Enclosure 1-2
(Non-Proprietary)

Framatome ANP Document No. 51-5015197-01,
"Surry 1 & 2 Reconciliation with Turkey Point 3 RV Hd & CRM Noz."

FRAMATOME ANP

ENGINEERING INFORMATION RECORD

Document Identifier 51 - 5015197 - 01

Title SURRY 1 & 2 RECONCILIATION WITH TURKEY POINT 3 RV HD & CRM NOZ.

PREPARED BY:		REVIEWED BY:	
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Signature	W. J. DeCooman	Signature	M. Hinderks
Date	10/31/2001	Date	10/31/2001

Technical Manager Statement: Initials ADM

Reviewer is Independent.

Remarks:

Purpose:

This report documents the applicability of engineering analyses performed for the Turkey Point 3 (TP-3) Nuclear Power Plant (NPP) with the Surry 1 & 2 NPPs for the reactor vessel (RV) closure head region of the control rod mechanism (CRM) nozzle penetrations; and the CRM nozzle inside diameter temper bead weld repair. The applicability will be accomplished by a comparison study that includes documenting the engineering data from both TP-3 and Surry NPPs, such as: applicable dimensions of features, materials, and plant operational transients to include time, temperature and pressure.

Both TP-3 and Surry 1 & 2 are Westinghouse Electric Co. pressurized light water reactors (PWR), 157 fuel assemblies, with "3-Loop" steam generator reactor coolant systems. The results of this comparative study of the critical parameters will show that the plants are nearly identical and that the engineering analyses performed for TP-3 are applicable to Surry. The results of this study are provided in the body of this report.

Introduction:

In order to demonstrate that the engineering analyses performed for the Turkey Point 3 NPP control rod drive mechanism nozzle inside diameter temper bead weld repair are applicable to Surry, a list of applicable parameters for each plant will be tabulated and compared. The list of parameters will include all features that are pertinent to the engineering analyses. Some typical parameters are the dimensions of the RV Closure Head radius, the number of CRM penetrations and spacing in the Closure Head, materials, and plant operational transients to include time, temperature and pressure.

Operating Transients Data:

The Framatome ANP Turkey Point 3 transients (Ref. 11, Appdx A) were compared with the transients submitted by Dominion Generation for Surry. The results of the transients bounding cases are given in Ref. 9. The results of the comparison concluded that the TP-3 transients bounding cases also bounded the transients listed in Table 1.

Engineering Analyses Parameters:

A number of pertinent engineering analysis data are contained in Tables 1, 2, and 3. These data are considered necessary to perform the various analyses. The components' dimensions/data provided or confirmed by Dominion Generation (Ref.s 1, 9, 10, 16, 22 through 31) were compared with the TP-3 data and are found to be acceptable.

Conclusion:

Based on the comparisons of Surry drawings and referenced engineering data received from Dominion Generation – Surry NPP, and TP-3 drawings and referenced engineering data, the engineering analyses for the CRM Nozzle ID Temper Bead Repair components for TP-3 are directly applicable to Surry 1 & 2 NPPs.

Record of Revision: Rev. 01 – See Page 5, Reference 18, removed reference to 32-5014129-01, reference to 32-5014129-00 is still applicable to this reconciliation document. Removed Ref. 19 as it is not used in Rev. 00 or 01. The Conclusions stated above and as in Rev. 00 of this document remains unchanged by this rev. Only Pages 1 and 5 are affected by Rev. 01. Oct. 31, 2001

* ALSO INCLUDES: Appdx A pg.s 1-10, Appdx B pg.s 1-2, Appdx C pg.s 1-25, Appdx D pg.s 1-15. Total Page Count = 58.

Table 1 RCS SPECIFICATIONS

Component	Turkey Point 3 Analyses (TP-3) Data Description	Reference Source	Surry Data Description	Reference Source
RCS Spec.s				
Design Conditions				
Design Pressure	2500 psia	Ref. 12, para. 3.15	2485 psig (2500 psia)	Ref. 1, Attmt 1-1, para. 1.1.2
Design Temperature	650 F	Ref. 12, para. 3.17	650 F	Ref. 1, Attmt 1-1, para. 1.1.2
Hydrotest Pressure	3125 psia	Ref. 12, Appdx B	3107 psig (3122 psia)	Ref. 1, Attmt 1-1, para. 1.1.2
Hydrotest Temperature			NDTT +60 F min.	Ref. 1, Attmt 1-1, para. 1.1.2
Hydrotest Temperature at Mfr			110 F	Ref. 1, Attmt 1-1, para. 1.1.2
Operating Conditions				
Coolant Fluid			Pressurizer Water	Ref. 1, Attmt 1-1, para. 1.1.3
Operating Pressure	2250 psia	Ref. 12, para. 3.16	2235 psig (2250 psia)	Ref. 1, Attmt 1-1, para. 1.1.3
Normal Operating Temperature	594 F	Ref. 12, Appdx B	543 F	Ref. 1, Attmt 1-1, para. 1.1.3
Inlet Temperature			543 F	Ref. 1, Attmt 1-1, para. 1.1.3
Outlet Temperature at Normal Temp.			605.8 F	Ref. 1, Attmt 1-1, para. 1.1.3
Initial Operating Limitations/Transients				
Heat Up and Cool Down Transients	200 HU and 200 CD Cycles, 5 Hydrotest Cycles at 2500psia at Operating Temp. and 1 cycle at 3125 psia at 100 F.	Ref. 11, Table 5.1, Ref. 12	The heating and cooling rate is limited to maximum 100 F per Hour. These rates will be safe for 200 Occurrences each. Thus, when starting at an isothermal condition at 100 F, the maximum heating rate is not to exceed 100 F per Hour up to operating temperature and, when starting at an isothermal condition at operating temperature, the maximum cooling rate is not to exceed 100 F per Hour returning to 100 F.	Ref. 9
			Plant Heatup at 100 F/Hr., 200 Occurrences, Normal Operating Condition: Plant Cooldown at 100 F/Hr., 200 Occurrences, Normal Operating Condition.	Ref. 9
Plant Loading and Unloading Transient	14,500 Cycles	Ref. 11, Table 5.1, Ref. 12	Plant Loading and Unloading at 5% Full Power per Minute, 29,000 Occurrences each at Normal Operating Condition. A total of 14,500 Cycles.	Ref. 9
Bounding of Remaining Transients Including:	2,800 Total Cycles	Ref. 11, Table 5.1, Ref. 12	2,800 Total Cycles	Ref. 9
10% Step Decrease	2,000 Cycles	Ref. 11, Table 5.1, Ref. 12	10% Step Load Increase and Decrease of Full power, 2,000 Occurrences,Normal Op. Cond.	Ref. 9
10% Step Increase		Ref. 11, Table 5.1, Ref. 12		
Large Step Decrease	200 Cyles	Ref. 11, Table 5.1, Ref. 12	Large Step Decrease, 200 Occurences, Normal Op. Cond.	Ref. 9
Loss-of-Load	80 Cycles	Ref. 11, Table 5.1, Ref. 12	Loss-of-Load, 80 Occurrences, Upset Condition	Ref. 9
Loss-of-Flow	80 Cycles	Ref. 11, Table 5.1, Ref. 12	Loss-of-Flow, 80 Occurrences, Upset Cond.	Ref. 9
Reactor Trip	400 Cycles	Ref. 11, Table 5.1, Ref. 12	Reactor Trip from Full power, 400 Occurences, Upset Cond.	Ref. 9
Loss-of-AC Power ,Trips, Step Changes, Etc.	40 Cycles	Ref. 11, Table 5.1, Ref. 12	Loss of Power, 40 Occurrences, Upset Cond.	Ref. 9

