are several orders of magnitude smaller than for FCG for which K_{max} and K_{min} are *not* negative.

4.0 ASSUMPTIONS

Basic assumptions for the analysis are listed below:

- Through-wall stresses are curve fitted with a third order polynomial. The use of the third order polynomial is limited by the crack model. In most cases the curve fit is more conservative than the actual plot (e.g., axial stress for Path 2 in Figure 4). The residual stresses provide enough compression in the steady state operating condition that any slight changes in the curve fit will have negligible effect on the overall crack growth.
- See Section 3.2 for assumed flaw models.
- See Section 3.4 for the crack growth laws and related assumptions.
- For FCG, there is no requirement to bound the load pairing between transients per the ASME Code Section XI [9]. Each thermal transient that was analyzed in the thermal and mechanical stress analysis calculation package [4] is analyzed sequentially per Table 4, and the cumulative effect of all transients is summed. In addition, incremental growth due to PWSCC (if active) is computed and added to incremental growth due to FCG. This approach is consistent with the ASME Code Section XI, C-3200.

5.0 CALCULATIONS

A Microsoft Excel VBA routine is implemented to calculate combined FCG and PWSCC growth. This combined FCG and PWSCC calculation is based on a yearly basis: one year of PWSCC followed by one year of FCG. Note that for more accuracy, crack growth may also be based on a monthly basis.

Combined FCG and PWSCC growth is calculated until the flaw depth reaches the interface of the base metal and overlay. The number of cycles and sequence of events for FCG are shown in Table 4 and are given for 60 years of operation. The PWSCC portion of the crack growth is only active if, during the growth of the flaw, the stress intensity factor at steady state normal operating conditions (NOC) is a positive value, which is in accordance with MRP-115 [11, page 4-2], which states that "there is insufficient data to justify a stress intensity factor threshold other than zero." The Ks from spreadsheet "StressIntensityFactors1.xls" are imported into spreadsheet "CG_SPRAY_DMW1.xls" to compute crack growth for DMW1; similarly, "StressIntensityFactorsSE.xls" are imported into spreadsheet "CG_SPRAY_DMWSE.xls" and "StressIntensityFactors2.xls" are imported into spreadsheet "CG_SPRAY_DMW2.xls".

FCG

For FCG, the individual terms that constitute nominal K_{max} and K_{min} for the calculation of ΔK in Equations (2) and (4) are summarized in the tabulations below. The individual Ks for nominal K_{max} are combined (summed) with all appropriate scale factors applied. Similarly, the individual Ks for nominal K_{min} are combined (summed) with all appropriate scale factors applied. ΔK is computed by taking the difference of the resulting summed K_{max} and K_{min}. Note that $K_{residual}$ and $K_{dead\ weight}$ are constant loads.

K_{max}	K_{min}
$K_{residual}$	$K_{residual}$
$K_{pressure}$	$K_{pressure}$
$K_{dead\ weight}$	$K_{dead\ weight}$
$K_{thermal\ piping\ load\text{-}state\ 1}$	$K_{thermal\ piping\ load\text{-}state\ 2}$
$K_{thermal\ state\ 1}$	$K_{thermal\ state\ 2}$
$K_{stratification\ state\ 1}$	$K_{stratification\ state\ 2}$

Thermal K_{max} and K_{min} values of Transient 1A at time 0 seconds are used for Hydrostatic Test. Similarly thermal K_{max} and K_{min} values of Transient 1B at time 0 seconds are used for Stratification event. OBE is treated as a separate event that combines with the highest K value for the K_{max} side and the lowest K value for the K_{min} side for 660 cycles [5].

PWSCC

The K-vs-a curves for both circumferential and axial flaws at normal operating conditions (NOC) are calculated in the PWSCC worksheets of spreadsheet "CG_SPRAY_DMW1.xls" and shown in Figure 9 for DMW1; "CG_SPRAY_DMWSE.xls (Figure 10) for safe end; "CG_SPRAY_DMW2.xls" (Figure 11) for DMW2. The stresses at steady state NOC include internal pressure stresses (P = 2155 psig [5]), residual stresses (at 70°F), steady state thermal stresses at 650°F, and stresses due to the non-cyclic piping loads (including deadweight). Note that an additional 2155 psig [5] was added to the C_0 coefficients for the stresses labeled "Resid+press+temp" in Table 1 to account for crack face pressure.

This crack face pressure is only applicable for the PWSCC evaluation. For both axial and circumferential flaws, the models described in Section 3.2 were used to calculate the stress intensity factors, but with an aspect ratio of a/2c = 0.5 for the axial flaw.
PWSCC is a time dependent phenomenon and occurs at a sustained loading condition. Given that the great majority of plant operation is at normal steady state operating conditions (NOC), PWSCC is defined by stress conditions at NOC. The 75% initial crack is grown using the cyclical loadings described previously. At steps in the evaluation, the value of the crack tip K is continuously checked. If the K is less than zero no PWSCC is assumed for the next step of fatigue crack growth. If the crack tip K becomes greater than zero, then the PWSCC crack growth rate in Section 3.4.2 is used to calculate an incremental PWSCC crack growth, which is added to the total crack growth.

In this case the Ks at steady state NOC were negative for all flaw depths for both the circumferential and axial flaws except for axial flaw at safe end. Thus, PWSCC is not active for all flaw depths between 75% and 100% of the original base metal except for axial flaw at safe end.

6.0 RESULTS AND CONCLUSIONS

The crack growth results are shown in Table 5. At the susceptible material region, it takes greater than 60 years for an initial flaw of 75% of the original base metal thickness at the analyzed section to reach the overlay for the circumferential flaw and the axial flaw.

It was also shown that the Ks at steady state NOC were negative for all flaw depths for both the circumferential and axial flaws except for axial flaw at Safe End. Thus, PWSCC is not active for all flaw depths between 75% and 100% of the original base metal except for axial flaw at Safe End.

7.0 REFERENCES

1. SI Calculation No. 1000320.312, "Material Properties and Finite Element Models for Pressurizer Spray Nozzle with Weld Overlay Repair," (for revision number refer to SI Project Revision Log, latest revision).

2. Zahoor, A., EPRI Report No. NP-6301-D, Ductile Fracture Handbook, Volumes 1, 2, and 3, (N14-1), Research Project 1757-69, June 1989.

3. Hiroshi Tada, Paul C. Paris, and George R. Irwin, "The Stress Analysis of Cracks Handbook," Third Edition, ASME Press, 2000.

4. SI Calculation No. 1000320.313, "Pressurizer Spray Nozzle Thermal and Mechanical Stress Analysis Calculation," (for revision number refer to SI Project Revision Log, latest revision).

5. SI Calculation No. 1000320.311, "Design Loads for Pressurizer Spray Nozzle with Weld Overlay Repair," (for revision number refer to SI Project Revision Log, latest revision).

6. SI Calculation No. 1000320.314, "Residual Stress Analysis of Pressurizer Spray Nozzle with Weld Overlay Repair," (for revision number refer to SI Project Revision Log, latest revision).

7. NUREG/CR-6907, "Crack Growth Rates of Nickel Alloy Welds in a PWR Environment," U.S. Nuclear Regulatory Commission (Argonne National Laboratory), May 2006.

8. NUREG/CR-6721, "Effects of Alloy Chemistry, Cold Work, and Water Chemistry on Corrosion Fatigue and Stress Corrosion Cracking of Nickel Alloys and Welds," U.S. Nuclear Regulatory Commission (Argonne National Laboratory), April 2001.

9. ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 2004 Edition.

10. Lenets, Y. N., "Compression Fatigue Crack Growth Behavior of Metallic Alloys: Effect of Environment," Engineering Fracture Mechanics, Vol. 52, No. 5, 1997.

11. Materials Reliability Program Report MRP-115, "Materials Reliability Program: Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Alloy 82, 182, and 132 Welds," September 2004.

12. SI Calculation 0800554.301, "Computation of Influence Coefficients for Two Stress Intensity Factor Solutions From EPRI Ductile Fracture Handbook," Rev. 0.

Table 1: Stress Coefficients for Various Loadings at the DMW1

Transient/Load Name	Time (sec)	Path Used	Axial Stress Coefficients, psi				Time (sec)	Path Used	Hoop Stress Coefficients, psi			
			C_0	C_1	C_2	C_3			C_0	C_1	C_2	C_3
Unit Pressure [1]	--	2	1661.9	-67	500.4	-286.1	--	7	3341.9	-1912.3	1470.5	-557.3
Unit Axial	--	2	66.7	7.6	-12.2	5.2	--	7	-0.3	2.1	-2.1	-0.2
Unit Moment	--	2	69					8	1.1	--	0.3	-0.2
Resid70, Path 1	--	1	7465	-322363	548734.7	-200332	--	1	-67148	-228622	719933	-365302
Resid70, Path 2	--	2	-1861	-295011	657991	-304460	--	2	-65863	-378679	1327293	-812842
Resid+press+temp, Path 1 [2]	--	1	-18011	-92847	199113	-57561	--	1	-57281	-145167	552343	-293078
Resid+press+temp, Path 2 [2]	--	2	-12593.2	-175063	461698.7	-222685	--	2	-51924.3	-319382	1159462	-723909
Transient1HIGH	10956	1	-4687.3	65569.9	-104067	40865.5	10908	8	7398.1	6794.9	-41470.2	22438.4
Transient1LOW	360	2	-534.6	2500.2	-3219.2	1271.2	360	2	-406	2169.1	-2812.2	1121.4
Transient2HIGH	21681	1	-1343.9	44385.2	-75139.5	29820.4	21681	2	7146.7	-227.6	-27767.3	16212.2
Transient2LOW	0	2	-11134.5	83554.2	-132163	56576.1	39600	1	313.8	7906.6	-15394.3	6399.7
Transient3HIGH	308.4	13	-19020.6	136265.1	-193031	74191.1	316.8	7	-1263.1	52219.8	-88485.8	35445.1
Transient3LOW	51.6	2	-14590.1	92995.3	-139203	58413	51.6	14	-2363.4	45917	-81903.7	36658.2
Transient4HIGH	99	13	-20370	139017.8	-194329	74416.1	99	7	-2863.1	56302.1	-91277.3	36191.1
Transient4LOW	773.4	2	-19096.1	105262.4	-148215	60734.5	773.4	14	-6886.5	60933	-94304.2	40207.8
Transient5HIGH	692	13	-20100.9	138753.1	-194619	74624.2	692	7	-2639.6	55655.4	-90812.1	36091.1
Transient5LOW	22	2	-13457.3	91128.6	-139137	58722.9	22	14	-1391.1	43795.9	-81671.6	36961.9
Transient6HIGH	900	13	-17173.7	126330	-180092	69353.5	915	8	3807.5	27050.5	-68106.9	33221.1
Transient6LOW	0	2	-11478	86207.3	-136460	58464.1	0	14	973	36027.9	-75495.6	35363.2

Notes:

(1) 1000 psig was added to the C_0 coefficient term of the Unit Pressure case to account for crack face pressure.

(2) 2155psig was conservatively added to the C_0 coefficient term of the residual stresses and normal operating pressure and temperature cases to account for crack face pressure. This is needed for calculating stress intensity factors at normal steady state operating conditions.

Table 1: Stress Coefficients for Various Loadings at the Safe End (continued)

Transient/ Load Name	Time (sec)	Path Used	Axial Stress Coefficients, psi				Time (sec)	Path Used	Hoop Stress Coefficients, psi			
			C_0	C_1	C_2	C_3			C_0	C_1	C_2	C_3
Unit Pressure (1)	--	3	1815.7	-656.9	980.1	-494.2	--	4	3357	-1791.2	722.1	-117.8
Unit Axial	--	15	68.4	-4.5	7.1	-3.6	--	16	47.7	-88.3	45.1	-14.2
Unit Moment	--	10	71					16	1.1	--	0.3	64.9
Resid70, Path 3	--	3	-20214	-232640	624324	-317131	--	3	-66326	21866	454429	-344296
Resid70, Path 4	--	4	-19821	-208347	559612	-294667	--	4	-51795	-305618	909433	-479645
Resid+press+temp, Path 3 (2)	--	3	-8952.2	-207804	538416	-276023	--	3	-49674.4	33872.59	363978.6	-289718
Resid+press+temp, Path 4 (2)	--	4	-12181.3	-152053	409736.6	-214737	--	4	-32756.2	-261646	753794.8	-392351
Transient1HIGH	10932	3	10594.2	-4386.8	-27209.4	16065.7	10932	16	13909.9	-14666	-15256.8	12242.7
Transient1LOW	360	16	-483.3	1344.6	-1169.3	401.5	360	16	-584.8	1926.6	-1865	655.7
Transient2HIGH	21654	16	12179.8	-9985.9	-19986.3	13406.9	21654	16	17218.4	-28839.8	404.4	6670.3
Transient2LOW	39600	4	938.4	3301.9	-9813.3	4835.5	39600	4	1639.1	1157.6	-7631.8	4167.2
Transient3HIGH	299.8	15	8189.6	5471.6	-38123.8	20063.8	286.5	10	13687.7	-9626.6	-21915.1	14826.6
Transient3LOW	31.8	16	-4149.4	26808.8	-38059	15537.5	31.8	16	-3511.5	31334.3	-46023.7	19138.3
Transient4HIGH	99	15	5257.6	12655	-42512.8	21052.7	99	10	9661.5	-587.5	-26310.4	15285.5
Transient4LOW	753.4	16	-11382.9	41376.2	-43413.1	15482.9	753.4	16	-12818.8	55509.2	-62616.4	23008.8
Transient5HIGH	712	15	5711.5	12030.5	-42473.7	21022.9	692	10	9633.6	-401.9	-26534.7	15349.2
Transient5LOW	19	10	-2065.5	27765.9	-47520.9	20240.8	20	16	149.9	26957.4	-48768	21438.3
Transient6HIGH	900	15	8475.2	5921.8	-40356.8	21325.4	900	10	12617.7	-6175.7	-26074.6	16461
Transient6LOW	0	10	4410.4	10815.8	-36157.4	17955.3	0	3	4456.3	15949.2	-48490.3	24342.3

Notes:

(1) 1000 psig was added to the C_0 coefficient term of the Unit Pressure case to account for crack face pressure.

(2) 2155psig was conservatively added to the C_0 coefficient term of the residual stresses and normal operating pressure and temperature cases to account for crack face pressure. This is needed for calculating stress intensity factors at normal steady state operating conditions.

Table 1: Stress Coefficients for Various Loadings at the DMW2 (continued)

Transient/ Load Name	Time (sec)	Path Used	Axial Stress Coefficients, psi				Time (sec)	Path Used	Hoop Stress Coefficients, psi			
			C_0	C_1	C_2	C_3			C_0	C_1	C_2	C_3
Unit Pressure (1)	--	5	2414.7	-316.1	-1777	1511.8	--	18	3739.4	-2153.5	1223.9	-400.9
Unit Axial	--	6	96	24.4	-107.6	103.7	--	18	82.4	-164.8	93.5	-40.2
Unit Moment	--	12	95					18	1.1	--	0.3	85.6
Resid70, Path 5	--	5	-9408.89	-342880	1142648	-802714	--	5	-50760.7	-504408	2185410	-1729247
Resid70, Path 6	--	6	6829.818	-462574	1215647	-751711	--	6	-48229.1	-416755	1560161	-1064928
Resid+press+temp, Path 5 (2)	--	5	-17922.2	-160572	689345.1	-513050	--	5	-32677.3	-405929	1803947	-1442403
Resid+press+temp, Path 6 (2)	--	6	-9071.46	-272521	848615.8	-545389	--	6	-32883.7	-290259	1194809	-826460
Transient1HIGH	10908	5	532.8	37006.3	-95231.6	54415.2	10884	12	9500.6	6657.8	-46437.5	28134.2
Transient1LOW	28092	6	-16624.3	80523.4	-85666	26101.5	360	6	-377.9	1693.6	-2209	1147.3
Transient2HIGH	21654	5	7208.5	4916.6	-52212.9	35713.8	21654	12	13225.1	-14969.4	-19240.2	17075.7
Transient2LOW	0	6	-15574.7	78097.9	-84573.7	26002.9	39600	6	1377	-105.8	-7547.3	6160
Transient3HIGH	282	5	-7508.8	81611.5	-159843.2	82195.8	282	12	8305.9	29280.1	-78884.1	41625.7
Transient3LOW	18.6	6	-25293	107206.1	-105607.3	30333.5	18.6	6	-3084.1	8844.3	-2051.7	4800.2
Transient4HIGH	64.5	5	-10314.3	88758.5	-162540.2	81514.5	64.5	12	5128.9	37375.3	-82733.5	41781.5
Transient4LOW	743.4	6	-32923.5	129912.5	-123085.4	35037.3	743.4	6	-10435.1	31226.1	-17714.2	8606.7
Transient5HIGH	672	5	-10516.9	90022	-164417.3	82304.6	652	12	4883.7	38531.1	-84252	42366.4
Transient5LOW	18	6	-22172	100807.1	-105732.4	32555.4	19	6	521.6	-533.1	2008.5	4964.7
Transient6HIGH	900	5	-6493.5	76835.8	-154357	80489.8	900	12	7576	28710.8	-77505.3	41178.8
Transient6LOW	0	6	-15834.2	80348.1	-88159.6	27599.2	0	6	7433.8	-23141.1	19870.1	760.1

Notes:

(1) 1000 psig was added to the C_0 coefficient term of the Unit Pressure case to account for crack face pressure.

(2) 2155psig was conservatively added to the C_0 coefficient term of the residual stresses and normal operating pressure and temperature cases to account for crack face pressure. This is needed for calculating stress intensity factors at normal steady state operating conditions.

Table 2: Spray Nozzle Piping Interface Loads

	Forces, lb			Moments, lb-in		
Load Case	**Fx**	**Fy**	**Fz**	**Mx**	**My**	**Mz**
Deadweight	3	14	13	252	1222	781
OBE	422	629	493	10932	20102	15723
Thermal	6	4	11	6468	704	348
Maximum Stratification Moment				Range = 173,263 lb-in[(3)]		

Notes:
1) Transformed forces and moments are listed on an absolute basis.
2) F_y is oriented in the axial direction of the nozzle.
3) The number of cycles is 7200 per [5].

Table 3: Bounding Thermal Transients for the Spray Nozzle

Transient	Time, sec	T_{PZR}, °F	T_{spray}, °F	h, Btu/hr-ft^2-°F Under TS	Elsewhere	P_{spray}, psig	Cycles	Factor
1A	0	70	70	173	1378	0	240	N/A
	10800	370	370	173	1378	159		1.000
	10800	370	70	22	21	216		1.000
	12240	410	110	26	26	319		0.082
	12240	410	110	141	427	319		0.082
	27432	650	532	160	739	2242		0.953
	27432	650	532	183	2149	2242		0.953
	28092	650	555	182	2123	2242		1.000
1B	0	650	555	179	1663	2242	240	1.000
	10800	430	300	177	1540	216		0.474
	21600	400	280	177	1484	216		0.433
	21600	400	210	152	578	159		0.289
	25920	330	150	147	494	15		0.165
	36000	200	125	141	427	0		0.113
7/8C/11	0	650	544	41	44	2242	65938	0.977
(bounds	0	650	566	182	2111	2242		1.023
2A, 3, 4,	4	682	586	182	2088	2792		1.064
6, 7, 8C,	12	682	590	182	2084	2792		1.072
10, 11,	144	682	590	182	2084	2792		1.072
14, and	144	639	575	182	2101	2092		1.041
20B)	192	633	562	182	2116	1997		1.014
	282	625	546	183	2134	1897		0.981
	372	616	540	183	2140	1777		0.969
8A/15	0	650	555	182	2123	2242	80	1.000
	8	662	570	174	1261	2442		1.031
	12	662	570	174	1261	2442		1.031
	20	650	555	164	844	2242		1.000
	30	632	550	154	612	1992		0.990
	720	643	550	154	612	1992		0.990
	720	643	636	173	1405	2142		1.167
		643	636	173	1405	2142		1.167
8B	0	650	544	183	2136	2242	180	0.977
(also	1	651	544	183	2136	2260		0.977
bounds	4	654	562	182	2116	2312		1.014
17A)	6	657	564	182	2113	2348		1.019
	10	661	560	182	2118	2419		1.010
	15	666	576	182	2100	2507		1.043
	22	653	568	182	2109	2297		1.027
	22	653	568	41	44	2297		1.027
	600	616	558	41	44	1757		1.006
	612	616	535	41	45	1757		0.959
9	0	650	580	182	2006	2242	1480	1.052
(also	900	519	500	182	2093	842		0.887
bounds 2B)	1200	515	490	182	2088	822		0.866
12			70			0	20	N/A
			70			3125		N/A

Note: The above table is reproduced from Reference 5.

Table 4: Sequence of Events and Cycles for Fatigue Crack Growth

Events	Event ID	60-yr Cycles	No. of peak/valley pairs
Transient 1 (Heatup)	1	240	1
Transient 2 (Cooldown)	2	240	1
Transient 3 (Step load reduction)	3	65938	1
Transient 4 (Reactor Trip with Loss of Flow/Loss of Station Power)	4	80	1
Transient 5 (Reactor Trip Due to High Reactor Temperature)	5	180	1
Transient 6 (Rapid Depressurization)	6	1480	1
Transient 7 (Hydro test)	7	20	1
Stratification Moment	8	7200	1
OBE	9	660	1

Table 5: Crack Growth Results

Flaw (1)	Time to Reach Overlay	Flaw Depth By Fatigue and PWSCC at 60 years
Circumferential Flaw at DMW1	>60	0.5625"
Axial Flaw at DMW1	>60	0.5625"
Circumferential Flaw at Safe End	>60	0.5367"
Axial Flaw at Safe End	>60	0.5367"
Circumferential Flaw at DMW2	>60	0.3124"
Axial Flaw at DMW2	>60	0.3124"

Notes:
(1) Initial flaw depth = 75% of original base metal thickness at the section analyzed = 0.563" for DMW1; 0.537" for Safe End; 0.313" for DMW2.

