ENCLOSURE 1

FRAMATOME CALCULATION

AREVA DOCUMENT 32-5054514-01, "PALISADES CRDM NOZZLE IDTB WELD REPAIR ANALYSIS," DATED DECEMBER 2004 (NON-PROPRIETARY)

115 Pages Follow

AREVA

CALCULATION SUMMARY SHEET (CSS)

Document Identifier 32 - 5054514 - 01

Title PALISADES CRDM NOZZLE IDTB WELD REPAIR ANALYSIS – NON-PROPRIETARY

PREPARED BY:		REVIEWED BY:	
		METHOD: ☒ DETAILED CHECK ☐ INDEPENDENT CALCULATION	
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TITLE ENGINEER	DATE 12-7-2004	TITLE ADV. ENGINEER	DATE 12/9/04
COST CENTER 41628	REF. PAGE(S) 68,69	TM STATEMENT: REVIEWER INDEPENDENCE	ADM

PURPOSE AND SUMMARY OF RESULTS:

Purpose

The purpose of 32-5054514-00 is to provide Non-Proprietary version of 32-5044089-03 document.

The purpose of 32-5054514-01 is to address customer comments. Pages 1-4, 14-17, 43, 44, 49, 51, 54, 55, 58, 59, 61-63, 68, 69, 71, 75, 76c are revised.

Conclusion

Revision 01 addresses customer comments. The changes do not have any effect on the results and conclusion of Revision 00. The number of pages of Revision 01 is 24. These pages substitute the corresponding pages in Revision 00 to form complete document. The total number of pages is 115.

Purpose of 32-5044089-03

The purpose of Revision 03 is to analyze the lower temperature limit of xxx°F for the three hours hold during cooldown. The analysis summarizes the stresses for this condition for use in fracture mechanic. The upper limit is xxx°F as previously documented in an earlier revision to this document.

Conclusion of 32-5044089-03

This revision analyzes the lower temperature limit of xxx°F for the three hours hold during cooldown. This additional analysis of cooldown does not have any significant effect on the previous analysis, results and conclusion of Revision 02.

Pages 1-4, 6, 69, 73, 76, 81, 106 are revised and pages 76a, 76b, 76c, 81a, 106a, 106b, 106c and 106d are added in Revision 03. Only the revised and added pages are included in Revision 03. Revision 03 consists of 18 pages. Revision 03, 02, 01 and 00 together form the complete document. The total number of pages is 115*.

Purpose of 32-5044089:

The purpose of Revision 02 is to update revision levels of References 13.1, 13.5, 13.7, and 13.20 and to document the effect of changes in these references.

The purpose of Revision 01 is to incorporate customer comments, update calculation in Appendix A and update reference revisions. These changes do not affect conclusions of the analysis in Revision 00.

This document contains the analysis and qualification of the repair in the Control Rod Drive Mechanism (CRDM) nozzles in the Reactor Vessel Closure Head (RVCH) in Palisades plant operated by Nuclear Management Company.

The purpose of this calculation is to fulfill the requirements of Reference 13.1. The repair design is qualified to meet the criteria of 1989 ASME Code, Section III, NB-3000 (Reference 13.2).

The stresses within the IDTB weld and original J-groove weld are also calculated in order to provide input for the fracture mechanics analysis.

Conclusion of 32-5044089:

Revision 02 updated levels of References 13.1, 13.5, 13.7, and 13.20. The changes in these do not have any significant effect on the analysis, results and conclusion of Revision 01.

Revision 02 consists of 5 pages – 1-4 and 68. Revision 02, 01 and 00 together form the complete document.

The presented calculations demonstrate that the Palisades CRDM IDTB weld repair design meets the stress and fatigue requirements of the Design Code (ASME Code, section III, 1989 edition w/o addenda – Reference 13.2).

Based on the loads and cycles specified in Reference 13.8 and Reference 13.1, the conservative fatigue analysis indicates that the repair has a cumulative usage factor of 0.73 for xxx years of operation compared to the ASME Code allowed maximum value of 1.0.

This calculation fulfills the requirements of Reference 13.1

Pages 1 - 5, 8, 10, 14 – 16, 18 – 22, 25, 48, 49, 51 – 53, 60, 61, 68, 73 – 76, 79, 80, 93 – 96 are revised and page 95a is added in Revision 01. Only the revised and added pages are included in Revision 01. These pages substitute the corresponding pages in Revision 00 to form the complete document. The total number of pages is 107*

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:		THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK
CODE/VERSION/REV	CODE/VERSION/REV	
		☐ YES ☒ NO

Framatome ANP, Inc., *an AREVA and Siemens company* *Includes 76a-c, 81a, 95a, 106a-d

RECORD OF REVISIONS

Revision Number	Description	Date
00	Original Release	12/2004
01	Partial Revision Updated pages 1, 2, 3, 4, 14, 15, 16, 17, 43, 44, 49, 51, 54, 55 ,58, 59, 61, 62, 63, 68, 69, 71, 75, and 76c to address customer comments.	12/2004

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DESIGN VERIFICATION CHECKLIST

Document Identifier 32 - 5054514 - 01

Title PALISADES CRDM NOZZLE IDTB WELD REPAIR ANALYSIS-NONPROPRIETARY

1.	Were the inputs correctly selected and incorporated into design or analysis?	☒ Y	☐ N	☐ N/A
2.	Are assumptions necessary to perform the design or analysis activity adequately described and reasonable? Where necessary, are the assumptions identified for subsequent re-verifications when the detailed design activities are completed?	☒ Y	☐ N	☐ N/A
3.	Are the appropriate quality and quality assurance requirements specified? Or, for documents prepared per FANP procedures, have the procedural requirements been met?	☒ Y	☐ N	☐ N/A
4.	If the design or analysis cites or is required to cite requirements or criteria based upon applicable codes, standards, specific regulatory requirements, including issue and addenda, are these properly identified, and are the requirements/criteria for design or analysis met?	☒ Y	☐ N	☐ N/A
5.	Have applicable construction and operating experience been considered?	☐ Y	☐ N	☒ N/A
6.	Have the design interface requirements been satisfied?	☐ Y	☐ N	☒ N/A
7.	Was an appropriate design or analytical method used?	☒ Y	☐ N	☐ N/A
8.	Is the output reasonable compared to inputs?	☒ Y	☐ N	☐ N/A
9.	Are the specified parts, equipment and processes suitable for the required application?	☒ Y	☐ N	☐ N/A
10.	Are the specified materials compatible with each other and the design environmental conditions to which the material will be exposed?	☒ Y	☐ N	☐ N/A
11.	Have adequate maintenance features and requirements been specified?	☐ Y	☐ N	☒ N/A
12.	Are accessibility and other design provisions adequate for performance of needed maintenance and repair?	☐ Y	☐ N	☒ N/A
13.	Has adequate accessibility been provided to perform the in-service inspection expected to be required during the plant life?	☐ Y	☐ N	☒ N/A
14.	Has the design properly considered radiation exposure to the public and plant personnel?	☐ Y	☐ N	☒ N/A
15.	Are the acceptance criteria incorporated in the design documents sufficient to allow verification that design requirements have been satisfactorily accomplished?	☒ Y	☐ N	☐ N/A
16.	Have adequate pre-operational and subsequent periodic test requirements been appropriately specified?	☐ Y	☐ N	☒ N/A
17.	Are adequate handling, storage, cleaning and shipping requirements specified?	☐ Y	☐ N	☒ N/A
18.	Are adequate identification requirements specified?	☐ Y	☐ N	☒ N/A
19.	Is the document prepared and being released under the FANP Quality Assurance Program? If not, are requirements for record preparation review, approval, retention, etc., adequately specified?	☒ Y	☐ N	☐ N/A

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DESIGN VERIFICATION CHECKLIST

Document Identifier 32 - 5054514 - 01

Comments:

Verified By:	JOHN F. SHEPARD	JF Shepard	12/7/04
(First, MI, Last)	Printed / Typed Name	Signature	Date

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose

Purpose of this document is to provide Non-Proprietary revision of document 32-5044089-03.

The document 32-5044089-03 contains the analysis and qualification of the repair in the Control Rod Drive Mechanism (CRDM) nozzles in the Reactor Vessel Closure Head (RVCH) in Palisades plant operated by Nuclear Management Company.

The purpose of this calculation is to fulfill the requirements of Reference 13.1. The repair design is qualified to meet the criteria of 1989 ASME Code, Section III, NB-3000 (Reference 13.2).

The analysis of the nozzle extension, nozzle to nozzle extension connection and support plate is performed in the Reference 13.20.

The stresses within the IDTB weld and original J-groove weld are also calculated in order to provide input for the fracture mechanics analysis.

1.2 Scope

The Palisades Unit 1 Reactor Vessel Closure Head (RVCH) contains, among others, forty five (45) CRDM nozzles (Reference 13.9). Each of the nozzles is aligned vertically. They are located at various radial distances from the vertical centerline of the RVCH hemisphere. Based on the distance from the center of the hemispherical head, the relative angle of the nozzle vertical centerline and the plane of the head curvature varies. This angle is referred to herein as the "hillside angle". Experience (with analyses for nozzles located at various hillside angles in the upper head) indicates that the larger the hillside angle, the more severe the stress level. Based on this experience, the model herein represents the largest hillside angle of any of the CRDM nozzle locations (the outermost nozzle, #38-45). This model is considered to produce results that are conservatively high for all nozzle locations that have a smaller angle. Qualification of the CRDM nozzle necessitated creations of a 3-D finite element model and stress analysis of the repair design. Thus, the model geometry uses the repair design and stress analysis is performed under conditions of the various Palisades RVCH loads.

2.0 ASSUMPTIONS

There are no major assumptions made for the analysis contained in this document. Minor assumptions are noted where applicable.

3.0 CALCULATION METHODOLOGY

The general methodology of model development and stress analysis consists of:

1) Building the finite element model including the reactor vessel closure head (RVCH), penetration, remaining part of the original CRDM nozzle, replacement nozzle, original J-groove weld & buttering, repair internal diameter temper bead (IDTB) weld, materials, and boundary conditions. There are two finite element models consisting of thermal and structural elements respectively to enable the thermal and structural analyses. The "meshes" of the two models are same.

2) Applying the design conditions of pressure and temperature to the structural finite element model and obtaining the deformation and stresses in the model. The deformation field is used to verify the correct behavior of the model and correct modeling of boundary and load conditions. Attenuation of stress effects at regions distant from the nozzle is also verified.

3) Applying the thermal loads resulting from the plant operating transients (in the form of transient temperatures versus time and corresponding heat transfer coefficients). Evaluating the results of the thermal analysis by examining the magnitude of temperature differences between key locations of the model. The time points of the maximum temperature gradient are those at which the maximum thermal stresses develop.

4) Applying the corresponding pressure and thermal loads (nodal temperature) at each time point identified in step 3 and other time points of interest on the structural finite element model and obtaining the stress results.

5) Performing the ASME Code stress evaluation based on the finite element analysis results, which includes the assurance that failure does not occur due to the application of the design loads as well as the repetitive service loads.

6) Document stresses for the original J-groove weld for the fracture mechanics analysis.

4.0 FINITE ELEMENT MODEL

The model simulates, in three-dimensional space, a 180-degree section of the CRDM nozzle and adjacent RVCH after the repair. The vertical plane containing the vertical central axis of the RVCH and vertical central axis of the CRDM nozzle forms the plane of symmetry for the modeled portion of the nozzle. The thermal and structural boundary conditions are reflective on this plane.

The RVCH is modeled for a sufficient distance away from the CRDM penetration (both in the uphill/downhill and circumferential directions) to assure that the stress effects have effectively attenuated. The adequacy of these distances is verified by review of solution runs for operational transients. In addition, due to the spacing of the CRDM Nozzles and the attenuation of the stress effects from the relatively small welds, no appreciable overlap of stress fields occurs between adjacent nozzles. Therefore, only a single CRDM nozzle is modeled.

The nozzle is modeled sufficiently beyond the head to include effect on the IDTB weld connection. The threaded connection is not modeled since this location is not the subject of interest in this analysis.

The finite element analyses in this document are performed using ANSYS 7.1 (Reference 13.3). The model is shown in Figure 4-1 to Figure 4-4. The element type chosen is the SOLID92 (3D 10-Node Tetrahedral Structural Solid) for the structural analysis. This element is converted to element type SOLID87 (3D 10-Node Tetrahedral Thermal Solid) for the thermal analysis. The model is comprised of approximately 96000 nodes and 60000 elements.

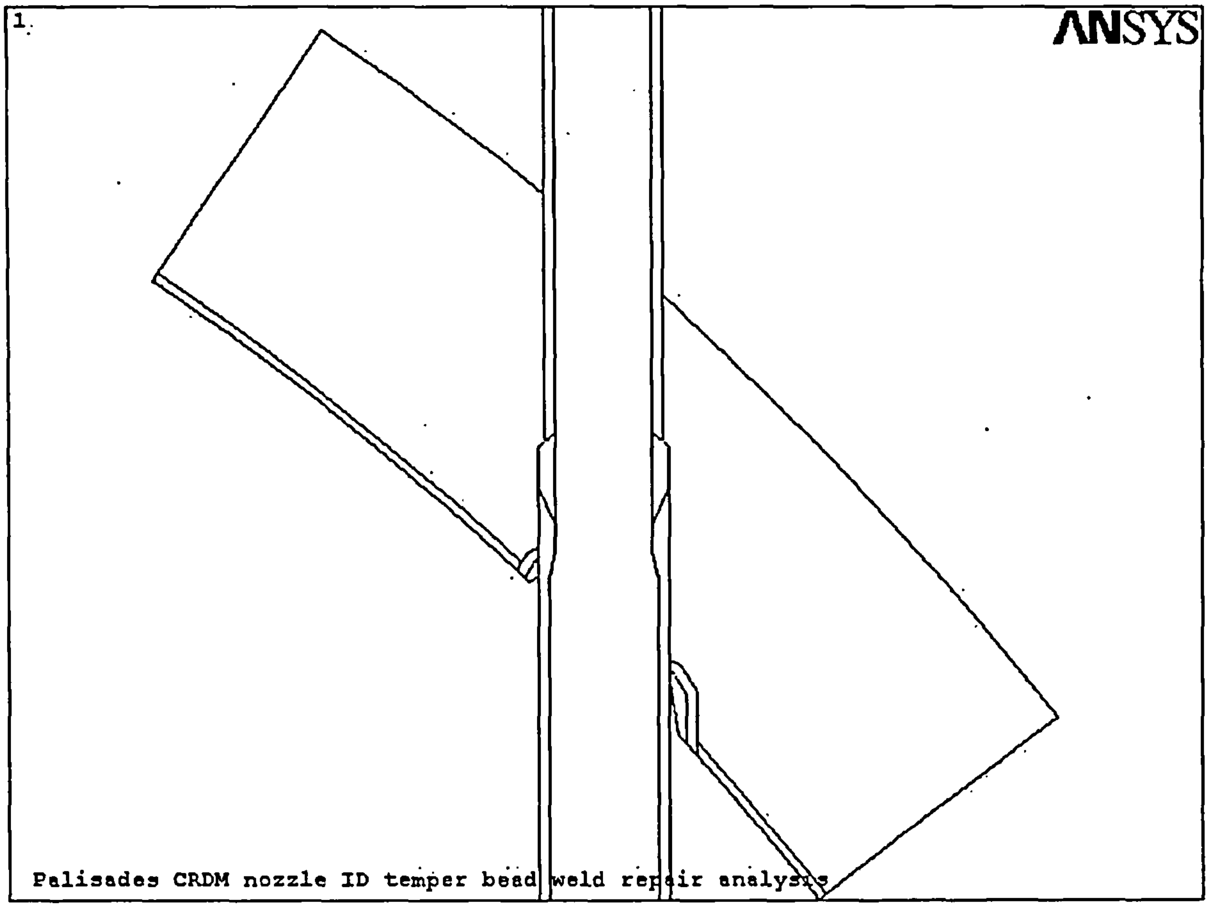

Figure 4-1 Solid model showing the closure head, the replacement and remaining original nozzles and the attachment welds