Table 2 REACTOR VESSEL CLOSURE HEAD ASSEMBLY

Component	Turkey Point 3 Analyses (TP-3) Data Description	Reference Source	Surry Data Description	Reference Source
CLOSURE HEAD ASSEMBLY				
Dry Weight			111,347 Lb.	Ref. 1, Attmt 1-4, para. 1.1.7
Closure Head Forging	184 in. OD x 2 Ft. 11-11/32 in. Length	Ref. 8, Part No. 51	15-Ft. 4 in. OD x 2-Ft. 11-11/32 in. Length	Ref. 30 & 31
Material				
Material	ASTM A-508, Class 2, Mn-Mo Steel, ASME Code Case 1332-2	Ref. 2, Part No. 51	ASTM A-508, Class 2, Mn-Mo Steel.	Ref. 22 & 23
Closure Head Plate	79-1/4 in. Inside Radius to basemetal x 6-3/16 in. min. thkns plus).156 min. Thkns cladding - SST.	Ref. 7, Part No. 50	79-1/4 in. Inside Radius to basemetal x 6-3/16 in. min. thkns plus).156 min. Thkns cladding - SST.	Ref. 28 & 29
Material (See Note 1 Below)	ASME SA-302, Grade B, Mn-Mo Steel	Ref. 2, Part No. 50	ASTM A-533, Grade B, Class 1, Mn-Mo Steel.	Ref. 22 & 23

Note 1 - An evaluation was performed to compare the material properties of SA-302 and SA-533. A review of Ref. 18, page 6, and Ref. 21, Page 9 demonstrates that the pertinent material properties at temperature are identical or nearly the same values that no significant difference would affect the results of the applicable stress analyses (Ref. 11 & 18).

Table 3 CONTROL ROD MECHANISM HOUSINGS

Component	Turkey Point 3 Analyses (TP-3) Data Description	Reference Source	Surry Data Description	Reference Source
Control Rod Mechanism Housing			Housing weldment consists of threaded 6-in. OD Adapter, and a 4-in. OD Body. Housing has an interference fit with the Closure Head and welded into the inside of the Closure Head with weld deposited Inconel.	Ref. 26 & 27
Quanity	65	Ref. 5, View: Key Plan	65	Ref.23 & 24
Spacing			8.466 in. centers	Ref.28 & 29
Material - CRM Adapter	ASME SA-182, Type 304, SST	Ref. 2, Part No. 1	ASME SA-182, Type 304, SST	Ref.23 & 24
Material - CRM Body	ASME SB-167 Inconel	Ref. 2, Part No. 2 - 14	ASME SB-167 Inconel	Ref.23 & 24
Vent Pipe			Nominal 1.00 in. Dia. Penetration.	Ref. 1, Attmt 3-4, para. 3.1.3
3-D FE Model Parameter List of CRM Housing (See Ref. 18 for Description of Parameters)				
thead	6+3/16 in.	Ref. 7	6.188 in.	Ref. 24 &25
tclad	0.156 in.	Ref. 7	0.156 in.	Ref.24 & 25
rbase	79+3/32+0.156 in.	Ref. 7	79+3/32+0.156 in.	Ref. 30 & 31
Rad To Noz (Max.)	53.544 in.	Ref. 5	53.544 in.	Ref. 30 & 31, Top View, calc'd value.
DiaPen	4.000 in.	Ref. 5	4.000 in.	Ref. 30 & 31, Detail for Hole No. 1, and Detail for All Adapter Holes Except Hole No. 1.
tButter	0.25 In	Ref. 5	0.25 in.	Ref. 30 & 31, Detail for Hole No. 1, and Detail for All Adapter Holes Except Hole No. 1.
WPirad	.5-tButter	Ref. 5	.5-tButter	Ref. 30 & 31, Detail for Hole No. 1, and Detail for All Adapter Holes Except Hole No. 1.
WidAngl	20 degrees	Ref. 5	20 degrees	Ref. 30 & 31, Detail for Hole No. 1, and Detail for All Adapter Holes Except Hole No. 1.
NozOD	4.025 in.	Ref. 5	4.025 in.	Ref. 26 & 27
NozTw	0.6375 in.	Ref. 5	0.6375 in.	Ref. 26 & 27

REFERENCES

Reference No.	Document No.	Description	Source
1*	78-S25 .	Final Design Surry Power Station, Part Length Control Rod Removal,Rev. 2, dated 7/18/80, Attachment.	Dominion Generation, Surry Power Station, Facsimile Transmittal, dated 10/5/2001, To: Alvin McKim - FRA-ANP, From: Doug Lawrence - Dominion -Surry, 25 Pages, time 13:05 hrs.
2	02-117877E, Rev. 5	Material List, Reactor Vessel, Westinghouse Atomic Power Div., Contr No. 610-0116-51 & 52	FRA-ANP Records Center, Lynchburg, VA
3	02-117878E, Rev. 5	Closure Head Assembly, Contr. No. 610-0116-52	FRA-ANP Records Center, Lynchburg, VA
4	02-117880E, Rev. 5	Detail & Sub-Assy, Control Rod Mech. Housing, Contr. No. 610-0116-52	FRA-ANP Records Center, Lynchburg, VA
5	02-117881E, Rev. 6	Closure Head Sub-Assembly, Contr. No. 610-0116-52	FRA-ANP Records Center, Lynchburg, VA
6	02-5012151E, Rev. 5	CRDM Nozzle ID Temperbead Weld Repair Boring Option B&W 177 FA Plants, dated 8/3/01.	FRA-ANP Records Center, Lynchburg, VA
7	02-88181C, Rev. 1	Closure Head Center Disc, Contr. No. 610-0116-52	FRA-ANP Records Center, Lynchburg, VA
8	02-117883E, Rev. 1	Details Closure Head Flange, Contr. No. 610-0116-52	FRA-ANP Records Center, Lynchburg, VA
9*	N/A	Surry Reactor Head Inspection - Design Information Transmital	Dominion Generation, Letter From Dean I. Price To: Paul Ulmer of FRA-ANP, dated Oct. 12, 2001.
10*	676500 Rev. 1	Equipment Specification, dated 4/29/71, "Addendum to Equipment Spec. 676413, Rev. 1, Project: SurryPower Station II, Eqpt: Reactor Vessel, System: Reactor Coolant.	Dominion Generation, Facsimile Transmittal, dated 10/12/2001, To: Paul Ulmer/Jim Dorman- FRA-ANP, From: Dean Price, 10 Pages, time 09:54 hrs.
11	32-5014640-00	Turkey Point - CRDM Temperbead Bore Weld Analysis	FRA-ANP Records Center, Lynchburg, VA
12	51-5014575-00	Turkey Point CRDM Noz. ID Temper Bead Weld Repair Reqmts	FRA-ANP Records Center, Lynchburg, VA
13	Not Used		
14	Not Used		
15	Not Used		
16*		Surry Reactor Head Inspection - Design Information Transmital	Dominion Generation, Letter From: Dean Price, To: Paul Ulmer- FRA-ANP, Subject - Surry Reactor Head Inspection, Design Information Transmittal, dated 10/17/2001.
17	32-5015219-00	Surry CRDM Noz IDTB Weld Anomaly Flaw Eval.	FRA-ANP Records Center, Lynchburg, VA
18	32-5014129-00	TP CRDM Conn. 3D FE Model	FRA-ANP Records Center, Lynchburg, VA
19	Not Used		
20	32-5015220-00	Surry CRDM Noz IDTB J-Groove Weld Flaw Eval.	FRA-ANP Records Center, Lynchburg, VA
21	32-5011864-00	CRDMH Connection 3D FE Model	FRA-ANP Records Center, Lynchburg, VA
22	02-131174E, Rev. 3	Material List, Contr No. 610-0137-51 & 52	FRA-ANP Records Center, Lynchburg, VA
23	02-134804E, Rev. 5	Material List, Contr No. 610-0147-51 & 52	FRA-ANP Records Center, Lynchburg, VA
24	02-131180E, Rev. 1	Closure Head Details, Contr No. 610-0137-52	FRA-ANP Records Center, Lynchburg, VA
25	02-134810E, Rev. 1	Closure Head Details, Contr No. 610-0147-52	FRA-ANP Records Center, Lynchburg, VA
26	02-131177E, Rev. 3	Control Rod Mech. Housing, Contr No. 610-0137-52	FRA-ANP Records Center, Lynchburg, VA
27	02-134807E, Rev. 1	Control Rod Mech. Housing, Contr No. 610-0147-52	FRA-ANP Records Center, Lynchburg, VA
28	02-131175E, Rev. 1	Closure Head Assembly, Contr No. 610-0137-52	FRA-ANP Records Center, Lynchburg, VA
29	02-134805E, Rev. 0	Closure Head Assembly, Contr No. 610-0147-52	FRA-ANP Records Center, Lynchburg, VA
30	02-131178E, Rev. 3	Closure Head Sub-Assembly, Contr No. 610-0137-52	FRA-ANP Records Center, Lynchburg, VA
31	02-134808E, Rev. 1	Closure Head Sub-Assembly, Contr No. 610-0147-52	FRA-ANP Records Center, Lynchburg, VA