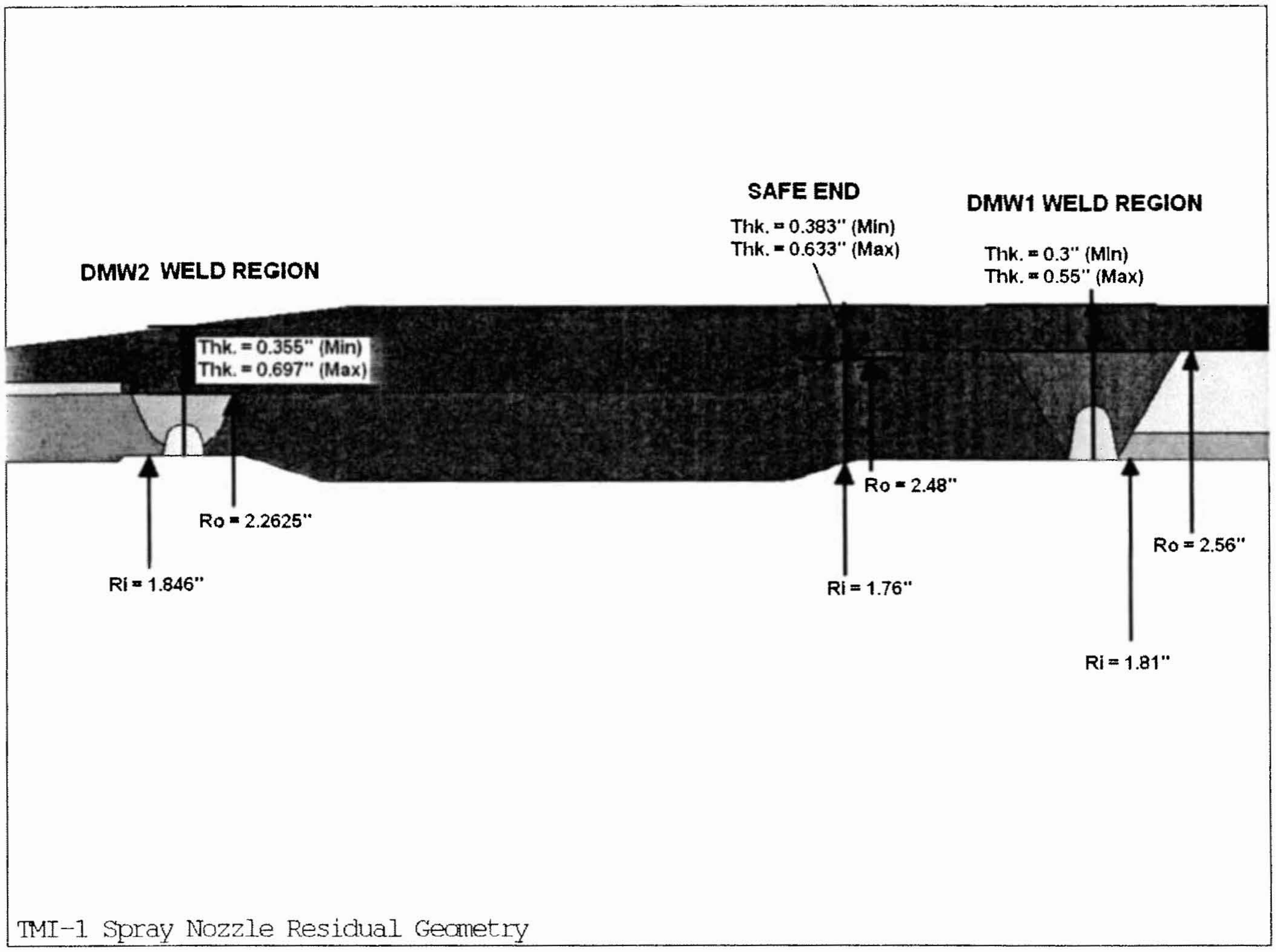
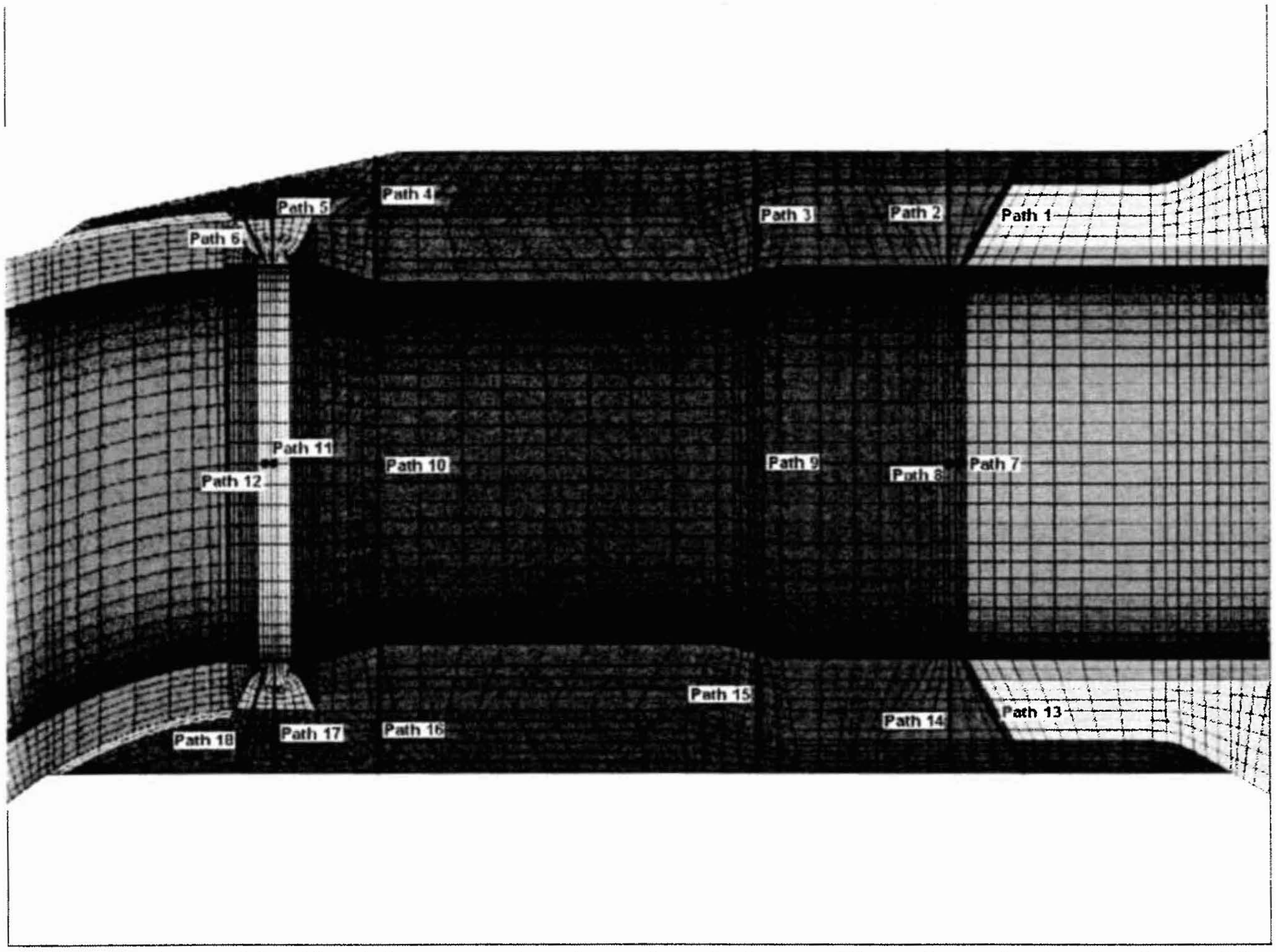
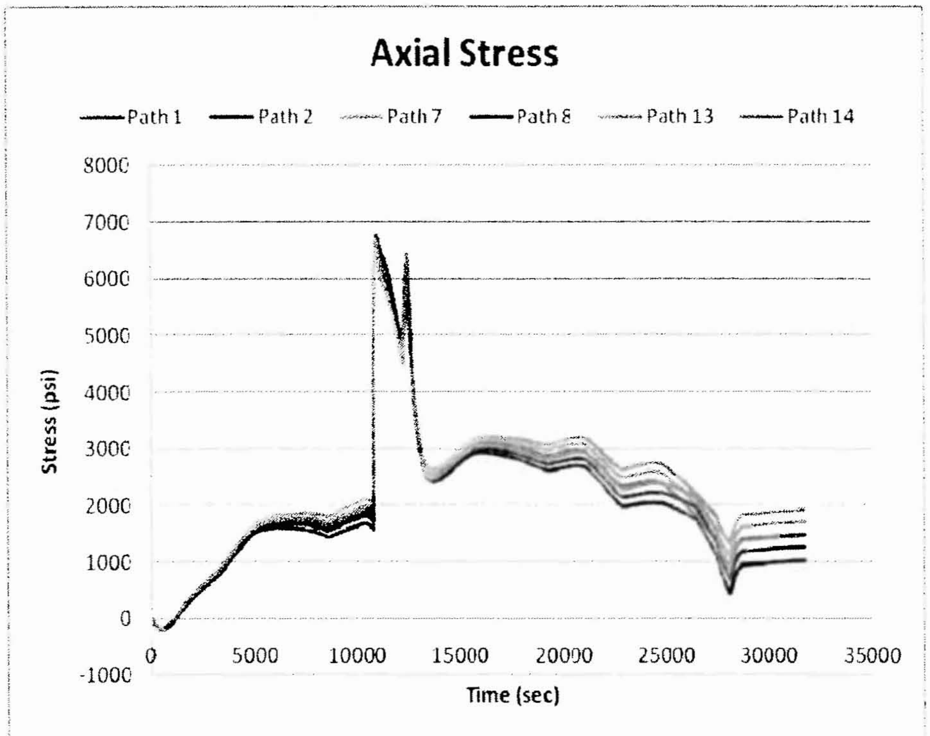


Figure 1: FEM Section Geometries Used For Crack Growth



Note: Only the model with minimum overlay dimensions is shown. The path numbering for the model with maximum overlay dimensions is similar.

Figure 2: Critical Paths Used for Linearized and Through-wall Mapped Stresses



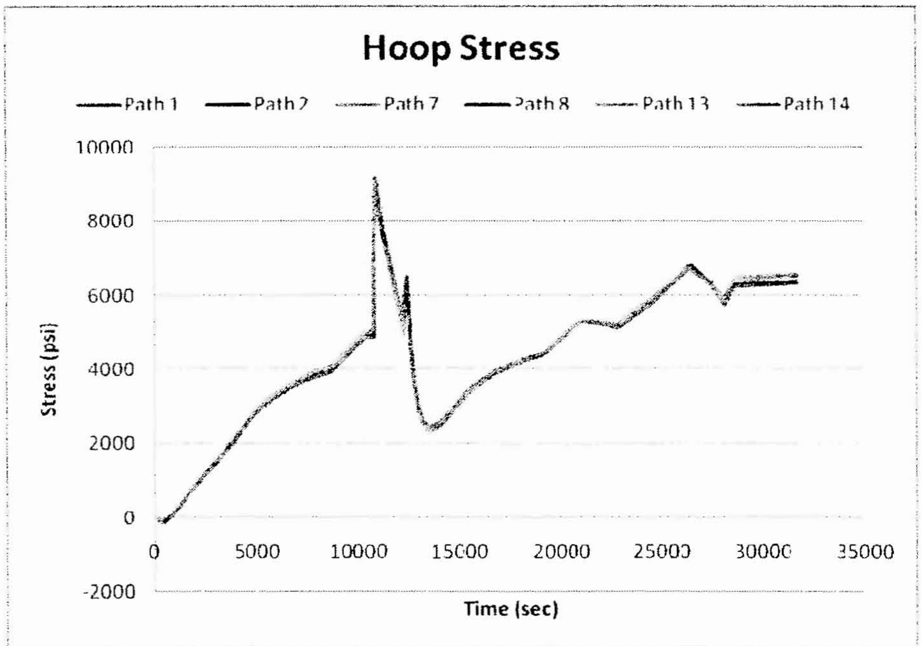


Figure 3: Time Histories of Linearized M + B Stress at the Inside Surface for Heatup Transient for DMW1

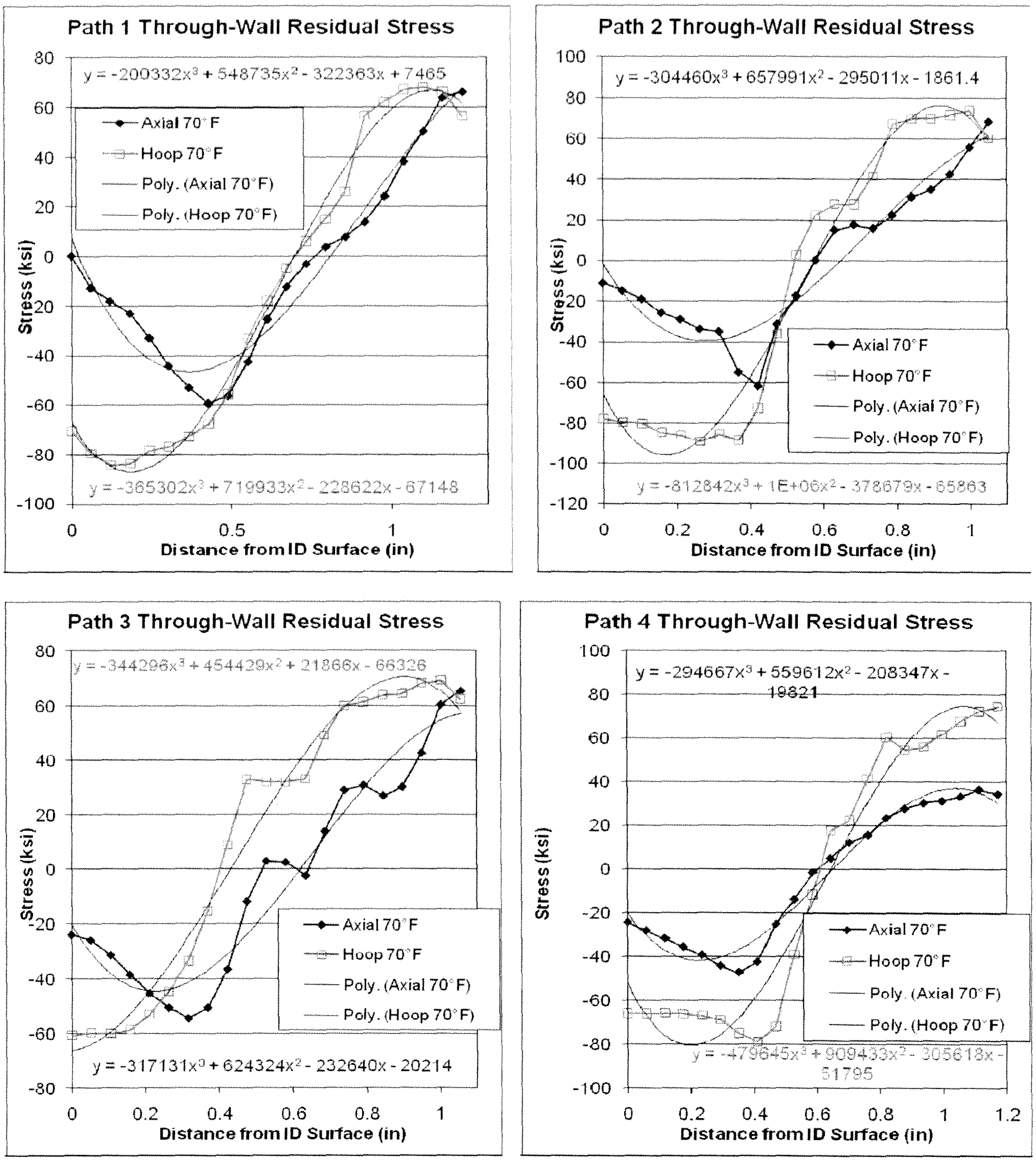
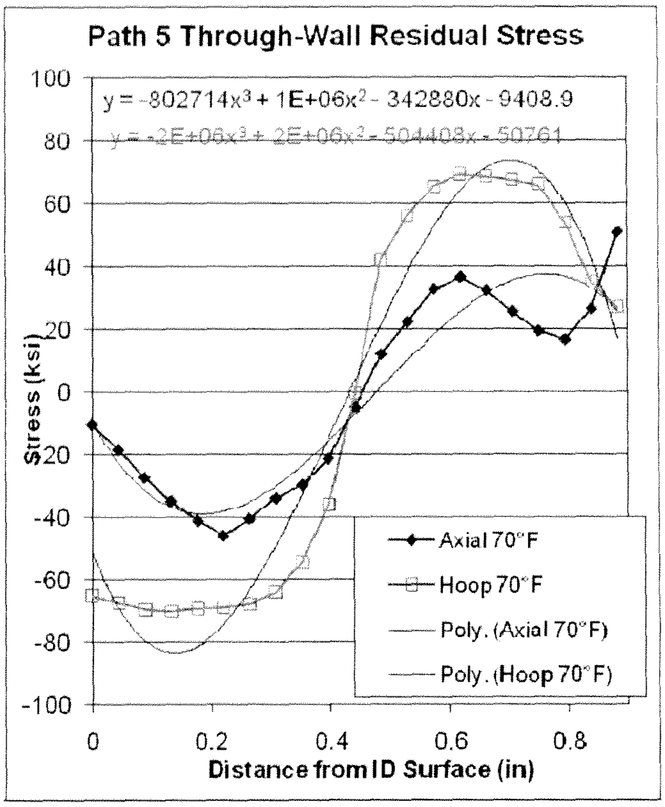


Figure 4: Through-wall Residual Stress Distribution at 70°F and Curve Fits

Note: Minimum overlay wall thickness is used to calculate residual stresses.



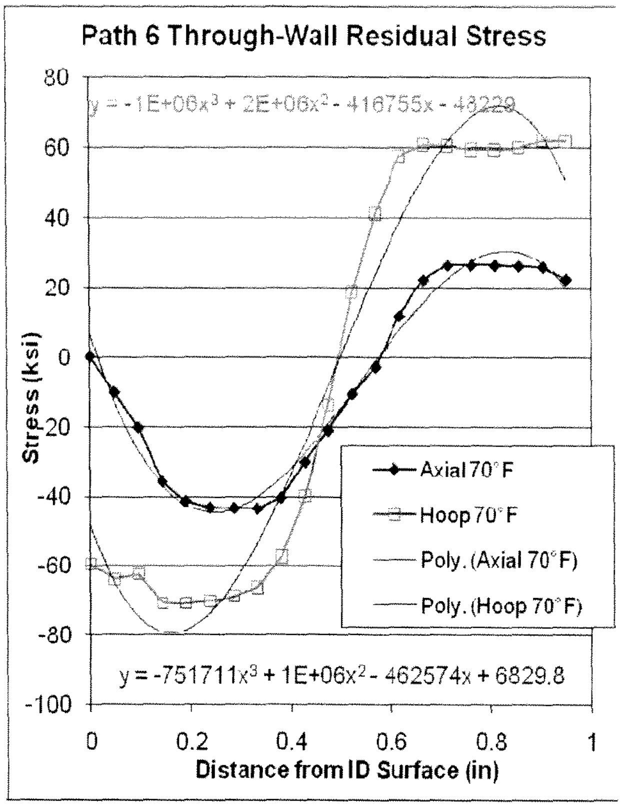
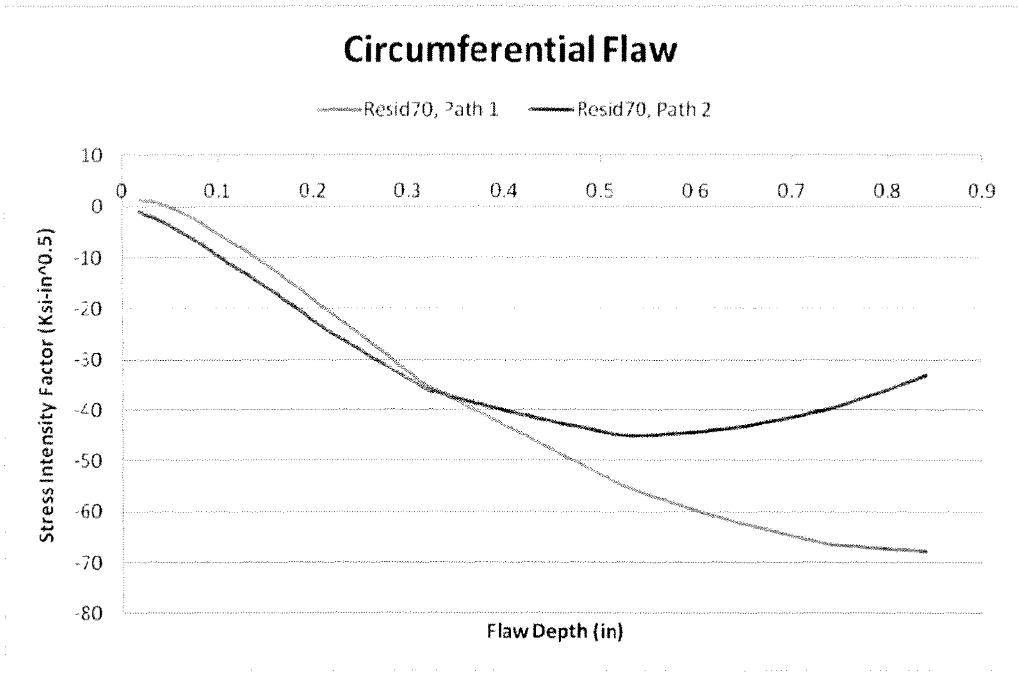


Figure 4: Through-wall Residual Stress Distribution at 70°F and Curve Fits (continued)

Note: Minimum overlay wall thickness is used to calculate residual stresses.



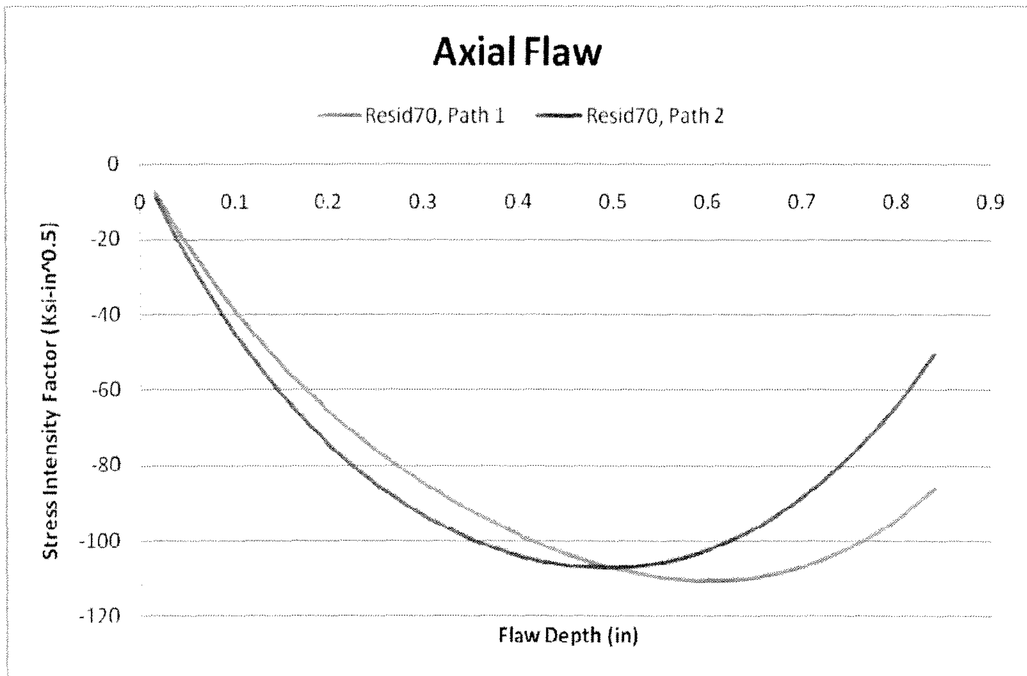
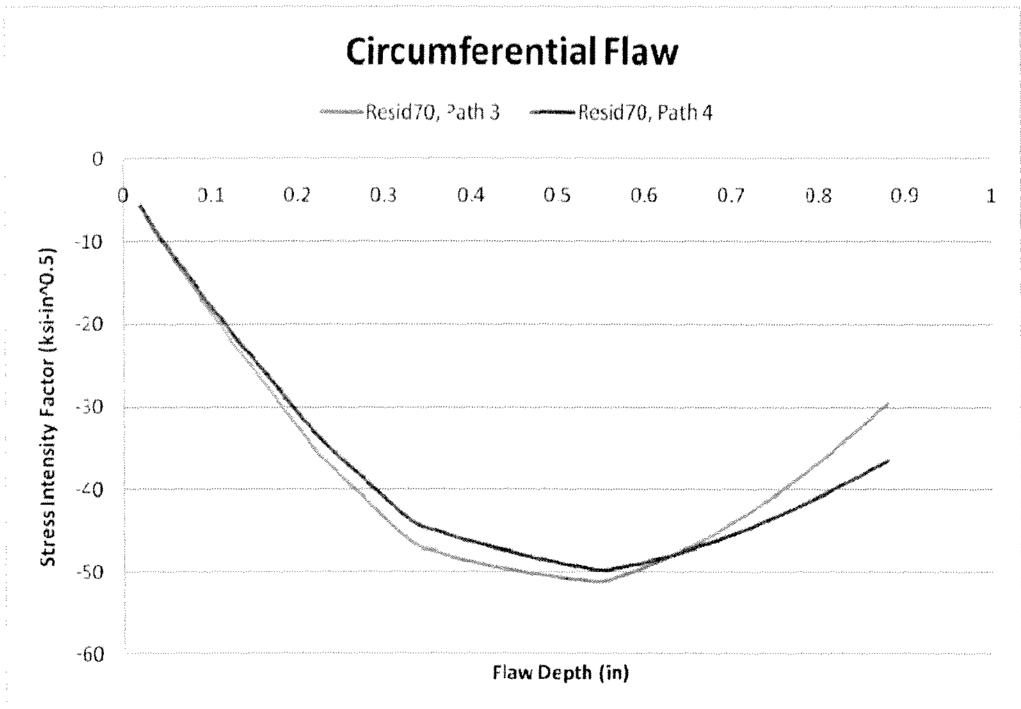


Figure 5: K-vs-a Plots for Paths 1 and 2 at DMW1 for Residual Stresses at 70°F

Note: Minimum overlay wall thickness is used to calculate residual stresses.



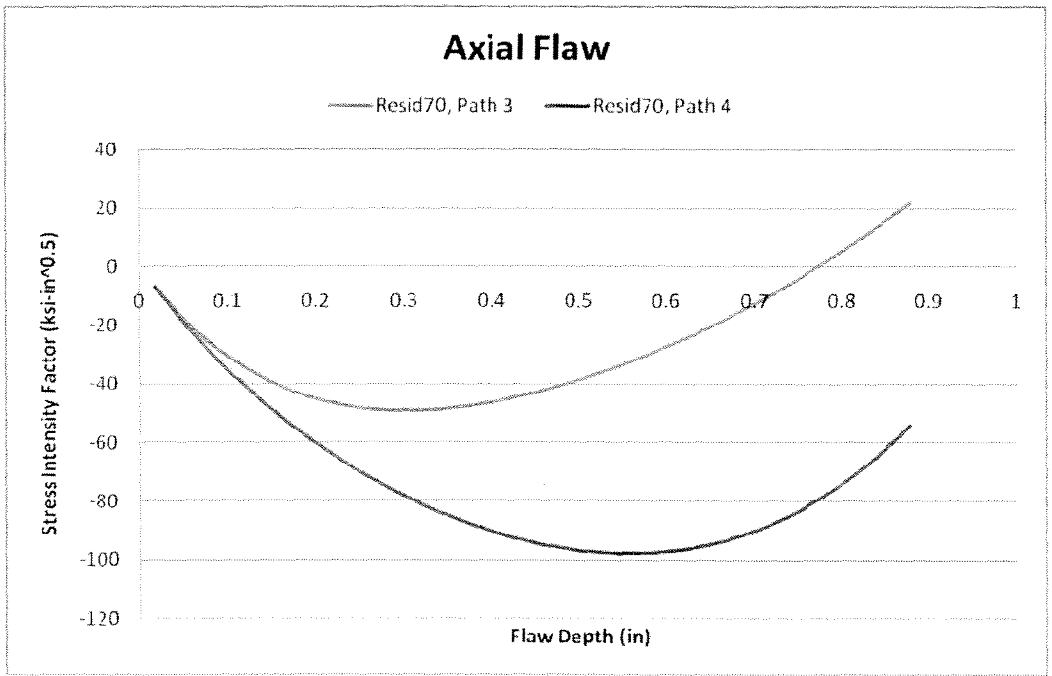
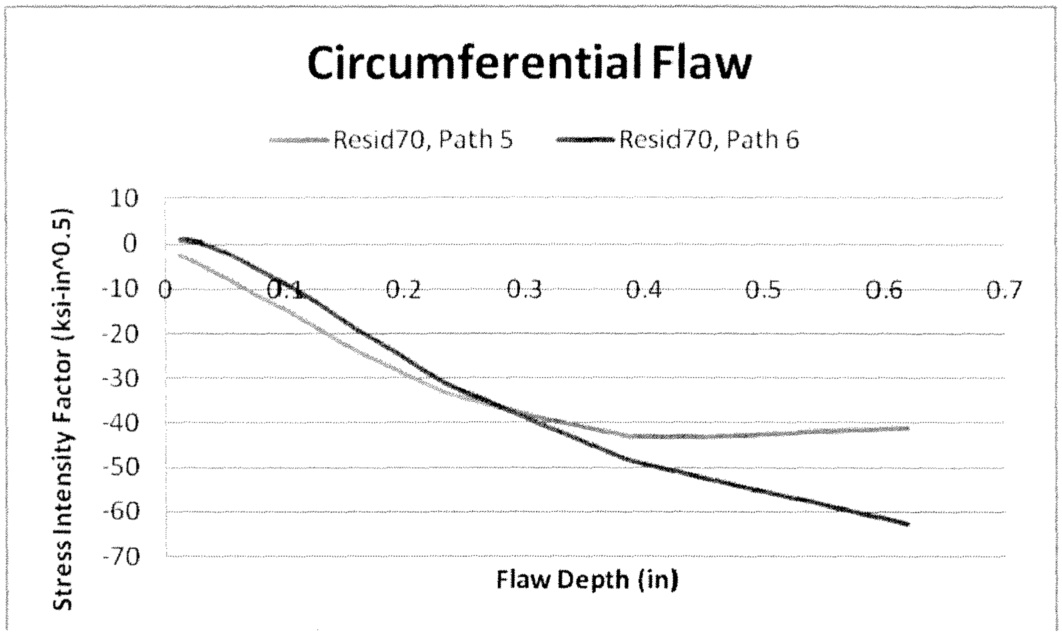


Figure 5: K-vs-a Plots for Paths 3 and 4 at Safe End for Residual Stresses at 70°F (cont'd.)