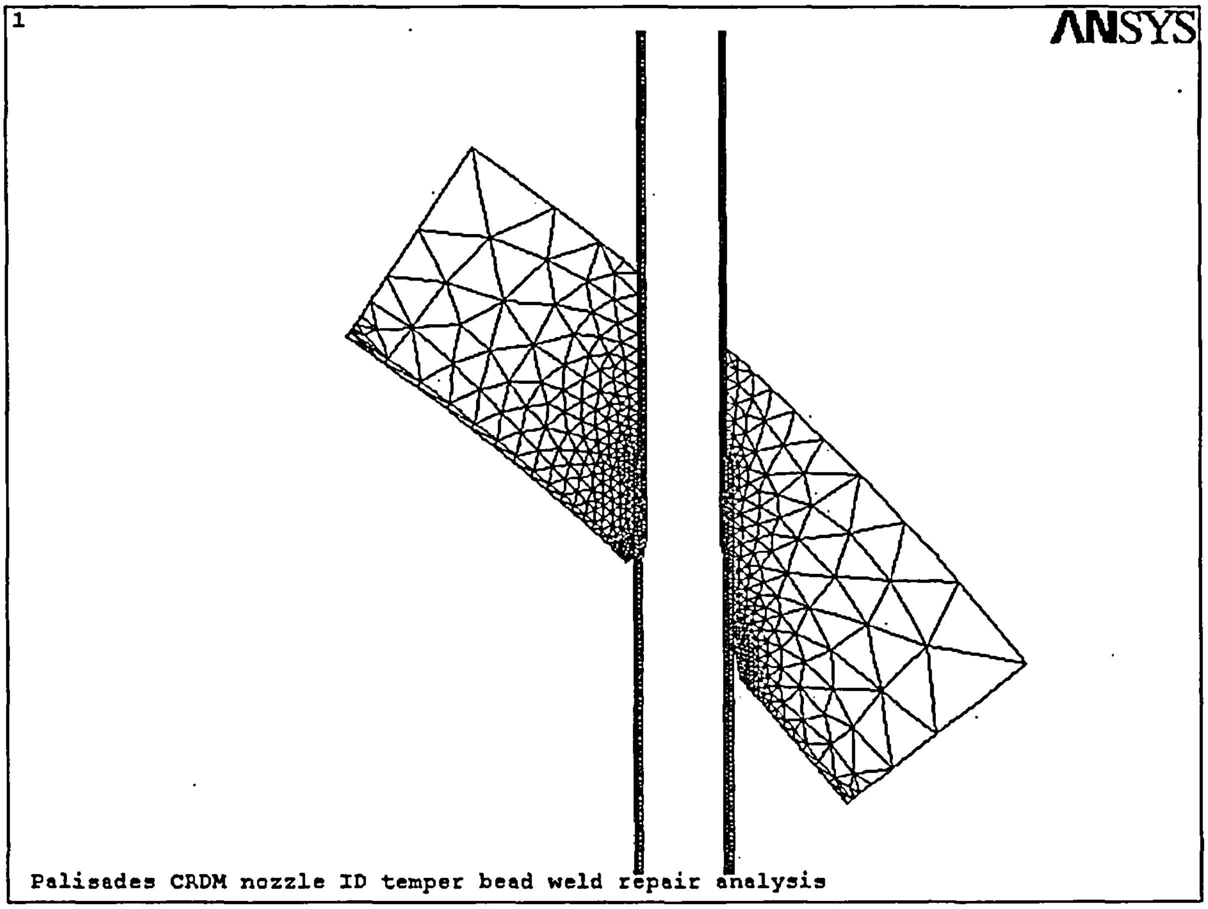

Figure 4-2 Finite element model showing mesh

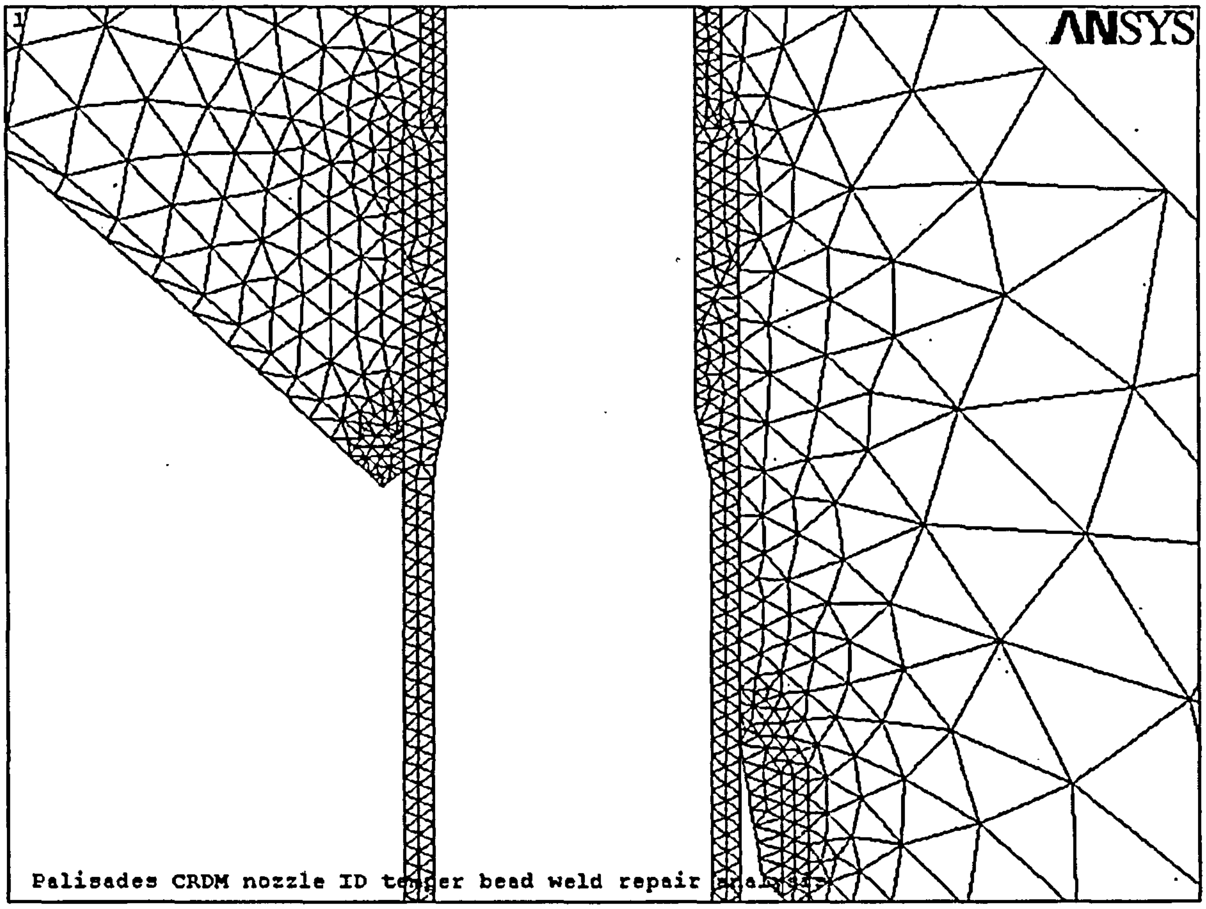

Figure 4-3 Finite element model showing mesh at the original J-groove weld area

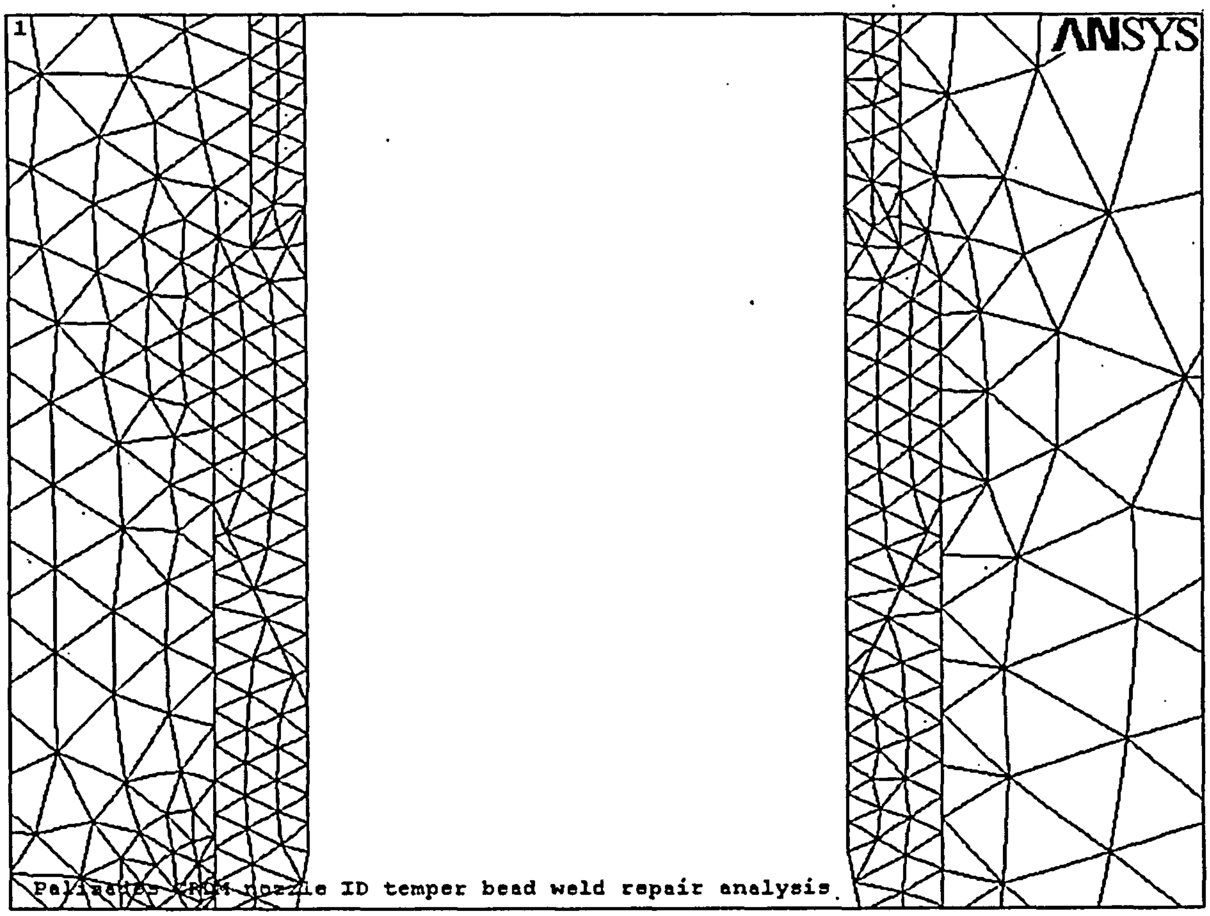

Figure 4-4 Finite element model showing mesh at the repair weld area

4.1 Geometry

The geometry of the model is based on Reference 13.4[4], 13.5, 13.9 through 13.12 for the outermost nozzle configuration (#38-45). Note that some of the small details in the geometry are not modeled since they have insignificant impact on the results and difference in the stresses is negligible[5]. Some of the key dimensions used are:

RVCH inside radius to base metal	= xxx in.	(Reference 13.11)
RVCH base metal thickness	= xxx in.	(Reference 13.5)
RVCH Head cladding thickness	= xxx in.	(Reference 13.11)
Remaining Original Nozzle OD	= xxx in.[1]	(Reference 13.9)
Remaining Original Nozzle ID	= xxx in. [2]	(Reference 13.5)
Replacement Nozzle OD	= xxx in. [1]	(Reference 13.5)
Replacement Nozzle ID (at repair weld)	= xxx in.	(Reference 13.5)
Replacement Nozzle ID (away from repair weld)	= xxx in. [3]	(Reference 13.4)

Notes: [1] The OD of the nozzle is assumed equal to penetration diameter.

[2] The maximum nozzle inside diameter near the IDTB weld is conservatively used for other locations of Remaining Original Nozzle.

[3] The maximum Replacement Nozzle inside diameter is conservatively used for the whole section away from the repair weld.

[4] The length of the upper thick part of the Replacement Nozzle and the length of the transition from the thick to the thin part of the nozzle are slightly different from the Reference 13.4. Since this change is away from the investigated location, the impact on the results will be negligible and therefore these differences are acceptable.

[5] See Section 10.0 for discussion of corrosion allowance.

4.2 Materials

Reference 13.1 provides the material designation of various components:

RV Closure Head	- xxx	(Reference 13.1, par. 5.1)
RV Head Cladding [1]	- xxx	(Reference 13.1, par. 5.10)
Remaining Original Nozzle	- xxx	(Reference 13.1, par. 5.2)
Original J-Groove Weld	- xxx	(Reference 13.1, par. 5.12)
Original J-Groove Buttering	- xxx	(Reference 13.1, par. 5.12)
Replacement Nozzle	- xxx	(Reference 13.1, par. 5.6)
Repair IDTB Weld [2]	- xxx	(Reference 13.1, par. 5.3)

(1) Note: Reference 13.1, par. 5.10 specifies that the material physical properties for the RVCH cladding shall be considered equivalent to stainless steel of xxx.

(2) Note: Reference 13.1, par. 5.3 provides specification of weld filler material for the repair IDTB weld as xxx, xxx. Based on its nominal chemical composition that is specified in Reference 13.19, xxx is considered representative of the weld material properties.

The analysis herein uses the thermal properties – mean coefficient of thermal expansion (α), specific heat (C), thermal conductivity (k) and the mechanical properties – modulus of elasticity (E), Poisson's ratio (μ), density (ρ). The pertinent properties (thermal & structural) for these materials are listed in the following tables.

The units of the properties listed below are:
E - psi (x 10^6)
μ - ratio (unitless)
ρ - lbs. / in^3
α - in. / in. / °F (x 10^{-6})
k - BTU/hr-in.-°F
C - BTU/(lb.-°F) [C is a calculated value based on C = k/(ρ x Thermal Diffusivity) where thermal diffusivity is taken from the same source as "k"]
Sm, Sy, Su – ksi

Table 4-1 RV Closure Head Base Material Properties

XXX									
Temp	E	μ	ρ	α	k	C	Sm	Sy	Su
70									
100									
200									
300									
400									
500									
600									
650									
700									
reference	*13.2*	*Typical*	*13.16*	*13.2*	*13.2*	*Calculated*	*13.2*	*13.2*	*13.2*

Table 4-2 Original J-Groove Weld & Buttering and Remaining Original Nozzle

XXX									
Temp	E	μ	ρ	α	k	C	Sm	Sy	Su
70									
100									
200									
300									
400									
500									
600									
650									
700									
reference	*13.2*	*Typical*	*13.16*	*13.2*	*13.2*	*Calculated*	*13.2*	*13.2*	*13.2*

Table 4-3 Repair IDTB Weld and Replacement Nozzle

XXX									
Temp	E	μ	ρ	α	k	C	Sm	Sy	Su
70									
100									
200									
300									
400									
500									
600									
650									
700									
reference	*13.17*	*Typical*	*13.16*	*13.17*	*13.17*	*Calculated*	*13.18*	*13.18*	*13.17*

Table 4-4 RV Head Cladding

XXX									
Temp	E	μ	ρ	α	k	C	Sm	Sy	Su
70							Not used in analysis		
100									
200									
300									
400									
500									
600									
650									
700									
reference	*13.2*	*Typical*	*13.16*	*13.2*	*13.2*	*Calculated*	*n.a.*	*n.a.*	*n.a.*

* Value of xxx is used in this analysis. The impact to the results is negligible.

4.3 Boundary Conditions and Loads

Thermal analysis

Structural Analysis

External loads

5.0 EXTERNAL LOADS

5.1 Applicable Loads

The remaining original nozzle is exposed to the attached piping loads.

Reference 13.13 specifies "Maximum loads for the Palisades CRDM's (worst combinations)" as:

Axial [kips]	Shear [kips]	Mb [in-kips]

Note: these values represent load per "*g*".

To obtain applicable loads, the unit loads are multiplied by the acceleration for CRDM specified in Reference 13.8:

	Design (OBE)	Safe Shutdown (SSE)
Horizontal		
Vertical		

Note: to be consistent with the original calculation (Reference 13.15), also axial unit load is multiplied by the horizontal acceleration.

Thus, the external applicable loads are:

Table 5-1 Applicable external loads

	Axial (F_a) [kips]	Shear (F_s) [kips]	Bending (M_b) [in-kips]
OBE			
SSE			

In addition Reference 13.8 specifies the CRDM SCRAM load of xxx kips each rod. Since this is a dynamic load, it will be conservatively multiplied by a factor of x. (F_{ax_SCRAM} = xxx x x = xxx kips). This load is axially compressive due to the weight of the control rod and its extension shaft (and buffer piston) slamming into the hard stop at the bottom of the dry scram gravity fall stroke. However, conservatively load will be considered as either compression or tension to maximize total stresses.

These loads are evaluated using hand calculation. The stresses due to these loads are added to the ANSYS results where appropriate for the ASME evaluation.

The above loads may be combined with ASME Code condition as follows:

Table 5-2 Load combinations

ASME Code condition	Load combination
Design	Design pressure + OBE or SCRAM(2)
Normal / Upset	Operating pressure + OBE or SCRAM(2)
Emergency	Operating pressure + SSE(1) or SCRAM(2)
Faulted	Operating pressure + SSE or SCRAM(2)
Test	Test pressure

(1) SSE is a Faulted event that is conservatively included in the Emergency Condition.

(2) The SCRAM load is conservatively combined with all conditions except "Test" condition.

5.2 Nozzles Cross Section

The dimensions of the nozzles used for cross section calculation are the same as are listed in Section 4.1. Based on these dimensions, the characteristics are calculated as is listed in the following table, where:

D [in] – Nozzle outside diameter

d [in] – Nozzle inside diameter

$I = \frac{\pi}{64}\left(D^4 - d^4\right)$ [in^4] - Moment of inertia.

$S = \frac{I}{\frac{D}{2}}$ [in^3] - Section Modulus of the nozzle.

$A = \frac{\pi\left(D^2 - d^2\right)}{4}$ [in^2] - Cross-section area of the nozzle.

$A_{in} = \frac{\pi \cdot d^2}{4}$ [in^2] - Inside nozzle cross-section area.

Table 5-3 Nozzle Cross Section

Nozzle No.	D	d	I	S	A	A_{in}
Remaining Original Nozzle						
Replacement Nozzle						

5.3 Remaining Original Nozzle Stress Calculation

Reference 13.8 specifies pressures for the considered ASME Code conditions. The applicable external loads are calculated and listed above (Section 5.1). External loads are combined with ASME Code conditions as is shown in Table 5-2.

Applied pressure loads on the remaining original nozzle for considered ASME Code conditions are as follows:

Table 5-4 Pressure load

ASME Code condition	Pressure P [ksi]	Axial Force $F_{ax\_P} = P \times A_{in}$ [kips]
Design		
Normal / Upset		
Emergency		
Faulted		
Test		

* Since no loads are specified for the Emergency and Faulted conditions, normal operating pressure is used for the purpose of this section.

The nozzle total axial stresses due to external and pressure load, and shear stress due to external load are calculated in the table below, where:

Axial membrane stress due to internal pressure is $\sigma_{ax\_P} = \frac{F_{ax\_P}}{A}$ [ksi]

Axial membrane stress due to external force (F_a) is $\sigma_{ax\_EX} = \frac{F_a}{A}$ [ksi]

Axial bending stress due to external bending (M_b) is $\sigma_{ax\_B} = \frac{M_b}{S}$ [ksi]

Axial membrane stress due to SCRAM load (F_{ax_SCRAM}) is $\sigma_{ax\_SCRAM} = \frac{F_{ax\_SCRAM}}{A}$ [ksi]

Total axial membrane stress is $\sigma_{ax\_M} = \sigma_{ax\_P} \pm \sigma_{ax\_EX} \pm \sigma_{ax\_SCRAM}$

Total axial membrane + bending stress is $\sigma_{ax\_M+B} = \sigma_{ax\_P} \pm \sigma_{ax\_EX} \pm \sigma_{ax\_B} \pm \sigma_{ax\_SCRAM}$ [ksi]

Shear stress due to external force (F_s) is $\tau_s = \frac{F_s}{A}$ [ksi]

Table 5-5 Axial and Shear stress

ASME Code condition	σ_{ax_P}	σ_{ax_EX}	σ_{ax_B}	σ_{ax_SCRAM}	σ_{ax_M}	σ_{ax_M+B}	τ_s
Design							
Normal / Upset							
Emergency							
Faulted							
Test							

The above calculation indicates that the component shear stress caused by shear force is of very low magnitude and significantly below all the ASME Code conditions allowable stress limits; therefore the shear stress components are considered negligible and are not considered any further.

For the remaining original nozzle the axial stresses (caused by the external loads and the internal pressure) are combined with the hoop and radial stresses from the internal pressure. Then stress intensity is calculated as follows:

Hoop stress due to internal pressure is $\sigma_{hoop\_P} = P\frac{D^2 + d^2}{D^2 - d^2}$ [ksi]

Radial stress due to internal pressure is $\sigma_{rad\_P} = -P$ [ksi]

Stress intensity (σ_{int}) is maximum algebraic difference from axial, hoop and radial stress [ksi]

Table 5-6 Membrane Stress intensity

	Principal stresses [ksi]			σ_{int} [ksi]
	Axial	Hoop	Radial	
ASME Code condition	σ_{ax_M}	σ_{hoop_P}	σ_{rad_P}	
Design				
Normal / Upset				
Emergency				
Faulted				
Test				

Table 5-7 Membrane + Bending Stress intensity

	Principal stresses [ksi]			σ_{int} [ksi]
	Axial	Hoop	Radial	
ASME Code condition	σ_{ax_M+B}	σ_{hoop_P}	σ_{rad_P}	
Design				
Normal / Upset				
Emergency				
Faulted				
Test				

These stresses are evaluated in Section 9.1.2.