* These references are not in the Framatome ANP Records Center. The use of these Customer Supplied Documents for Surry CRDM Weld Repair, Contr. No. 4160048, and the design input data contained therein are approved by the Project Manager. PM Signature: P. M. Ulmer ______

APPENDICES: Customer Supplied Documents

Appendix A - Dominion Generation Letter, Subject: Surry Reactor Head Inspection Design Information Transmital, From Dean I. Price, To: Paul Ulmer of FRA-ANP, Dated Oct. 12, 2001.

Appendix B - Dominion Generation Letter, Subject: Surry Reactor Head Inspection Design Information Transmital, From Dean I. Price, To: Paul Ulmer of FRA-ANP, Dated Oct. 17, 2001.

Appendix C - Dominion Generation, Surry Power Station, Facsimile Transmittal, dated 10/5/2001, To: Alvin McKim - FRA-ANP, From: Doug Lawrence - Dominion -Surry, 25 Pages, time 13:05 hrs.

Appendix D – Westinghouse Electric Co., Facsimile Transmittal, dated 10/12/2001, To: Dean Price of Dominion Gen. Surry NPP, From Justin Ledger, 15 Pages.

Dominion Generation
5000 Dominion Boulevard, Glen Allen, VA 23060

Dominion

Framatome ANP, Inc
3315 Old Forest Road
Lynchburg, BA 24506-0935

Attention: Mr. Paul Ulmer

October 12, 2001

Subject: Surry Reactor Head Inspection
Design Information Transmittal

Dear Mr. Ulmer

Please find attached a Memorandum from our Engineering Mechanics department to myself concerning design information such as transients, operating cycles, etc that you have requested to be used in the engineering for a potential reactor head penetration repair should one be needed. If additional information is needed in this area, please contact me at 804-273-3586.

Dean I. Price

Dean I. Price
Project Engineer

bcc: A. McKim
B. De Cooman
R. Dorman
M. Carpenter
D. Matthews
M. Sloman
R. Smith

APPENDIX A
51-5015197-00

Dominion

Memorandum

October 11, 2001

To: D. I. Price
Company: Dominion Resources Services, Inc.
Department: Nuclear Projects Department, Civil/Mechanical
Location: ITC-3NW

From: D. R. McGowan
Company: Dominion Resources Services, Inc.
Department: Nuclear Engineering Department, Engineering Mechanics Group
Location: ITC-3NW

Review of Framatome Transient Set for Surry CRDM Penetrations Analysis

Per your request, Engineering Mechanics (EM) has reviewed the transient data supplied by Framatome for the design of the Control Rod Drive Mechanisms (CRDMs) for Surry Units 1 and 2. The following comments apply.

The Surry reactor vessels (including the CRDM penetrations) are designed for the following thermal and pressure transient conditions (References 1 and 2):

1. Plant heatup at 100°F per hour, 200 occurrences, normal operating condition
2. Plant Cooldown at 100°F per hour, 200 occurrences, normal operating condition
3. Plant Loading at 5% of full power per minute, 29,000 occurrences, normal operating condition
4. Plant Unloading at 5% of full power per minute, 29,000 occurrences, normal operating condition
5. Step load increase of 10% of full power, 2000 occurrences, normal operating condition
6. Step load decrease of 10% of full power, 2000 occurrences, normal operating condition
7. Large step decrease in load (with steam dump), 200 occurrences, normal operating condition
8. Loss of load (without immediate turbine or reactor trip), 80 occurrences, upset condition
9. Loss of power (blackout with natural circulation in RCS), 40 occurrences, upset condition
10. Loss of flow (partial loss of flow – one pump only), 80 occurrences, upset condition
11. Reactor trip from full power, 400 occurrences, upset condition
12. Steam pipe break, 1 occurrence, faulted condition
13. Turbine roll test, 10 occurrences, normal operating condition
14. Primary side hydrostatic test before startup at 3105 psig, 5 occurrences, normal operating condition

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15. Primary side hydrostatic test at 2485 psig, 50 occurrences, normal operating condition

16. Steady state fluctuations, ∞ occurrences

Details of the review of Framatome's transients are discussed below. The number of occurrences for the transients assumed by Framatome are included in the Figures.

- For heatup, Framatome's heatup curve (Figure 1) shows a rate of 100°F/hr and a range of 100°F to 600°F. This heatup rate matches the design rate for Surry. The range bounds Surry's design range. For design purposes, an ambient temperature of 70°F was assumed, and the no-load RCS temperature is 547°F. Per Reference 4, the full power upper head mean fluid temperature for Surry is 597.8°F. Therefore, the heatup rate and range proposed by Framatome are judged to be bounding. Framatome's heatup pressurization curve (Figure 2) shows an approximate rate of 645 psig/hr. This number does not bound the design value of 740 psig/hr; however, it bounds the actual pressurization rates used during plant heatup.

- For cooldown, Framatome's cooldown curve (Figure 3) shows a rate of -100°F/hr and a range of 600°F to 100°F. This cooldown rate matches the design rate for Surry. The range bounds Surry's design range as discussed above. Framatome's cooldown pressurization curve (Figure 4) shows an approximate rate of -645 psig/hr. This number does not bound the design value of 740 psig/hr; however, it bounds the actual rates used during plant cooldown.

- For plant loading, the design basis for Surry is for 29,000 cycles, based on the assumption that the plant is operating in a load-follow mode. The Surry units do not operate in a load follow mode; thus, the number of cycles for this transient is very conservative. Per Reference 4, the temperature range for this transient would be 547°F to 597.8°F, and the transient would occur over a time period of 20 minutes (5% of full power per minute). The temperature range listed in Framatome's plant loading transient is 547°F to 618°F over 20 minutes (Figure 5). In all cases, the RCS pressure remains constant at 2235 psig (Figure 6). Framatome has assumed 14,500 cycles for this transient. The Framatome transient is bounding.

- For plant unloading, the design basis for Surry is for 29,000 cycles, again based on the assumption that the plant is operating in a load-follow mode. As discussed previously, the number of cycles for this transient is very conservative. Per Reference 4, the temperature range for this transient would be 597.8°F to 547°F, and the transient would occur over a time period of 20 minutes (5% of full power per minute). The temperature range listed in Framatome's plant loading transient is 618°F to 547°F over 20 minutes (Figure 7). In all cases, the RCS pressure remains constant at 2235 psig (Figure 8). Framatome has assumed 14,500 cycles for this transient. The Framatome transient is bounding.