Note: Minimum overlay wall thickness is used to calculate residual stresses.



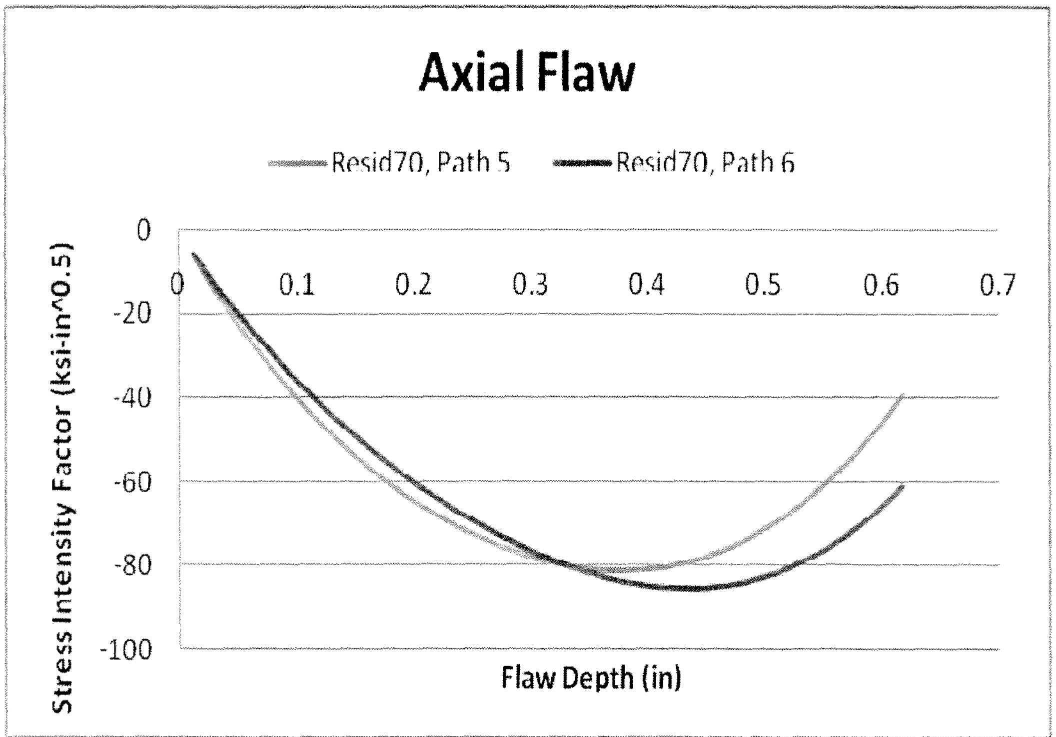
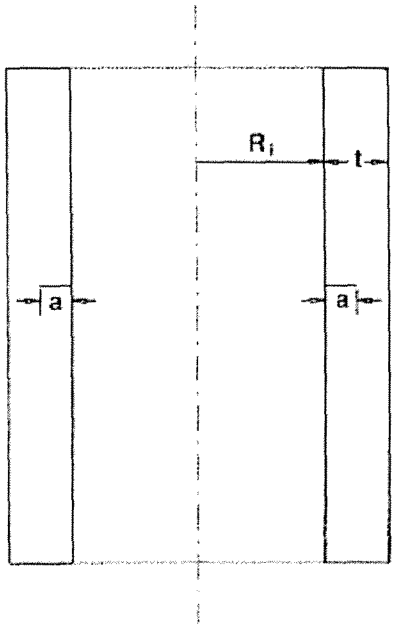


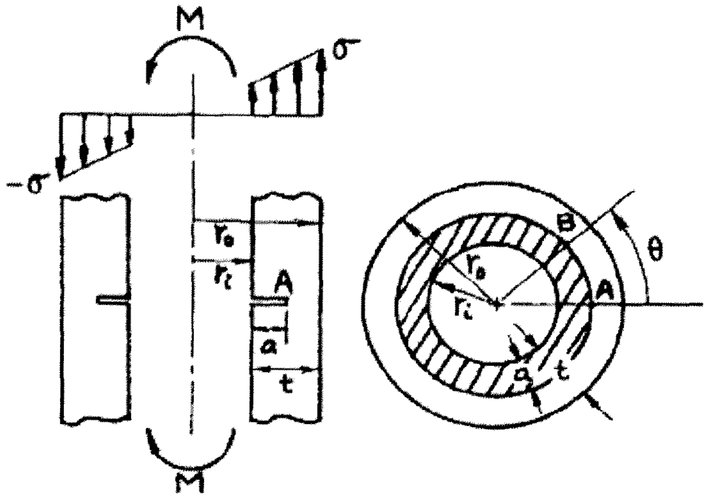
Figure 5: K-vs-a Plots for Paths 5 and 6 at DMW2 for Residual Stresses at 70°F (cont'd.)

Note: Minimum overlay wall thickness is used to calculate residual stresses.



Source: Reference 2 (Zahoor model, $1 \leq R_i/t \leq 10$)

Figure 6: Circumferential Flaw Model, Under Arbitrary Through-Wall Stress Distribution



$$\sigma = \frac{4Mr_o}{\pi\left(r_o^4 - r_i^4\right)}$$

$$K_{IA} = \sigma\sqrt{\pi a}\,F\left(\frac{r_i}{r_o}, \frac{a}{t}\right)$$

$$K_{IB} = K_{IA}\cos\theta$$

Source: Reference 3

"F" is defined below (also from Reference 3)

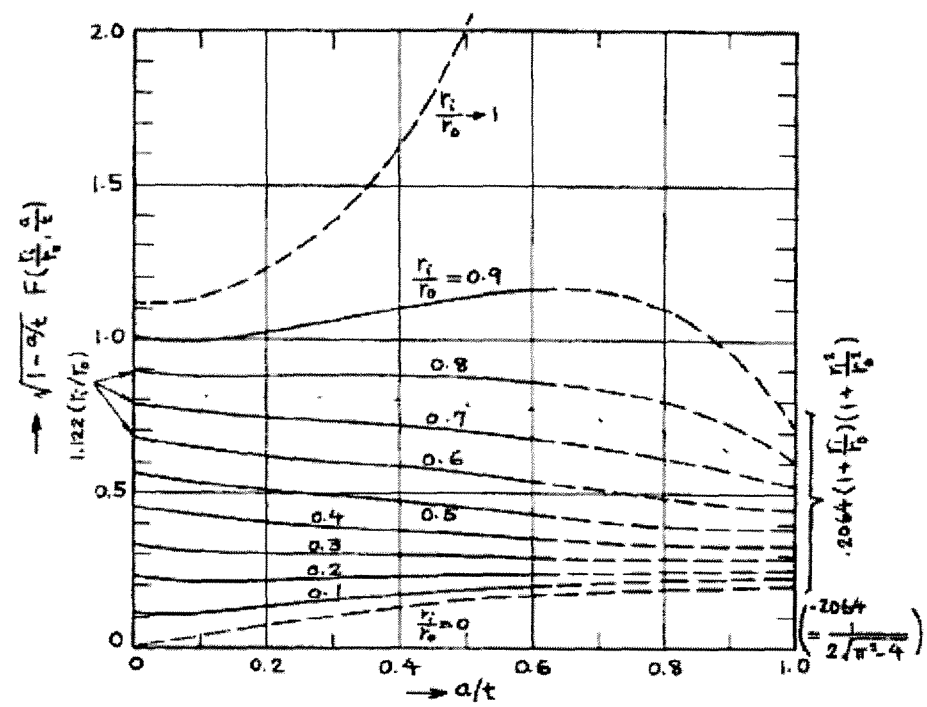
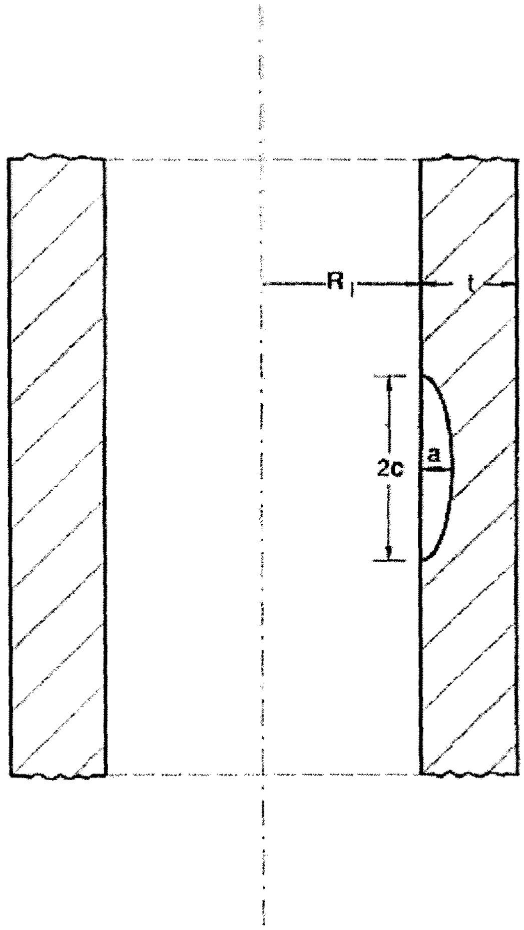
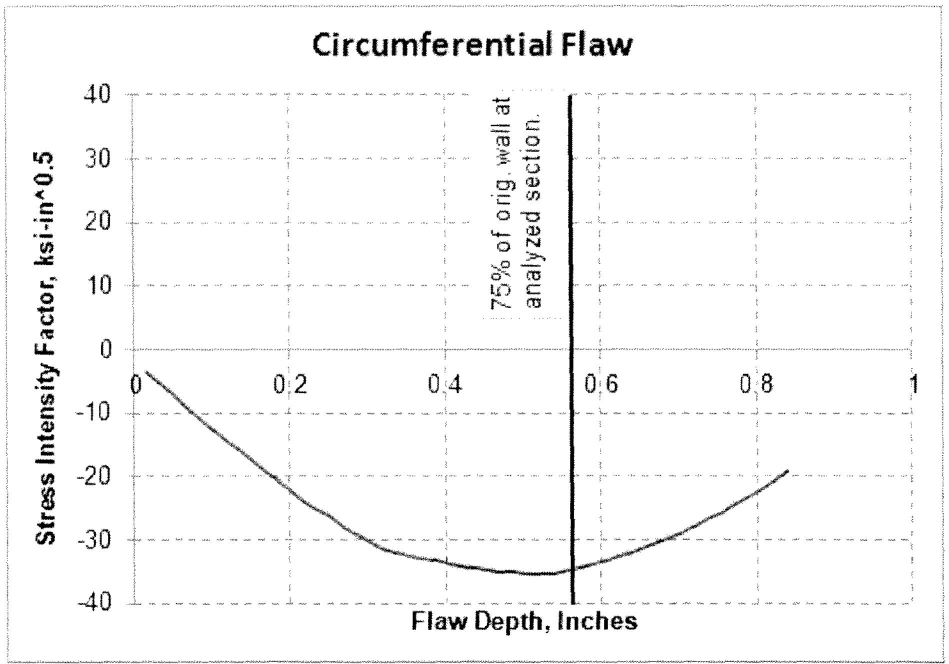


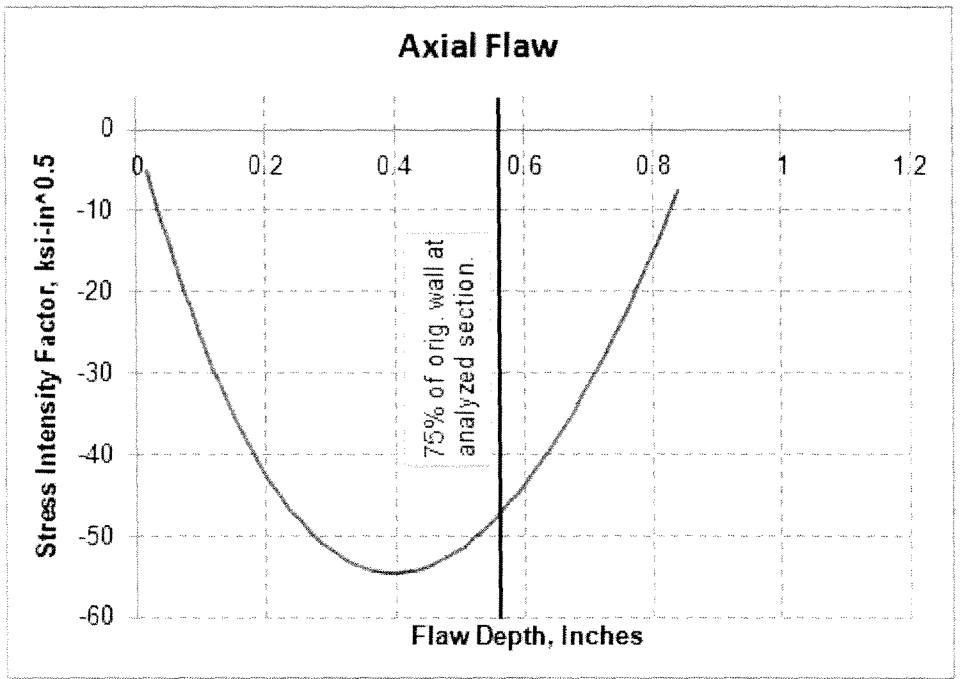
Figure 7: Circumferential Flaw Model, Moment Loading



Source: Reference 2 (Zahoor model, $1 \leq R_i/t \leq 10$)

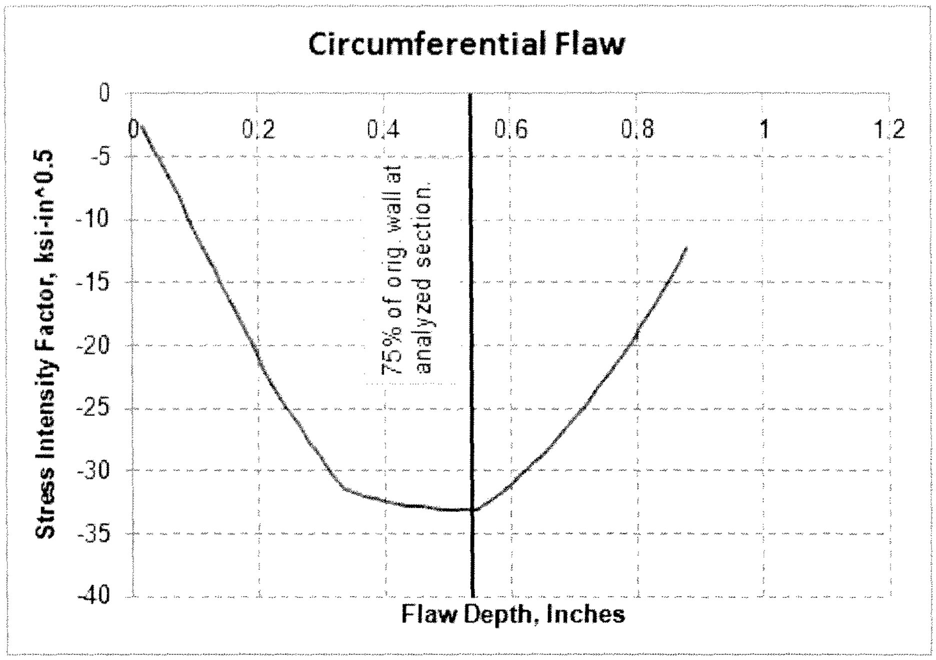
Figure 8: Axial Flaw Model, Under Arbitrary Through-Wall Stress Distribution

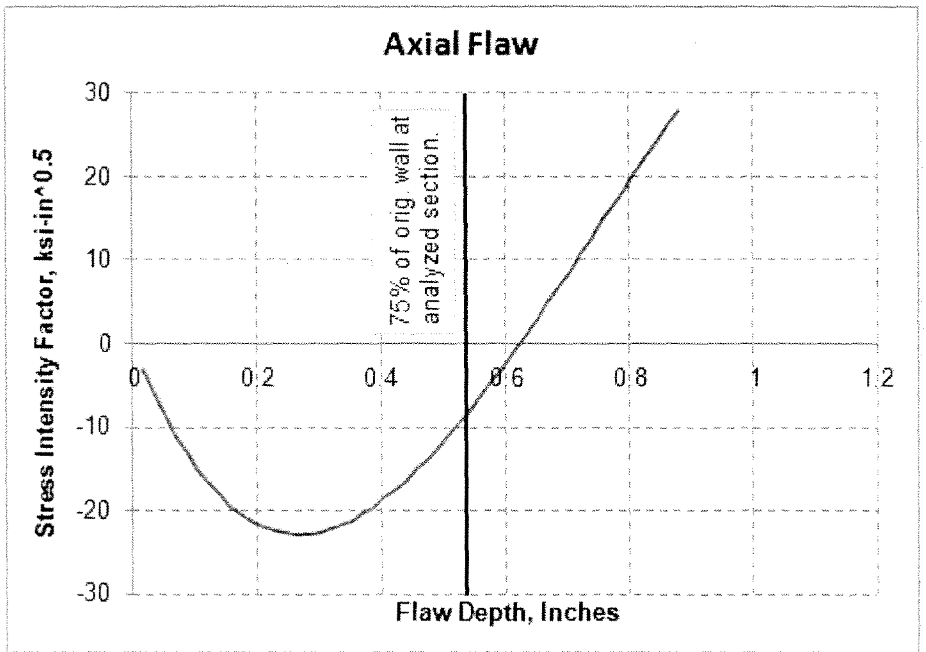




Note: Initial flaw depth = 75% of original base metal thickness at the analyzed section = 0.5625"

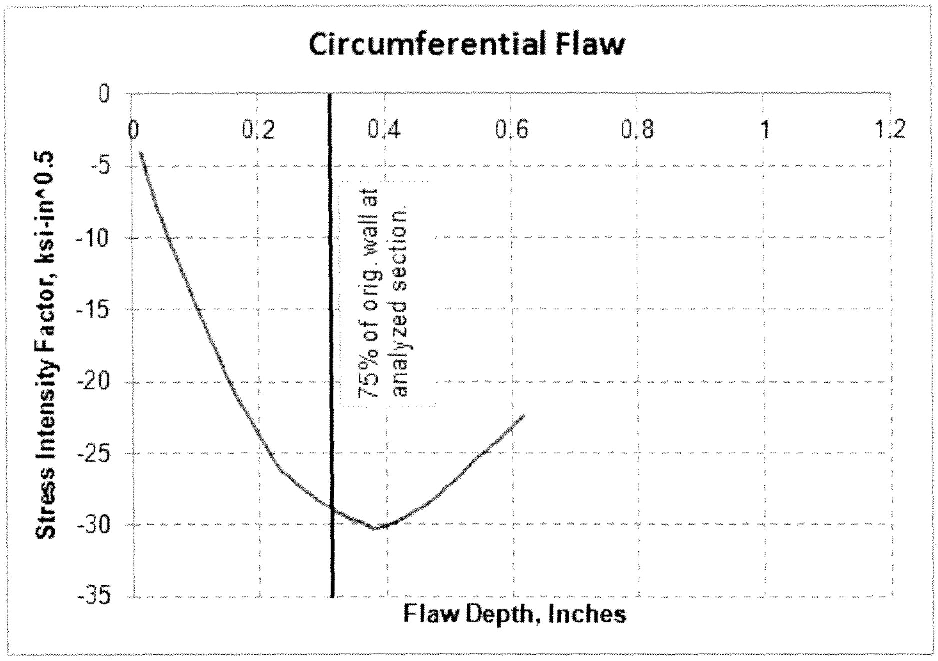
Figure 9: K-vs-a at Normal Steady State Operating Conditions for DMW1

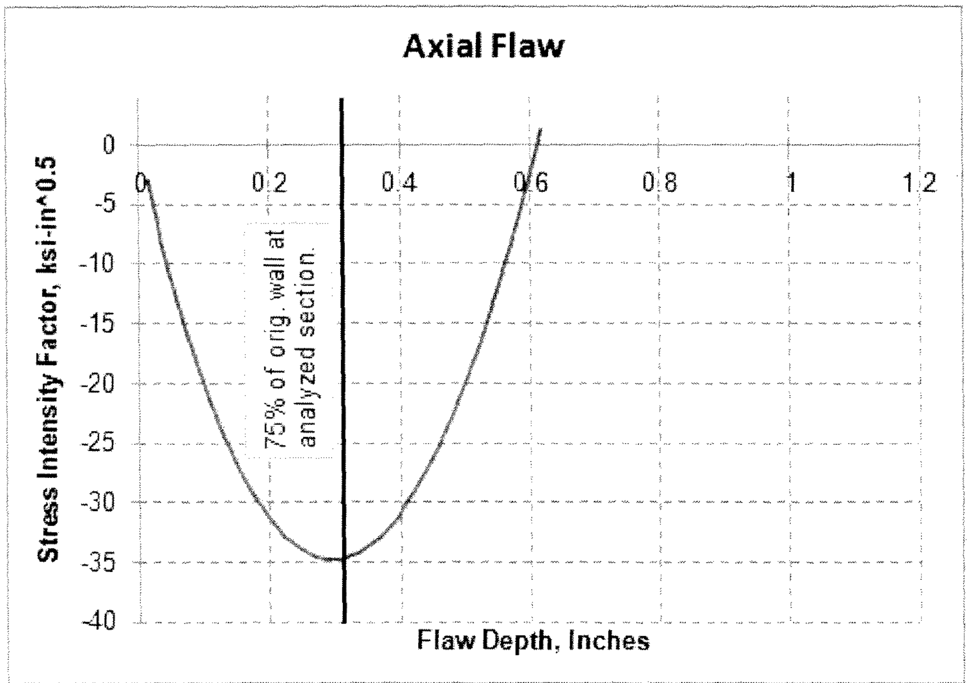




Note: Initial flaw depth = 75% of original base metal thickness at the analyzed section = 0.5367"

Figure 10: K-vs-a at Normal Steady State Operating Conditions for Safe End





Note: Initial flaw depth = 75% of original base metal thickness at the analyzed section = 0.3124"

Figure 11: K-vs-a at Normal Steady State Operating Conditions for DMW2

APPENDIX A

COMPUTER FILE DESCRIPTIONS

Stress Output

Filename	Description
TMI_STR_$_P*_MAP.CSV	Linearized stresses and mapped through-wall stresses for transient $ and path * * = path no. = 1 through 18 (Figure 2); $ = 1A, 1B, 7_8C_11, 8A_15, 8B, and 9
TMI_PR_P*_MAP.OUT (CSV file version also included)	Through-wall stresses for unit pressure run for path * where * = path no. = 1 through 18 (Figure 2)
TMI_AXIAL_P*_MAP.OUT (CSV file version also included)	Through-wall stresses for unit axial load run for path * where * = path no. = 1 through 18 (Figure 2)
TMI_MOM$_P*_MAP.OUT (CSV file version also included)	Through-wall stresses for unit moment load run for path * where * = path no. = 1 through 18 (Figure 2); $ = X and Z.

Spreadsheets

Filename	Description
StressIntensityFactors$.xls	Spreadsheets that contain Microsoft Visual Basic macros for calculating stress intensity factors at the susceptible material regions DMW1, Safe End and DMW2, where $ = 1, SE, and 2.
TMI_Spray_ThermMechStressCoeff_DMW$.xlsm	Spreadsheets that contain extraction of linearized stresses; source of Table 1. Where, $ = 1, SE, and 2
TableOfCoefficients.xls	Spreadsheet that contains stress coefficients for thermal transient stresses at the SMR; used as input to "StressIntensityFactors$" spreadsheets, where $ = 1, SE, and 2.
1000320-314.xls	Spreadsheet that contains through-wall residual stresses from Reference 6.
CG_SPRAY_DMW$.xls	Spreadsheet calculation of crack growth at the susceptible material regions for the circumferential and axial flaws at DMW1, Safe End and DMW2, where $ = 1, SE, and 2.