5.4 Replacement Nozzle Stress Calculation

For the replacement nozzle the external loads are taken from Reference 13.20. Per Appendix A of Reference 13.20 the stress intensity due to the thermal expansion is xxx ksi ("Run_c"). Also the stress intensity due to OBE and flow load is xxx ksi ("Run_b"). Therefore the external loads will result in a maximum stress intensity of xxx ksi. The stresses caused by internal pressure (Table 5-4) are calculated below.

Axial membrane stress due to internal pressure is $\sigma_{ax\_P} = -P$ [ksi]

Hoop stress due to internal pressure is $\sigma_{hoop\_P} = -P$ [ksi]

Radial stress due to internal pressure is $\sigma_{rad\_P} = -P$ [ksi]

Stress intensity (σ_{int}) is maximum algebraic difference from axial, hoop and radial stress [ksi]

Table 5-8 Stress intensity

	Principal stresses [ksi]			σ_{int} [ksi]
	Axial	Hoop	Radial	
ASME Code condition	σ_{ax_P}	σ_{hoop_P}	σ_{rad_P}	
Design				
Normal / Upset				
Emergency				
Faulted				
Test				

Since the stress intensity due to the pressure is zero, the total primary stress intensity in the Replacement nozzle is xxx ksi for all considered conditions.

This stress is evaluated in Section 9.1.3.

5.5 Applicable Stress intensity at the IDTB Weld due to External Loads

The remaining original nozzle is exposed to the external loads.

The total stress intensity due these loads (OBE and SCRAM) is calculated as follows:

Total axial stress is

$\sigma_{ax} = \sigma_{ax\_EX} + \sigma_{ax\_SCRAM} = xxx$ ksi

Where the stresses are taken from Table 5-5 for normal / upset condition.

Note that the remaining original nozzle is roll expanded during the repair. This roll expansion is considered to be hard enough to transfer bending loads to the RVCH and the IDTB weld will not be subjected to these loads. Therefore the axial bending stresses are not included in the total axial stresses. Also the axial membrane stress due to internal pressure is not used since this is already included in the ANSYS transient runs.

Since this is the only significant stress caused by external load (OBE and SCRAM), this axial stress also represents total stress intensity value.

Then $\sigma_{int} = xxx$ ksi

This stress will be used in the ASME Code evaluation (Section 9.2.2 and Section 9.2.3).

6.0 DESIGN CONDITION

The design temperature of xxxF together with the design pressure of xxx psia (Reference 13.1) is applied to the structural model for the design condition analysis. The ANSYS output file for the design conditions stress analysis is "PAL_des_pres.out".

Linearized stress components along predetermined paths through regions of high stress are tabulated in the output file "PAL_des_pres_Path". The location of these paths is shown Figure 9-1. These linearized stresses are used later in Section 9.1.1 for the ASME Code qualification.

Figure 6-1 shows the deformed shape of the model under the design pres sure along with the outline of the un-deformed shape. The stress intensity contours developed in the model under design pressure are shown in Figure 6-2 and Figure 6-3.

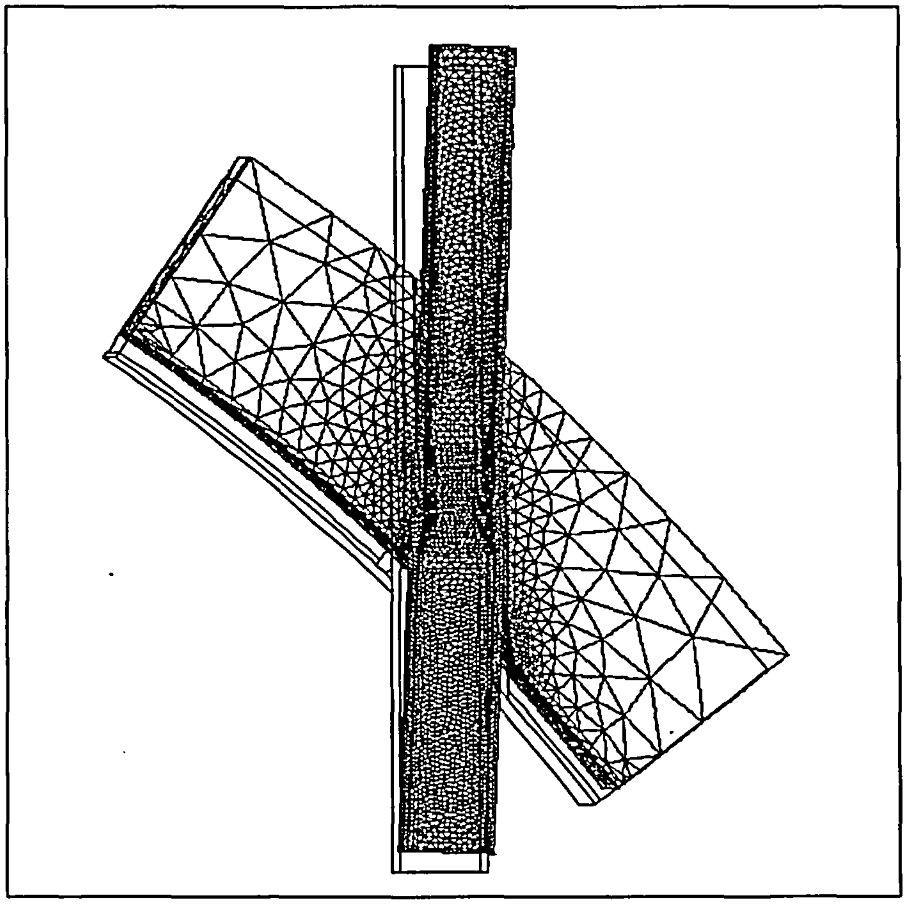

Figure 6-1 Deformed Shape versus Un-deformed Outline

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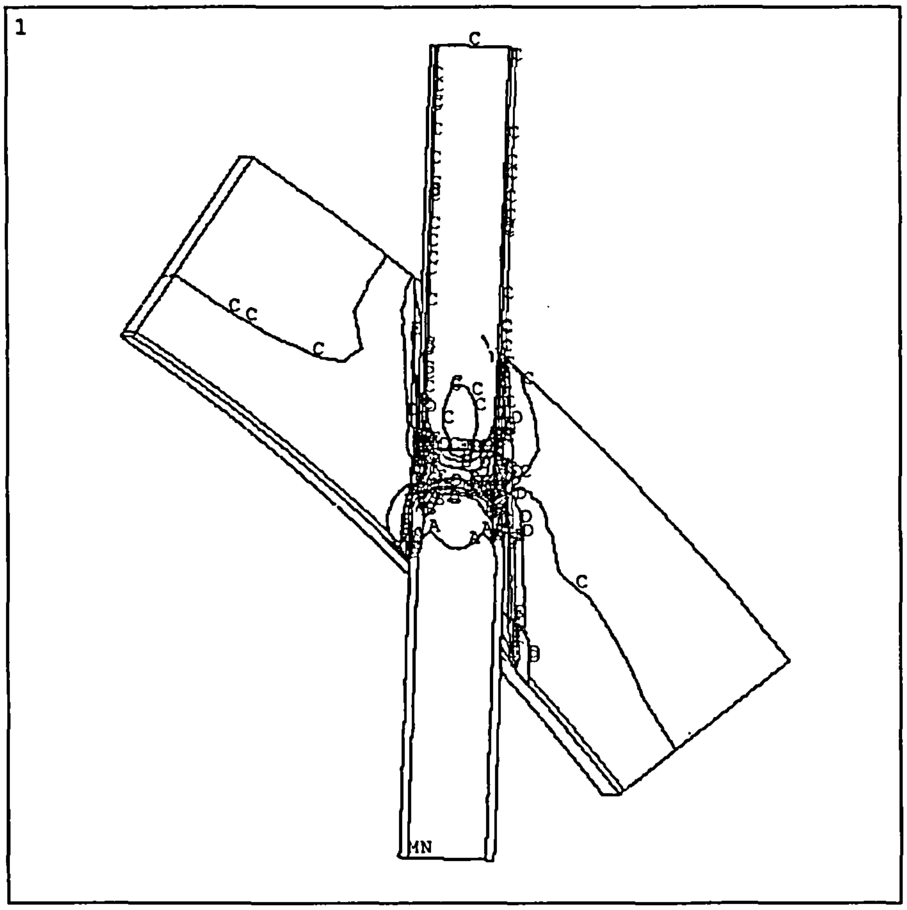

Figure 6-2 Stress Intensity Contours at Design Condition

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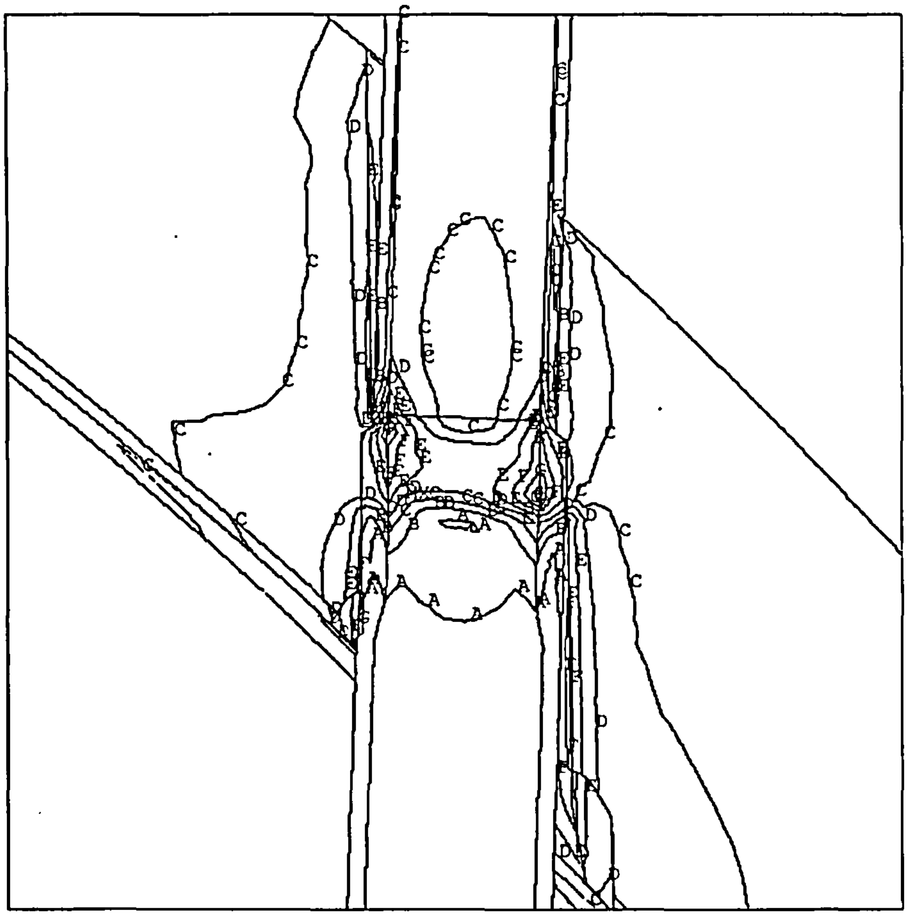

Figure 6-3 Stress Intensity Contours at Design Condition - detail

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7.0 THERMAL ANALYSIS

The operating thermal loads are defined by the thermal transient conditions as contained in Section 4.1.2 of Reference 13.8. Only those transients that cause significant stresses in the CRDM nozzle and RVCH region were considered in this analysis and they are listed below. The numbers of cycles listed below correspond to 40 years of plant design life. Numbers in () refer to the number of cycles for 27 years.

1. Heatup and Cooldown (HUCD) transient* = xxx (xxx) (Reference 13.8)
2. Normal power changes (NPCH) transient = xxx (xxx) (Reference 13.1)
3. Fast power changes (FPCH) transient = xxx (xxx) (Reference 13.1)
4. Normal step power changes (PLUL) transient = xxx (xxx) (Reference 13.1)
5. Loss of Load (LL) transient = xxx (xxx) (Reference 13.8)
6. Loss of Flow (LF) transient = xxx (xxx) (Reference 13.8)
7. Safety valves relieving (SVO) transient = xxx (xxx) (Reference 13.8)
8. Leak Test (Leak) transient = xxx (xxx) (Reference 13.8)

* This transient is also called startup and shutdown in the original reports.

The Steady State pressure variation transient (Reference 13.8, section 4.1.2.6) is only ±xxx psia at operating temperature. This will produce very small stress variation and thus is ignored.
The hydrostatic test consists of xxx cycles with a maximum pressure of xxxx psia. Per §NB-3226 (e), the hydrostatic test is not considered for fatigue qualification.

The reactor coolant temperature varies with time during each transient as shown in Tables 7.1 through 7.8.

Table 7-1 HUCD transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 7-2 NPCH transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 7-3 FPCH transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 7-4 PLUL transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 7-5 LL transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 7-6 LF transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 7-7 SVO transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 7-8 Leak transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Reference 13.8, par. 4.1.2.5 specifies the pressure of xxx psia and Reference 13.1, par. 3.25.4 specifies a hot shut down condition with the minimum temperature of xxx°F for the Leak test transient. The steady state case with pressure of xxx psia and uniform temperature of xxx°F is used as a representative for this transient. Higher temperature will not affect the results appreciably. Note that this transient does not require a thermal transient analysis.

The computer output files for the thermal analyses of the above transients are:

PAL_HUCD_th.out
PAL_NPCH_th.out
PAL_FPCH_th.out
PAL_PLUL_th.out
PAL_LL_th.out
PAL_LF_th.out
PAL_SVO_th.out

The computer output files that provide the temperatures at the selected locations listed in Table 7-9 and shown in Figure 7-1 are:

PAL_HUCD_DeltaT.out
PAL_NPCH_DeltaT.out
PAL_FPCH_DeltaT.out
PAL_PLUL_DeltaT.out
PAL_LL_DeltaT.out
PAL_LF_DeltaT.out
PAL_SVO_DeltaT.out

The temperature gradients between these key locations (Table 7-10) are also listed in the above output files. The results are plotted in Figure 7-2 through Figure 7-8. These figures are used only to show the trend. Specific data is taken from the computer output files. Computer file "PAL_inp_DeltaT.mac" contains definition of the node numbers for temperature and temperature gradients calculation.

Table 7-9 Nodes of Interest for Evaluation of Temperature / Gradients

Location Designation	Node No.	Location

Table 7-10 Temperature gradients of Interest

Gradient Designation	Gradient Location	Gradient Description

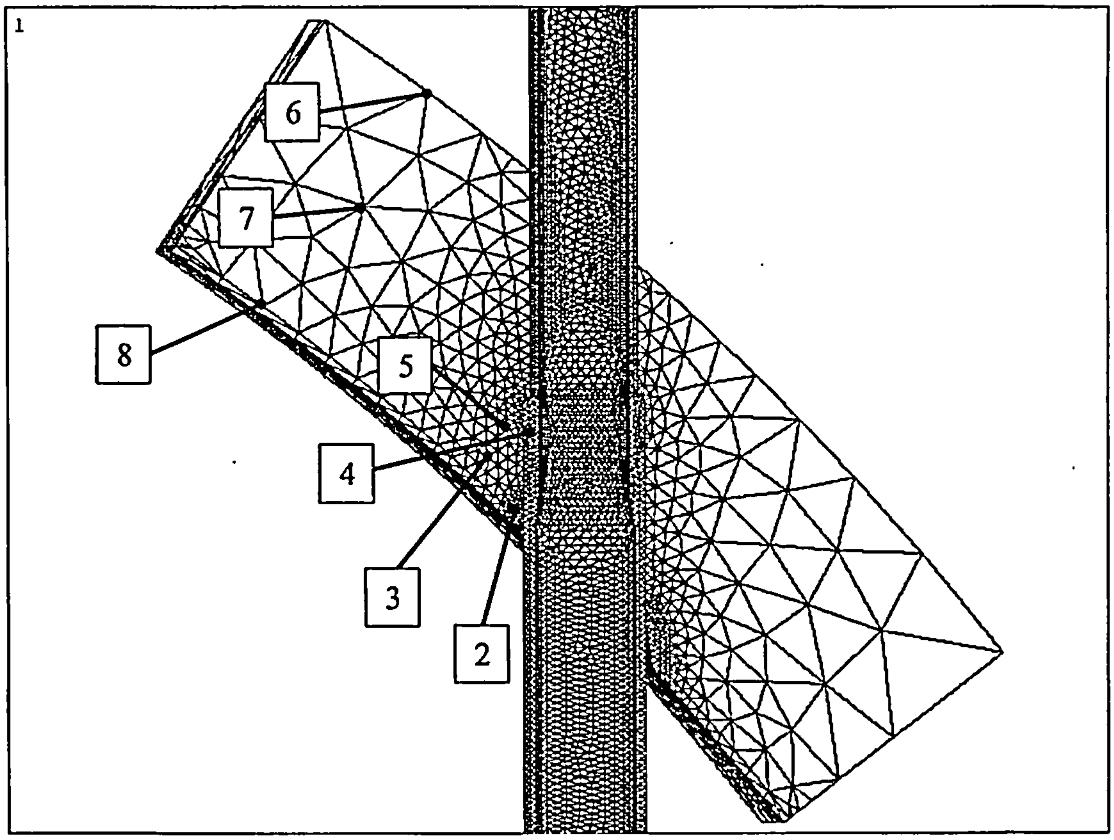

Figure 7-1 Nodes of Interest for Evaluation of Temperature and Temperature Gradient

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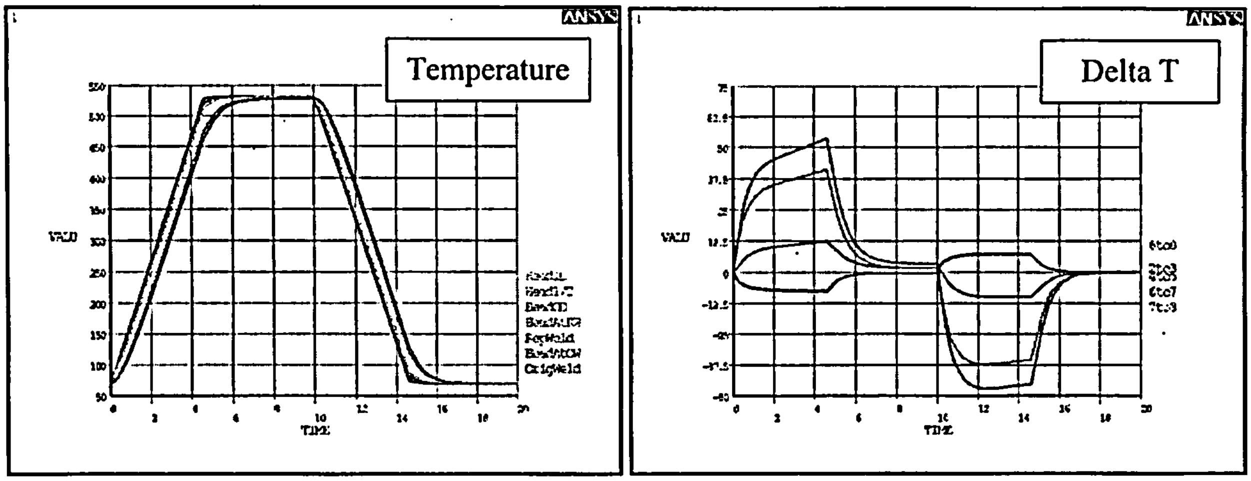