- For the remaining transients of increasing temperatures, Framatome proposes 2800 occurrences of a transient from 577°F to 617°F (+40°F) in 10 seconds (Figure 9), accompanied by a rise in pressure from 2235 to 2585 psig (+350 psi) (Figure 10). For the remaining transients of decreasing temperatures, Framatome proposes 2800 occurrences of a transient from 617°F to 517°F (-100°F) in 10 seconds (Figure 11), accompanied by a drop in pressure from 2235 to 1735 psig (-500 psi) (Figure 12). Review of the 10% step increase, 10% step decrease, large step decrease in load (with steam dumps), loss of load, loss of flow, reactor trip, turbine roll, and loss of power design basis transients show that they are collectively bounded by the transients assumed by Framatome, both in magnitude and number of occurrences.

- For the hydrostatic pressure tests, one planned test to 3107 psi occurred during pre-operational testing. No additional testing is planned. Also, no additional testing above normal operating pressure is to be performed, as allowed by ASME Code Case N-498-1. Thus, the hydrotstatic test transients do not need to be considered.

References:

1. Equipment Specification 676499, Revision 1, dated 4/28/71, "Addendum to Equipment Specification 676413, Rev. 1, Project: Surry Power Station I, Equipment: Reactor Vessel, System: Reactor Coolant."

2. Equipment Specification 676500, Revision 1, dated 4/29/71, "Addendum to Equipment Specification 676413, Rev. 1, Project: Surry Power Station II, Equipment: Reactor Vessel, System: Reactor Coolant."

3. Calculation 30660-1130, "Reactor Vessel – Final Stress Report," Revision 1 (North Anna Units 1 and 2).

4. Engineering Transmittal NAF 95-162, Rev. 0, "Reactor Vessel Coolant Temperature Design Input for Use in Upper Head Penetration Inspection Program, Surry Power Station Units 1 and 2."

Prepared by: D. McG[signature] Date: 10-11-01

Reviewed by: K. K. Dwivedy Date: 10-11-01

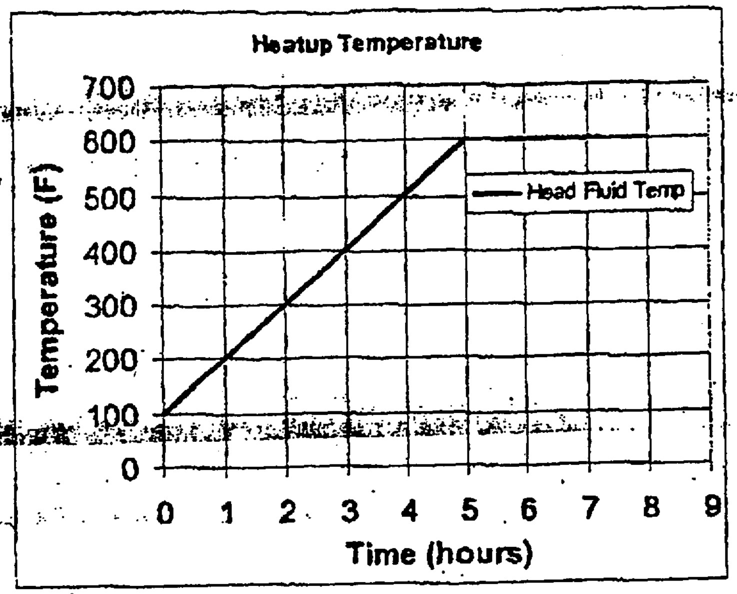


Figure 1

Occurrences = 200

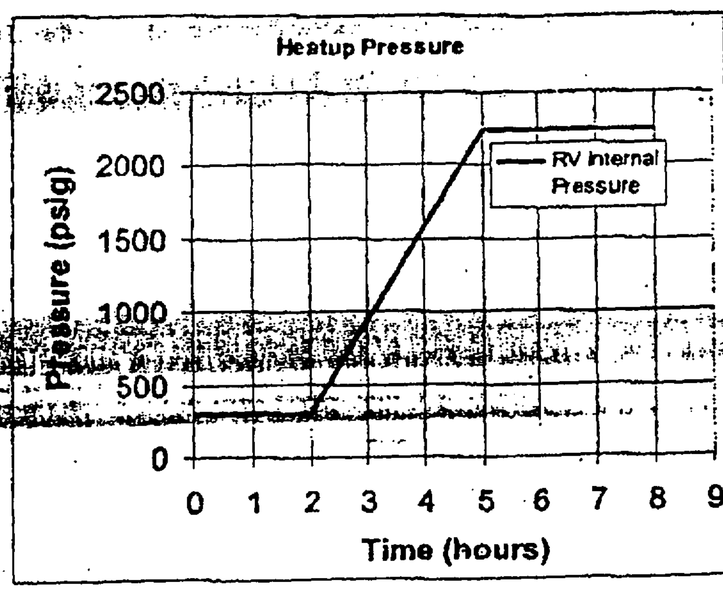


Figure 2.

Occurrences = 200

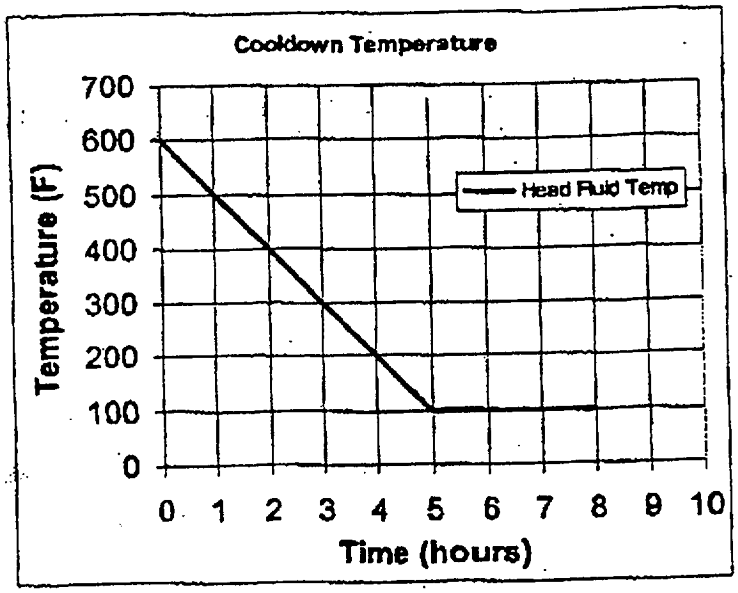


Figure 3

Occurrences = 200

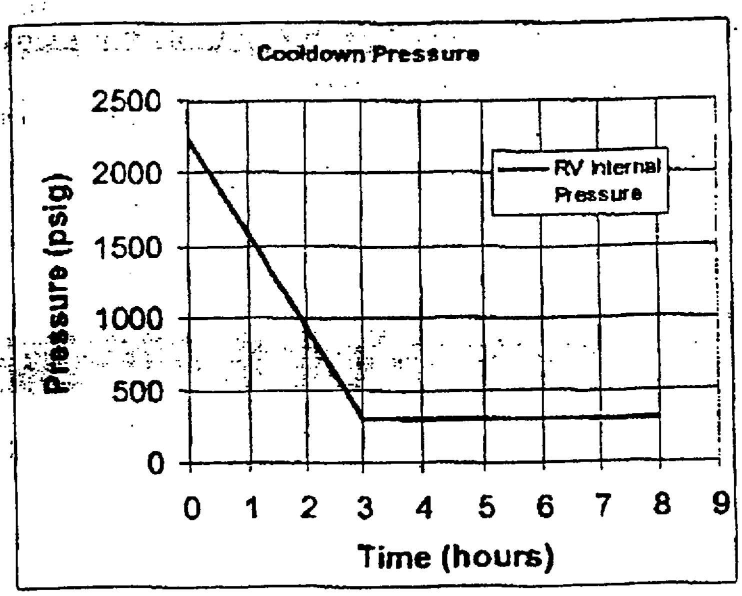


Figure 4.