<u>ATTACHMENT 5</u>

Non-Proprietary Version

Calculation No. 1000320.310 and Calculation No. 1000320.314

Structural Integrity Associates, Inc.®

CALCULATION PACKAGE

File No.: 1000320.310

Project No.: 1000320

Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
TMI Pressurizer Spray Nozzle WOL

CONTRACT NO.:
59091

CLIENT:
Welding Services Inc. (WSI)

PLANT:
Three Mile Island Nuclear Generating Station, Unit 1

CALCULATION TITLE:
Pressurizer Spray Nozzle Weld Overlay Sizing Calculation

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 - 18	Initial Issue	R. L. Bax RLB 03/11/11	Nader Sadeghi N. Sadeghi NS 03/10/11 A. Alleshwaram AA 03/10/11

Table of Contents

List of Tables

List of Figures

1.0 INTRODUCTION

A weld overlay repair is being designed for the 4" nominal diameter pressurizer spray nozzle-to-safe end dissimilar metal weld (DMW1) and the safe end-to-elbow dissimilar metal weld (DMW2) at Three Mile Island Nuclear Generating Station, Unit 1 (TMI-1). This calculation documents the required structural sizing calculations for a full structural weld overlay (FSWOL) repair of these welds, based on plant-specific geometry and loadings, and the design requirements of ASME Code, Section XI, Code Cases N-504-3 [4] and N-638-1 [5] (Note: A relief request will be prepared to allow the use of these two Code Cases).

2.0 DESCRIPTION OF CONFIGURATION AND REPAIR PROCESS

The pressurizer spray nozzle is [redacted] the safe end is [redacted] and the attached spray line elbow is [redacted]

The FSWOL repair will be performed using primary water stress corrosion cracking (PWSCC) resistant Alloy 52M material deposited around the circumference of the configuration. The overlay material will be deposited using the machine gas tungsten arc welding (GTAW) process. For the Alloy 52M weld overlay filler metal, the selected material is SB-166, Rod & Bar [3], corresponding to Alloy 690 (58Ni-29Cr-9Fe).

3.0 ASME CODE CRITERIA

The applicable ASME Code of repair and replacement for TMI-1 is the 2004 Edition of ASME Code, Section XI [1] per Reference 6. The basis for FSWOL sizing is the ASME Code, Section XI, Code Case N-504-3 [4] and the ASME Code, Section XI, Division 1, Class 1 [1] rules for allowable flaw sizes in austenitic and ferritic piping (IWB-3640). The ASME Code, Section XI, Code Case N-504-3 [4], and the temper bead welding approach documented in Code Case N-638-1 [5], are used herein and are applied to dissimilar metal welds using nickel alloy filler, Alloy 52M. To determine the overlay thickness, Code Case N-504-3 refers to the requirements of ASME Code, Section XI, IWB-3640. IWB-3640 of the 2004 edition of the Code refers to Appendix C, which contains the specific methodology for meeting the allowable flaw sizes. The overlays are to be applied using the GTAW process, which is a non-flux process. Therefore, for circumferential flaws, the source equations in Reference 1, Appendix C, Section C-5320 (limit load criteria) are the controlling allowable flaw size equations for combined loading (membrane plus bending) and membrane-only loading. These equations are valid for flaw depth-to-thickness ratios for flaw lengths ranging from 0 to 100% of the circumference as defined in Reference 1, Section C-5320 of Appendix C. For purposes of designing the overlay, a circumferential flaw is assumed to be 100% through the original wall thickness for the entire circumference of the item being overlaid.

The overlay is sized by using the source equations in Section C-5320 [1].

The allowable bending stress under combined membrane plus bending loads is given by the equation:

$$S_c = \frac{\sigma_b^c}{SF_b} - \sigma_m \left[1 - \frac{1}{SF_m}\right]$$

Reference 1, C-5321,

where,

$$\sigma_b^c = \frac{2\sigma_f}{\pi}\left(2 - \frac{a}{t}\right)\sin\beta, \text{ for } (\theta + \beta) > \pi,$$

$$\beta = \frac{\pi}{2 - \frac{a}{t}}\left(1 - \frac{a}{t} - \frac{\sigma_m}{\sigma_f}\right).$$

The allowable membrane stress is given by the equation:

$$S_t = \frac{\sigma_m^c}{SF_m}$$

Reference 1, C-5322,

where,

$$\sigma_m^c = \sigma_f\left[1 - \left(\frac{a}{t}\right)\left(\frac{\theta}{\pi}\right) - \frac{2\varphi}{\pi}\right],$$

$$\varphi = \arcsin\left[0.5\left(\frac{a}{t}\right)\sin\theta\right],$$

and

S_c	=	allowable bending stress for a circumferentially flawed pipe
$\sigma^c{}_b$	=	bending stress at incipient plastic collapse
SF_m	=	safety factor for membrane stress based on Service Level as shown in Table 1 [1, C-2621]
SF_b	=	safety factor for bending stress based on Service Level as shown in Table 1 [1, C-2621]
a	=	flaw depth
t	=	total wall thickness (includes overlay thickness, in this case)
S_t	=	allowable membrane stress for a circumferentially flawed pipe
$\sigma^c{}_m$	=	membrane stress at incipient plastic collapse
θ	=	half flaw angle [1, Figure C-4310-1], 180° or π for a 100% full circumferential flaw
β	=	angle to neutral axis of flawed pipe in radians

σ_m = unintensified primary membrane stress at the flaw location
σ_f = flow stress = $(S_y + S_u)/2$ [1, C-8200(a)]
S_y = specified value for material yield strength taken at the evaluation (operating) temperature from Reference 3
S_u = specified value for material ultimate strength taken at the evaluation (operating) temperature from Reference 3

Safety factors are provided in Appendix C of Section XI for evaluation of flaws in austenitic stainless steel piping. The safety factors used for the weld overlay sizing are shown in Table 1 and are taken from C-2621 [1].

Table 1: Safety Factors for Sizing – Circumferential Flaw

Service Level	Membrane Stress Safety Factor, SF_m	Bending Stress Safety Factor, SF_b
A	2.7	2.3
B	2.4	2.0
C	1.8	1.6
D	1.3	1.4

The overlay thickness must be established so that the flaw assumption herein meets the allowable flaw depth-to-thickness ratio requirement of the source equations [1, C-5320], for the thickness of the weld-overlaid item, considering combined primary membrane-plus-bending stresses and membrane-only stresses, per the source equations defined previously. Since the weld overlay is an austenitic material and applied with a non-flux welding process, which has high fracture toughness, the limit load failure mode is applicable [1, Figure C-4210-1 for non-flux welds] and hence, limit load evaluation techniques are used here.

The non-overlaid piping stresses for use in the equations are usually obtained from the applicable stress reports for the items to be overlaid. However, in this calculation, they are calculated based on forces and moments at the welds using equations from C-2500 of Section XI, Appendix C as described below.

Primary membrane stress (σ_m) is given by:

$\sigma_m = pD/(4t)$, where:

p = operating pressure for the Service Level being considered
D = outside diameter of the component including the overlay
t = thickness, consistent with the location at which the outside diameter is taken including the overlay (note that the inside diameter (ID) cladding is not counted toward wall thickness)

Primary bending stress (σ_b) is given by:

$\sigma_b = DM_b/(2I)$, where:

D	=	outside diameter of the component including the overlay
d	=	inside diameter, consistent with the point at which the outside diameter is taken (note that the ID cladding is not counted in the inside diameter)
M_b	=	resultant moment for the appropriate primary load combination for each Service Level (square root of the sum of the squares (SRSS) of three moment components in X, Y, and Z directions)
I	=	moment of inertia, $(\pi/64)\,(D^4 - d^4)$

The contribution of axial and shear forces to piping stress (other than force couples contributing to moments) is not included based on C-2500 of Section XI, Appendix C [1].

The following load combinations are used for the full structural weld overlay. [redacted]

Service Level A (Normal):	Pressure (P) + Deadweight (DW)
Service Level B (Upset):	P + DW + Operational Basis Earthquake (OBE)
Service Level C (Emergency):	P + DW + Safe Shutdown Earthquake (SSE)
Service Level D (Faulted):	P + DW + SSE

Service Levels A, B, C, and D in the ASME Code [1] are alternatively referred as Normal, Upset, Emergency, and Faulted conditions, respectively, in this evaluation. Per ASME Code, Section XI C-5311 for the Combined Loading case, test conditions shall be included with the Service Level B Load Combination. However, the hydrostatic pressure test is not applicable to the weld overlay repair and is not included in the FSWOL design.

The weld overlay sizing is an iterative process, in which the allowable stresses are calculated and then compared to the stresses in the overlaid component. If the stresses in the component are larger than the allowable stresses in the component then the overlay thickness is increased, and the process is repeated until it converges to an overlay thickness which meets the allowable stresses.

The thickness of the weld overlay is determined through an iterative process. The thickness of the overlay (t_{ol}) is assumed resulting in a total thickness of ($t_p + t_{ol}$) where t_p is the original pipe thickness. The applied flaw size-to-thickness ratio based on a FSWOL (flawed through the original pipe wall thickness, t_p) is $t_p/(t_p + t_{ol})$. The allowable stresses are then determined from the source equations (see the beginning of Section 3.0). If this allowable stress value is greater than the calculated stress for the overlaid component, the overlay thickness (t_{ol}) is reduced. On the other hand, if the allowable stress value is less than the calculated stress for the overlaid component, the overlay thickness (t_{ol}) is increased. The process is repeated until the assumed overlay thickness results in a stress ratio of the calculated stress to the allowable stress that is equal or less than 1.0. As the maximum allowed value for a/t is 0.75 [1, C-5320], t_{ol} is initially set as $t_p/3$. If the overlay thickness of $t_p/3$ meets the allowable stresses for pure membrane and combined membrane plus bending stresses, then no more iterations are performed. If the allowable stresses are not met, then the overlay thickness is increased until the ratio of the computed stress to the allowable stress is less than or equal to 1.0.

In this process, the allowable stresses and adjusted stresses due to overlay thickness iterations are calculated for all applicable Service Levels (A, B, C, and D) and compared. The service level with the maximum ratio of the calculated stress to the allowable stress will control the overlay thickness.

The axial length and end slope of the FSWOL are sized to be sufficient to provide for load redistribution (considering both axial force due to pressure and bending loads) from the overlaid component to the weld overlay and back, such that applicable stress limits of the ASME Code, Section III, NB-3200 [2] are satisfied. Shear stress calculations are performed to assure that the weld overlay length meets these requirements.

4.0 LOADS AND DESIGN INPUTS

[redacted] In order to determine the loads at the nozzle-to-safe end weld, the forces and moments must be transformed such that the revised coordinate system is aligned with the nozzle axis. After the transformation performed in the spreadsheet TMI.xlsx, the loads are in a local coordinate system with local-y axial to the nozzle. See Table 2 for the transformed results.

Tables 2 and 3 do not include forces and moments due to thermal expansion of the piping attached to the nozzle. For designing FSWOLs, only primary loads are considered and the secondary loads, such as thermal expansion, need not be included in the design calculations. For the transformed result, all forces and moments are taken on an absolute basis. That is, in Table 2 (Post-Transformation), all forces and moments are taken as positive.

The loads shown in Table 2 are assumed to be applied at the safe end-to-elbow weld. These moments are adjusted for the nozzle-to-safe end weld to account for the eccentricity between the shear forces (transformed F_y and F_z) at the safe end-to-elbow weld and the nozzle-to-safe end weld centerlines. [redacted]

Structural Integrity Associates, Inc.

Table 2: Specified Forces and Moments at the Safe End-to-Elbow Weld Location

[redacted]

Table 3: Forces and Moments at Weld Locations

	Forces and Moments, Nozzle-to-Safe End Weld (DMW1)[1][2]							Forces and Moments, Safe End-to-Elbow Weld (DMW2)						
	Fx (lbs)	*Fy* (lbs)	*Fz* (lbs)	*Mx* (in-lbs)	*My* (in-lbs)	*Mz* (in-lbs)	*MRSS* (in-lbs)	*Fx* (lbs)	*Fy* (lbs)	*Fz* (lbs)	*Mx* (in-lbs)	*My* (in-lbs)	*Mz* (in-lbs)	*MRSS* (in-lbs)
DW	3	14	13	347	1222	803	----	3	14	13	252	1222	781	----
OBE	422	629	493	14628	20102	18888	----	422	629	493	10932	20102	15723	----
SSE	844	1257	986	29257	40203	37776	----	844	1257	986	21864	40203	31446	----
Service Level A (Normal)	3	14	13	347	1,222	803	**1,503**	3	14	13	252	1,222	781	**1,472**
Service Level B (Upset)	425	643	506	14,976	21,324	19,691	**32,661**	425	643	506	11,184	21,324	16,504	**29,192**
Service Level C (Emergency)	847	1,271	998	29,604	41,425	38,580	**63,881**	847	1,271	998	22,116	41,425	32,227	**56,954**
Service Level D (Faulted)	847	1,271	998	29,604	41,425	38,580	**63,881**	847	1,271	998	22,116	41,425	32,227	**56,954**

Notes: 1) The nozzle-to-safe end weld moments account for the eccentricity of 7.5" between the centerlines of DMW1 and DMW2.
2) Forces at the nozzle-to-safe end weld are assumed equivalent to the forces at the safe end-to-elbow weld.

5.0 WELD OVERLAY THICKNESS SIZING

The normal operating pressure [6], [redacted] and overlay thickness are shown in Table 4. At the nozzle side of the DMW1, Location 1B includes the thickness of the nozzle plus the thickness of the ID cladding, while Location 1A considers only the thickness of the nozzle (excluding the thickness of the ID cladding) (see Figure 1). An initial *a/t* value of 0.75 (the limiting value as stated in C-5322 of Appendix C of Section XI [1]) was the initial input to the iteration. The assumed 360° flaw results in a flaw length to circumference ratio of 1.0. Figure 1 shows the locations for FSWOL sizing.

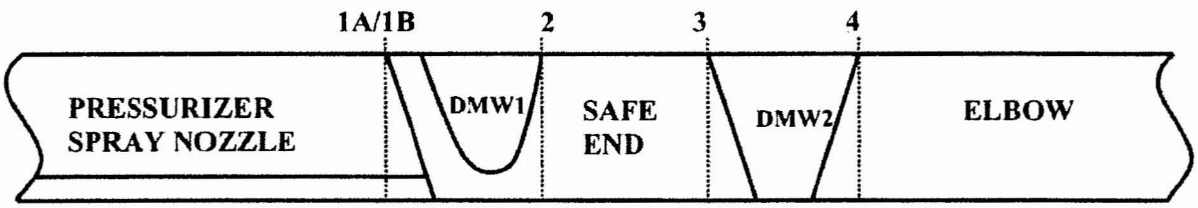


Figure 1: Locations Examined for FSWOL Sizing

Table 4: Dimensions for Overlay Sizing

	Location 1A	Location 1B	Location 2	Location 3	Location 4
	Nozzle Side of DMW1 w/o Clad	Nozzle Side of DMW1 w/ Clad	Safe End Side of DMW1	Safe End Side of DMW2	Elbow Side of DMW2
p, psig[5]	2155	2155	2155	2155	2155
[redacted]					
t_{base}, in	0.563	0.750	0.750	0.435	0.404
a/t	0.748	0.750	0.750	0.744	0.743
t_{ol}, in	**0.19**	**0.25**	**0.25**	**0.15**	**0.14**
$t_{base+ol}$, in	0.753	1.000	1.000	0.585	0.544
D_{ol}, in	5.505	5.625	5.625	4.863	4.780
$I_{base+ol}$, in^4	32.515	40.667	40.667	18.321	16.506

[redacted]

(5) Normal operating pressure of 2155 psig [6] is used.

The final calculated membrane stresses (σ_m) and bending stresses (σ_b) at each service level for the pipe + overlay configuration are shown in Table 5. This table also shows the ratio of the membrane stress (σ_m)

to the flow stress (σ_f) at the selected locations. The material properties are evaluated at the normal operating temperature of 650° F [6] using Section II, Part D of the ASME Code [3].

Table 5: Calculated Stresses

		Location 1A	Location 1B	Location 2	Location 3	Location 4
		Nozzle Side of DMW1 w/o Clad	Nozzle Side of DMW1 w/ Clad	Safe End Side of DMW1	Safe End Side of DMW2	Elbow Side of DMW2
Service Level	σ_m, psi	3941	3030	3030	4476	4734
	S_y, psi	27,500	27,500	27,500	27,500	27,500
	S_u, psi	80,000	80,000	80,000	80,000	80,000
	σ_f, psi	53,750	53,750	53,750	53,750	53,750
	σ_m/σ_f	0.0733	0.0564	0.0564	0.0833	0.0881
A	Normal σ_b, psi	127	104	104	195	213
B	Upset σ_b, psi	2765	2259	2259	3874	4227
C	Emergency σ_b, psi	5408	4418	4418	7558	8247
D	Faulted σ_b, psi	5408	4418	4418	7558	8247

Table 6 shows the allowable stresses as determined from the source equations discussed in Section 3.0. The membrane and bending stresses from Table 5 are compared to the allowable stresses as shown by the ratios in Table 6. The limiting cases for the membrane and bending stresses are shown in bold. In the limit load analyses, the flow stress of the Alloy 52M weld overlay material is used, consistent with the assumption of a full 360° flaw through the original pipe wall for the design of the full structural weld overlay.

Table 6: Allowable Stresses and Calculated Stress to Allowable Stress Ratios

Service Level		Location 1A	Location 1B	Location 2	Location 3	Location 4
		Nozzle Side of DMW1 w/o Clad	Nozzle Side of DMW1 w/ Clad	Safe End Side of DMW1	Safe End Side of DMW2	Elbow Side of DMW2
	β in radians	0.4494	0.4866	0.4866	0.4327	0.4230
	σ^c_b, psi	18619	20002	20002	18025	17660
Level A	Normal S_c, psi	5613	6789	6789	5019	4698
Level B	Upset S_c, psi	7010	8233	8233	6401	6069
Level C	Emergency S_c, psi	9885	11155	11155	9276	8934
Level D	Faulted S_c, psi	12389	13588	13588	11842	11522
Level A	Normal σ_b/S_c	0.0227	0.0153	0.0153	0.0389	0.0454
Level B	Upset σ_b/S_c	0.3944	0.2743	0.2743	0.6051	0.6965
Level C	Emergency σ_b/S_c	**0.5471**	**0.3961**	**0.3961**	**0.8148**	**0.9231**
Level D	Faulted σ_b/S_c	0.4365	0.3251	0.3251	0.6382	0.7158
	σ^c_m, psi	13571	13438	13438	13776	13833
Level A	Normal S_t, psi	5026	4977	4977	5102	5123
Level B	Upset S_t, psi	5655	5599	5599	5740	5764
Level C	Emergency S_t, psi	7540	7465	7465	7653	7685
Level D	Faulted S_t, psi	10440	10337	10337	10597	10641
Level A	Normal σ_m/S_t	**0.7841**	**0.6089**	**0.6089**	**0.8773**	**0.9240**
Level B	Upset σ_m/S_t	0.6970	0.5413	0.5413	0.7798	0.8213
Level C	Emergency σ_m/S_t	0.5227	0.4059	0.4059	0.5849	0.6160
Level D	Faulted σ_m/S_t	0.3775	0.2932	0.2932	0.4224	0.4449

Notes:
σ^c_b = Bending stress at incipient plastic collapse [1, C-5320]
S_c = Allowable bending stress [1, C-5320]
S_t = Allowable membrane stress [1, C-5320]
σ^c_m = Membrane stress at incipient plastic collapse [1, C-5320]
(All terms defined in Section 3.0)

6.0 WELD OVERLAY LENGTH REQUIREMENTS

The weld overlay length must consider three requirements: (1) length required for structural reinforcement, (2) length required for preservice examination access of the overlaid weld, and (3) limitation on the area of the nozzle surface that can be overlaid.

6.1 Structural Reinforcement

Structural reinforcement requirements are expected to be satisfied if the weld overlay length is $0.75\sqrt{Rt}$ on either side of the susceptible weld being overlaid [4], where R is outside radius of the item and t is the nominal thickness of the item at the applicable side of the overlay. However, to assure ASME Code, Section III, NB-3200 [2] compliance, detailed shear stress calculations are instead performed to determine the minimum required structural length.

The section along the length of the overlay is evaluated for axial shear due to transfer of axial load and moment from the overlaid item to the overlay. Subparagraph NB-3227.2 [2] limits pure shear due to Design Loadings, Test Loading or any Service Level loadings except Service Level D to $0.6S_m$. For Service Level D (Faulted) conditions, the stress intensity limit is the lesser of $2.4S_m$ and $0.7S_u$ [2, NB-3225 and Appendix F], equivalent to the lesser of $1.2S_m$ and $0.35S_u$ for shear stress, since stress intensity is equal to twice the shear stress. These values are shown in Table 7 for the spray nozzle, attached elbow, and weld overlay materials.

Shear stress around the circumference at the overlay-base material interface due to axial force and moment loading equals:

$$\tau = p \times \pi \times R_o^2/A_s + M/S_s,$$

where,

R_o	=	outside radius of overlaid item at crack
L	=	length of overlay at outside surface of overlaid item on one side of crack
A_s	=	shear area, $2\pi R_o L$
S_s	=	$\pi R_o^2 L$
p	=	pressure
M	=	resultant moment from piping interface loads at crack

Thus $\qquad \tau = p\pi R_o^2/(2\pi R_o L) + M/(\pi R_o^2 L)$

Solving for L and equating τ with the allowable shear stress (S_{allow}) yields:

$L = [pR_o/2 + M/(\pi R_o^2)]/S_{allow}$, where,

$S_{allow} = 0.6S_m$ (Service Levels A, B, and C)

S_{allow} = Lesser of $1.2S_m$ and $0.35S_u$ (Service Level D)

The evaluation for required length is documented in Table 7 for the pressurizer spray nozzle and elbow. The overlay weld metal is also evaluated as it may control if the base metal has a higher value of S_m *or* S_u. The greater value of the required overlay length will be taken. The material properties are evaluated at the normal operating temperature of 650°F [6] using Section II, Part D of the ASME Code [3].

Since the overlay ends on the pressurizer spray nozzle at one end and the elbow at the other end, and extends over the safe end, the surface shear transfer into the base metal occurs onto the nozzle and elbow only. In this configuration, the requirements for shear lengths at intermediate locations (safe end) are not relevant and would have no influence on the required overlay. Therefore, they are not included herein.

The required overlay length is calculated at Locations 1 and 4 along the nozzle and elbow configuration (both sides of the DMW1 and DMW2). The evaluation results are presented in Table 7. The design drawing implements a configuration that meets all the designed FSWOL thickness and length requirements. The lengths shown in Table 7 ensure adequate shear stress transfer along the length of the weld overlay. Service Level C is the most limiting of all cases. This length is sufficient to transfer the imposed loads and maintain stresses (shear) within the appropriate ASME Code allowable limits [2].

Table 7: Minimum Required Overlay Length

	Location 1A/1B	Location 1A/1B	Location 4	Location 4
	Nozzle Side of DMW1	Nozzle Side of DMW1	Elbow Side of DMW2	Elbow Side of DMW2
R_o, in	2.563	2.563	2.25	2.25
Material	Alloy 52M	SA-508 Class 1	Alloy 52M	SA-403 WP316
S_m, ksi	23.30	17.80	23.30	16.60
Service Level A $0.6S_m$, ksi	13.980	10.680	13.980	9.960
Service Level B $0.6S_m$, ksi	13.980	10.680	13.980	9.960
Service Level C $0.6S_m$, ksi	13.980	10.680	13.980	9.960
Service Level D $1.2S_m$, ksi	27.960	21.360	27.960	19.920
S_u, ksi	80.00	70.00	80.00	71.80
Service Level D $0.35S_u$, ksi	28.000	24.500	28.000	25.130
Service Level A L, in	0.2027	0.2654	0.1800	0.2527
Service Level B L, in	0.3108	0.4068	0.3047	0.4277
Service Level C L, in	**0.4190**	**0.5485**	**0.4296**	**0.6030**
Service Level D L, in	0.2095	0.2742	0.2148	0.3015

6.2 Preservice Examination

Weld overlay access for preservice examination requires that the overlay length and profile be such that the overlaid weld and any adjacent welds can be inspected using the required NDE techniques. This requirement could cause the overlay length to be longer than required for structural reinforcement. The specific overlay length required for preservice examination is determined based on the examination techniques and proximity of adjacent welds to be inspected.

6.3 Area Limitation on Nozzle

The total weld overlay surface area is limited to 500 in^2 (this value will be specified in the relief request) on the nozzle (carbon steel base material) when using ambient temperature temper bead welding to apply the overlay. Using an outside diameter of 5.125", the maximum length is limited to $500/(\pi D_o) = 31.0$" on the carbon steel nozzle material. The required overlay length on the nozzle will be less than this limit (see Table 7).

6.4 Maximum Overlay Sizing

This calculation documents the minimum overlay thickness and length necessary for structural requirements. Additional thickness and length may be added to address inspectability and crack growth concerns. In addition, a maximum overlay thickness (typically an additional 0.25") and a maximum overlay length will be determined. The determination of the maximum length is based on implementation factors and is intended to be large enough so as to not unnecessarily constrain the overlay process. These dimensions will be indicated on a subsequent design drawing to create a "box" within which the overlay is analyzed. In the subsequent analyses, the finite element models use the geometry (minimum or maximum) that will produce conservative results.

7.0 DISCUSSIONS AND CONCLUSIONS

Table 8 and Figure 2 summarize the minimum required overlay dimensions. This calculation documents the development of a weld overlay design for the 4" nominal diameter pressurizer spray nozzle-to-safe end dissimilar metal weld and the safe end-to-elbow dissimilar metal weld at TMI-1. The design meets the requirements of the ASME Code, Section XI, Code Case N-504-3 [4] and ASME Code, Section XI, Appendix C [1] for a full structural weld overlay.