Figure 7-2 Temperature and Thermal Gradients Plots of Selected Locations for HUCD Transient

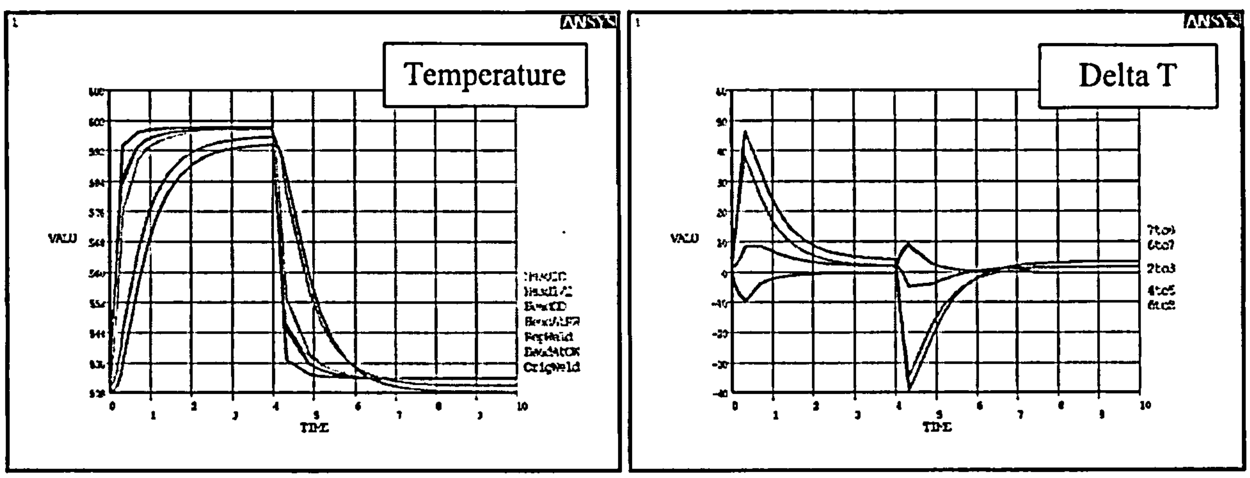

Figure 7-3 Temperature and Thermal Gradients Plots of Selected Locations for NPCH Transient

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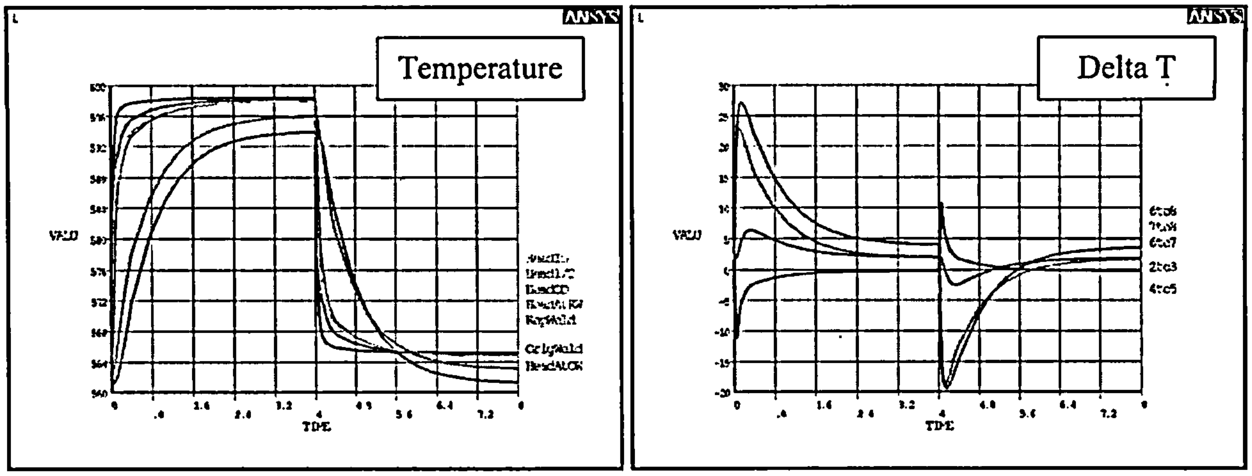

Figure 7-4 Temperature and Thermal Gradients Plots of Selected Locations for FPCH Transient

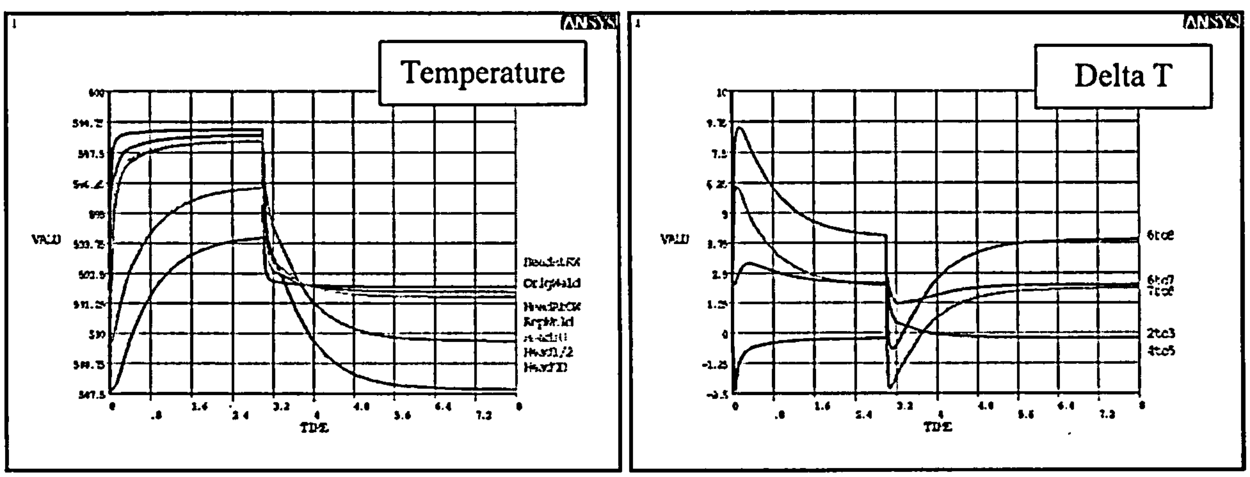

Figure 7-5 Temperature and Thermal Gradients Plots of Selected Locations for PLUL Transient

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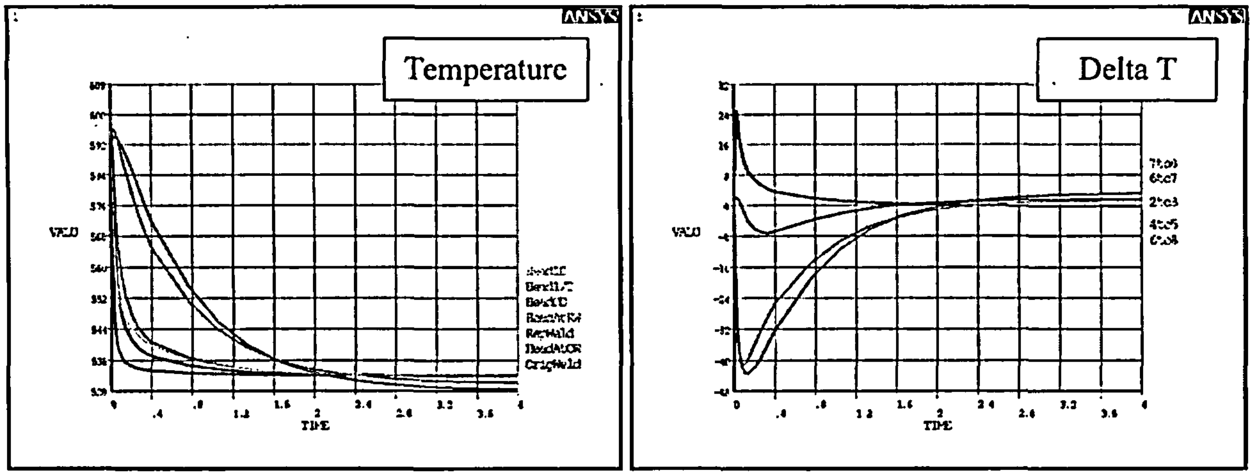

Figure 7-6 Temperature and Thermal Gradients Plots of Selected Locations for LL Transient

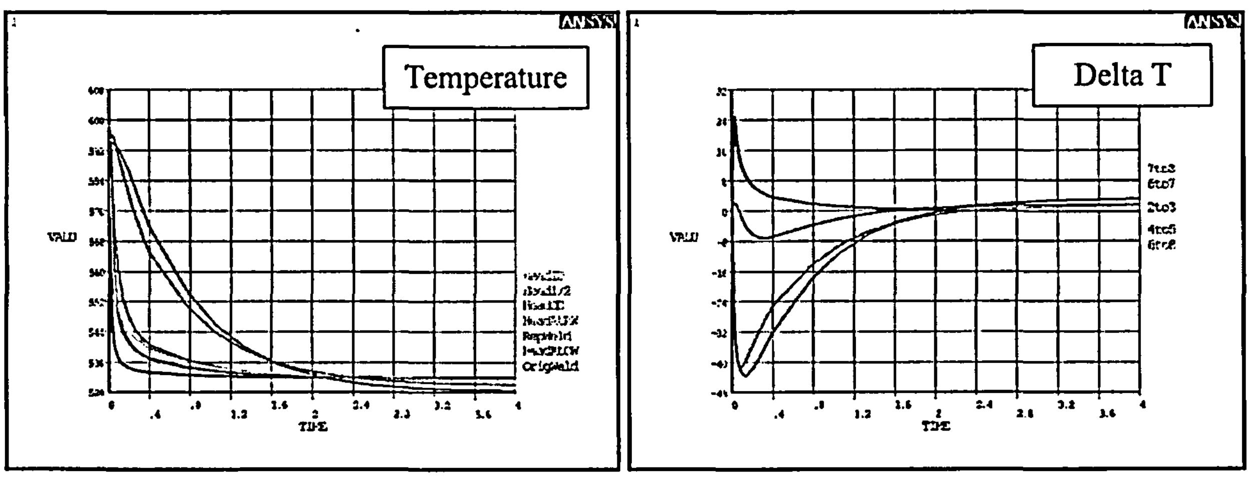

Figure 7-7 Temperature and Thermal Gradients Plots of Selected Locations for LF Transient

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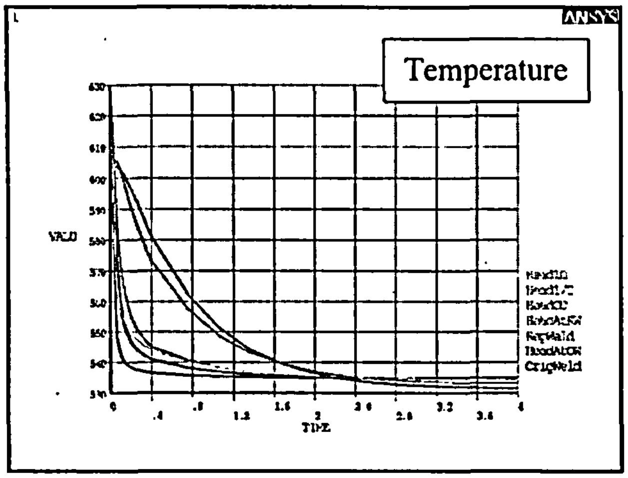

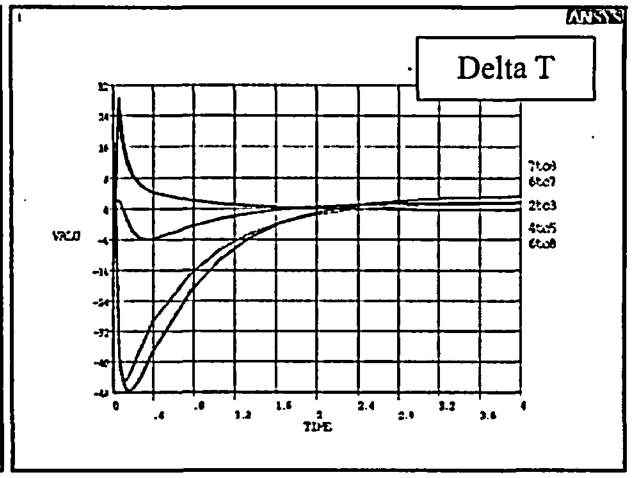

Figure 7-8 Temperature and Thermal Gradients Plots of Selected Locations for SVO Transient

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(for legibility concerns)

8.0 STRUCTURAL ANALYSIS

Stress analyses are performed at the time points listed in Table 8-1 through Table 8-8. These time points include those at which the maximum temperature gradients (maximum thermal stresses) at investigated locations (around the CRDM nozzle) and the maximum pressures occur, as well as those of analytical interest. The nodal temperature at the particular time point is read into the structural model directly from the result file of the thermal analysis (except for the Leak Transient, since in this case a uniform temperature only is applied). The corresponding pressure is obtained from Reference 13.8. The computer output files for the structural analyses are:

PAL_HUCD_st.out
PAL_NPCH_st.out
PAL_FPCH_st.out
PAL_PLUL_st.out
PAL_LL_st.out
PAL_LF_st.out
PAL_SVO_st.out
PAL_Leak_st.out

Table 8-1 Time points of interest for structural analysis of HUCD transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

(1) The maximum temperature gradient occurs at several time points for different locations; this time is considered to be representative for all of these time points.
(2) These time points also envelop the stress results for time=xxx hr (xxx°F and xxx psia).

Table 8-2 Time points of interest for structural analysis of NPCH transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 8-3 Time points of interest for structural analysis of FPCH transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 8-4 Time points of interest for structural analysis of PLUL transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 8-5 Time points of interest for structural analysis of LL transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 8-6 Time points of interest for structural analysis of LF transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 8-7 Time points of interest for structural analysis of SVO transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Table 8-8 Time points of interest for structural analysis of Leak transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

Reference 13.1, par. 3.25.4, defines Leak Test as starting at Hot Shutdown at a temperature greater than xxx°F, which would be similar to the end of Heatup. Thus, the beginning pressure would be about xxx psia, the end pressure xxx psia, and there would be no temperature change. For conservatism (to increase the range), the beginning of the Leak Test is taken as zero stress when doing the fatigue analysis.

9.0 ASME CODE CRITERIA

The ASME code qualification involves meeting two basic sets of criteria to:

1) Assure that failure does not occur due to a single application of the design loads.

2) Assure that failure does not occur due to repetitive service loads.

In general, the Primary Stress Intensity criteria of the ASME Code (Reference 13.2) demonstrate that the design is adequate for the application of design loads.

The ASME Code criteria for cumulative fatigue usage factor assure that the design is adequate for repetitive service loads.

9.1 ASME Code Primary Stress Intensity (SI) Criteria

The following tables list the allowable stresses for ASME Code conditions considered in this section.

Table 9-1 ASME Allowable Stresses @ 650 °F for Design Conditions (per Par. NB-3221 and figure NB-3221-1, Ref. 13.2)

Material	P_m [ksi]	P_L [ksi]	$P_L + P_b$ [ksi]
XXX	26.7	40.05	40.05
XXX	23.3	34.95	34.95

Table 9-2 ASME Allowable Stresses @ 650 °F for Level B (per Par. NB-3223 and figure NB-3221-1, Ref. 13.2)

Material	P_m [ksi]	P_L [ksi]	$P_L + P_b$ [ksi]
XXX	29.37	44.05	44.05
XXX	25.63	38.44	38.44

Table 9-3 ASME Allowable Stresses @ 650 °F for Level C (per Par. NB-3224 and figure NB-3224-1, Ref. 13.2)

Material	P_m [ksi]	P_L [ksi]	$P_L + P_b$ [ksi]
XXX	43.5*	65.25	65.25
XXX	27.96	41.94	41.94

* But not greater than 39.15 ksi for pressure alone.

Table 9-4 ASME Allowable Stresses @ 650 °F for Level D (per Par. NB-3225 and Par. F-1331.1, Ref. 13.2)

Material	P_m [ksi]	P_L [ksi]	$P_L + P_b$ [ksi]
XXX	56.0	84.0	84.0
XXX	56.0	84.0	84.0

Table 9-5 ASME Allowable Stresses @ 100 °F for Test Conditions (per Par. NB-3226, Ref. 13.2)

Material	P_m [ksi]	$P_m + P_b$ [ksi]
XXX	45.0	67.5* (2.15Sy-1.2Pm)*
XXX	31.5	47.25* (2.15Sy-1.2Pm)*

*Note: The primary membrane plus bending stress intensity Pm+Pb shall not exceed the applicable limits given below:

For $P_m \leq 0.67S_y$ $P_m+P_b \leq 1.35\ S_y$; For $0.67S_y < P_m \leq 0.90S_y$ $P_m+P_b \leq (2.15S_y-1.2P_m)$

9.1.1 RVCH Base Material

The ANSYS Post Processor is used to tabulate the stresses along paths through the head and classify them in accordance with the ASME Code Criteria. The Paths are shown in Figure 9-1. Path "Head 1" is taken away from the discontinuity and represents the general membrane stresses in the RV head. Path "Head 2" is taken about one radius away from the penetration and represents the local stresses.

The results from stress classification post processing run (in the local cylindrical coordinate system x, y and z coinciding with the nozzle center line) are contained in the computer file "PAL_des_pres_Path.out".

This run calculates the classified stress components (membrane, bending, and peak) for each of the stress paths shown in Figure 9-1.