Occurrences = 200

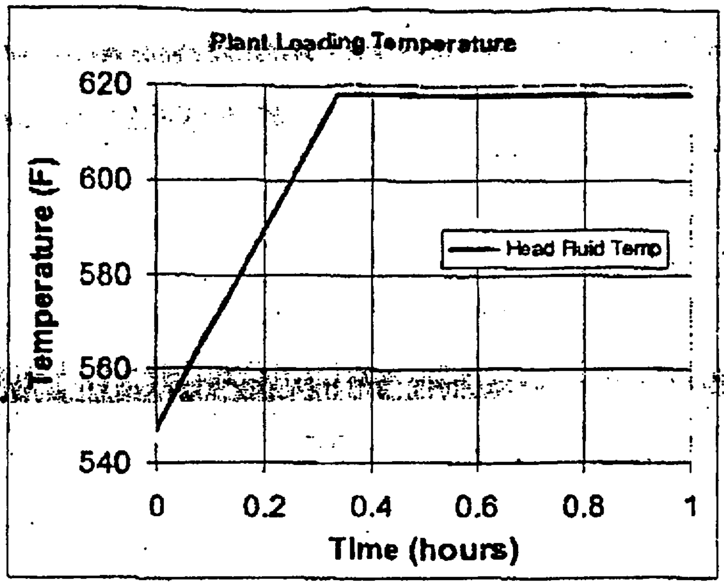


Figure 5

Occurrences = 14,500

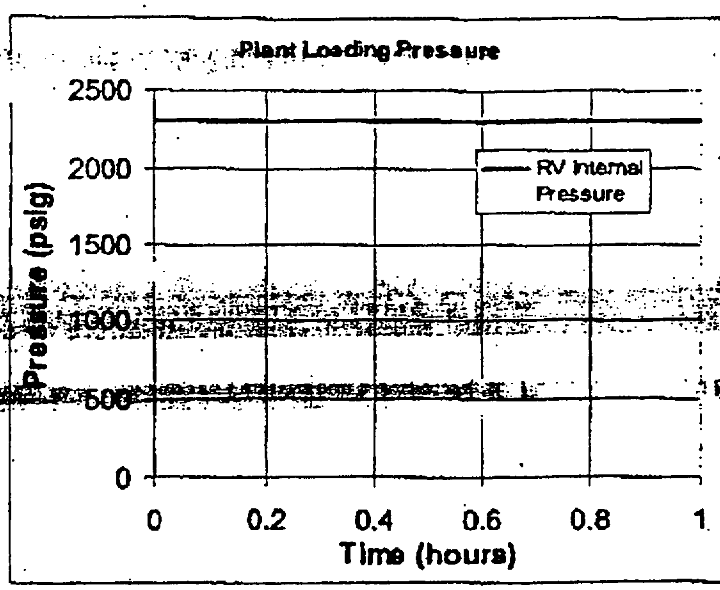


Figure 6

Occurrences = 14,500

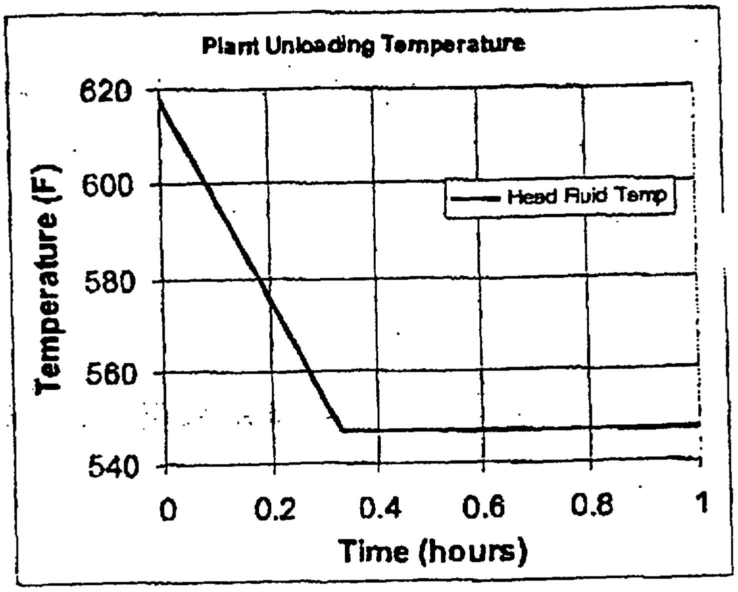


Figure 7

Occurrences = 14,500

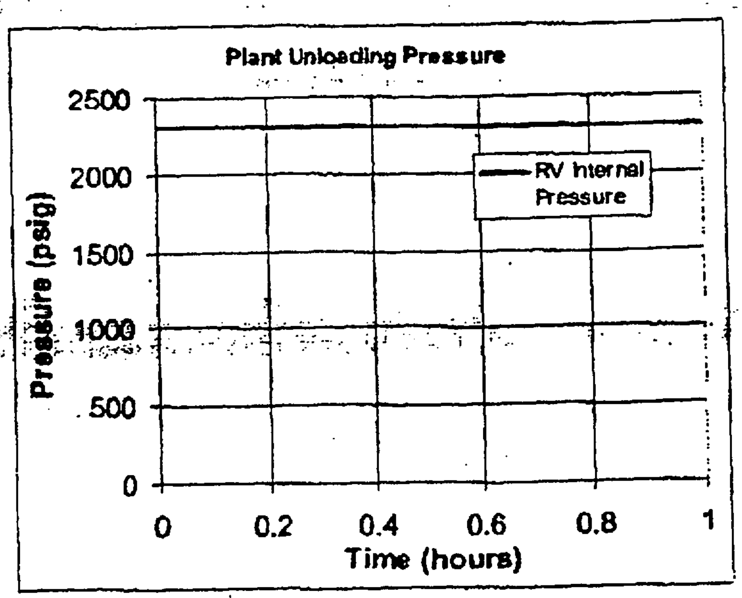


Figure 8

Occurrences = 14,500

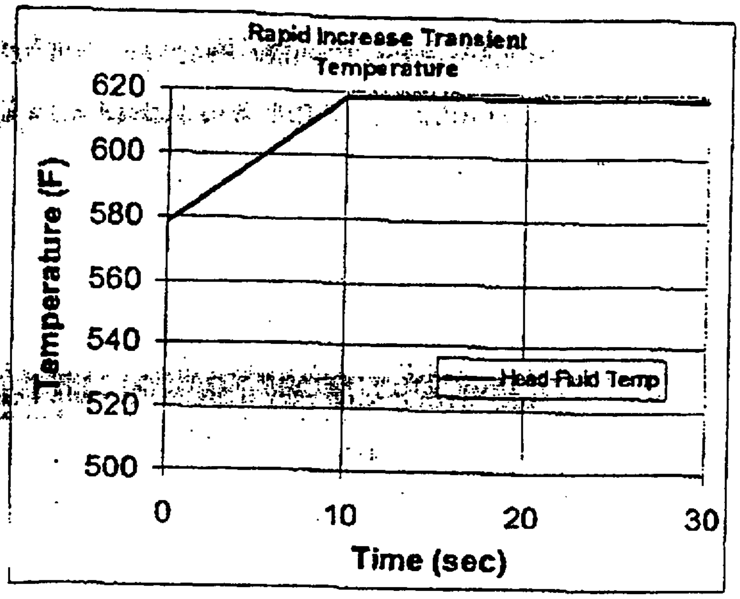


Figure 9

Occurrences = 2800

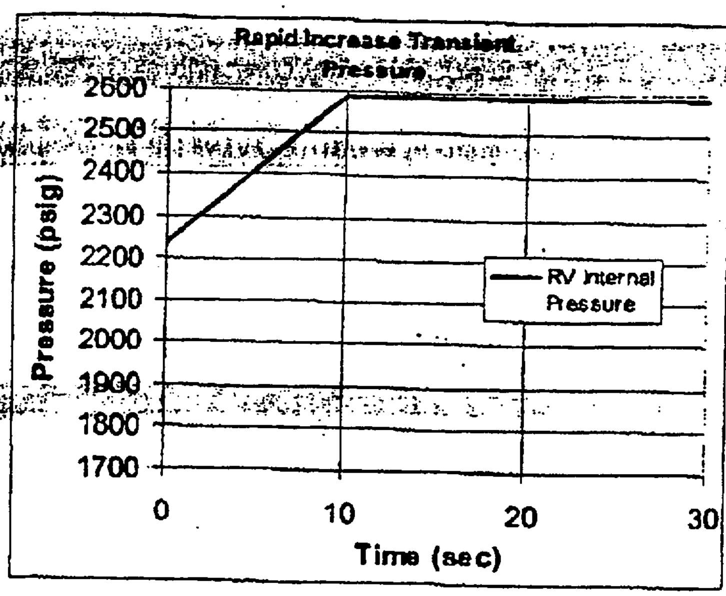


Figure 10

Occurrences = 2800

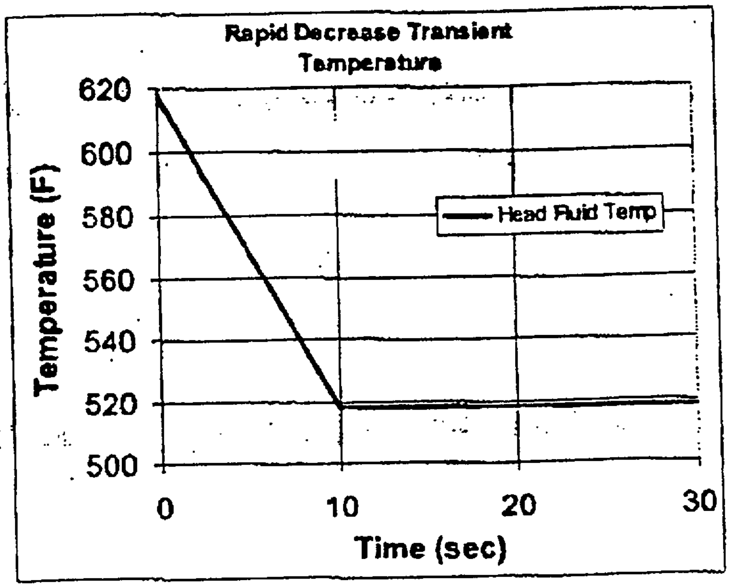


Figure 11

Occurrences = 2800

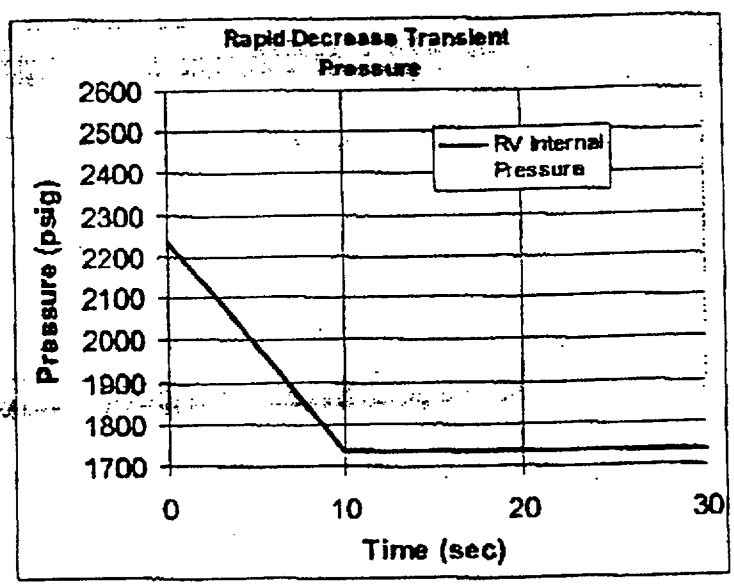


Figure 12

Occurrences = 2800

Dominion Generation
Nuclear Engineering
Innsbrook Technical Center
5000 Dominion Boulevard, Glen Allen, VA 23060

Dominion

APPENDIX B
Doc. Id 51-5015197-00
Page 1 of 2

Framatome ANP, Inc
3315 Old Forest Road
Lynchburg, BA 24506-0935

October 17, 2001

Attention: Mr. Paul Ulmer

Subject: Surry Reactor Head Inspection
Design Information Transmittal

Dear Mr. Ulmer:

Attached to this letter are the highlighted drawings that Framatome sent to Dominion for design information verification with the corresponding Westinghouse information. This information has been verified with the exceptions listed below (which were sent to Framatome in an earlier e-mail) and so indicated with additional highlighting next to the requested information. This information can be used as design input for the Surry Units 1 and 2 Reactor Vessel Head Repair.

Exceptions:

1. Drawing 131175E--I can't verify the original material thickness of 6 9/16" for the head.

2. Drawing 131174E--I have not been able to verify notes 2, 3, 4, 5, 6, 9, 11, 12. I'm still working on this. Also I have not confirmed the appreciable stress due to bolting. Our engineering mechanics guys think this is a good assumption but we will have the stress report on Thursday and will verify this.

3. Drawing 131178E--Cannot verify Westinghouse weld procedures are the same as Framatome's. The NDE requirements are the same as far as calling for a PT.

4. Drawing 131177E--Section "Machining of Control Rod Mechanism Housing" shows 2 blocks at the right end of the housing. I can verify the left block and everything in the right block except the last word or number. It is also unclear on the drawings that Westinghouse has. They said that it is "/308" but that really doesn't seem to make any sense.