The weld overlay sizing presented in Table 8 is based upon the primary loadings documented in Section 4.0 and using the criteria from the ASME Code, Section XI, Appendix C. The overlay thicknesses and lengths listed in Table 8 meet ASME Code stress criteria.

Table 8: Minimum Required Overlay Dimensions

	Location	Thickness, in.	Length, in.
Nozzle Side of DMW1	1A/1B	0.19/0.25	0.55
Safe End Side of DMW1	2	0.25	NA
Safe End Side of DMW2	3	0.15	NA
Elbow Side of DMW2	4	0.14	0.61

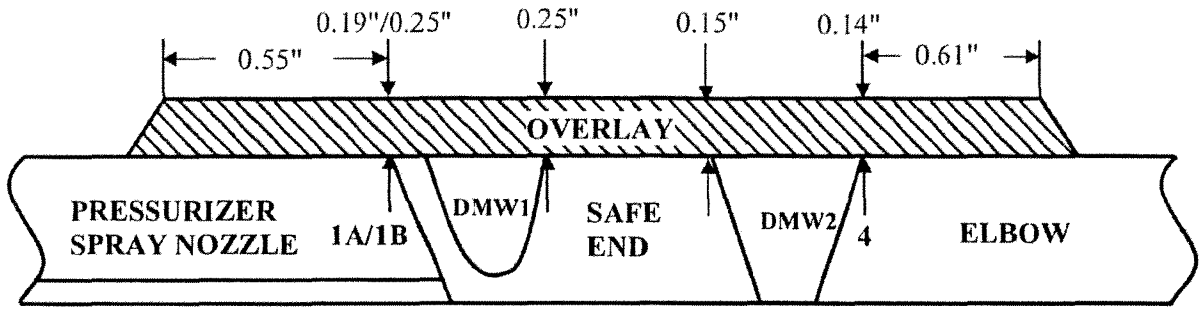


Figure 2: Full Structural Weld Overlay Geometry, Minimum Dimensions (Schematic Representation)

8.0 REFERENCES

1. ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 2004 Edition.
2. ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Facility Components, 2004 Edition.
3. ASME Boiler and Pressure Vessel Code, Section II, Part D, Material Properties, 2004 Edition.
4. ASME Boiler and Pressure Vessel Code, Code Case N-504-3, "Alternative Rules for Repair of Classes 1, 2, and 3 Austenitic Stainless Steel Piping, Section XI, Division 1."
5. ASME Boiler and Pressure Vessel Code, Code Case N-638-1, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique, Section XI, Division 1."
6. Email from William McSorley (Exelon) to Norman Eng (SI), dated March 02, 2011, Subject: "Status of Pzr Spray SWOL Analysis," includes attached file "GDeBoo Review of 310, 314, 315 & 316.doc", SI File No. 1000320.212.

[redacted]

[redacted]

15. Crane Company, Technical Paper No. 410, "Flow of Fluids through Valves, Fittings, and Pipe," 1976.

16. GPU Nuclear Drawing No. ID-212-23-028, Sheet 2 of 6, Rev. 1, "LPSI/Decay Heat Removal, Piping Analysis," SI File No. 1000320.204.

Structural Integrity Associates, Inc.® CALCULATION PACKAGE	File No.: 1000320.314
	Project No.: 1000320 Quality Program: ☒ Nuclear ☐ Commercial

PROJECT NAME:
TMI-1 Pressurizer Spray Nozzle WOL

CONTRACT NO.:
59091

CLIENT:	**PLANT:**
Welding Services Inc. (WSI)	Three Mile Island Nuclear Generating Station, Unit 1

CALCULATION TITLE:
Residual Stress Analysis of Pressurizer Spray Nozzle with Weld Overlay Repair

Document Revision	Affected Pages	Revision Description	Project Manager Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1 – 32 Computer Files	Initial Issue	G. Mukhim GSM 03/17/11	Aparna Alleshwaram AA 03/17/11 Craig Jenson CEJ 03/17/11

Table of Contents

List of Tables

List of Figures

1.0 OBJECTIVE

The objective of this evaluation is to perform a weld residual stress analysis using the ANSYS finite element software [1] on the pressurizer spray nozzle due to a weld overlay (WOL) repair for Three Mile Island Nuclear Generating Station, Unit 1 (TMI-1). The WOL is applied on the spray nozzle-to-safe end dissimilar metal weld (DMW) and safe end-to-attached pipe dissimilar metal weld (DMW). This analysis includes simulating weld repairs at the inner diameter (ID) surface for postulated flaws within the nozzle-to-safe end weld and the safe end-to-attached pipe weld. The ID weld repairs are simulated to provide an unfavorable stress condition (prior to applying the weld overlay) due to the original fabrication of these welds, which are used as the initial condition for the WOL evaluation.

The results will be evaluated to demonstrate that the weld overlay repair has indeed generated a favorable stress condition for the pressurizer spray nozzle, safe end, and the local attached spray pipe by inducing a compressive stress condition on the ID surface. The favorable stress condition minimizes and/or arrests crack initiation/propagation caused by Primary Water Stress Corrosion Cracking (PWSCC) in the susceptible DMW material.

Furthermore, the as-modeled weld overlay repair corresponds to the minimum design dimensions of the pressurizer spray nozzle overlay [2], and thus is considered to bound the case for an as-built weld overlay (typically longer and thicker upon installation).

2.0 DESIGN INPUTS

2.1 Finite Element Model

The finite element model (FEM) of the pressurizer spray nozzle, including material properties, is obtained from Reference 3 (input file *TMI-SPRAY-RES_64bit.INP*). The FEM is modeled as an axisymmetric model even though the elbow is present after the safe end-to-pipe weld. This is because the results from the residual analyses are extracted through the nozzle-to-safe end weld and safe end-to-pipe weld, which are sufficiently far away from the elbow. Two ID weld repairs, nozzle-to-safe end weld repair (ID repair1) and the safe end-to-attached pipe weld repair (ID repair2) are simulated in this analysis to show that the weld overlay repair overcomes the tensile stresses generated by these postulated ID repairs.

Figure 1 shows the applied structural boundary conditions on the axisymmetric finite element model, while Figure 2 identifies the different components of the pressurizer spray nozzle. The weld overlay nugget layout used for the residual stress evaluation is shown in Figure 3. [redacted]

Axisymmetric PLANE55 elements are used in the thermal analysis, while axisymmetric PLANE182 elements are used in the stress analysis. The weld bead depositions are simulated using the element "birth and death" feature in ANSYS.

The element "birth and death" feature in ANSYS allows for the deactivation (death) and reactivation (birth) of the elements' stiffness contribution when necessary. It is used such that elements that have no contribution to a particular phase of the weld simulation process are deactivated (via EKILL command) because they have not been deposited. The deactivated elements have near-zero conductivity and stiffness contribution to the structure. When those elements are required in a later welding phase, they are then reactivated (via EALIVE command).

The analyses consist of a thermal pass to determine the temperature distribution due to the welding process, and an elastic-plastic stress pass to calculate the residual stresses through the thermal history induced by each weld pass. Appropriate weld heat efficiency, along with sufficient cooling time, are utilized in the thermal pass to ensure that the temperature between weld layer nuggets meets the required interpass temperature as well as obtain acceptable overall temperature distribution within the FEM (i.e., peak temperature, sufficient resolution of results, etc.).

2.2 Material Properties

The materials of the various components of the model are listed below per Table 1 of Reference 3.

- Pressurizer Hemispherical Head: SA-516 Grade 70
- Pressurizer Hemispherical Head and Nozzle Cladding: SA-240 TP304
- Pressurizer Spray Nozzle: SA-508 Class 1
- Nozzle-to-Safe End Weld: Alloy 82/182
- Safe End: SB-166 (Taken as Alloy 600)
- Safe End-to-attached Pipe Weld: Alloy 82/182
- Spray Piping: SA-403 WP316 (Elbow)
- Buffer Layer: ER-308L
- Weld Overlay: Alloy 52M
- Nozzle-to-Safe End Weld ID Repair: Alloy 82/182
- Safe End-to- attached Pipe Weld ID Repair: Alloy 82/182

The temperature dependent nonlinear material property values are obtained from Reference 3 (input file *MProp_MISO_NLinear_TMI.INP*). This analysis applies the multilinear isotropic hardening material behavior available within the ANSYS finite element program.

3.0 ASSUMPTIONS

The following assumptions are used in the residual stress evaluation:

1. Assumptions in Reference 3 are applicable in this calculation.
2. The nozzle-to-safe end weld is not included in the residual stress determination as the resulting stress state will be conservatively assumed to be zero, as studies have shown [12] that the as-welded (butt weld) stress state is typically compressive at the ID surface. Imposing the residual effect of the ID repair on a zero stress state is conservative, as this increases the tensile stresses at the ID. Reference 12 documents that even with the significant compressive stresses of the as-welded butt weld, the residual stress state of the final ID weld repair is adverse, with significant axial and hoop tensile stresses. The same assumption holds true for the safe end-to-attached pipe weld.
3. A convection heat transfer coefficient of 5.0 Btu/hr-ft^2-°F at 70°F bulk ambient temperature is applied to simulate an air environment at the inside surface during the application of both the ID weld repairs.
4. The outside surfaces have a heat transfer coefficient of 5.0 Btu/hr-ft^2-°F at 70°F bulk ambient temperature during the application of the ID weld repairs to simulate an air environment.
5. During the weld overlay process (for the buffer (stainless steel) layer), the applied heat transfer boundary condition of 5.0 Btu/hr-ft^2-°F at 70°F bulk ambient temperature was used on the inside surface to simulate an air environment.
6. It is assumed that during the weld overlay process, for the transition from the buffer layer (stainless steel) to the weld overlay (Alloy 52M), the buffer layer cools down to the ambient temperature of 70°F.
7. During the weld overlay process (for the weld overlay (Alloy 52M) material), the applied heat transfer boundary condition of 5.0 Btu/hr-ft^2-°F at 70°F bulk ambient temperature was used on the inside surface to simulate an air environment.
8. The outside surfaces have a heat transfer coefficient of 5.0 Btu/hr-ft^2-°F at 70°F bulk ambient temperature during the WOL process (for both the buffer layer (stainless steel) and weld overlay (Alloy 52M) layers) to simulate an air environment.
9. A maximum interpass temperature of 350°F between the depositions of weld nuggets is assumed for all welding processes [5].
10. Additional assumptions including details on the heat source and heat efficiency values can be obtained from Reference 6.
11. For the boundary conditions, symmetry is applied at the free end of the vessel, and the nodes at the free end of the modeled pipe are coupled in the axial direction to simulate the attached piping.

4.0 METHODOLOGY

The residual stresses due to welding are controlled by various welding parameters, thermal transients due to application of the welding process, temperature dependent material properties, and elastic-plastic stress reversals. The analytical technique uses finite element analysis to simulate the multi-pass ID weld repairs, and weld overlay processes.

A residual stress evaluation process was previously developed in an internal Structural Integrity Associates (SI) project. Details of the process and its comparison to actual test data are provided in Reference 6. The same process is used herein. The finite element model of the pressurizer spray nozzle was developed in Reference 3. This model consists of a local portion of the pressurizer top head, pressurizer top head and nozzle cladding, the pressurizer spray nozzle, the nozzle-to-safe end weld, a postulated ID weld repair for the nozzle-to-safe end weld, the safe end, the safe end-to-attached pipe weld, a postulated ID weld repair for the safe end-to-attached pipe weld, a local portion of the spray attached piping, and the weld overlay repair (including the buffer layer). The as-modeled weld overlay repair meets minimum structural requirements as well as nondestructive examination (NDE) requirements [13].

4.1 Weld Bead Simulation

In order to reduce computational time, but yet obtain a valid solution, individual weld beads or passes can be lumped together into weld nuggets. This methodology is based on the approach presented in References 7, 8, 9 and 10.

The number of equivalent bead passes is estimated by dividing each nugget area by the area of an individual bead. The resulting number of equivalent bead passes per nugget is used as a multiplier to the heat generation rate. The welding direction is taken to be from the nozzle to the attached pipe. A summary of nuggets for the welds are as follows (see Figure 3):

- The ID weld repair for the nozzle-to-safe end weld is performed in three layers, with one nugget for each layer. A total of three nuggets are defined for this ID weld repair.
- The ID weld repair for the safe end-to-attached pipe weld is performed in two layers, with one nugget for each layer. A total of two nuggets are defined for this ID weld repair
- The weld overlay is performed in six layers. A total of one hundred thirty three nuggets are defined for the weld overlay:
    - Layer one is comprised of nineteen nuggets (including six nuggets for the buffer layer)
    - Layer two is comprised of eighteen nuggets
    - Layer three is comprised of nineteen nuggets
    - Layer four is comprised of thirty nuggets
    - Layer five is comprised of twenty seven nuggets
    - Layer six is comprised of twenty six nuggets

4.2 Welding Simulation

The ID repair1 is applied first. The safe end and the attached pipe are in place when the repair is applied, however the ID repair2 elements are deactivated. After the ID repair1 is completed, the model is cooled down to a uniform ambient temperature of 70°F. The ID repair2 simulation is then applied. After the ID repair2 is completed, the model is again cooled to a uniform ambient temperature of 70°F. This is followed by the application of the buffer layer, cooling it to an ambient temperature of 70°F, and finally followed by the weld overlay simulation. After the weld overlay is completed, the model is cooled to a uniform ambient temperature of 70°F to obtain residual stresses at room temperature. Then it is heated to a uniform operating temperature of 650°F [14], and an operating pressure of 2155 psig [11] to obtain the combined residual stresses at operating temperature and pressure.

4.2.1 Internal Pressure Loading

The operating pressure of 2155 psig is applied to the interior surfaces of the model. An end-cap load is applied to the free end of the attached piping in the form of tensile axial pressure, and the value is calculated below. See Figure 4 for the applied pressure loading. Symmetric boundary conditions are applied at the circumferential free end of the pressurizer top head, and the nodes at the free end of the attached piping are coupled in the axial direction as shown in Figure 1, to simulate continuity.

$$P_{\text{end-cap}} = \frac{P \cdot r_{inside}^{2}}{\left(r_{outside}^{2} - r_{inside}^{2}\right)} = \frac{2155 \cdot 1.8007^{2}}{\left(2.2437^{2} - 1.8007^{2}\right)} = 3900 \text{ psig}$$

where,

$P_{\text{end-cap}}$	=	End cap pressure on attached pipe (psig)
P	=	Internal pressure (psig)
r_{inside}	=	Inside radius of attached pipe (in) [3, as modeled]
$r_{outside}$	=	Outside radius of attached pipe (in) [3, as modeled]

The ANSYS input and output files for the analysis are listed in Table 1.

5.0 WELDMENT TEMPERATURE GUIDELINE

The analytical procedure described in Section 4.0 has provided reasonable results as seen in previous similar analyses [6] when compared to results from test data. This can be demonstrated by observing the fusion boundary prediction of the welds. Figures 5 through 8 show the predicted fusion boundaries for all the welding processes as generated by ANSYS for this specific overlay. The fusion boundaries represent the predicted maximum temperature contour mapping that the weld nugget elements will reach during each welding process. Note that the figures are composites showing the maximum temperature among all nuggets of each weld. This is made possible by an ANSYS macro (MapTemp.MAC) that reads in the maximum predicted temperatures across the different weld nugget elements during the welding process, and displays them as a temperature contour plot.

The figures show that all weld elements have reached temperatures between 2,674°F and 3,000°F. It also shows that the heat penetration depth, where temperatures are above 1,300°F, is similar in size to the heat affected zone (HAZ) of between 1/8" and 1/4".

6.0 RESULTS OF ANALYSIS

Figures 9 and 10 depict the axial and hoop residual stress distribution for the post ID weld repair of the nozzle-to-safe end weld condition at 70°F, respectively. The axial direction and the hoop direction are with respect to the global coordinate system of the finite element model. The axial stress is SY and the hoop stress is SZ. It is shown that extensive tensile axial and hoop residual stresses occur along the inside surface of the nozzle in the vicinity of the nozzle-to-safe end ID weld repair.

Figures 11 and 12 depict the axial and hoop residual stress distribution for the post ID weld repair of the safe end-to-attached pipe weld condition at 70°F, respectively. Figures 13 and 14 depict the axial and hoop residual stress distribution for the post WOL condition at 70°F, respectively. Figures 15 and 16 depict the resultant residual plus operating condition stress distributions for the post WOL configuration at the operating temperature of 650°F and operating pressure of 2155 psig in the axial and hoop directions, respectively.

Figures 17 and 18 are ID surface stress plots for the axial and hoop directions as a function of distance from the ID weld repair centerline, respectively. The results are plotted for post ID weld repair of nozzle-to-safe end weld, post ID weld repair of safe end-to-attached pipe weld, post WOL at 70°F, and post WOL at 650°F and 2155 psig.

Furthermore, Figures 17 and 18 show that post weld overlay compressive stresses for both the 70°F and operating conditions (650°F/2155 psig) are largely present at the ID surfaces of the susceptible material. This would indicate that at any intermediate steady state operating condition (i.e., temperature and pressure) the residual stresses would remain compressive. Any additive loads (i.e., thermal transients) are short term in nature and are not relevant to PWSCC concerns. The results suggest that the weld overlay has indeed mitigated the susceptible material against PWSCC.

In addition, through-wall axial and hoop stress results are extracted for various paths defined in Figure 19. Three stress paths are defined through the DMW of nozzle-to-safe end and three paths are defined through the DMW of safe end-to-attached pipe. The stress path results are shown in Figures 20 and 21. The results will be used for a subsequent crack growth evaluation in a separate calculation package. Two sets of data are extracted, which are for post WOL at 70°F and for post WOL at 650°F/2155 psig.

The post-processing outputs are listed in Table 1. They are further processed in Excel spreadsheet *1000320-314.xls*.

7.0 REFERENCES

1. ANSYS Mechanical and PrepPost, Release 11.0 (w/Service Pack 1), ANSYS, Inc., August 2007.

2. SI Drawing No. 1000320.510 "Pressurizer Spray Nozzle Full Structural (FSWOL) Weld Overlay Design Drawing," (for revision number refer to SI Project Revision Log, latest revision).

3. SI Calculation No. 1000320.312, "Material Properties and Finite Element Models for Pressurizer Spray Nozzle with Weld Overlay Repair," (for revision number refer to SI Project Revision Log, latest revision).

[redacted]

5. ASME Boiler and Pressure Vessel Code, Code Case N-740-2, "Full Structural Dissimilar Metal Weld Overlay for Repair or Mitigation of Class 1, 2 and 3 Items," Section XI, Division 1.

6. SI Calculation No. 0800777.304, Rev. 1, "Residual Stress Methodology Development and Benchmarking of a Small Diameter Pipe Weld Overlay, Using MISO Properties."

7. Dong, P., "Residual Stress Analyses of a Multi-Pass Girth Weld: 3-D Special Shell Versus Axisymmetric Models," Journal of Pressure Vessel Technology, Vol. 123, May 2001.

8. Rybicki, E. F., et al., "Residual Stresses at Girth-Butt Welds in Pipes and Pressure Vessels," U.S. Nuclear Regulatory Commission Report NUREG-0376, R5, November 1977.

9. Rybicki, E. F., and Stonesifer, R. B., "Computation of Residual Stresses due to Multipass Welds in Piping Systems," Journal of Pressure Vessel Technology, Vol. 101, May 1979.

10. *Materials Reliability Program: Technical Basis for Preemptive Weld Overlays for Alloy 82/182 Butt Welds in PWRs (MRP-169), Revision 1,* EPRI, Palo Alto, CA: 2008. 1016602.

11. E-mail attachment, Document 5971-2010-015, Rev. 0, "Design Input for TMI-1 Pressurizer Spray Nozzle SWOL," from Bill McSorley (Exelon) to Norman Eng (SI), "Three Mile Island Transmittal of Design Information," September 17, 2010, SI File No. 1000320.210.

12. *Materials Reliability Program: Welding Residual and Operating Stresses in PWR Alloy 182 Butt Welds (MRP-106),* EPRI, Palo Alto, CA: 2004. 1009378.

13. SI Calculation No. 1000320.310, "Pressurizer Spray Nozzle Weld Overlay Sizing Calculation," (for revision number refer to SI Project Revision Log, latest revision).

14. Email from William McSorley (Exelon) to Norman Eng (SI), dated March 02, 2011, Subject: "RE: Status of Pzr Spray SWOL Analysis," SI File No. 1000320.212.

Table 1: ANSYS Input and Output Files

Input File	Description/Comment
TMI-SPRAY-RES_64bit.INP	Structural geometry for 2D axisymmetric geometry [3]
MProp_MISO_NLinear_TMI.INP	Material Property data of E, alpha, conductivity, specific heat, and stress strain curves [3]
BCNUGGET2D.INP	Weld nuggets definition and boundary conditions file
PICK2D.INP	Writes boundary conditions and nugget definitions into BCNUGGET2D.INP file
THERMAL2D.INP	Thermal pass for simulating weld processes
STRESS2D.INP	Stress pass for simulating weld processes
WELD1_mntr.INP	Contains LDREAD commands for ID Repair1 portion of the stress pass
WELD2_mntr.INP	Contains LDREAD commands for ID Repair2 portion of the stress pass
WELD3_mntr.INP	Contains LDREAD commands for buffer layer portion of the stress pass
WELD4_mntr.INP	Contains LDREAD commands for weld overlay portion of the stress pass
POST_PATH.INP	Post processing file to extract path stresses
POST_ID.INP	Post processing file to extract ID surface stresses
Output File	**Description/Comment**
PATH_T70.OUT	Path stress outputs for post WOL at 70°F
PATH_T650_P2155.OUT	Path stress outputs for post WOL at 650°F and 2155 psig
ID_NLIST.OUT	ID surface nodal coordinate outputs
ID_WELD1.OUT	ID surface stress outputs for post ID Repair1 at 70°F
ID_WELD2.OUT	ID surface stress outputs for post ID Repair2 at 70°F
ID_T70.OUT	ID surface stress outputs for post WOL at 70°F
ID_T650_P2155.OUT	ID surface stress outputs for post WOL at 650°F and 2155 psig
1000320-314.xls	Excel spreadsheet containing all output data

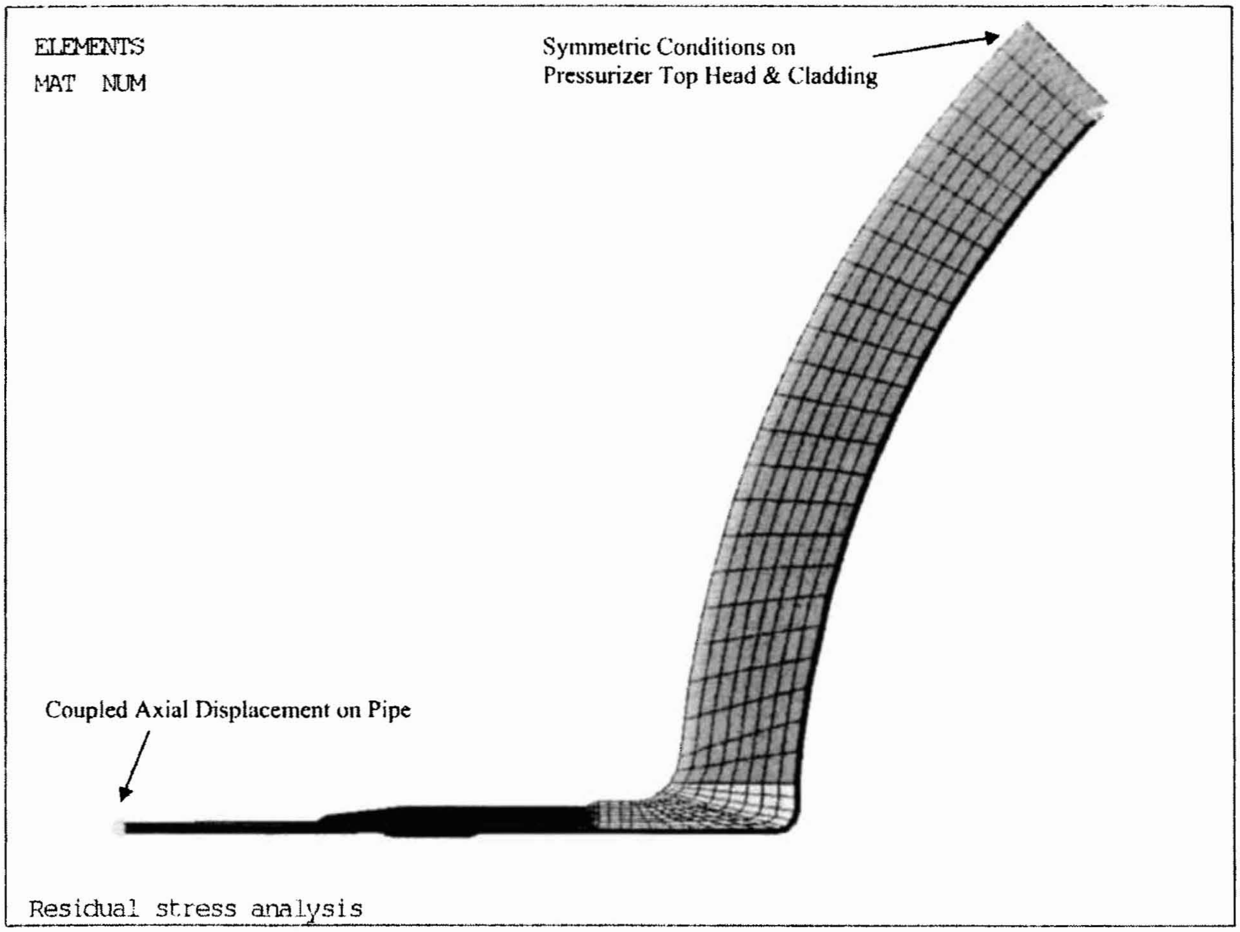


Figure 1: Applied Structural Boundary Conditions to the Pressurizer Spray Nozzle Finite Element Model