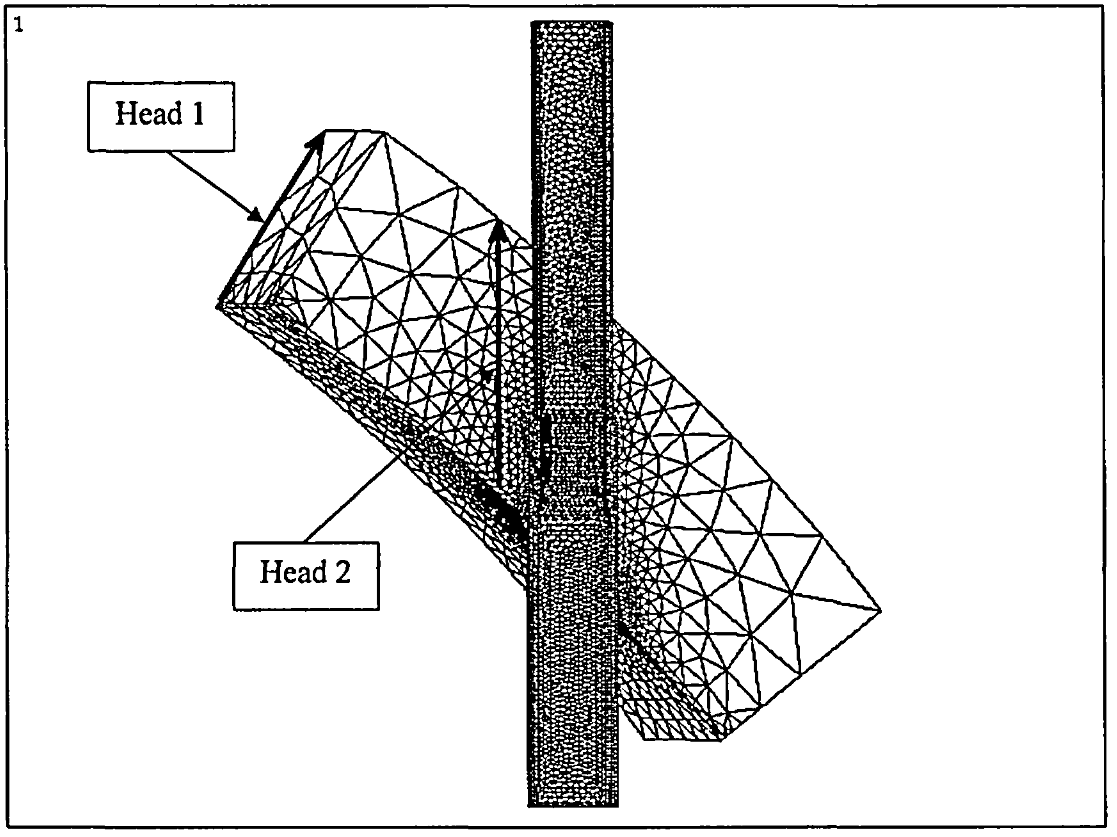

Figure 9-1 Stress Paths through the RVCH

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(for legibility concerns)

9.1.1.1 Primary Stress Intensities for Design Conditions

The analysis of primary stress intensities for the Design Condition is made to satisfy the requirements for the application of design load in accordance with Reference 13.2, NB-3221.

Other related criteria include the design limits for minimum required pressure thickness (NB-3324) and reinforcement area (NB-3330). The requirements for minimum required pressure thickness and the reinforcement area are effectively addressed by meeting NB-3221.1, NB-3221.2 and NB-3221.3 as shown below.

NB-3221.1 – General Primary Membrane Stress Intensity ($P_m \leq 1.0S_m$)

The applicable value occurs remote from discontinuities and includes no local effect. Path 'Head1' (called as "Path1" in output file) depicts an appropriate location for the RVCH base material. From "PAL_des_pres_Path.out", the membrane stress intensity of path 'Head1' is **13.32** ksi. For the RVCH base material, 1.0*Sm = **26.7** ksi (Table 9-1). Therefore, the requirement is met.

NB-3221.2 – Local Primary Membrane Stress Intensity ($P_L \leq 1.5S_m$)

The applicable value occurs across any solid section, considering discontinuities but not stress concentrations. Path 'Head2' (called as "Path2" in output file), which is taken one penetration radius away from the discontinuity into the head, depicts an appropriate location for the RVCH base material. From "PAL_des_pres_Path.out", the local membrane stress intensity of path 'Head2' is **15.05** ksi. For the RVCH base material, allowable stress = **40.05** ksi (Table 9-1). Therefore, the requirement is met.

NB-3221.3 – Local Membrane + Primary Bending Stress Intensity ($P_L + P_b \leq 1.5S_m$)

The applicable value is taken from path 'Head2' (called as "Path2" in output file). The maximum membrane + bending stress intensity of path 'Head2' is **16.44** ksi. For the RVCH base material, allowable stress = **40.05** ksi (Table 9-1). Therefore, the requirement is met. Note, this is very conservative since Table NB-3217-1 of the ASME Code classifies this type of wall bending stress as a secondary stress

9.1.1.2 Primary Stress Intensities for Level B Conditions

Reference 13.8 indicates that there are three Upset condition transients – Loss of Load, Loss of Flow and Safety valves relieving. Per Reference 13.8, the maximum internal pressure is 2750 psia (for steady-state), the temperature varies from ~535°F to 643°F. Since the pressure is higher than the Design Condition pressure, the pressure stresses induced by the Upset condition need to be evaluated and considered in this paragraph.

To quantify the Primary Stresses due to Upset Condition, the stresses of the Design Condition are multiplied by the ratio of the respective pressure values (xxx/xxx=xxx). To account for the difference in temperatures, the stresses are conservatively again multiplied by the maximum ratio

of modulus of elasticity at xxx°F (minimum transient temperature) and at xxx° (Design Temperature) for the RVCH base material.

$$F = \frac{E_c}{E_h}\frac{P_t}{P_D} = \, = 1.14$$

Where E_c = xxx psi (elastic modulus at xxx°F) and E_h = xxx psi (elastic modulus at the design temperature of xxx°F) (Table 4-1). P_t and P_D are the transient and design pressure (Reference 13.8).

The calculated stresses due to Upset Condition and allowable stresses are presented in the following table.

	Design Stress [ksi]	Upset Stress [ksi]	Level B Allowable Stresses (Table 9-2) [ksi]
P_m	13.32	15.18	29.37
P_L	15.05	17.16	44.05
$P_L + P_b$	16.44	18.74	44.05

Since all Upset Condition stresses are lower than the allowable stresses, the requirement is met.

9.1.1.3 Primary Stress Intensities for Level C Conditions

Reference 13.8 indicates that there is no transient specified as an Emergency. Therefore, no additional evaluation for the RVCH is required.

9.1.1.4 Primary Stress Intensities for Level D Conditions

Reference 13.8 indicates that there is no transient specified as a Faulted. Therefore, no additional evaluation for the RVCH is required.

9.1.1.5 Primary Stress Intensities for Test Conditions

The RVCH nozzles are affected by two test conditions; Hydrotest and Leak test (Reference 13.8). Hydrotest is controlling because the RVCH is subjected to a pressure of xxx psia and temperature of xxx°F.

The pressure on this transient is greater than those calculated for the Design Condition. To quantify the Primary Stresses due to Hydrotest Condition, the stresses of the Design Condition are multiplied by the ratio of the respective pressure values (xxx/xxx=xxx).. To account for the difference in temperatures, the stresses are conservatively again multiplied by the ratio of

modulus of elasticity at xxx°F (hydro test temperature) and at xxx° (Design Temperature) for the RVCH base material.

$$F = \frac{E_c}{E_h}\frac{P_t}{P_D} = \ = 1.40$$

Where E_c = xxx psi (the "cold" elastic modulus at xxx°F) and E_h = xxx psi (the "hot" elastic modulus at the design temperature of xxx°F) (Table 4-1). P_t and P_D are the test and design pressure (Reference 13.8).

The test stresses and allowable stresses are presented in the following table. The stresses for the Design Condition are taken from output file "PAL_des_pres_Path.out" path 'Head1' (called as "Path1" in output file).

	Design Stress [ksi]	Test Stress [ksi]	Test Allowable Stresses (Table 9-5) [ksi]
General Membrane	13.32	18.65	45.0
General Membrane + Bending	15.37	21.52	67.5

Since all Test Condition stresses are lower than the Test allowable stresses, the Test stresses are acceptable.

9.1.2 Remaining Original Nozzle

For the qualification of the primary stresses in the remaining original nozzle, the maximum membrane and membrane plus bending stresses calculated in Section 5.3 are compared to the allowable stresses (Table 9-1 through Table 9-5).

9.1.2.1 Primary Stress Intensities for Design Conditions

The calculated primary stress intensities for the Design Condition are compared against the ASME Code allowable limits for Design Loadings in accordance with Reference 13.2, NB-3221.

Other related criteria include the design limits for minimum required pressure thickness (NB-3324) and reinforcement area (NB-3330). The requirements for minimum required pressure thickness and the reinforcement area are effectively addressed by meeting NB-3221.1, NB-3221.2 and NB-3221.3 as shown below.

NB-3221.1 – General Primary Membrane Stress Intensity ($P_m \le 1.0S_m$)

The maximum General Primary Membrane stress intensity in the remaining original nozzle for design condition as calculated in Table 5-6 is **16.183** ksi. This stress is compared with the general membrane allowable for the design condition for xxx = **23.3** ksi (Table 9-1). Since the maximum stress is lower than the allowable stress, the criterion is met.

NB-3221.2 – Local Primary Membrane Stress Intensity ($P_L \le 1.5S_m$)

The maximum Local Primary Membrane stress intensity in the remaining original nozzle for design condition as calculated in Table 5-6 is **16.183** ksi. This stress is compared with the local membrane allowable for the design condition for xxx = **34.95** ksi (Table 9-1). Since the maximum stress is lower than the allowable stress, the criterion is met.

NB-3221.3 – Local Membrane + Primary Bending Stress Intensity ($P_L + P_b \le 1.5S_m$)

The maximum Primary Membrane plus Bending stress intensity in the remaining original nozzle for design condition as calculated in Table 5-7 is **23.601** ksi. This stress is compared with the membrane plus bending allowable for the design condition for xxx = **34.95** ksi (Table 9-1). Since the maximum stress is lower than the allowable stress, the criterion is met.

9.1.2.2 Primary Stress Intensities for Level B (Upset) Conditions

The calculated primary stress intensities for the Level B Service Conditions are compared against the ASME Code allowable limits for Level B Service Loadings in accordance with Reference 13.2, NB-3223.

Primary Stress Intensity Criteria (NB-3223):

The maximum primary stress intensities are calculated in the Table 5-6 and Table 5-7. These stresses are compared against the allowable stresses (Table 9-2).

	Upset Stresses (Table 5-6 and Table 5-7) [ksi]	Level B Allowable Stresses (Table 9-2) [ksi]
P_m	17.801	25.63
P_L	17.801	38.44
$P_L + P_b$	24.411	38.44

Since all Upset Condition stresses are lower than the allowable stresses, the requirement is met.

9.1.2.3 Primary Stress Intensities for Level C (Emergency) Conditions

The calculated primary stress intensities for the Level C Service Conditions are compared against the ASME Code allowable limits for Level C Service Loadings in accordance with Reference 13.2, NB-3224.

Primary Stress Intensity Criteria (NB-3224):

The maximum primary stress intensities are calculated in the Table 5-6 and Table 5-7. These stresses are compared against the allowable stresses (Table 9-3).

	Emergency Stresses (Table 5-6 and Table 5-7) [ksi]	Level C Allowable Stresses (Table 9-3) [ksi]
P_m	15.295	27.96
P_L	15.295	41.94
$P_L + P_b$	32.098	41.94

Since all Emergency Condition stresses are lower than the allowable stresses, the requirement is met.

9.1.2.4 Primary Stress Intensities for Level D (Faulted) Conditions

The calculated primary stress intensities for the Level D Service Conditions are compared against the ASME Code allowable limits for Level D Service Loadings in accordance with Reference 13.2, NB-3225.

Primary Stress Intensity Criteria (NB-3225):

The maximum primary stress intensities are calculated in the Table 5-6 and Table 5-7. These stresses are compared against the allowable stresses (Table 9-4).

	Faulted Stresses (Table 5-6 and Table 5-7) [ksi]	Level D Allowable Stresses (Table 9-4) [ksi]
P_m	15.295	56.0
P_L	15.295	84.0
$P_L + P_b$	32.098	84.0

Since all Faulted Condition stresses are lower than the allowable stresses, the requirement is met.

9.1.2.5 Primary Stress Intensities for Test Conditions

The calculated primary stress intensities for the Test Conditions are compared against the ASME Code allowable limits for Test Loadings in accordance with Reference 13.2, NB-3226.

Primary Stress Intensity Criteria (NB-3226):

The maximum primary stress intensities are calculated in the Table 5-6 and Table 5-7. These stresses are compared against the allowable stresses (Table 9-5).

	Test Stresses (Table 5-6 and Table 5-7) [ksi]	Test Allowable Stresses (Table 9-5) [ksi]
P_m	20.229	31.5
$P_m + P_b$	20.229	47.25

Since all Test Condition stresses are lower than the allowable stresses, the requirement is met.

9.1.3 Replacement Nozzle

For the qualification of the primary stresses in the replacement nozzle, the maximum stresses from the Design, Emergency, Faulted and Test conditions are compared to the Design allowable stresses (these allowable stresses are the lowest of all of these considered conditions, see Table 9-1 to Table 9-5). If the stresses are less than the design general membrane allowable stresses no further justification is required.

Primary Stress Intensity Criteria (NB-3221.1, NB-3221.2 and NB-3221.3):

The maximum stress intensity calculated in Section 5.4 is **9.7** ksi. This stress is compared with the general membrane allowable for the design condition for xxx = **23.3** ksi (Table 9-1). Since the maximum stress is lower than the design general membrane allowable these service levels are conservatively satisfied. Thus, no further qualification is required.

9.1.4 Partial Penetration Weld Size

The repair configuration consists of two partial penetration weld connections – 1] between the remaining original nozzle and the RVCH; 2] between the replacement nozzle and the RVCH. The ASME Code required geometry of this weld is specified in paragraph NB-3352.4(d) (Reference 13.2) and Figure NB-4244(d)-1 (Reference 13.2).

Remaining Original Nozzle-to-RVCH weld

Nominal thickness of remaining original nozzle, $t_n = (D - d) / 2 = (xxx - xxx) / 2 = xxx$ in

(Diameters 'D' and 'd' are taken from Section 4.1)

The required dimensions of weld connection are:

Minimal depth of the weld attachment along head is 1 ½ t_n = xxx in

Minimal depth of the weld is ¾ t_n = xxx in

Minimal thickness of the weld is ¾ t_n = xxx in

Minimal throat thickness of the weld $t_c = 0.7\ t_n$ = xxx in

As depicted in Figure 9-2 below, the actual repair weld dimensions are larger than the ASME Code requirements. Therefore, the weld sizing requirement is met.

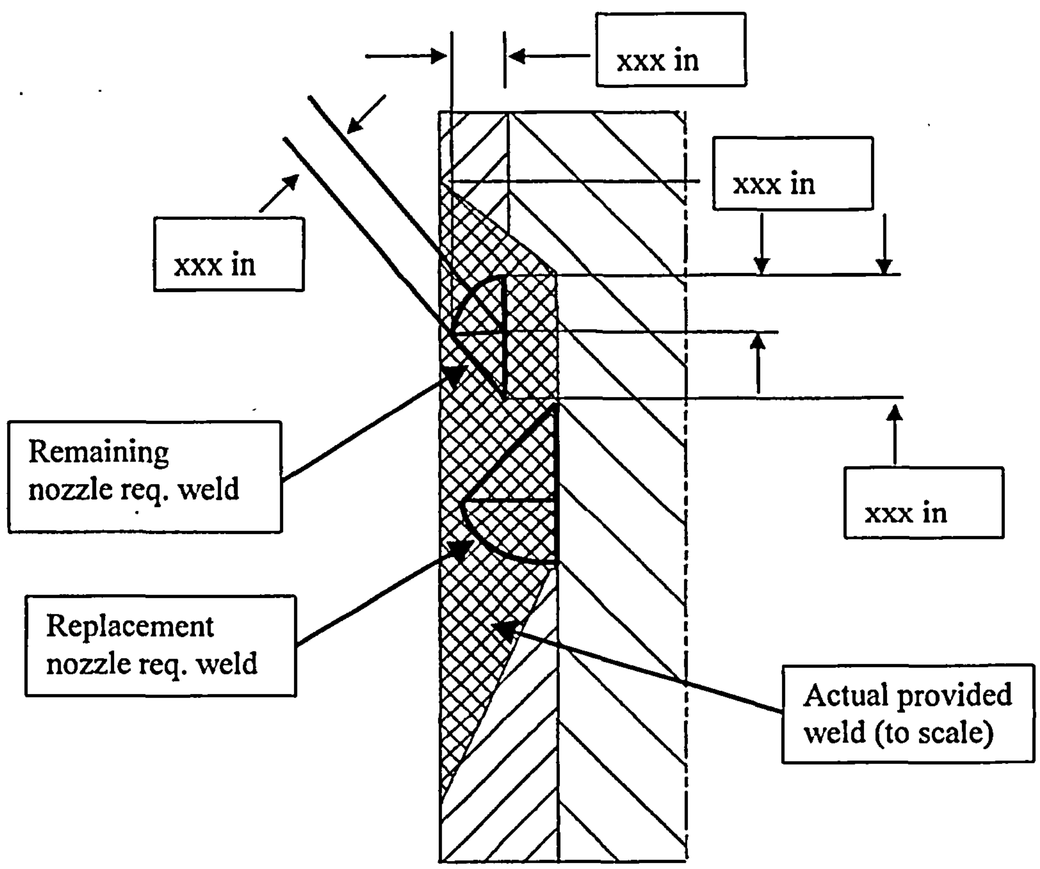

Figure 9-2 Dimensions of actual repair weld between remaining original nozzle and RVCH

Replacement Nozzle-to-RVCH weld

Nominal thickness of replacement nozzle, $t_n = (D - d) / 2 = (xxx - xxx) / 2 = xxx$ in

(Diameters 'D' and 'd' are taken from Section 4.1)

The required dimensions of weld connection are:

Minimal depth of the weld attachment along nozzle is 1 ½ t_n = xxx in

Minimal depth of the weld in Lower Head is ¾ t_n = xxx in

Minimal thickness of the weld is ¾ t_n = xxx in

Minimal thickness of the weld in perpendicular direction $t_c = 0.7\ t_n$ = xxx in

As depicted in Figure 9-3 below, the actual repair weld dimensions are larger than the ASME Code requirements. Therefore, the weld sizing requirement is met.