5. Drawing 134809E--Section 15--I'm not sure what is meant by "2" dia (and then a triangle)" but I have not been able to verify this.

6. Drawing 131179E--There are a couple of areas circled on this drawing and they appear to be head vent piping details. I have verified that the Unit 2 drawings agree with the Westinghouse drawings but I can't read your unit 1 details. I am assuming that these are the same as the unit 2 details.

7. Drawing 5015107D--Most of these dimensions have been verified and a couple are fractionally different and are listed on the marked up drawing.
8. Additional information was requested on CRDM housing material and welding. This is listed below with the response in bolded type.

As part of your design input response letter can you please confirm that the following materials are applicable to the Surry 1 and 2 CRM penetrations?

1) CRM Housing Nozzle = SB-167 (Inconel). **Correct**

2) Closure Head Cladding = Austenitic Stainless Steel, Type 316. **It is austenitic stainless but I have not been able to verify the 316. All of the Westinghouse specs say "304 or better".**

3) Closure Head/CRM Housing Nozzle, J-Groove weld buttering = Alloy 600 (Inconel). **According to our welding experts, the weld material comparable to Inconel 600 is Inconel 82/182. According to them, Inconel 600 is not a weld filler material.**

4) Closure Head/CRM Housing Nozzle, J-Groove weld filler metal = Alloy 600 (Inconel). **See item 3 response.**

If you have any additional questions or need any more information please do not hesitate to call me at 804-273-3586

Dean I. Price
Project Engineer

APPENDIX B
Doc. Id. 51-5015197-00
Page 2 of 2

APPENDIX C
Doc. Id. 51-5015197-00

Ref. 1

Dominion
Generation
Surry Power Station

FACSIMILE TRANSMITTAL

TO: AL McKIM / PAUL ULMER
PHONE:
FAX:

FROM: DOUG LAWRENCE
PHONE: (757) 365-2755
FAX: - 2750

E-MAIL :

DATE: 10/5/01 TIME: 1305

OF PAGES 25 (INCLUDING THIS PAGE)

MESSAGE:

HERE IS PART LENGTH CONTROL ROD AND VESSEL MATERIAL & DESIGN DATA. WILL FAX STRESS REPORT NEXT.