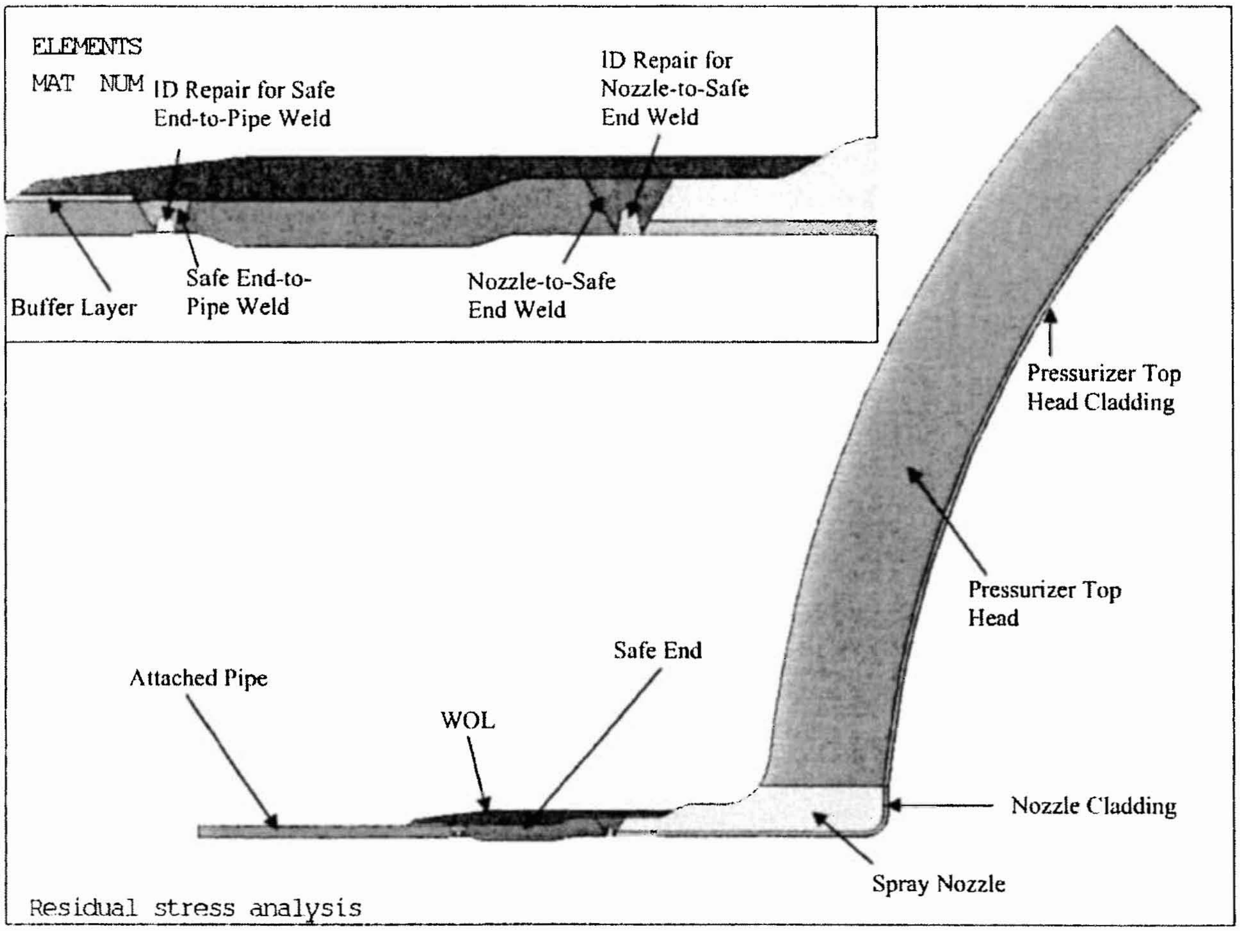


Figure 2: As-Modeled Components for the Pressurizer Spray Nozzle

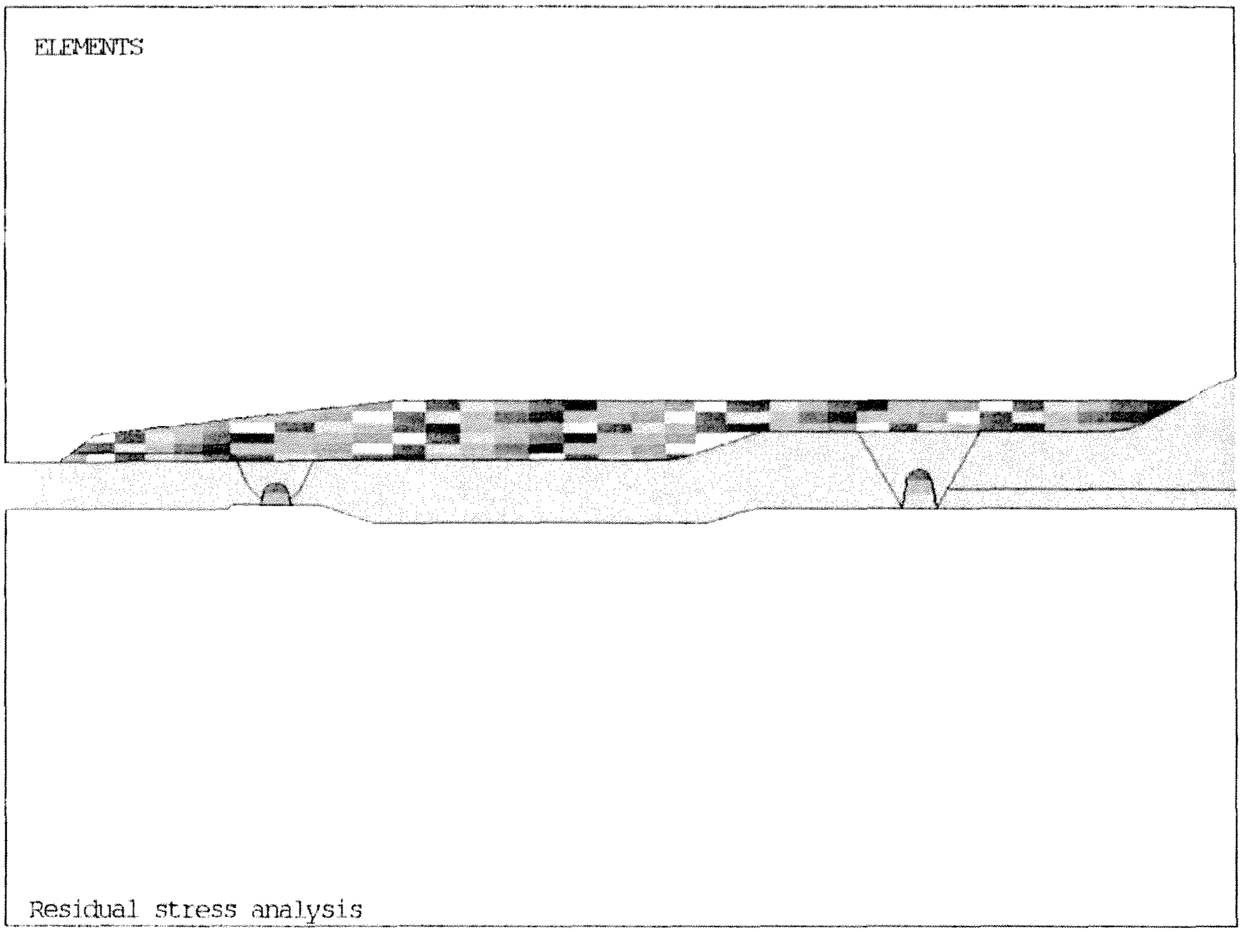


Figure 3: As-Modeled Nuggets for ID Repair1 (3), ID Repair2 (2) and WOL (133)

(Numbers in parenthesis indicate the number of nuggets used for the corresponding simulation)

(In all instances, ID Repair1 corresponds to the nozzle-to-safe end weld and ID Repair2 corresponds to the safe end-to-pipe weld)

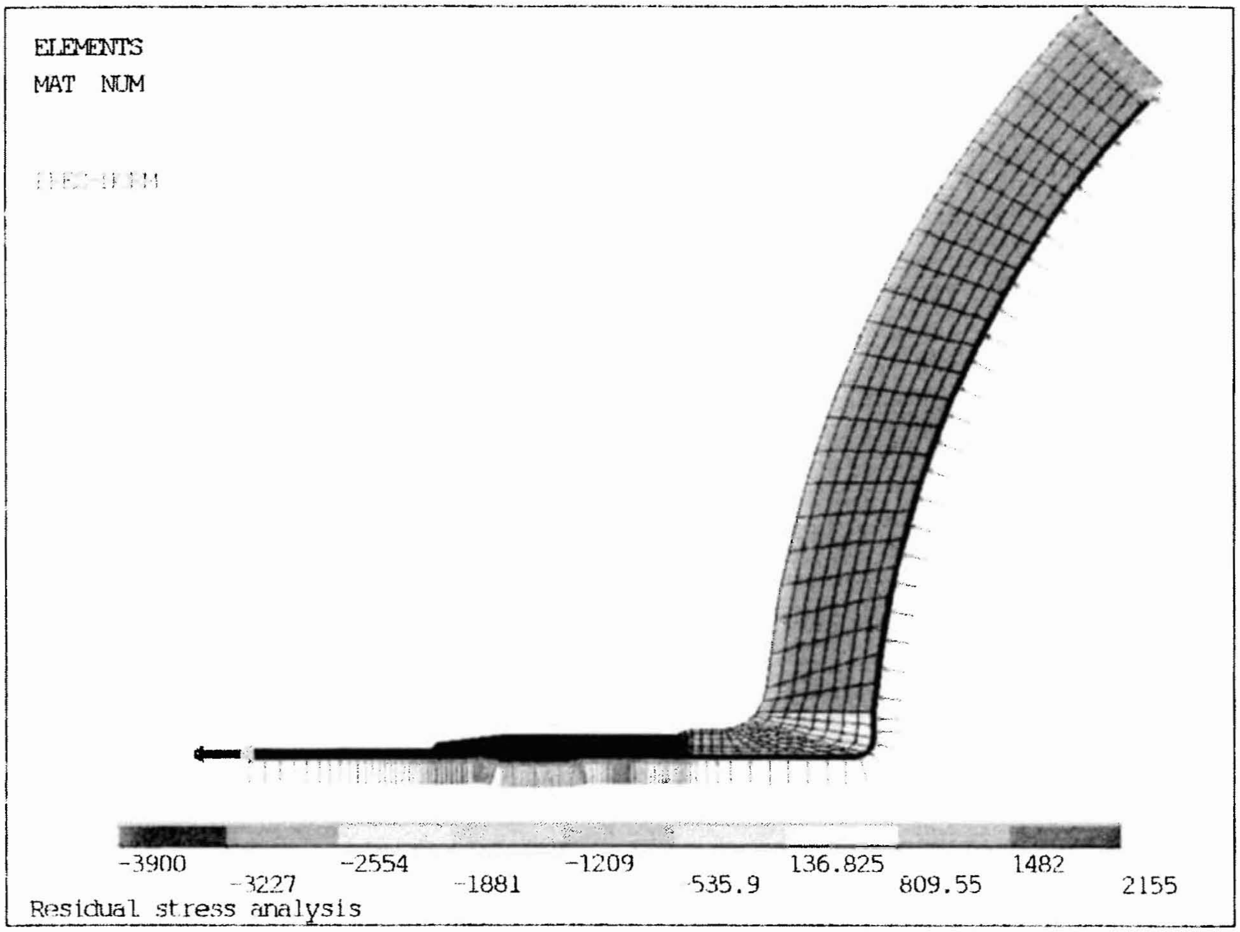


Figure 4: Internal Pressure Loading
(Units are in terms of psi)

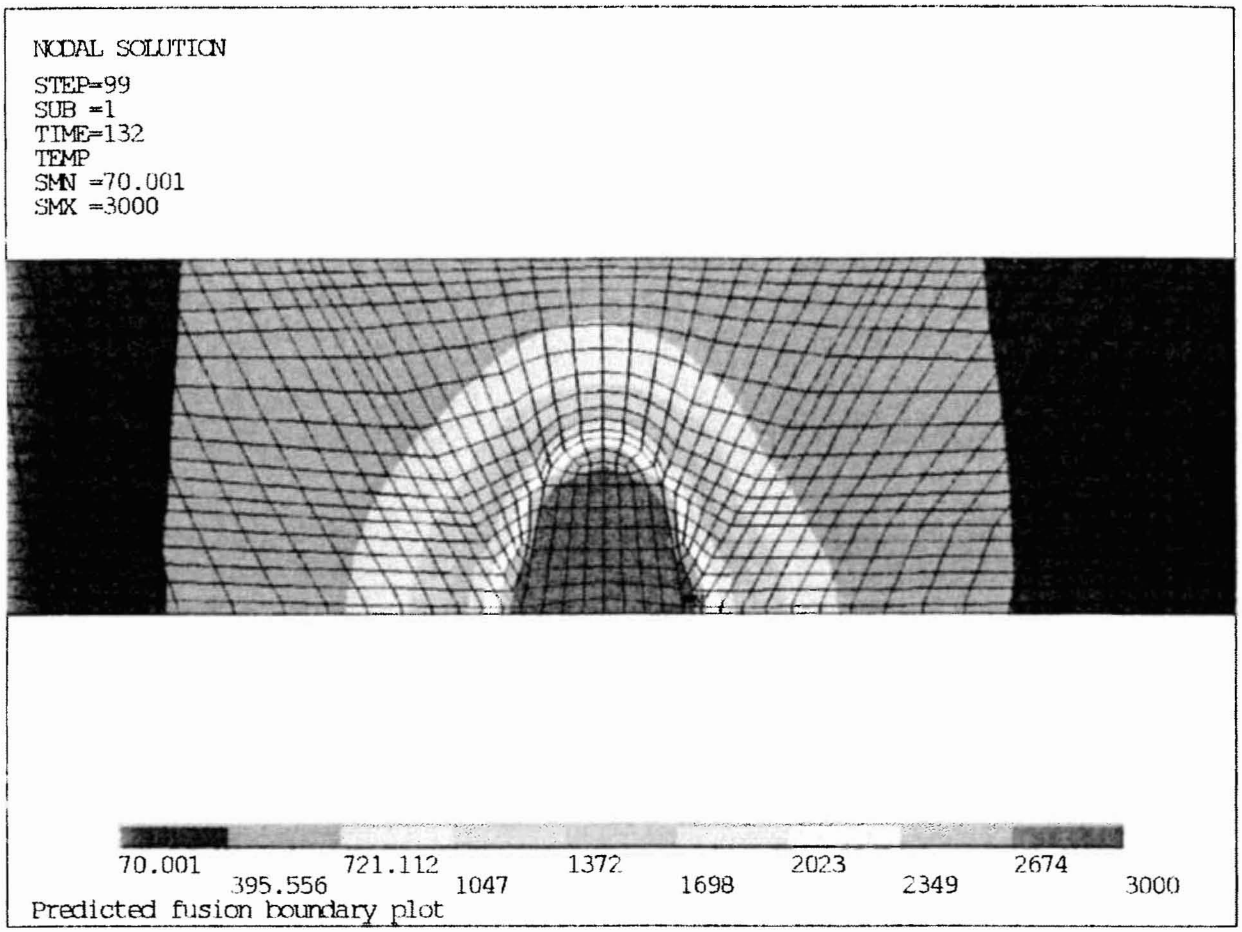


Figure 5: Predicted Fusion Boundary for ID Repair1
(Units are in terms of °F)

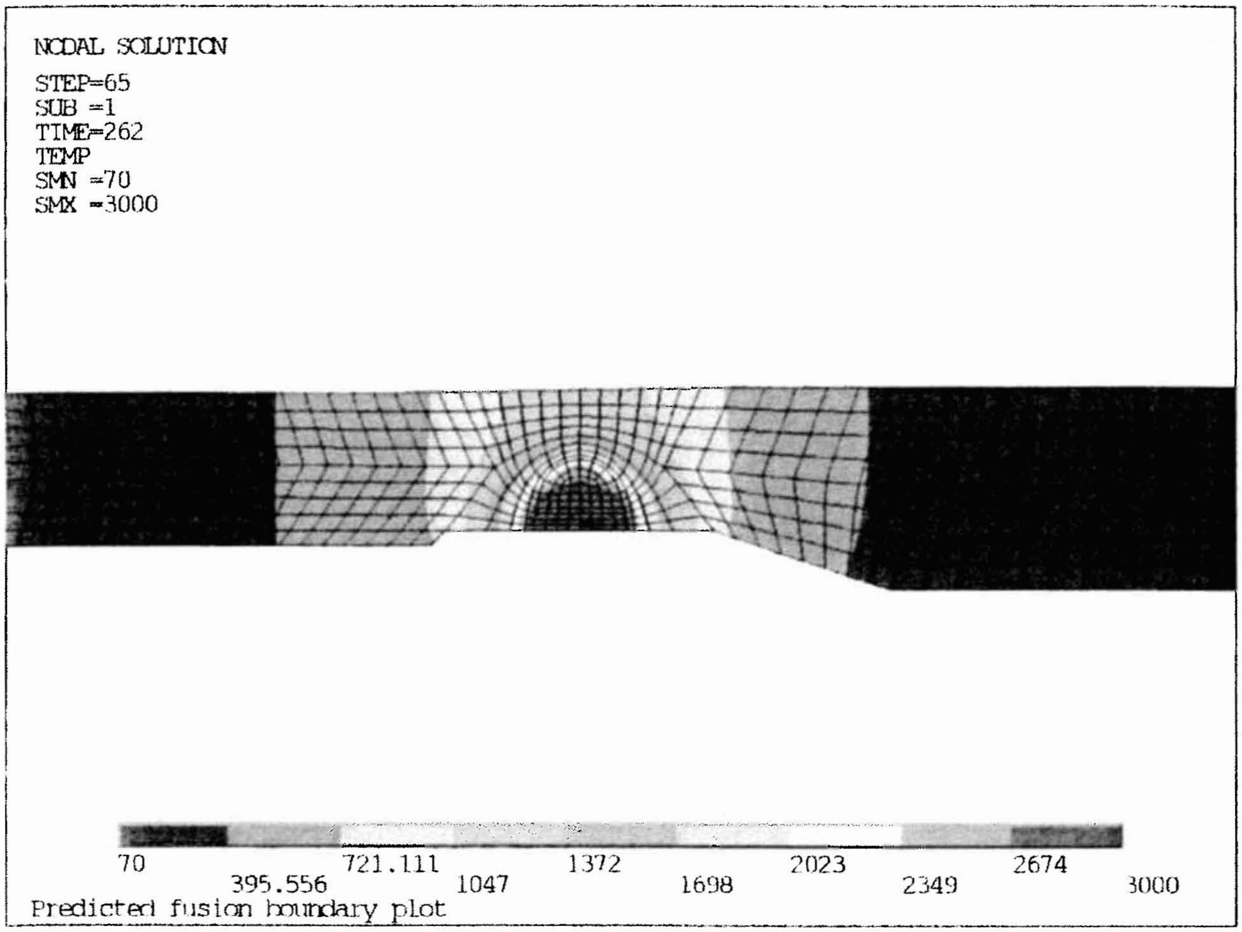


Figure 6: Predicted Fusion Boundary for ID Repair2

(Units are in terms of °F)

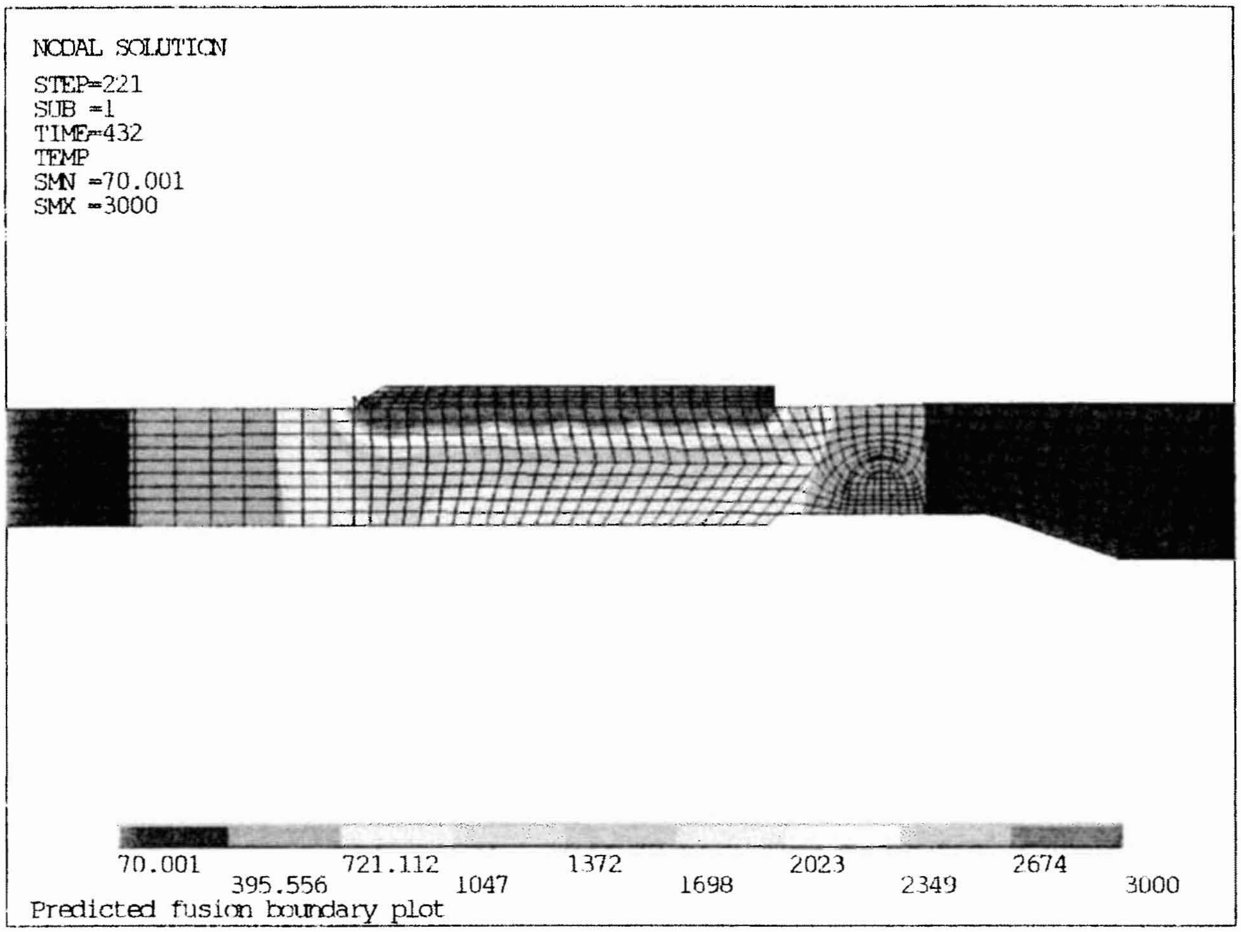


Figure 7: Predicted Fusion Boundary for Buffer Layer

(Units are in terms of °F)

(Note: The buffer layer is located in the safe end-to-pipe DMW region)

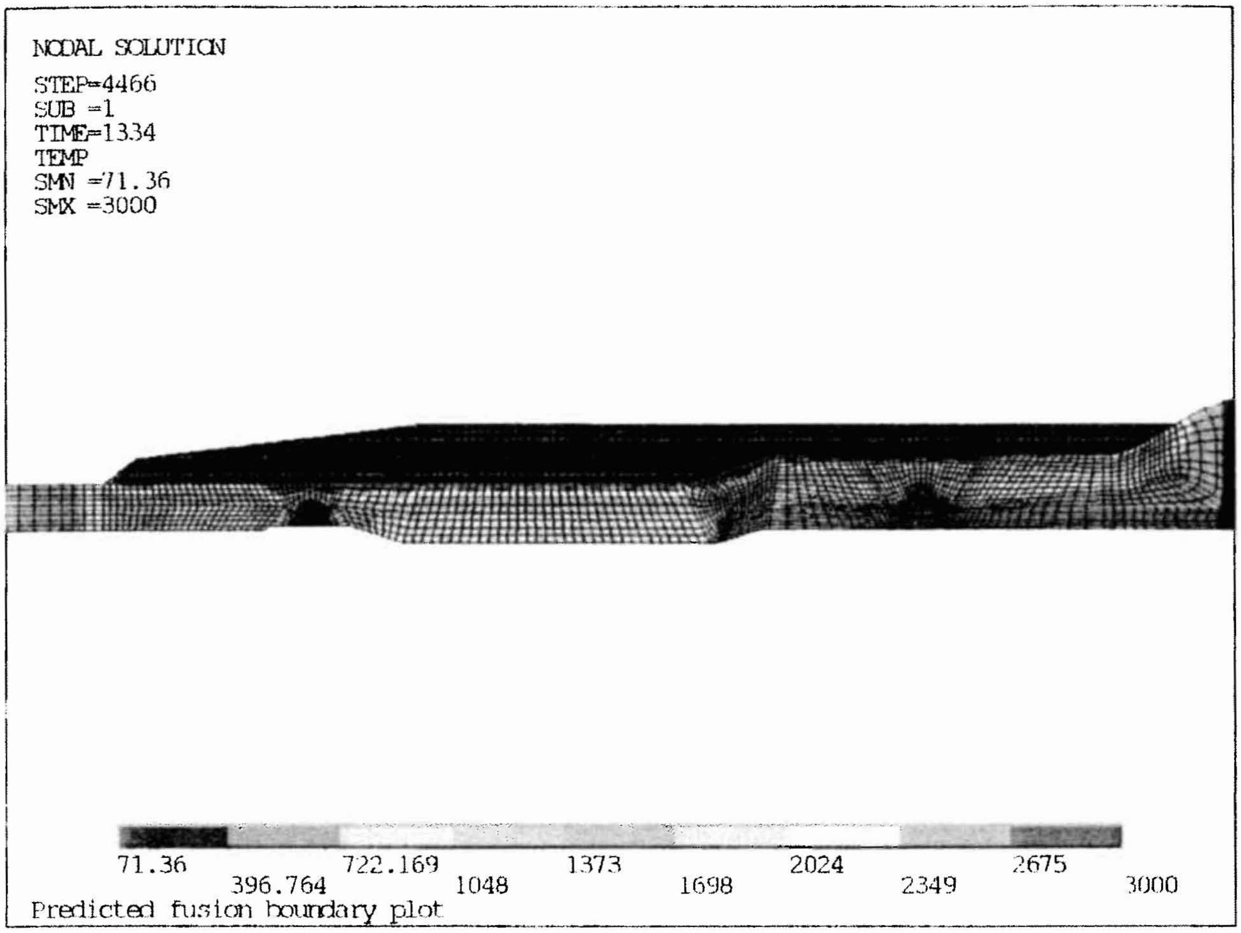


Figure 8: Predicted Fusion Boundary for Weld Overlay

(Units are in terms of °F)