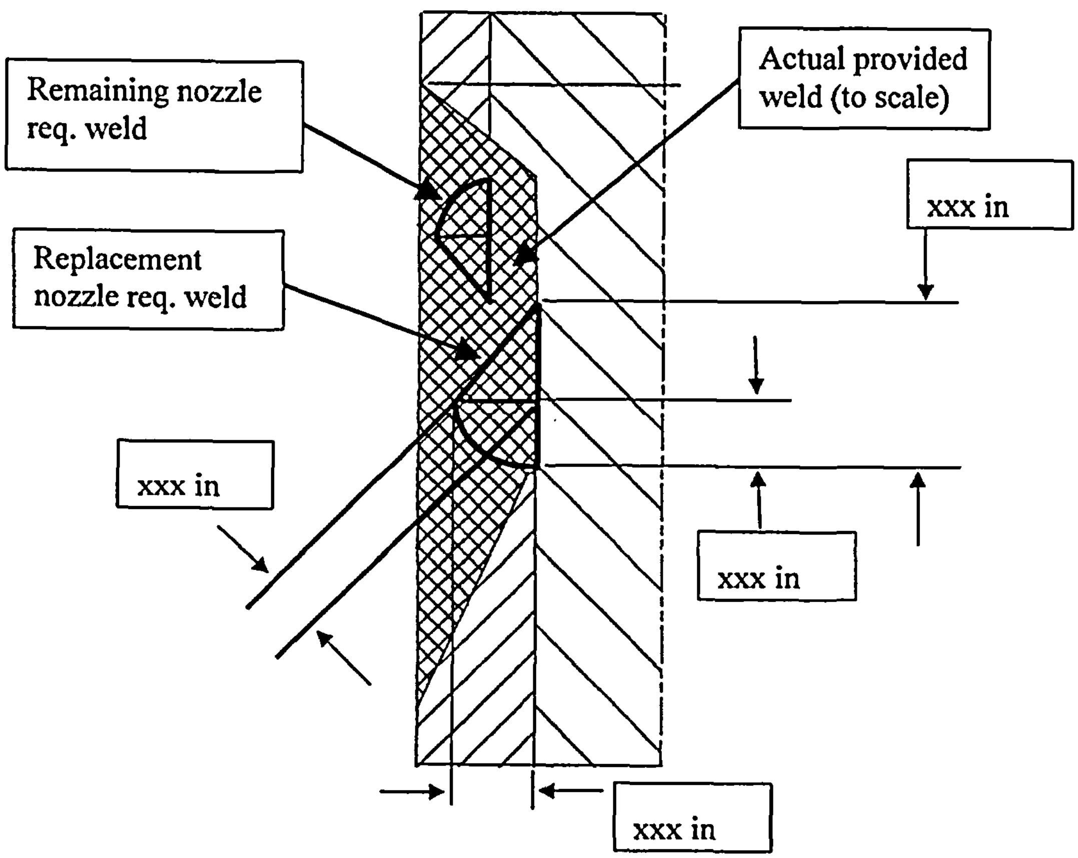

Figure 9-3 Dimensions of actual repair weld between replacement nozzle and RVCH

9.2 ASME Code Primary + Secondary Stress Intensity (SI) Criteria

As stated previously, the analyses of stresses for transient conditions are required to satisfy the requirements for the repetitive loadings. The following discussion describes the fatigue analysis process employed herein for the repair design.

Overall stress levels are reviewed and assessed to determine which model locations require detailed stress/fatigue analysis. The objective is to assure that:

1. The most severely stressed locations are evaluated.

2. The specified region is quantitatively qualified.

9.2.1 Path Stress Evaluation

The structural analysis of the transients indicates that the locations of high stresses are at the repair weld and the adjacent RVCH. The ANSYS Post Processor is used to tabulate the linearized stresses along paths through these locations and classify them in accordance with the ASME Code Criteria (i.e., membrane, membrane + bending, total etc). These paths are defined at the repair weld (material xxx) and the head area (material xxx) to allow stress evaluation in these materials separately. Review of the stress results and experience with analyses of similar configurations indicates that these sections include the location of the maximum stress/usage.

Note that paths in the nozzles are not required for the fatigue analysis, since these locations show smaller stresses, a FSRF of 2.0 can be used and the high alloy fatigue curve can be used for analysis.

The paths are shown in Figure 9-4 to Figure 9-5 and are described in Table 9-6. For post processor calculation, the definition of these paths is contained in the computer file "PAL_path_fat.mac". The linearized stress components for these paths are contained in the following computer output files:

PAL_HUCD_fat.out	PAL_LL_fat.out
PAL_NPCH_fat.out	PAL_LF_fat.out
PAL_FPCH_fat.out	PAL_SVO_fat.out
PAL_PLUL_fat.out	PAL_Leak_fat.out

Table 9-6 Paths Description

Path Name	Inside Node No.	Outside Node No.	Path Location
Path1			Repair temper bead weld area (xxx)
Path2			
Path3			
Path4			
Path5			
Path6			
Path7			RVCH area (xxx)
Path8			
Path9			
Path10			

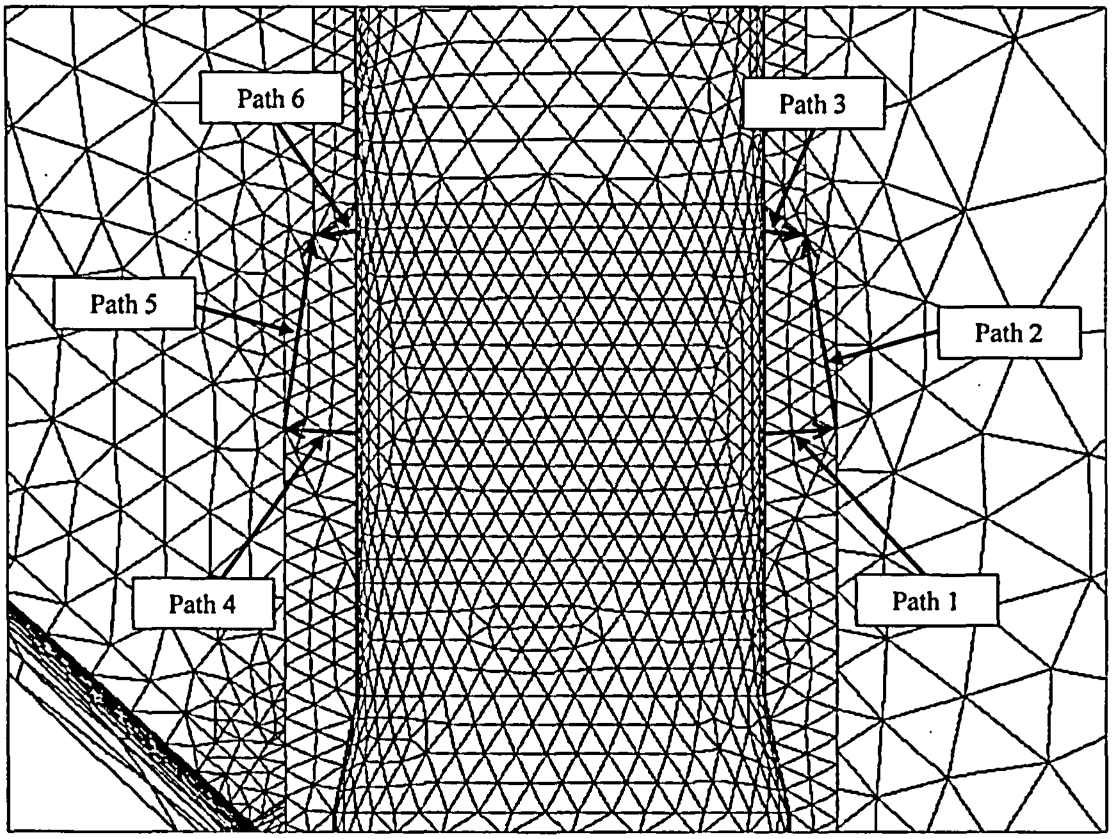

Figure 9-4 Stress Paths at the Repair Temper Bead Weld Area

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Karl Kral 12-3-2004
(for legibility concerns)

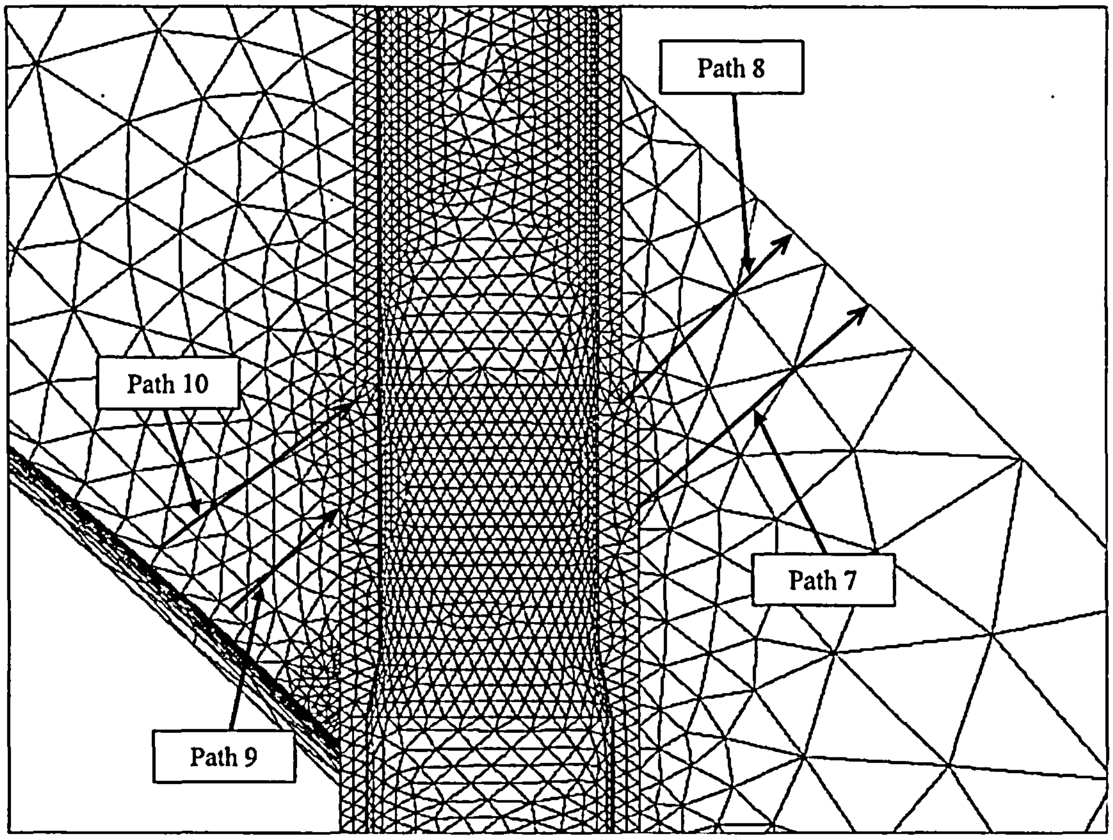

Figure 9-5 Stress Path at the RVCH Area

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(for legibility concerns)

9.2.2 Primary + Secondary Stress Intensity Range

The computer program Stress Range version 1.9 (Reference 13.6) is used to calculate membrane + bending stress intensity range based on the method prescribed in paragraph NB-3216.2 of the ASME Code. The computer run containing the results of the stress range calculation for membrane + bending stresses is PAL_Range(M+B).txt. Note that the Zero Stress State (ZSS) is included in this run.

The maximum membrane + bending range values as determined in this run are compared directly to the Primary + Secondary Stress Intensity Range criteria of the ASME Code. The summary of Maximum Stress Intensity Ranges is tabulated in Table 9-7

Table 9-7 Summary of Maximum Primary + Secondary Stress Intensity Range

Path Name	Maximum Primary + Secondary SI Range at Inside Node. [psi]	Maximum Primary + Secondary SI Range at Outside Node. [psi]	Path Location
PATH1			Repair weld area (xxx)
PATH2			
PATH3			
PATH4			
PATH5			
PATH6			
PATH7			RVCH area (xxx)
PATH8			
PATH9			
PATH10			

Maximum Primary + Secondary Stress Intensity Range Qualification (NB 3222.2):

The maximum Primary + Secondary Stress Intensity Range in the entire model is **xxx ksi** (Path 6, Inside Node, Table 9-7). To this we need to add the external nozzle load stress of 5.985 ksi, calculated in Section 5.5. Then xxx + xxx = **63.431 ksi**

Maximum allowable Primary + Secondary Stress Intensity Range for the xxx material is 3*Sm = **69.9 ksi** (From Table 4-3, Sm = 23.3 ksi)

Thus, the ASME Code requirement is met.

For the xxx material, the maximum Primary + Secondary Stress Intensity Range is **xxx ksi** (Path 9, Inside Node, Table 9-7). Reference 13.20 Section 9.0 calculates the stress intensity ranges due to external loads in the connection IDTB weld – replacement nozzle. These stresses are conservatively added to the ranges due to transient operating. The stresses are xxx + xxx = xxx ksi. Thus the total is xxx + xxx = 41.361 ksi

Maximum allowable Primary + Secondary Stress Intensity Range for the xxx material is 3*Sm = **80.1 ksi** (From Table 4-1, Sm = 26.7 ksi)

Thus, the ASME Code requirement is met.

9.2.3 Fatigue Usage Factor Calculation

For consideration of the fatigue usage, the Peak Stress Intensity Ranges are calculated. These values must include the 'total' localized stresses.

The geometry of the original and the repaired design results in a crevice-like configuration between the nozzle OD and the head penetration bore diameter. Therefore, the linearized 'membrane + bending' stress intensity range ("PAL_Range(M+B).txt") at the crevice-like location is multiplied by a Fatigue Strength Reduction Factor (FSRF) of 4.0 (NB-3352.4(d), Reference 13.2) to represent the Peak Stress Intensity Range.

The model used in the analysis may not depict all of the potential peak stresses for the fatigue analysis at the other locations. Therefore to bound the potential effect of this consideration, the other locations used in fatigue analysis are conservatively multiplied by a FSRF of 2.0.

The resulting values are confirmed to be greater than the 'total' stress intensities calculated directly from the model.

The following pages contain the calculation of the cumulative fatigue usage factor for the limiting point. The usage factor is calculated based on the design cycles shown in Reference 13.8 and Reference 13.1.

Per Reference 13.14, the maximum existing usage factor for the original nozzle is xxx for xxx years. Reference 13.14 also shows the existing usage factor of xxx for the Head Flange. Since this location is evaluated as the critical location of the Head, it is considered, that this is the maximum existing usage factor for the RVCH material. Therefore, this calculation considers the existing usage factor in repair design additional life calculation. Conservatively the xxx usage factor for xx years is added to the usage calculated from this analysis without adjusting for the years in service.

Upon reviewing the stress range results (from "PAL_Range(M+B).txt") and after taking into account the FSRF=4 for crevice-like location and FSRF=2 for the other locations, it is determined that the SI Ranges at path "Path5" outside node #14770 produce the highest usage factor for upper part of the IDTB weld connection (connected to the remaining original nozzle) and SI Range at path "Path9" outside node #11181 produce the highest usage factor for the lower part of the IDTB weld connection (connected to the replacement nozzle). Two locations are investigated because remaining original nozzle and replacement nozzle are exposed to the different external loads which are included in the fatigue calculation. Therefore, the fatigue qualification for these two locations is shown in this section. Conservatively, the low alloy fatigue curve is used for both locations, since these triple points also contain RVCH material.

The following calculation is provided to show the usage factor for xxx years of operation.

"Path5" outside node #14770 fatigue calculation:

EVALUATION TITLE:	Palisades CRDM Nozzle IDTB Weld Repair Analysis – Path 5, outside node

REFERENCE: PAL_Range(M+B).txt

MATERIAL: RVCH
TYPE: xxx
UTS (psi) = 80000 (at T = 100°F)
E matl (psi) = xxx (at T = xxx°F) [1] E ratio = ('E curve' / 'E analysis')

	RANGE NUMBER	TRANSIENTS WITH RANGE EXTREMES	REQ'D CYCLES 27 years	PEAK SI RANGE	E mat	S alt	(E ratio) x S alt	ALLOWABLE CYCLES "N"	USAGE FACTOR "U"
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
								Total Low-Alloy Usage =	xxx

Note: The 'Peak SI Range' = 'Linearized Membrane + Bending' x Fatigue Strength Reduction Factor (FSRF)

For Range 1, 'Linearized Memb + Bending' SI Range =	[2]	ksi;	FSRF=	4.0	
For Range 2, 'Linearized Memb + Bending' SI Range =		ksi;	FSRF=	4.0	
For Range 3, 'Linearized Memb + Bending' SI Range =		ksi;	FSRF=	4.0	
For Range 4, 'Linearized Memb + Bending' SI Range =		ksi;	FSRF=	4.0	
For Range 5, 'Linearized Memb + Bending' SI Range =		ksi;	FSRF=	4.0	
For Range 6, 'Linearized Memb + Bending' SI Range =		ksi;	FSRF=	4.0	
For Range 7, 'Linearized Memb + Bending' SI Range =		ksi;	FSRF=	4.0	
For Range 8, 'Linearized Memb + Bending' SI Range =		ksi;	FSRF=	4.0	

[1] Note that T=xxx°F is approximately the maximum temperature occurring during the plant operating.

[2] Reference 13.1 shows that the total number of OBE cycles is xxx and numbers of cycles for SCRAM load is xxx. Per Calculation in Section 5.5, the stress intensity range due to OBE and SCRAM event in the Remaining Original Nozzle is xxx ksi. Conservatively, this stress intensity range is added to the highest range for the first xxx cycles (prorated to xxx cycles for xxx years).

Usage = xxx + xxx = 0.5866 < 1.0. Therefore, the ASME Code requirement is met for this location.

"Path9" outside node #11181 fatigue calculation:

EVALUATION TITLE:	Palisades CRDM Nozzle IDTB Weld Repair Analysis – Path 9, outside node

REFERENCE: PAL_Range(M+B).txt

MATERIAL: RVCH
TYPE: xxx
UTS (psi) = 80000 (at T = 100°F)
E matl (psi) = xxx (at T = xxx°F)[1] E ratio = ('E curve' / 'E analysis')

	RANGE NUMBER	TRANSIENTS WITH RANGE EXTREMES	REQ'D CYCLES 27 years	PEAK SI RANGE	E mat	S alt	(E ratio) x S alt	ALLOWABLE CYCLES "N"	USAGE FACTOR "U"
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
								Total Low-Alloy Usage =	xxx

Note: The 'Peak SI Range' = 'Linearized Membrane + Bending' x Fatigue Strength Reduction Factor (FSRF)

For Range 1, 'Linearized Memb + Bending' SI Range =	[2]	ksi;	FSRF=	4.0	
For Range 2, 'Linearized Memb + Bending' SI Range =	[2]	ksi;	FSRF=	4.0	
For Range 3, 'Linearized Memb + Bending' SI Range =	[2]	ksi;	FSRF=	4.0	
For Range 4, 'Linearized Memb + Bending' SI Range =	[2]	ksi;	FSRF=	4.0	
For Range 5, 'Linearized Memb + Bending' SI Range =	[2]	ksi;	FSRF=	4.0	
For Range 6, 'Linearized Memb + Bending' SI Range =	[2]	ksi;	FSRF=	4.0	
For Range 7, 'Linearized Memb + Bending' SI Range =	[2]	ksi;	FSRF=	4.0	
For Range 8, 'Linearized Memb + Bending' SI Range =	[2]	ksi;	FSRF=	4.0	

(1) Note that T=xxx°F is approximately the maximum temperature occurring during the plant operating.