Doug

51-5015197-00

Ref 1

888.15A

FINAL DESIGN
SURRY POWER STATION
VIRGINIA ELECTRIC AND POWER COMPANY

TO: SUPERVISOR – ENGINEERING SERVICES (1)	DESIGN CHANGE NO: 78-S25 (2)
TITLE: Part Length Control Rod Removal (3)	UNIT NO: 1 & 2 (4)

FINAL DESIGN: (5)
(FINAL DESIGN SHALL CONSIST OF: 1. REFERENCES; 2. DESCRIPTION; 3. DRAWINGS; 4. DESIGN BASIS; 5. OPERATIONAL REQUIREMENTS; 6. PERIODIC TEST REQUIREMENTS; 7. MATERIALS LIST AND 8. EQUIPMENT SPECIFICATIONS.)

FINAL DESIGN DEVELOPED BY: Lawrence Lobo *Lawrence Lobo* (6)	COMPLETION DATE: 3/20/79 (7)
PROJECT ENGINEER: Lawrence Lobo *Lawrence Lobo* (8)	DATE: 3/20/79 (9)
REVIEWED BY DESIGN CONTROL ENGINEER: R. H. Coupe *[signature]* (10)	DATE: 4-4-79 (11)
REVIEWED BY SUPERVISOR-ENGINEERING SERVICES: D. A. Christian *David A Christian* (12)	DATE: 4-9-79 (13)
REVIEWED BY SUPERVISOR-NUCLEAR ENGR. SERVICES: *[signature]* (14)	DATE: 10-1-79 (15)
REVIEWED BY STATION NUCLEAR SAFETY AND OPERATING COMMITTEE: CHAIRMAN'S SIGNATURE: *[signature]* (16)	DATE: APR 9 1980 (17)

PROJECT AUTHORIZATION (ATTACH, IF REQUIRED.) (18)
[X] REQUIRED; NO.: Surry No. 1 81216406 / Surry No. 2 81216506 [ ] NOT REQUIRED

REVISIONS TO FINAL DESIGN (ATTACH "FIELD CHANGE"): (19)

REVISION NUMBER:	1	2									
DATE:	4/25/80	7/11/80									

REMARKS: (20)

F 888.10

FINAL DESIGN (SUPPLEMEN
SURRY POWER STATION
VIRGINIA ELECTRIC AND POWER COMPANY

ATTACH TO: FINAL DESIGN 1	DESIGN CHANGE NO. 2
	78-S25

FINAL DESIGN (CONTINUED): 3

1.0 REFERENCES:

1.1 Royal Industries, Model 121 J001 Part Lenth Control Rod Drive Manual.

1.2 MMP-C-RC-035

1.3 OP-4.5

1.4 Vepco Quality Assurance Manual, Section 3

1.5 FSAR Section 3

1.6 W FS-78-1, Rev. October 18, 1978

2.0 DESCRIPTION:

2.1 Description of the anti-rotation devices can be found in the Westinghouse proposal for the Removal of Part Length Control Rods dated April 25, 1978. A copy is attached for reference.

3.0 DRAWINGS:

3.1 The appropriate drawings are attached.

3.2 Figure 1: Partial Length Anti Rotation Housing

Figure 2: Partial Length Up Position Leadscrew Clamp

Figure 3: Partial Length Conoseal Assembly

Figure 4: Partial Length Up Position Lead Screw Retainer

Figure 5: Locations of P/L Control Rods

4.0 DESIGN BASIS:

4.1 The intent of the Part Length Control Rods was to control axial power distribution and to suppress xenon oscillations.

4.2 The utilization of Part Length Control Rdds for axial power distribution is not desirable. The insertion of the Part Length Control Rods would cause the lowering of power in the axial region just below and above the neutron absorbing material of the Part Length Control Rod.

4.3 At the time the Surry Units were designed, there was no stringent restriction on $\Delta\phi$ band. At the present time, there is a restriction on maintaining a narrow $\Delta\phi$ band of ± 5% which reduces xenon oscillations to a very low level.

888.16

FINAL DESIGN (SUPPLEME)
SURRY POWER STATION
VIRGINIA ELECTRIC AND POWER COMPANY

ATTACH TO: FINAL DESIGN 1	DESIGN CHANGE NO. 2
	78-S25

FINAL DESIGN (CONTINUED): 3

4.0 DESIGN BASIS: (CONTINUED)

4.4 Technical Specifications for Surry Power Station Units 1 and 2 do not allow the use of the part length control rods during operation. Westinghouse's study on part length control rod removal and operational experience in Surry indicate that the removal of the part length control rods is desirable.

5.0 OPERATIONAL REQUIREMENTS:

5.1 The reactor coolant system is to be at refueling shutdown condition in accordance with the plant technical specifications.

5.2 Once the part length control rods are removed, additional operational requirements are not necessary.

6.0 PERIODIC TEST REQUIREMENTS:

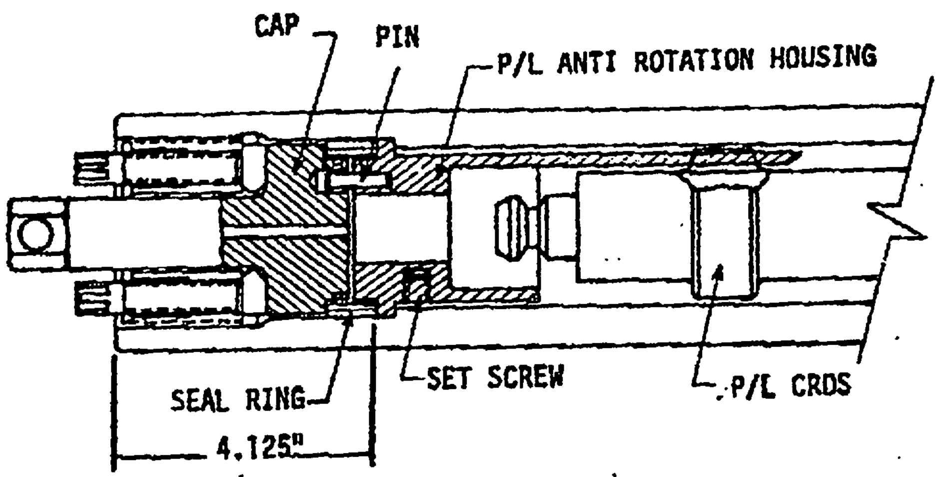
6.1 After the part length control rods are removed, the seals at the top of the part length lead screw travel housing need never be opened during a refueling. Since the seal is never broken, any possibility of leakage during plant startup following an outage is virtually eliminated. Therefore, there is no need for periodic testing.