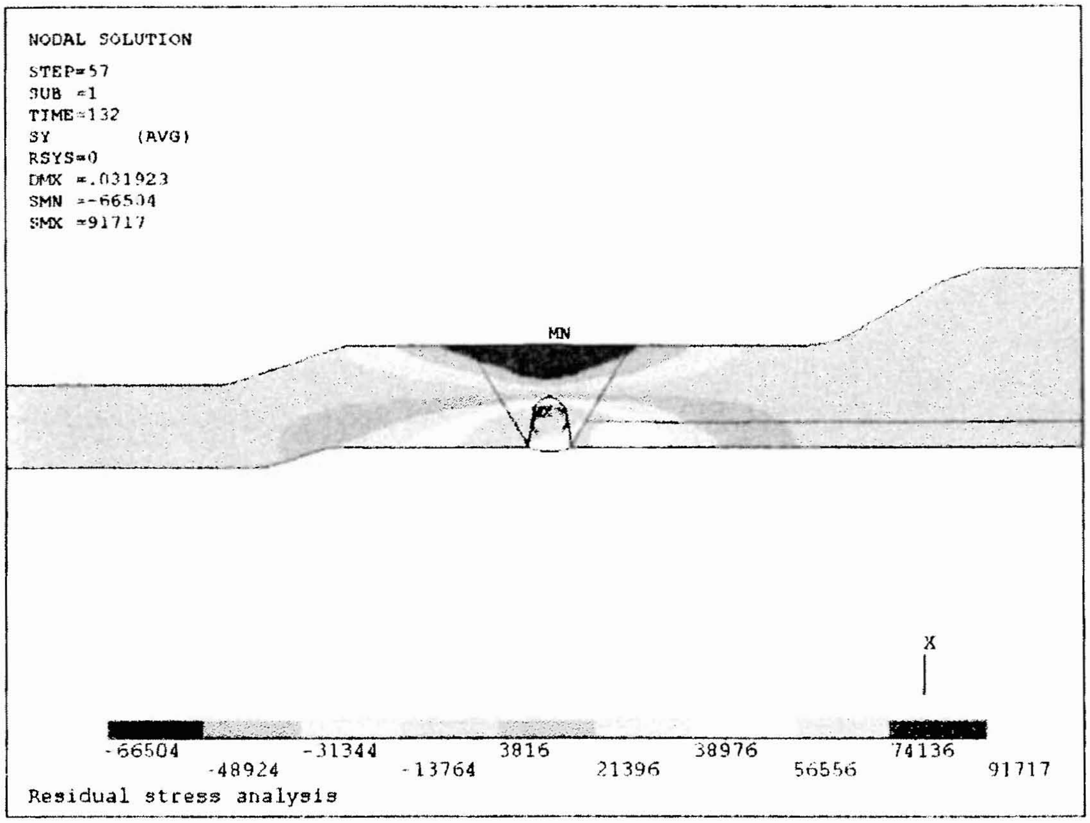


Figure 9: Post ID Repair1 Axial Stress at 70°F

(Units are in terms of psi)

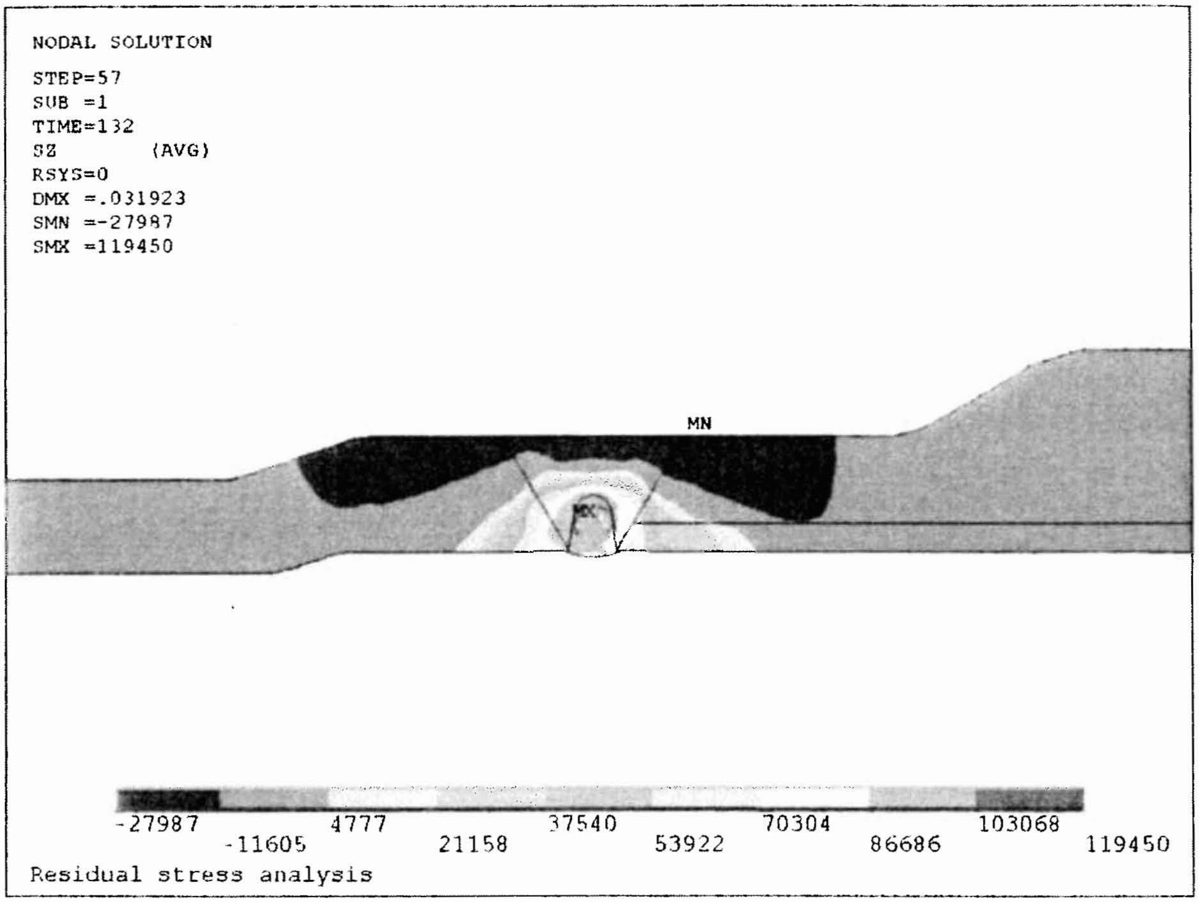


Figure 10: Post ID Repair1 Hoop Stress at 70°F
(Units are in terms of psi)

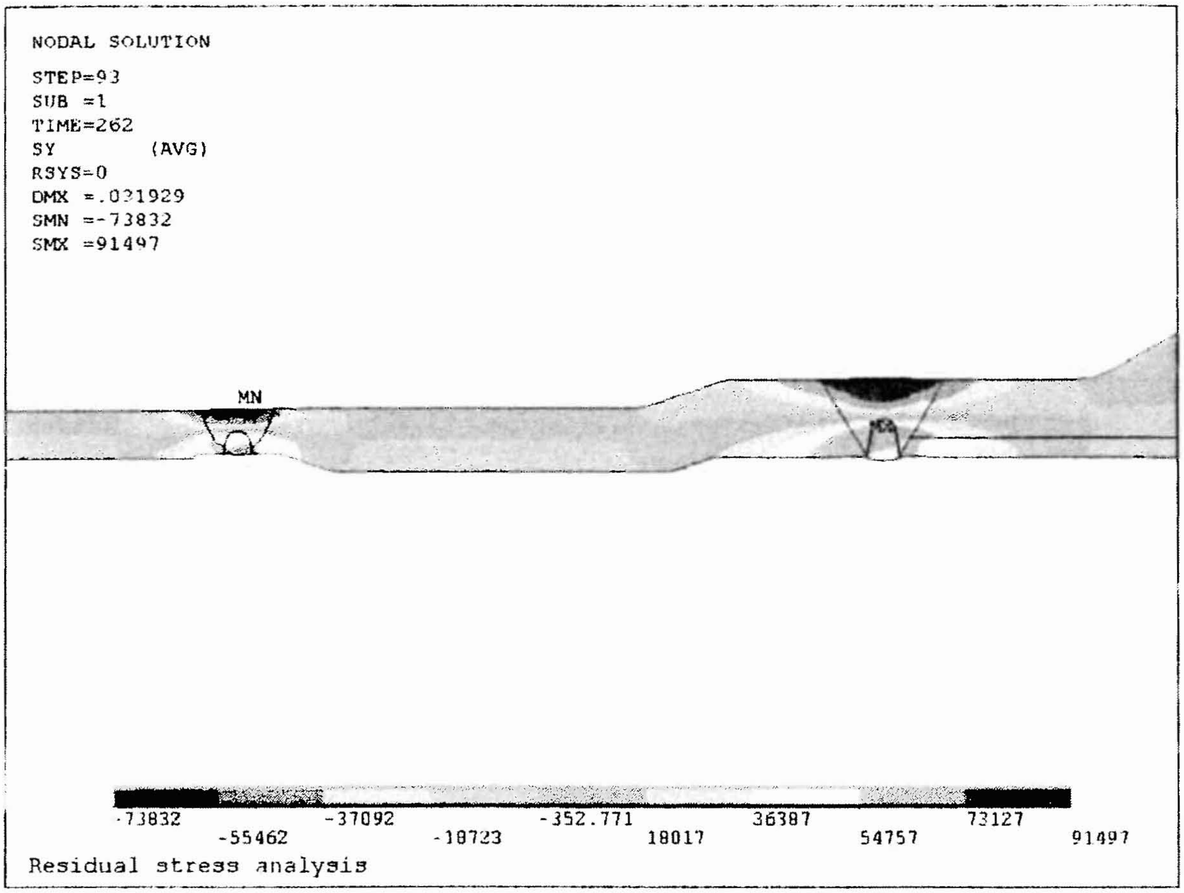


Figure 11: Post ID Repair2 Axial Stress at 70°F
(Units are in terms of psi)

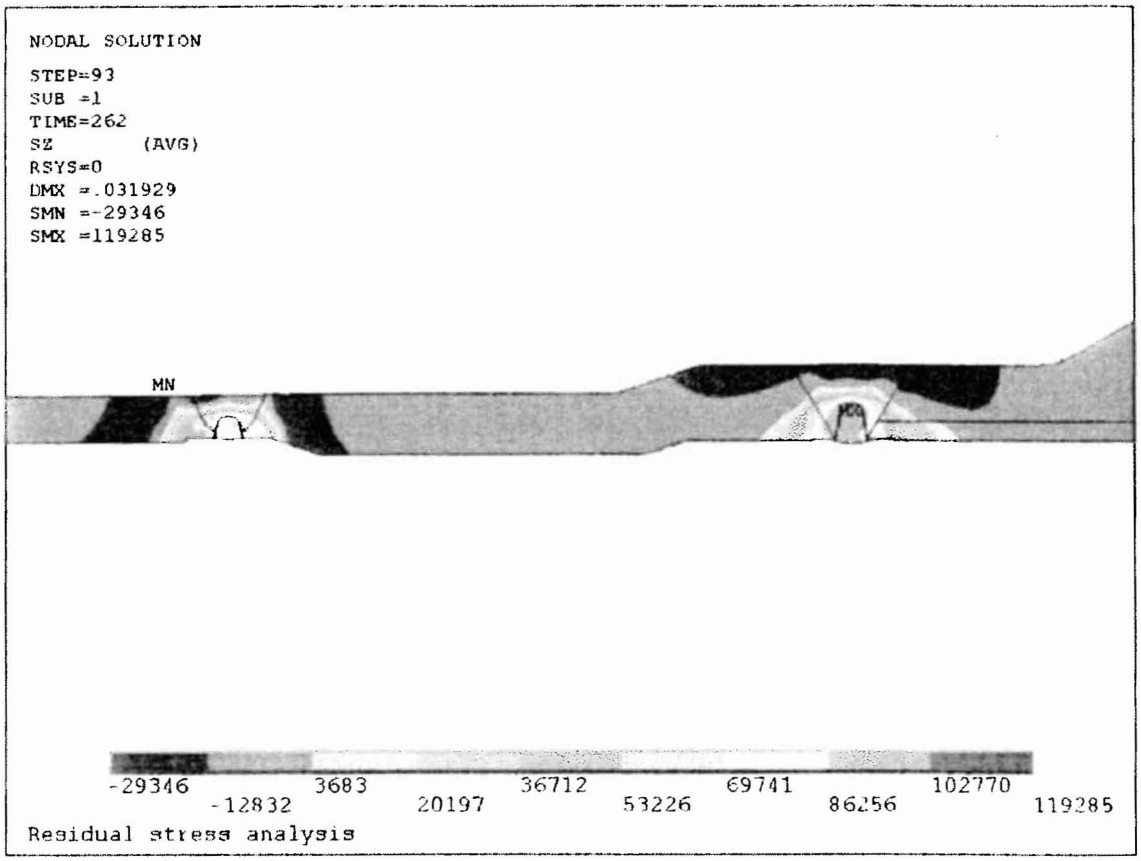


Figure 12: Post ID Repair2 Hoop Stress at 70°F

(Units are in terms of psi)

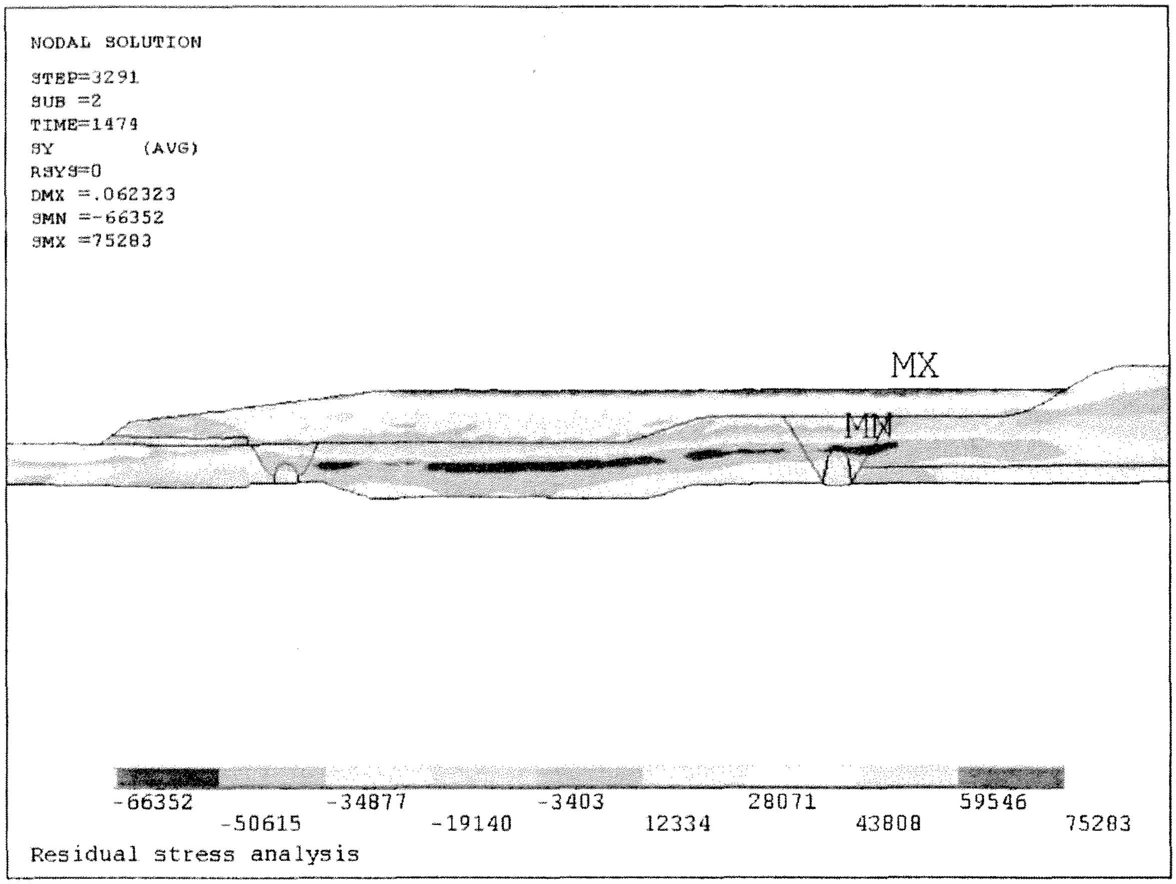


Figure 13: Post Weld Overlay Axial Stress at 70°F

(Units are in terms of psi)

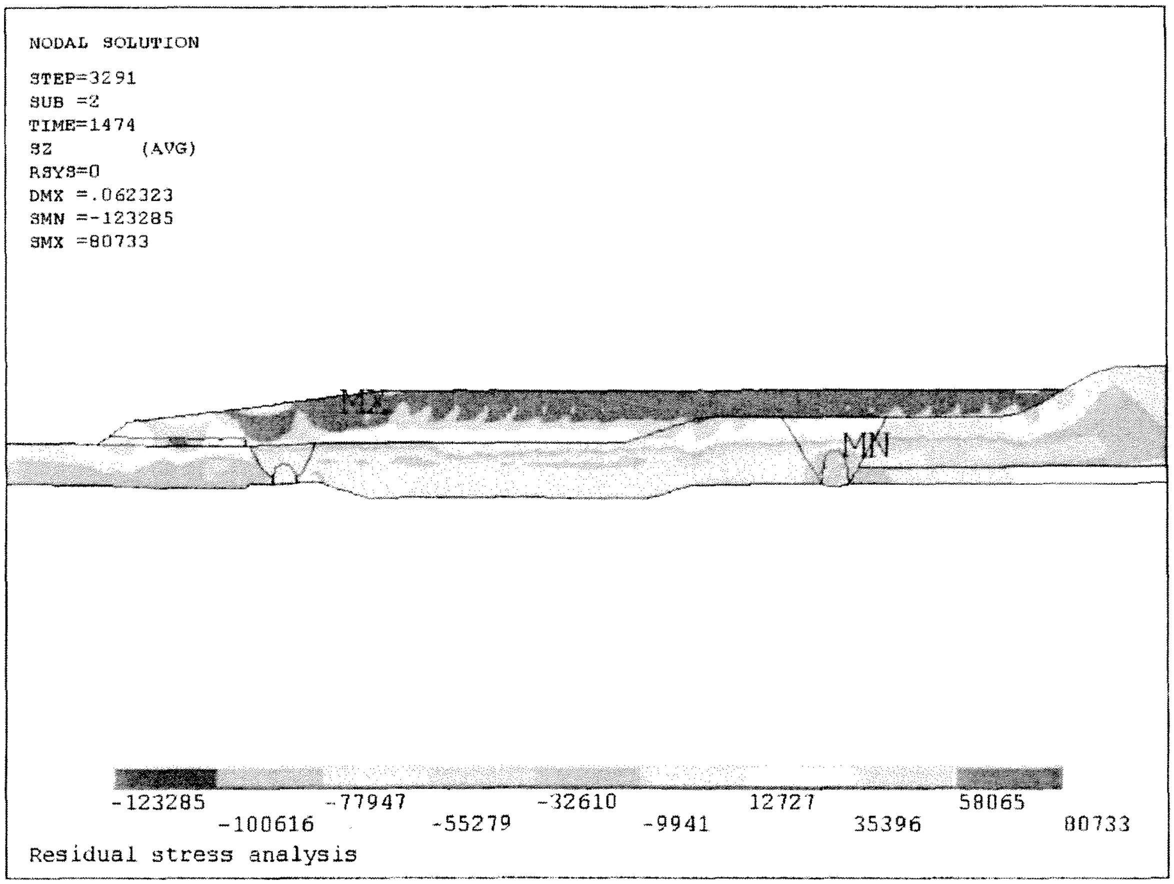


Figure 14: Post Weld Overlay Hoop Stress at 70°F

(Units are in terms of psi)

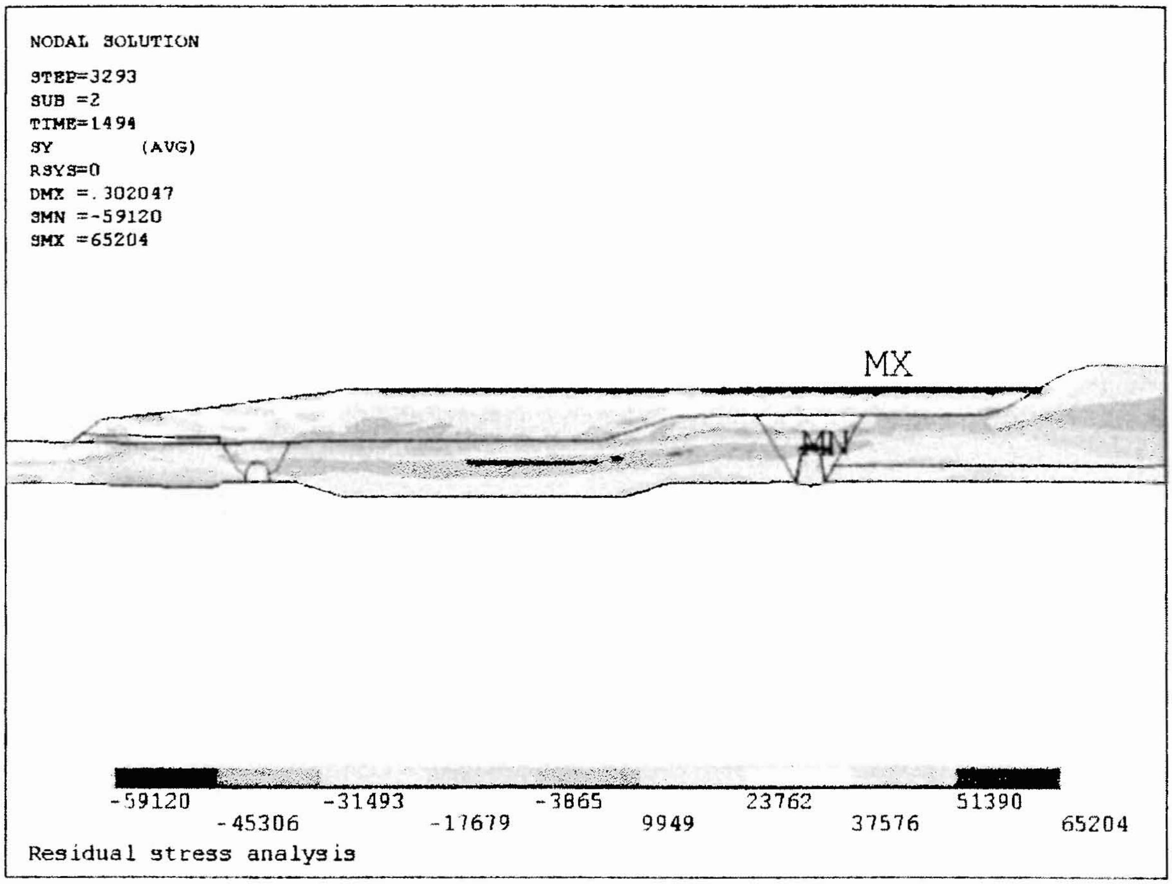


Figure 15: Post Weld Overlay Axial Stress at 650°F and 2155 psig

(Units are in terms of psi)