(2) Reference 13.20 Section 9.0 calculates the stress intensity ranges due to external loads in the connection IDTB weld – replacement nozzle. These stresses are conservatively added to the ranges due to transient operating. Reference 13.20 also specifies number of applicable cycles for stresses due to external loads and how these stresses may be combined.

Usage = xxx + xxx = 0.7236 < 1.0. Therefore, the ASME Code requirement is met for this location.

10.0 CONSIDERATION OF CORROSION OF RVCH BASE MATERIAL

The design configuration of the nozzle repair results in a small area of the RVCH base material (Low Alloy Steel xxx) being exposed to continuous contact with Reactor Coolant water. The chemistry of the Reactor Coolant combined with the properties of the RVCH wall material result in corrosion of the wetted surface.

The corrosion rate is determined to be xxx inch per year (Reference 13.7). At this rate, the total surface corrosion after xxx years of plant life (see Section 3.11 of Reference 13.1) is only 0.086 inch. This small amount of corrosion volume loss will not have a significant impact on the analysis.

Note that the loss of metal is expected to be much smaller in the annulus between the nozzle OD the bore due to the lack of flow. However, for conservatism, the loss of metal is assumed to be through the thickness of the low alloy steel material. The 0.086" increase in radius has a negligible effect on the stress levels and stress distributions in the wall. In addition, based on the diameter and thickness of the nozzle as well as the corrosion rate, the corrosion will not have any appreciable effect on the nozzle stresses and will not cause any denting. Thus, the larger bore diameter does not impact the stress / fatigue usage for the assembly and is acceptable.

In conclusion, the corrosion of the exposed low alloy steel material has negligible impact on the response of the RVCH nozzle repair and is therefore acceptable for 27 years from the time the modification is installed.

11.0 CONCLUSIONS

The preceding calculations demonstrate that the Palisades CRDM IDTB weld repair design meets the stress and fatigue requirements of the Design Code (ASME Code, section III, 1989 edition w/o addenda – Reference 13.2).

Based on the loads and cycles specified in Reference 13.8 and Reference 13.1, the conservative fatigue analysis indicates that the repair has a cumulative usage factor of 0.73 for xxx years of operation compared to the ASME Code allowed maximum value of 1.0.

This calculation fulfills the requirements of Reference 13.1

12.0 ANSYS VERIFICATION AND COMPUTER OUTPUT FILES

The finite element analyses in this calculation use the computer program ANSYS 7.1 (Reference 13.3). Test cases verifying the suitability and accuracy of this program for this analysis are analyzed and the results of the analyses are included in the files "Vm187.out" and "Vm96.out".

The Stress Intensity Range calculations, documented in this report, are performed using StressRange v1.9 program (Reference 13.6). The suitability and accuracy of the StressRange v1.9 are verified by comparing the calculated SI range listed in the file "PAL_Range_verif.txt" with Table H3 in Reference 13.6.

These files reside on the COLD storage system.

Table 12-1 Computer Output Files

(see also Table A-3 for additional computer output files)

File Name	Date	Description
PAL_geo.out	03/22/04	Output file to develop finite element model
PAL_inp_DeltaT.mac	03/23/04	Input file defining nodes for temperature and thermal gradient evaluation
PAL_path_fat.mac	05/12/04	Input file contains path definition for stress component for fatigue calculation
Design Condition		
PAL_des_pres.out	03/22/04	Output file for Design Condition
PAL_des_pres_Path.out	03/25/04	Output file contains stress components along the paths for Design Condition
HUCD Transient		
PAL_HUCD_th.out	03/23/04	Output file for thermal analysis of HUCD
PAL_HUCD_DeltaT.out	03/23/04	Output file contains thermal gradients of HUCD
PAL_HUCD_st.out	03/24/04	Output file for stress analysis of HUCD
PAL_HUCD_fat.out	05/12/04	Output file contains stress components along the paths for HUCD transient
NPCH Transient		
PAL_NPCH_th.out	03/24/04	Output file for thermal analysis of NPCH
PAL_NPCH_DeltaT.out	03/24/04	Output file contains thermal gradients of NPCH
PAL_NPCH_st.out	03/24/04	Output file for stress analysis of NPCH

PAL_NPCH_fat.out	05/12/04	Output file contains stress components along the paths for NPCH transient
FPCH Transient		
PAL_FPCH_th.out	03/24/04	Output file for thermal analysis of FPCH
PAL_FPCH_DeltaT.out	03/24/04	Output file contains thermal gradients of FPCH
PAL_FPCH_st.out	03/25/04	Output file for stress analysis of FPCH
PAL_FPCH_fat.out	05/12/04	Output file contains stress components along the paths for FPCH transient
PLUL Transient		
PAL_PLUL_th.out	03/24/04	Output file for thermal analysis of PLUL
PAL_PLUL_DeltaT.out	03/24/04	Output file contains thermal gradients of PLUL
PAL_PLUL_st.out	04/08/04	Output file for stress analysis of PLUL
PAL_PLUL_fat.out	05/12/04	Output file contains stress components along the paths for PLUL transient
LL Transient		
PAL_LL_th.out	03/24/04	Output file for thermal analysis of LL
PAL_LL_DeltaT.out	03/24/04	Output file contains thermal gradients of LL
PAL_LL_st.out	03/25/04	Output file for stress analysis of LL
PAL_LL_fat.out	05/12/04	Output file contains stress components along the paths for LL transient
LF Transient		
PAL_LF_th.out	03/24/04	Output file for thermal analysis of LF
PAL_LF_DeltaT.out	03/24/04	Output file contains thermal gradients of LF
PAL_LF_st.out	03/25/04	Output file for stress analysis of LF
PAL_LF_fat.out	05/12/04	Output file contains stress components along the paths for LF transient
SVO Transient		
PAL_SVO_th.out	03/25/04	Output file for thermal analysis of SVO
PAL_SVO_DeltaT.out	03/25/04	Output file contains thermal gradients of SVO
PAL_SVO_st.out	03/25/04	Output file for stress analysis of SVO
PAL_SVO_fat.out	05/12/04	Output file contains stress components along the paths for SVO transient

Leak Transient		
PAL_Leak_st.out	06/07/04	Output file for stress analysis of Leak
PAL_Leak_fat.out	06/07/04	Output file contains stress components along the paths for Leak transient
SI Range Calculation		
PAL_Range(M+B).txt	06/07/04	Stress range results for membrane + bending stresses
Verification files		
vm96.out	04/01/04	ANSYS verification case for thermal analysis
vm187.out	04/01/04	ANSYS verification case for structural analysis
PAL_Range_verif.txt	04/01/04	Verification file for StressRange v1.9 program

13.0 REFERENCES

13.1 AREVA Document 51-5039171-04, "Palisades CRDM and ICI Nozzle ID Temper Bead Weld Repair Requirements"

13.2 ASME Code, Section III, "Nuclear Power Plant Components," 1989 Edition, no addenda

13.3 "ANSYS" Finite Element Computer Code, Version 7.1, ANSYS, Inc., Canonsburg, Pa.

13.4 AREVA Drawing 02-5039266D-01, "Palisades CRDM Replacement Nozzle"

13.5 AREVA Drawing 02-5038702E-03, "Palisades CRDM Nozzle ID Temper Bead Weld Repair"

13.6 AREVA Document 32-5032987-00, "STRESSRANGE Program Verification"

13.7 AREVA Document 51-5041852-02, "Palisades CEDM & ICI Nozzle Repair Corrosion Evaluation"

13.8 Consumers Power Specification No. 70P-003, "Engineering Specification for a Reactor Vessel Assembly for Consumers Power Company Palisades Plant Contract 2966".

13.9 Combustion Engineering Drawing E 232-120-3, "Closure Head Penetrations"

13.10 Combustion Engineering Drawing E 232-119-11, "Closure Head Nozzle Details"

13.11 Combustion Engineering Drawing E 232-118-9, "Closure Head Forming and Welding"

13.12 Combustion Engineering Drawing E 232-122-11, "Closure Head Assembly"

13.13 Consumers Power Document No. TR-ESE-437 "Palisades CRDM Dynamic Analysis Report"

13.14 Combustion Engineering Document No. CENC-1116 "Analytical Report for Consumers Power Reactor Vessel", Contract No. 2966A

13.15 Consumers Power Document No. EA-EAR-2001-0426-02 "A Review of CRD Seismic Design"

13.16 FRA-ANP Document NPGD-TM-500 rev D, "NPGMAT", NPGD Material Properties Program, User's Manual

13.17 FRA-ANP Document 51-1176533-00, "Alloy 690 Material Properties"

13.18 ASME Code Case N-474-2 "Design Stress Intensities and Yield Strength Values for UNS N06690 With a Minimum Specified Yield Strength of 35 ksi, Class 1 Components Section III, Division 1", December 9, 1993

13.19 ASME Code Case 2142-1 "F-Number Grouping for Ni-Cr-Fe, Classification UNS N06052 Filler Metal", June 5, 1995

13.20 AREVA Document 32-5044090-01, "Palisades Unit 1 CRDM Extension Connection Analysis"

13.21 AREVA Document 38-5053376-00, "Design information transmittal for revised cooldown curve"

References 13.8 thru Reference 13.15 are not retrievable from the AREVA document control system but are referenced here in accordance with AREVA procedure 0402-01, Appendix 2.

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Project Manager

APPENDIX A

Stresses used for IDTB Weld and Original J-Groove Weld Fracture Mechanics Analysis

A-1.0 PURPOSE

The purpose of this appendix is to provide supplemental stress results of the transient analysis for Fracture Mechanic Analysis of the IDTB weld and the original J-Groove weld.

A-2.0 IDTB WELD STRESS EVALUATION

For this purpose 6 paths (P11 thru P16) are defined through the IDTB repair weld (xxx). Paths are as shown in Figure A-2. All these paths are defined in the computer file "PAL_path_fract.mac".

The stresses are evaluated in the nozzle cylindrical coordinate system as is shown in Figure A-1. The stresses are listed at four equidistant intervals along all the paths for all time points and used as input for a Fracture Mechanics Analysis. These resulting stresses are tabulated on the following pages (Table A-4) and are contained in the computer files:

PAL_HUCD_fract.out	PAL_LL_fract.out
PAL_NPCH_fract.out	PAL_LF_fract.out
PAL_FPCH_fract.out	PAL_SVO_fract.out
PAL_PLUL_fract.out	PAL_Leak_fract.out

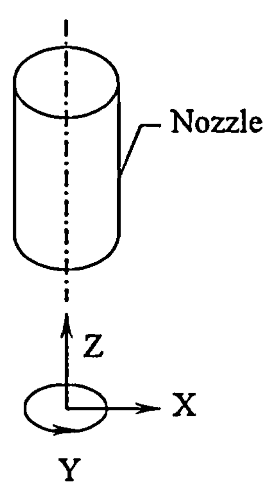

Figure A-1 Nozzle cylindrical coordinate system

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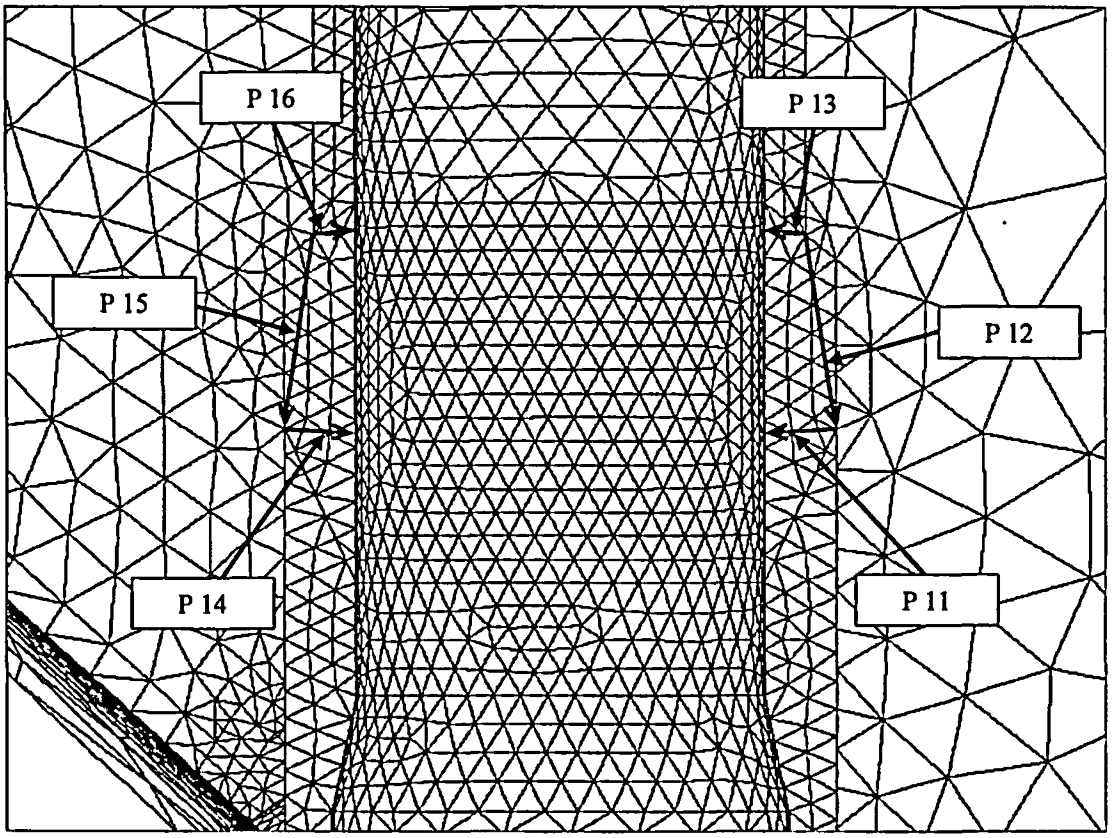

Figure A-2 Paths in the IDTB Weld Defined for Fracture Mechanics Evaluation

A-3.0 ORIGINAL J-GROOVE WELD STRESS EVALUATION

For the purpose of the fracture mechanics analysis of the original J-Groove weld, Reference 13.1 and 13.21 specifies the modified HUCD transient (xxx°F – lower cooldown limit, xxx°F – upper cooldown limit) that is less conservative than that used in the thermal and the structural analyses, as are described in the Section 7.0 and Section 8.0. The analyses are re-performed in this appendix and results supersede those obtained in the Section 7.0 and Section 8.0 for the original J-Groove weld fracture mechanics analysis.

A-3.1 Modified HUCD Transient (3 hours hold at xxx°F)

A-3.1.1 Thermal Analysis

The operating loads are defined by the thermal transient conditions as contained in the Reference 13.1. The reactor coolant temperature varies with time during transient as is shown in Table A-1.

Table A-1 Modified HUCD transient (3 hours hold at xxx°F)

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

The computer output file for the thermal analysis of the above transient is "PAL_HUCD_3_th.out".

The computer output file that provide the temperatures at the selected locations listed in Table 7-9 and shown in Figure 7-1 is "PAL_HUCD_3_DeltaT.out".

The temperature gradients between these key locations (Table 7-10) are also listed in the above output file. The results are plotted in Figure A-3. This figure is used only to show the trend. Specific data is taken from the computer output file. Computer file "PAL_inp_DeltaT.mac" contains definition of the node numbers for temperature and temperature gradients calculation.

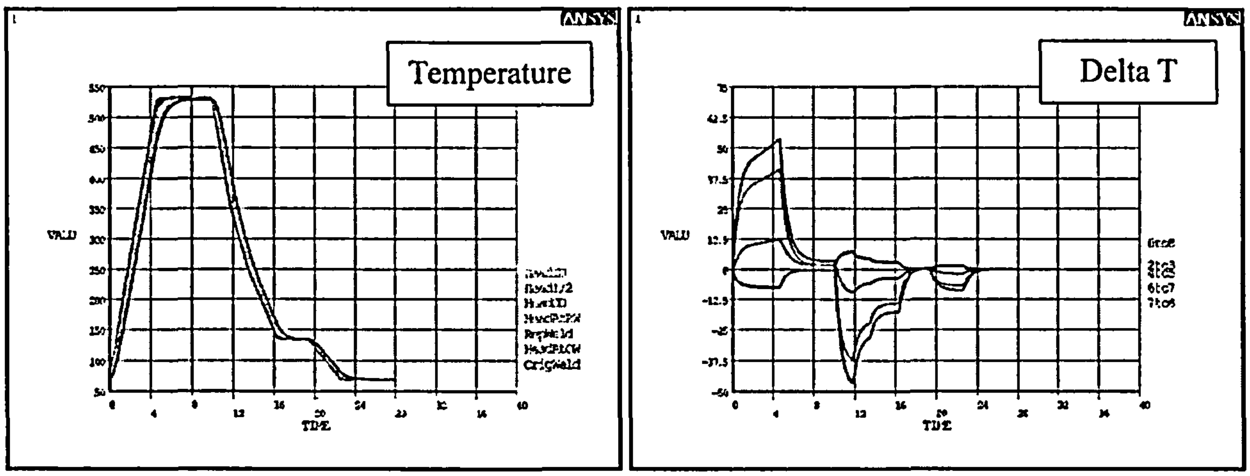

Figure A-3 Temperature and Thermal Gradients Plots of Selected Locations for modified HUCD Transient

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A-3.1.2 Structural Analysis

Stress analysis is performed at the time points listed in Table A-2. These time points include those at which the maximum temperature gradients (maximum thermal stresses) at investigated locations (around the CRDM nozzle) and the maximum pressures occur, as well as those of analytical interest. The nodal temperature at the particular time point is read into the structural model directly from the result file of the thermal analysis. The corresponding pressure is obtained from Reference 13.1. The computer output file for the structural analysis is "PAL_HUCD_3_st.out".

Table A-2 Time points of interest for structural analysis of modified HUCD transient

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

A-3.2 Stress Evaluation

For this purpose 15 points (P1 thru P15) are defined at the original J-Groove weld, J-Groove weld buttering (xxx) and RVCH (xxx) for uphill side and downhill side separately. The points are as shown in Figure A-4 and Figure A-5. All these points are defined in the computer file "PAL_points_Jfract.mac" (uphill side) and "PAL_points_JfractD.mac" (downhill side).

The stresses are evaluated in the nozzle cylindrical coordinate system as is shown in Figure A-1. For the uphill side the stresses are evaluated for all transients and used as an input for a Fracture Mechanics Analysis. For the downhill side the stresses are evaluated only for NPCH transient. These resulting stresses are tabulated on the following pages (Table A-5) and are contained in the computer files:

Uphill side:

PAL_HUCD_3_Jfract.cfs
PAL_NPCH_Jfract.cfs
PAL_FPCH_Jfract.cfs
PAL_PLUL_Jfract.cfs
PAL_LL_Jfract.cfs
PAL_LF_Jfract.cfs
PAL_SVO_Jfract.cfs
PAL_Leak_Jfract.cfs

Downhill side:

PAL_NPCH_JfractD.cfs

Note that "x" coordinate in these tables correspond to the "x" distance from the penetration outside diameter and the "y" coordinate correspond to the vertical distance from the lowest node, i.e. "P1" for the uphill side and "P5" for the downhill side.

The calculation is documented in the computer files:

Uphill side:

PAL_HUCD_3_Jfract.out
PAL_NPCH_Jfract.out
PAL_FPCH_Jfract.out
PAL_PLUL_Jfract.out
PAL_LL_Jfract.out
PAL_LF_Jfract.out
PAL_SVO_Jfract.out
PAL_Leak_Jfract.out

Downhill side:

PAL_NPCH_JfractD.out

See inserted pages 76a, 76b and 76c

A-3.3 Modified HUCD Transient (3 hours hold at xxx °F)

A-3.3.1 Thermal Analysis

The operating loads are defined by the thermal transient conditions as contained in the Reference 13.21. The reactor coolant temperature and pressure varies with time during transient as is shown in Table A-6.

Table A-6 Modified HUCD transient (3 hours hold at 110 °F)

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

The computer output file for the thermal analysis of the above transient is "PAL_HUCD_4_th.out".

The computer output file that provide the temperatures at the selected locations listed in Table 7-9 and shown in Figure 7-1 is "PAL_HUCD_4_DeltaT.out".

The temperature gradients between these key locations (Table 7-10) are also listed in the above output file. The results are plotted in Figure A-6. This figure is used only to show the trend. Specific data are taken from the computer output file. Computer file "PAL_inp_DeltaT.mac" contains definition of the node numbers for temperature and temperature gradients calculation.

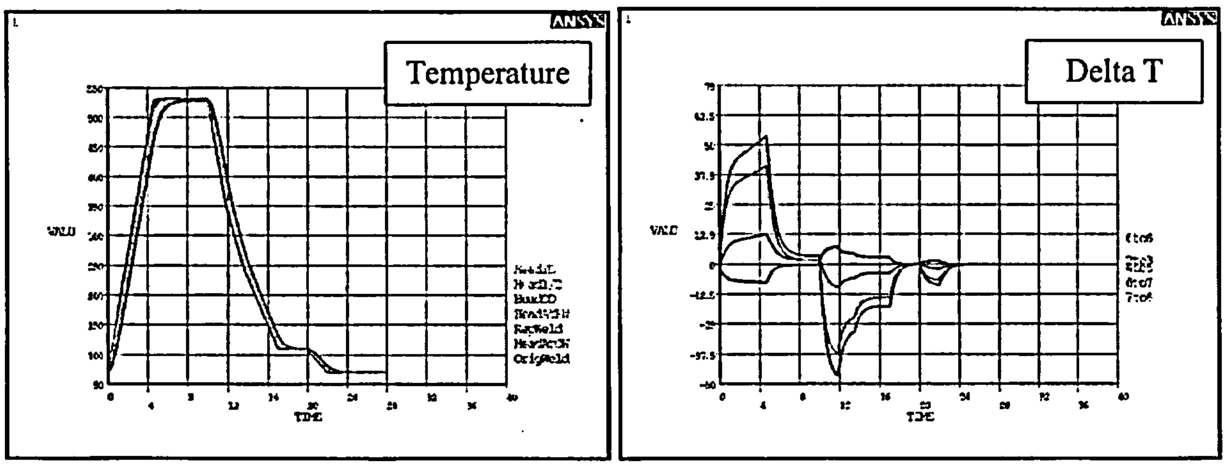

Figure A-6 Temperature and Thermal Gradients Plots of Selected Locations for modified HUCD Transient

This figure is not essential to this document.
12-3-2004
(for legibility concerns)

A-3.3.2 Structural Analysis

Stress analysis is performed at the time points listed in Table A-7. These time points include those at which the maximum temperature gradients (maximum thermal stresses) at investigated locations (around the CRDM nozzle) and the maximum pressures occur, as well as those of analytical interest. The nodal temperature at the particular time point is read into the structural model directly from the result file of the thermal analysis. The corresponding pressure is obtained from Reference 13.21. The computer output file for the structural analysis is "PAL_HUCD_4_st.out".

Table A-7 Time points of interest for structural analysis of modified HUCD transient (3 hours hold at xxx °F)

Time, hrs	Fluid Temperature, °F	Pressure, psia	Comment

A-3.4 Stress Evaluation for HUCD transient (3 hours hold at xxx °F)

For this purpose, the 15 points (P1 thru P15) are defined at the original J-Groove weld, J-Groove weld buttering (xxx) and RVCH (xxx). The points are shown in Figure A-4. All these points are defined in the computer file "PAL_points_Jfract.mac".

The stresses are evaluated in the nozzle cylindrical coordinate system as is shown in Figure A-1. The stresses are evaluated for all transients and used as an input for a Fracture Mechanics Analysis. These resulting stresses are tabulated on the following pages (Table A-8) and are contained in the computer file PAL_HUCD_4_Jfract.cfs.

Note that "x" coordinate in these tables correspond to the "x" distance from the penetration outside diameter and the "y" coordinate correspond to the vertical distance from the lowest node, i.e. "P1" for the uphill side and "P5" for the downhill side.

The calculation is documented in the computer files PAL_HUCD_4_Jfract.out.

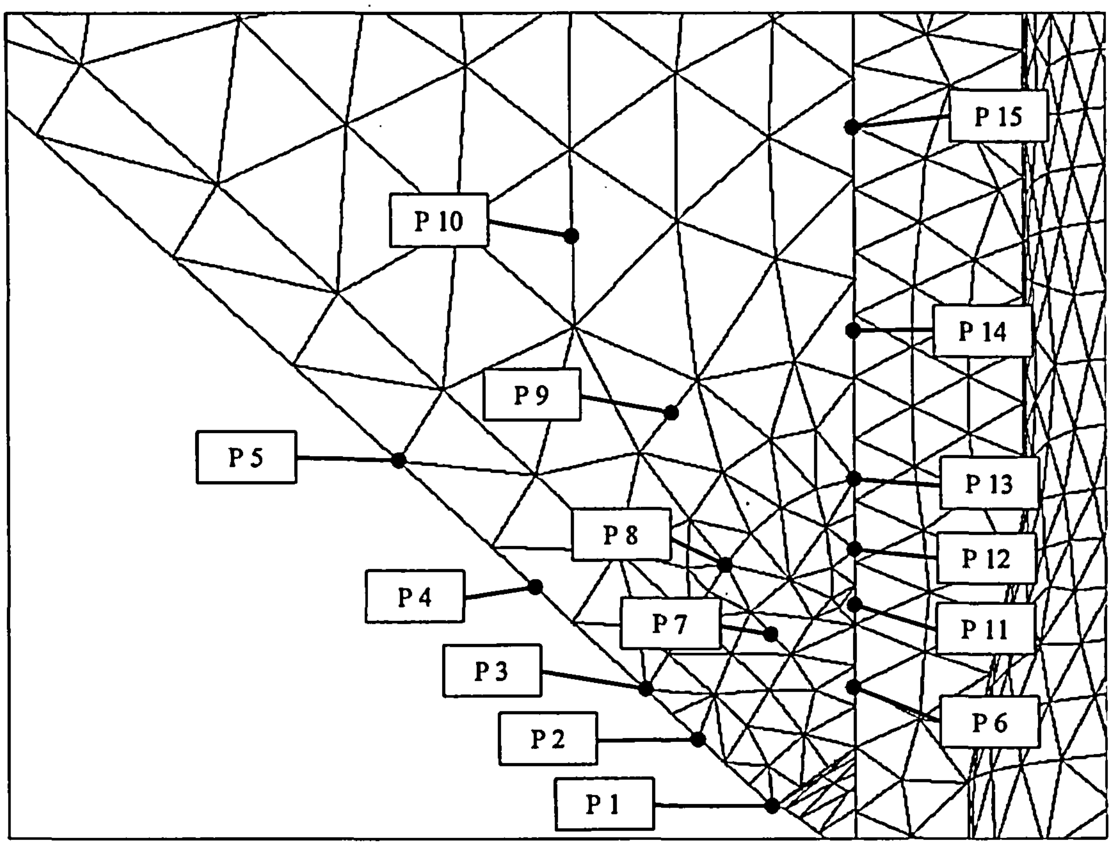

Figure A-4 Points at Uphill Side Original J-Groove Weld and RVCH Defined for Fracture Mechanics Evaluation

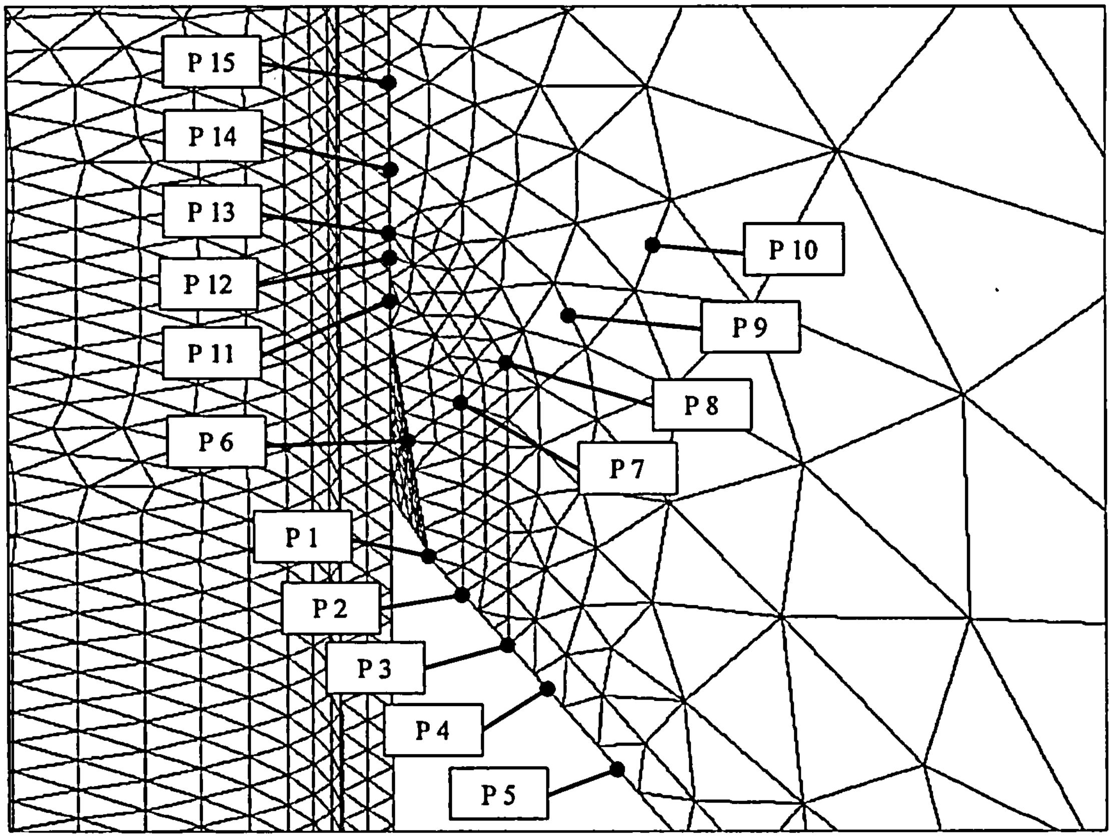

Figure A-5 Points at Downhill Side Original J-Groove Weld and RVCH Defined for Fracture Mechanics Evaluation

A-4.0 COMPUTER OUTPUT FILES

These files resides on the COLD storage system

Table A-3 Computer output files

File Name	Date	Description
PAL_HUCD_3_th.out	06/23/04	Output file for thermal analysis of HUCD transient based on Table A-1
PAL_HUCD_3_DeltaT.out	06/23/04	Output file contains thermal gradients of HUCD transient based on Table A-1
PAL_HUCD_3_st.out	07/08/04	Output file for stress analysis of HUCD transient based on Table A-1
PAL_path_fract.mac*	04/26/04	Input file contains path definition for stress component for fracture mechanics evaluation
PAL_HUCD_fract.out*	04/26/04	Output file contains stress components along the paths for HUCD transient (based on Table 7-1) for fracture mechanics evaluation
PAL_NPCH_fract.out*	04/26/04	Output file contains stress components along the paths for NPCH transient for fracture mechanics evaluation
PAL_FPCH_fract.out*	04/26/04	Output file contains stress components along the paths for FPCH transient for fracture mechanics evaluation
PAL_PLUL_fract.out*	04/26/04	Output file contains stress components along the paths for PLUL transient for fracture mechanics evaluation
PAL_LL_fract.out*	04/26/04	Output file contains stress components along the paths for LL transient for fracture mechanics evaluation
PAL_LF_fract.out*	04/26/04	Output file contains stress components along the paths for LF transient for fracture mechanics evaluation
PAL_SVO_fract.out*	04/26/04	Output file contains stress components along the paths for SVO transient for fracture mechanics evaluation
PAL_Leak_fract.out*	06/07/04	Output file contains stress components along the paths for Leak transient for fracture mechanics evaluation
PAL_points_Jfract.mac*	05/05/04	Input file contains point definition for stress component for fracture mechanics evaluation at uphill side
PAL_points_JfractD.mac*	05/12/04	Input file contains point definition for stress component for fracture mechanics evaluation at downhill side

* These files are on Cold Server for Revision 00.

PAL_HUCD_3_Jfract.out	07/09/04	Output file contains stress components evaluation for HUCD transient (based on Table A-1) for fracture mechanics evaluation
PAL_NPCH_Jfract.out*	05/05/04	Output file contains stress components evaluation for NPCH transient for fracture mechanics evaluation
PAL_FPCH_Jfract.out*	05/05/04	Output file contains stress components evaluation for FPCH transient for fracture mechanics evaluation
PAL_PLUL_Jfract.out*	05/05/04	Output file contains stress components evaluation for PLUL transient for fracture mechanics evaluation
PAL_LL_Jfract.out*	05/05/04	Output file contains stress components evaluation for LL transient for fracture mechanics evaluation
PAL_LF_Jfract.out*	05/05/04	Output file contains stress components evaluation for LF transient for fracture mechanics evaluation
PAL_SVO_Jfract.out*	05/05/04	Output file contains stress components evaluation for SVO transient for fracture mechanics evaluation
PAL_Leak_Jfract.out*	06/07/04	Output file contains stress components evaluation for Leak transient for fracture mechanics evaluation
PAL_NPCH_JfractD.out*	05/12/04	Output file contains stress components evaluation for NPCH transient for fracture mechanics evaluation
PAL_HUCD_3_Jfract.cfs	07/09/04	Output file contains stress components along the paths for HUCD transient (based on Table A-1) for fracture mechanics evaluation
PAL_NPCH_Jfract.cfs*	05/05/04	Output file contains stress components along the paths for NPCH transient for fracture mechanics evaluation
PAL_FPCH_Jfract.cfs*	05/05/04	Output file contains stress components along the paths for FPCH transient for fracture mechanics evaluation
PAL_PLUL_Jfract.cfs*	05/05/04	Output file contains stress components along the paths for PLUL transient for fracture mechanics evaluation
PAL_LL_Jfract.cfs*	05/05/04	Output file contains stress components along the paths for LL transient for fracture mechanics evaluation
PAL_LF_Jfract.cfs*	05/05/04	Output file contains stress components along the paths for LF transient for fracture mechanics evaluation
PAL_SVO_Jfract.cfs*	05/05/04	Output file contains stress components along the paths for SVO transient for fracture mechanics evaluation
PAL_Leak_Jfract.cfs*	06/07/04	Output file contains stress components along the paths for Leak transient for fracture mechanics evaluation

* These files are on Cold Server for Revision 00.

PAL_NPCH_JfractD.cfs	05/12/04	Output file contains stress components along the paths for NPCH transient for fracture mechanics evaluation

See inserted page 81a

Table A-8 Computer output files (3 hours hold at xxx °F)

File Name	Date	Description
PAL_HUCD_4_th.out	10/27/04	Output file for thermal analysis of HUCD transient based on Table A-6
PAL_HUCD_4_DeltaT.out	10/28/04	Output file contains thermal gradients of HUCD transient based on Table A-6
PAL_HUCD_4_st.out	10/28/04	Output file for stress analysis of HUCD transient based on Table A-6
PAL_points_Jfract.mac*	05/05/04	Input file contains point definition for stress component for fracture mechanics evaluation at uphill side
PAL_HUCD_4_Jfract.out	10/28/04	Output file contains stress components evaluation for HUCD transient (based on Table A-6) for fracture mechanics evaluation
PAL_HUCD_4_Jfract.cfs	10/28/04	Output file contains stress components along the paths for HUCD transient (based on Table A-6) for fracture mechanics evaluation

* This file is on Cold Server for Revision 00.

Table A-4 List of Stress Results for IDTB Weld

Path Summary from file: PAL_HUCD_fract.out

Path Summary from file: PAL_NPCH_fract.out

Proprietary information deleted

Path Summary from file: PAL_FPCH_fract.out

Path Summary from file: PAL_PLUL_fract.out

Path Summary from file: PAL_LL_fract.out

Proprietary information deleted

Path Summary from file: PAL_LF_fract.out

Path Summary from file: PAL_SVO_fract.out

Proprietary information deleted

Path Summary from file: PAL_Leak_fract.out

Table A-5 List of Stress Results for Original J-Groove Weld

List of results from file: PAL_HUCD_3_Jfract.cfs

Table A-5 List of Stress Results for Original J-Groove Weld

List of results from file: PAL_HUCD_3_Jfract.cfs

Proprietary information deleted

Proprietary information deleted

List of results from file: PAL_NPCH_Jfract.cfs

List of results from file: PAL_FPCH_Jfract.cfs

Proprietary information deleted

List of results from file: PAL_PLUL_Jfract.cfs

Proprietary information deleted.

List of results from file: PAL_LL_Jfract.cfs

List of results from file: PAL_LF_Jfract.cfs

List of results from file: PAL_SVO_Jfract.cfs

PROPRIETARY INFORMATION DELETED

List of results from file: PAL_Leak_Jfract.cfs

List of results from file: PAL_NPCH_JfractD.cfs

PROPRIETARY INFORMATION DELETED

 See inserted pages 106a, 106b, 106c and 106d

List of results from file: PAL_HUCD_4_Jfract.cfs

PROPRIETARY INFORMATION DELETED

PROPRIETARY INFORMATION DELETED

PROPRIETARY INFORMATION DELETED