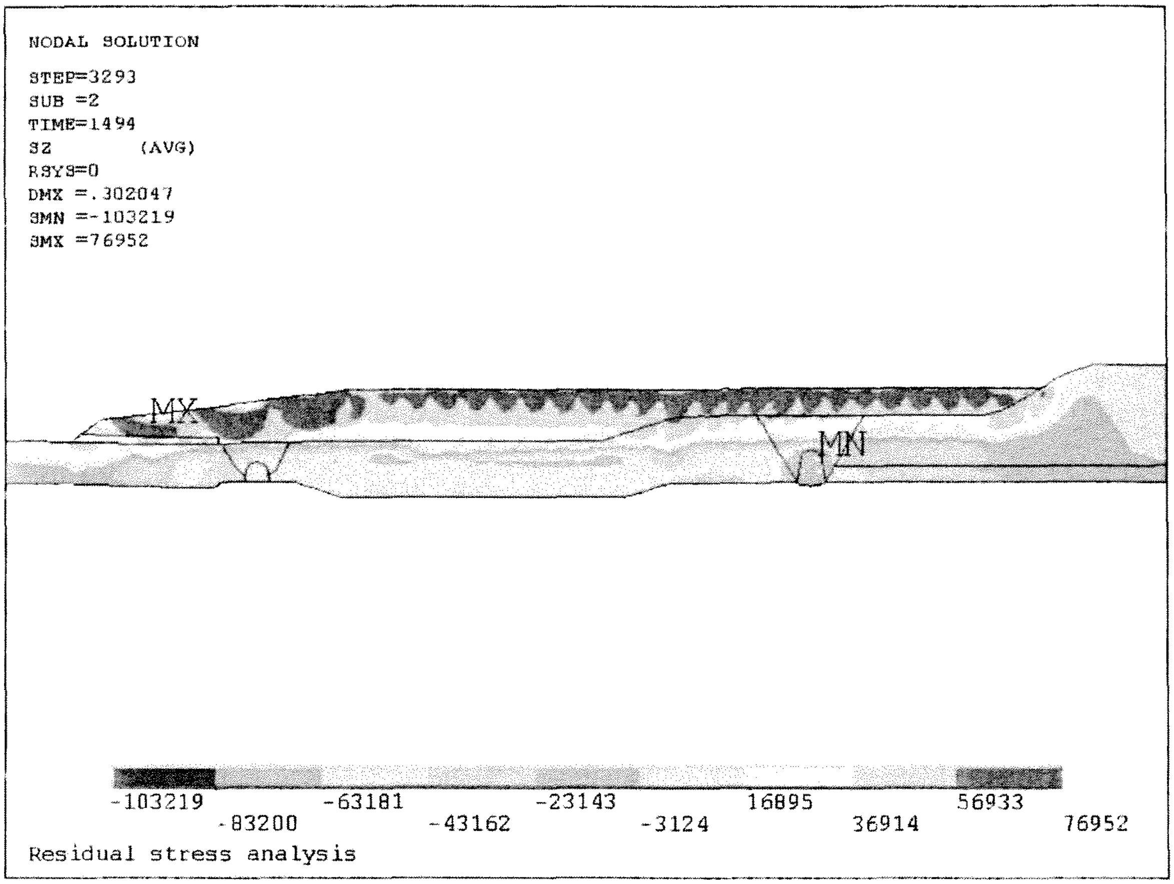


Figure 16: Post Weld Overlay Hoop Stress at 650°F and 2155 psig
(Units are in terms of psi)

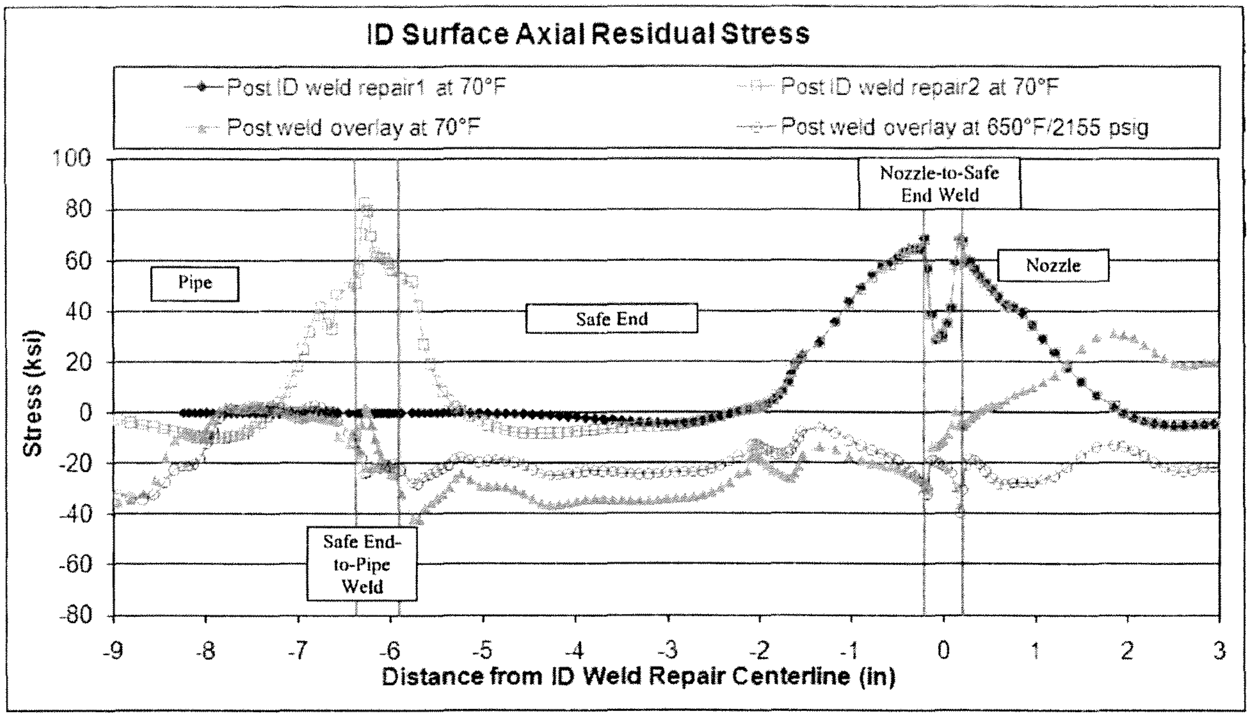


Figure 17: ID Surface Axial Residual Stresses

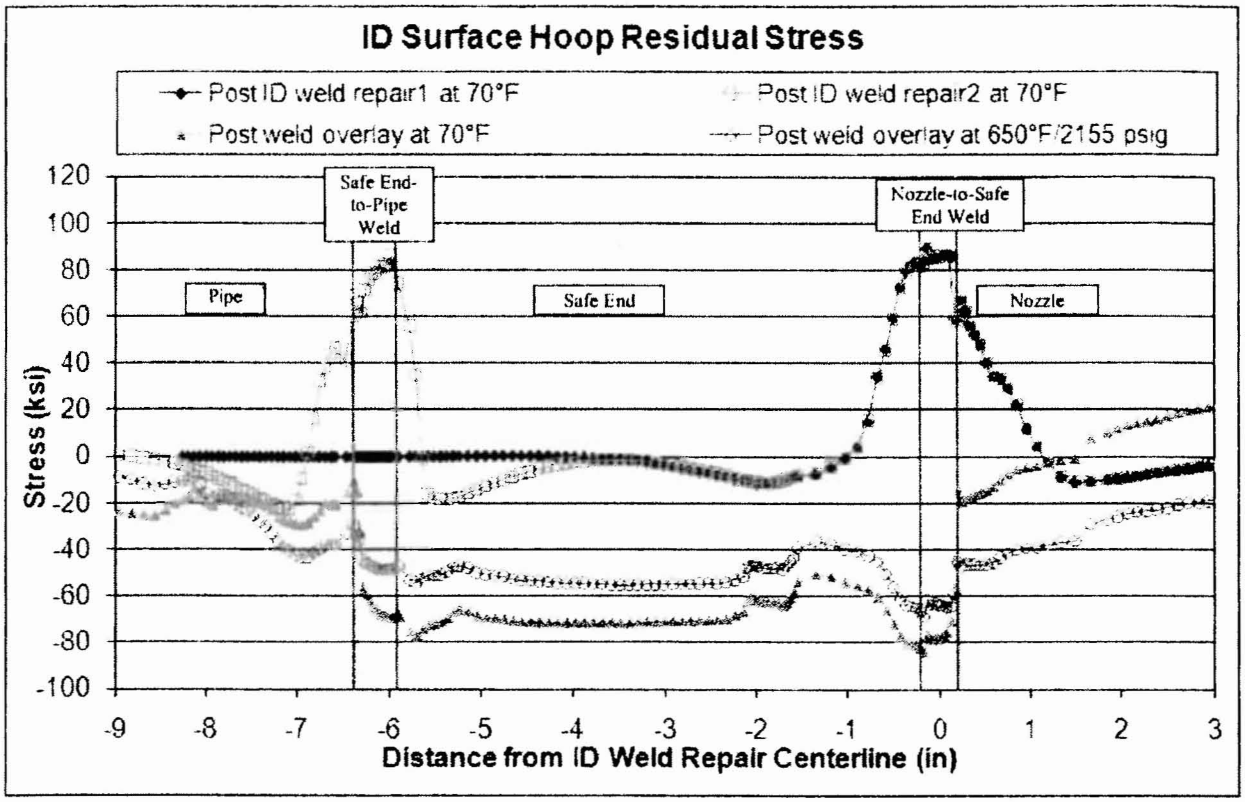


Figure 18: ID Surface Hoop Residual Stresses

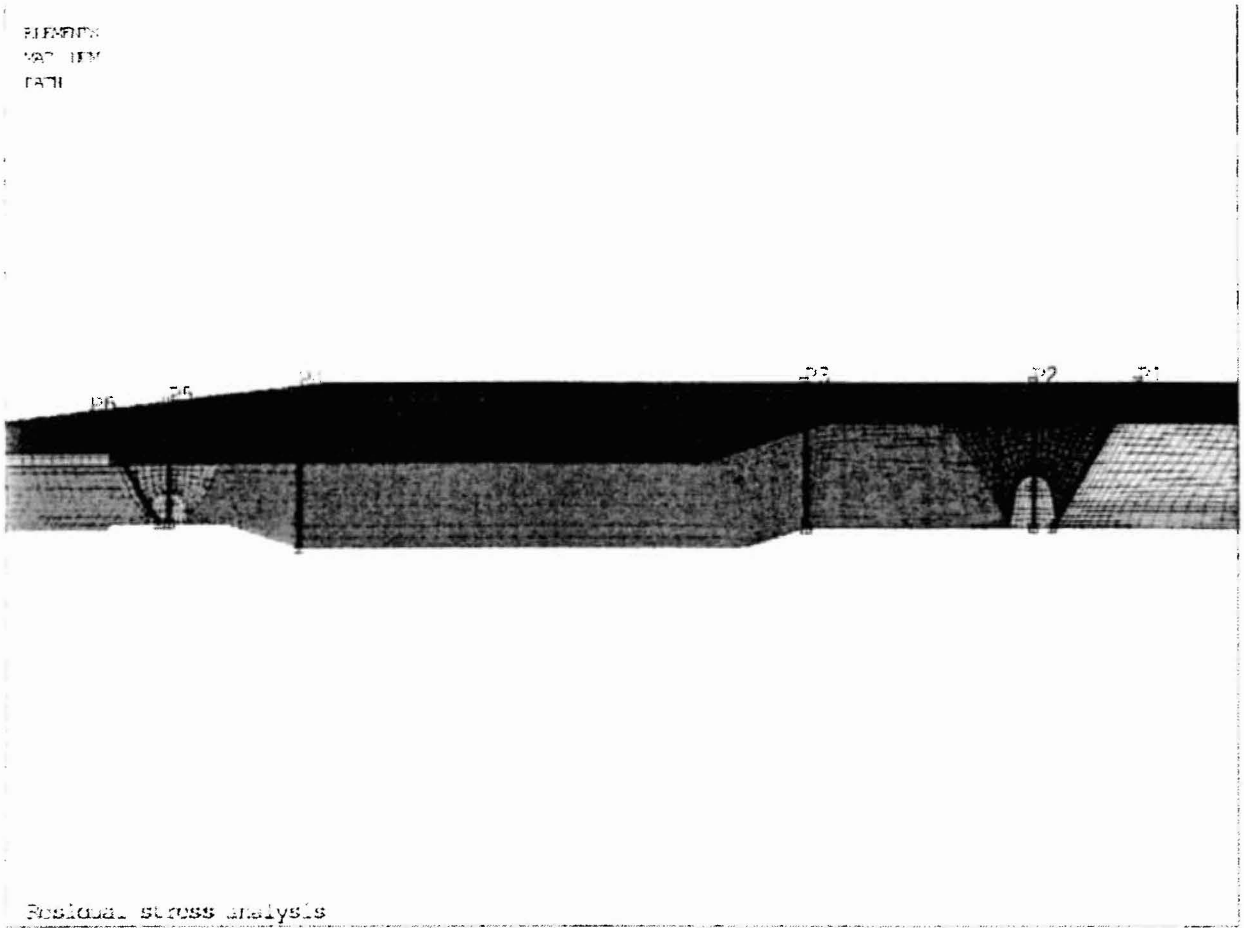


Figure 19: Path Definitions
(P1, P2, P3, P4, P5 and P6 denote Stress Paths 1, 2, 3, 4, 5 and 6)

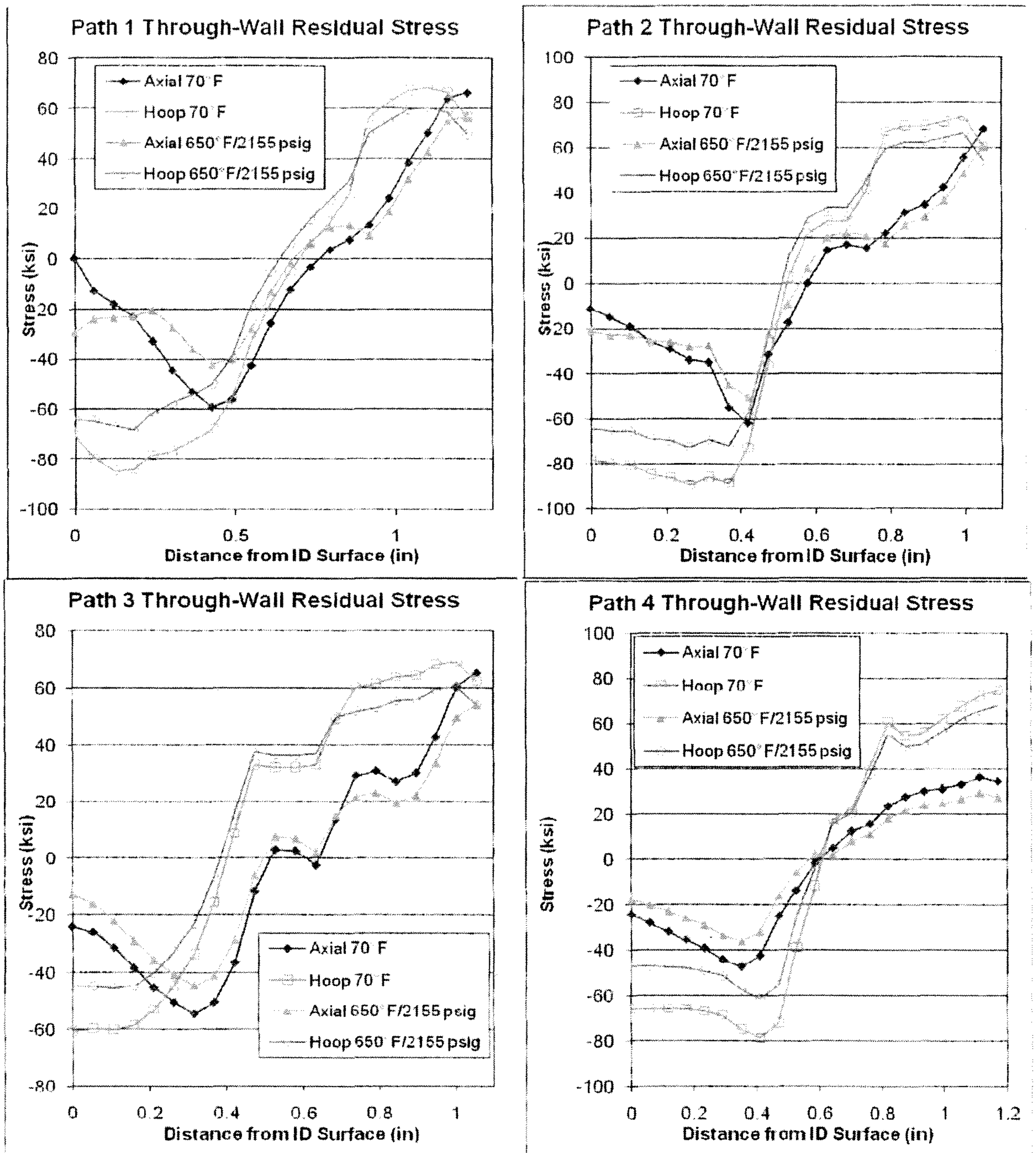


Figure 20: Post WOL Through-Wall Stress Plots, Paths 1 through 4

(See Figure 19 for stress path locations)

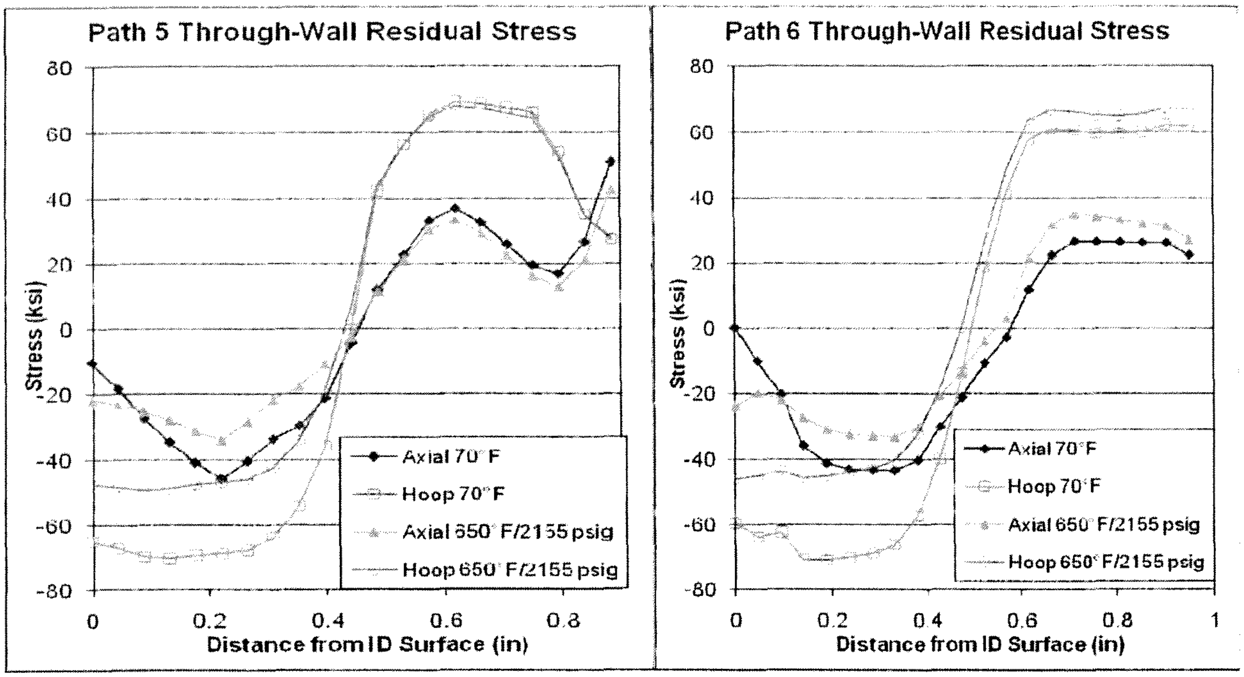


Figure 21: Post WOL Through-Wall Stress Plots, Paths 5 and 6

(See Figure 19 for stress path locations)

<u>ATTACHMENT 6</u>

Affidavits

A F F I D A V I T

COMMONWEALTH OF VIRGINIA)
) ss.
CITY OF LYNCHBURG)

1. My name is Gayle F. Elliott. I am Manager, Product Licensing, for AREVA NP Inc. (AREVA NP) and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in the Structural Integrity Associates, Inc. Calculation Package, No. 1000320.310, Revision 0, entitled "Pressurizer Spray Nozzle Weld Overlay Sizing Calculation," and referred to herein as "Document." Information contained in this Document has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is

made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b) and 6(c) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 22nd

day of March, 2011.

Sherry L. McFaden
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 10/31/14
Reg. # 7079129

SHERRY L. MCFADEN
Notary Public
Commonwealth of Virginia
7079129
My Commission Expires Oct 31, 2014

Structural Integrity Associates, Inc.®

5215 Hellyer Ave.
Suite 210
San Jose, CA 95138-1025
Phone: 408-978-8200
Fax: 408-978-8964
www.structint.com

March 23, 2011

AFFIDAVIT

I, Marcos Legaspi Herrera, state as follows:

(1) I am a Vice President of Structural Integrity Associates, Inc. (SI) and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in SI Calculation 1000320.310, Rev. 0, "Pressurizer Spray Nozzle Weld Overlay Sizing Calculation." This calculation is to be treated as SI proprietary information, because it contains significant information that is deemed proprietary and confidential to AREVA NP. AREVA NP design input information was provided to SI in strictest confidence so that we could generate the aforementioned calculation on behalf of SI's client, Exelon Nuclear Company, LLC (Exelon).

Paragraph 3 of this Affidavit provides the basis for the proprietary determination.

(3) SI is making this application for withholding of proprietary information on the basis that such information was provided to SI under the protection of a Proprietary/Confidentiality and Nondisclosure Agreement between SI and AREVA NP. In a separate Affidavit requesting withholding of such proprietary information prepared by AREVA NP, AREVA NP relies upon the exemption of disclosure set forth in NRC Regulation 10 CFR 2.390(a)(4) pertaining to "trade secrets and commercial or financial information obtained from a person and privileged or confidential" (Exemption 4). As delineated in AREVA NP's Affidavit, the material for which exemption from disclosure is herein sought is considered proprietary for the following reasons (taken directly from Items 6(b) and 6(c) of AREVA NP's Affidavit):

a) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service; and

b) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

Public disclosure of the information sought to be withheld is likely to cause substantial harm to AREVA NP with which SI has established a Proprietary/Confidentiality and Nondisclosure Agreement.

I declare under penalty of perjury that the above information and request are true, correct, and complete to the best of my knowledge, information, and belief.

Executed at San Jose, California on this 23rd day of March, 2011.

Marcos Legaspi Herrera, P.E.
Vice President
Nuclear Plant Services

State of California

County of Santa Clara

Subscribed and sworn to (or affirmed) before me

on this 23 (Date) day of March (Month), 20 11 (Year),
by

(1) Marcos Legaspi Herrera
Name of Signer

proved to me on the basis of satisfactory evidence to be the person who appeared before me (.) (x)
(and

(2) ______________________
Name of Signer

proved to me on the basis of satisfactory evidence to be the person who appeared before me.)

C. METZGER
Commission # 1866327
Notary Public - California
Santa Clara County
My Comm. Expires Sep 27, 2013

Place Notary Seal and/or Stamp Above

Signature ______________________
Signature of Notary Public

Structural Integrity Associates, Inc.®

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
CITY OF LYNCHBURG)

1. My name is Gayle F. Elliott. I am Manager, Product Licensing, for AREVA NP Inc. (AREVA NP) and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in the Structural Integrity Associates, Inc. Calculation Package, No. 1000320.314, Revision 0, entitled "Residual Stress Analysis of Pressurizer Spray Nozzle with Weld Overlay Repair," and referred to herein as "Document." Information contained in this Document has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is

made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b) and 6(c) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 22nd

day of March, 2011.

Sherry L. McFaden
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 10/31/14
Reg. # 7079129

SHERRY L. MCFADEN
Notary Public
Commonwealth of Virginia
7079129
My Commission Expires Oct 31, 2014

Structural Integrity Associates, Inc.®

5215 Hellyer Ave.
Suite 210
San Jose, CA 95138-1025
Phone: 408-978-8200
Fax: 408-978-8964
www.structint.com

March 23, 2011

AFFIDAVIT

I, Marcos Legaspi Herrera, state as follows:

(1) I am a Vice President of Structural Integrity Associates, Inc. (SI) and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in SI Calculation 1000320.314, Rev. 0, "Residual Stress Analysis of Pressurizer Spray Nozzle with Weld Overlay Repair." This calculation is to be treated as SI proprietary information, because it contains significant information that is deemed proprietary and confidential to AREVA NP. AREVA NP design input information was provided to SI in strictest confidence so that we could generate the aforementioned calculation on behalf of SI's client, Exelon Nuclear Company, LLC (Exelon).

Paragraph 3 of this Affidavit provides the basis for the proprietary determination.

(3) SI is making this application for withholding of proprietary information on the basis that such information was provided to SI under the protection of a Proprietary/Confidentiality and Nondisclosure Agreement between SI and AREVA NP. In a separate Affidavit requesting withholding of such proprietary information prepared by AREVA NP, AREVA NP relies upon the exemption of disclosure set forth in NRC Regulation 10 CFR 2.390(a)(4) pertaining to "trade secrets and commercial or financial information obtained from a person and privileged or confidential" (Exemption 4). As delineated in AREVA NP's Affidavit, the material for which exemption from disclosure is herein sought is considered proprietary for the following reasons (taken directly from Items 6(b) and 6(c) of AREVA NP's Affidavit):

a) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service; and

b) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

Public disclosure of the information sought to be withheld is likely to cause substantial harm to AREVA NP with which SI has established a Proprietary/Confidentiality and Nondisclosure Agreement.

I declare under penalty of perjury that the above information and request are true, correct, and complete to the best of my knowledge, information, and belief.

Executed at San Jose, California on this 23rd day of March, 2011.

Marcos Legaspi Herrera, P.E.
Vice President
Nuclear Plant Services

State of California

County of Santa Clara

Subscribed and sworn to (or affirmed) before me

on this 23 (Date) day of March (Month), 2011 (Year),
by

(1) Marcos Legaspi Herrera
Name of Signer

proved to me on the basis of satisfactory evidence to be the person who appeared before me (.) (X)
(and

(2) ______
Name of Signer

proved to me on the basis of satisfactory evidence to be the person who appeared before me.)

C. METZGER
Commission # 1866327
Notary Public - California
Santa Clara County
My Comm. Expires Sep 27, 2013

Place Notary Seal and/or Stamp Above

Signature ______
Signature of Notary Public