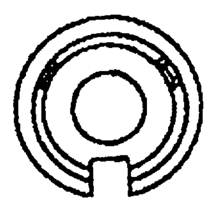
7.0 MATERIALS LIST:

7.1 See Westinghouse proposal dated April 25, 1978 attached.

8.0 EQUIPMENT SPECIFICATIONS:

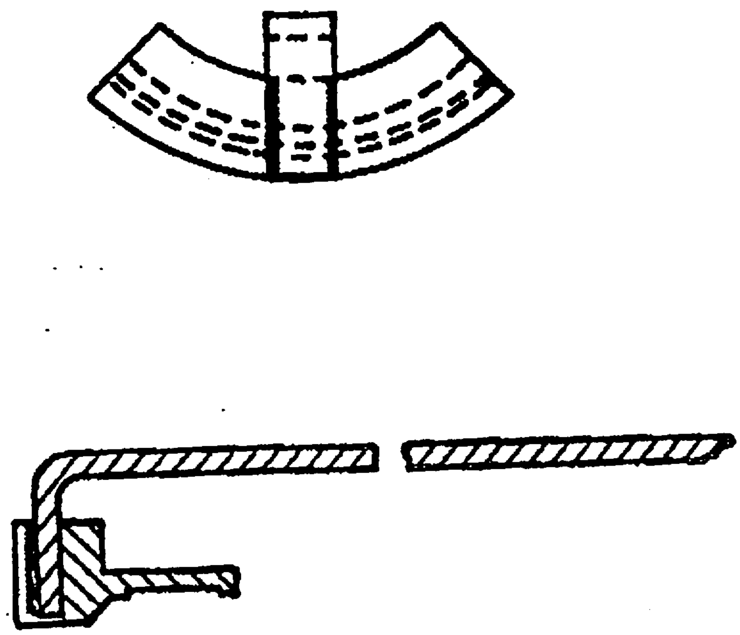
8.1 Not required





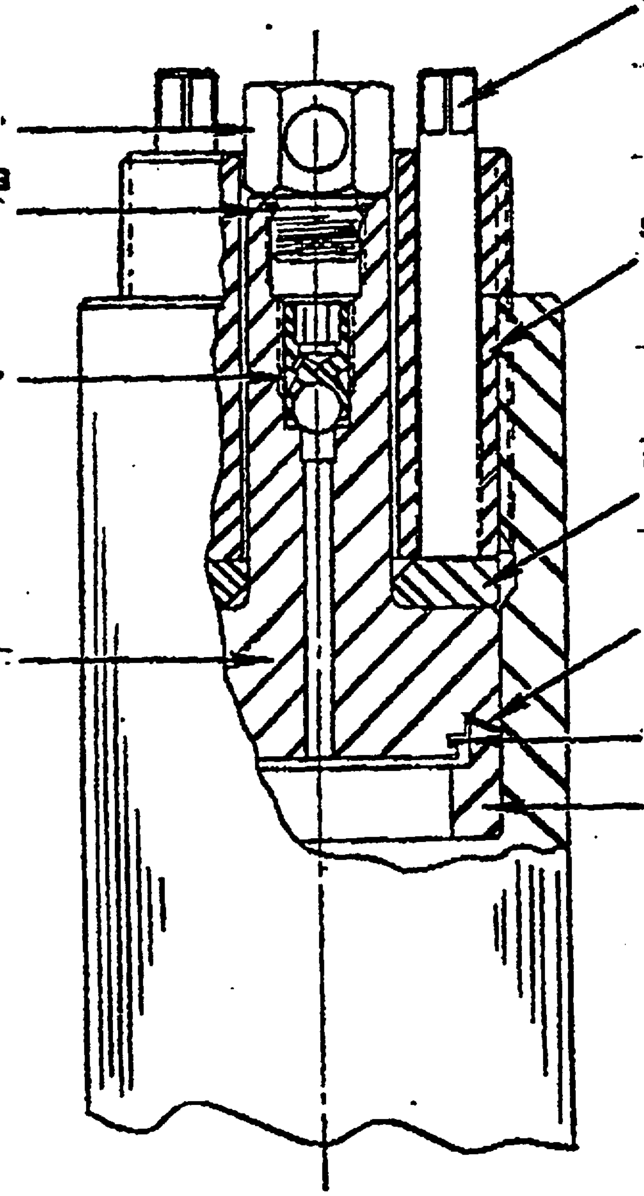
PARTIAL LENGTH ANTI ROTATION HOUSING

FIGURE 1



PARTIAL LENGTH UP POSITION LEADSCREW CLAMP

FIGURE 2

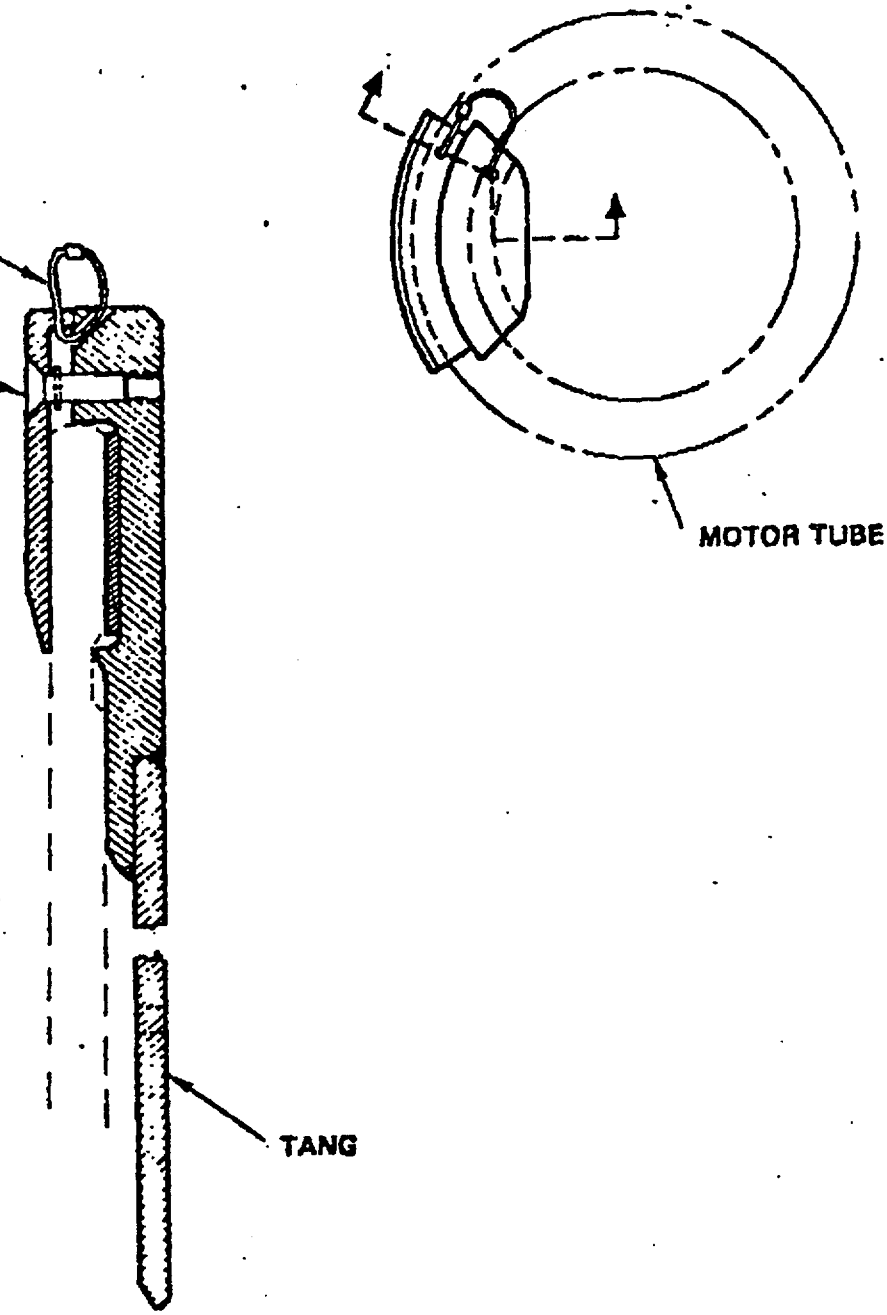


PARTIAL LENGTH CONOSEAL ASSEMBLY

FIGURE 3

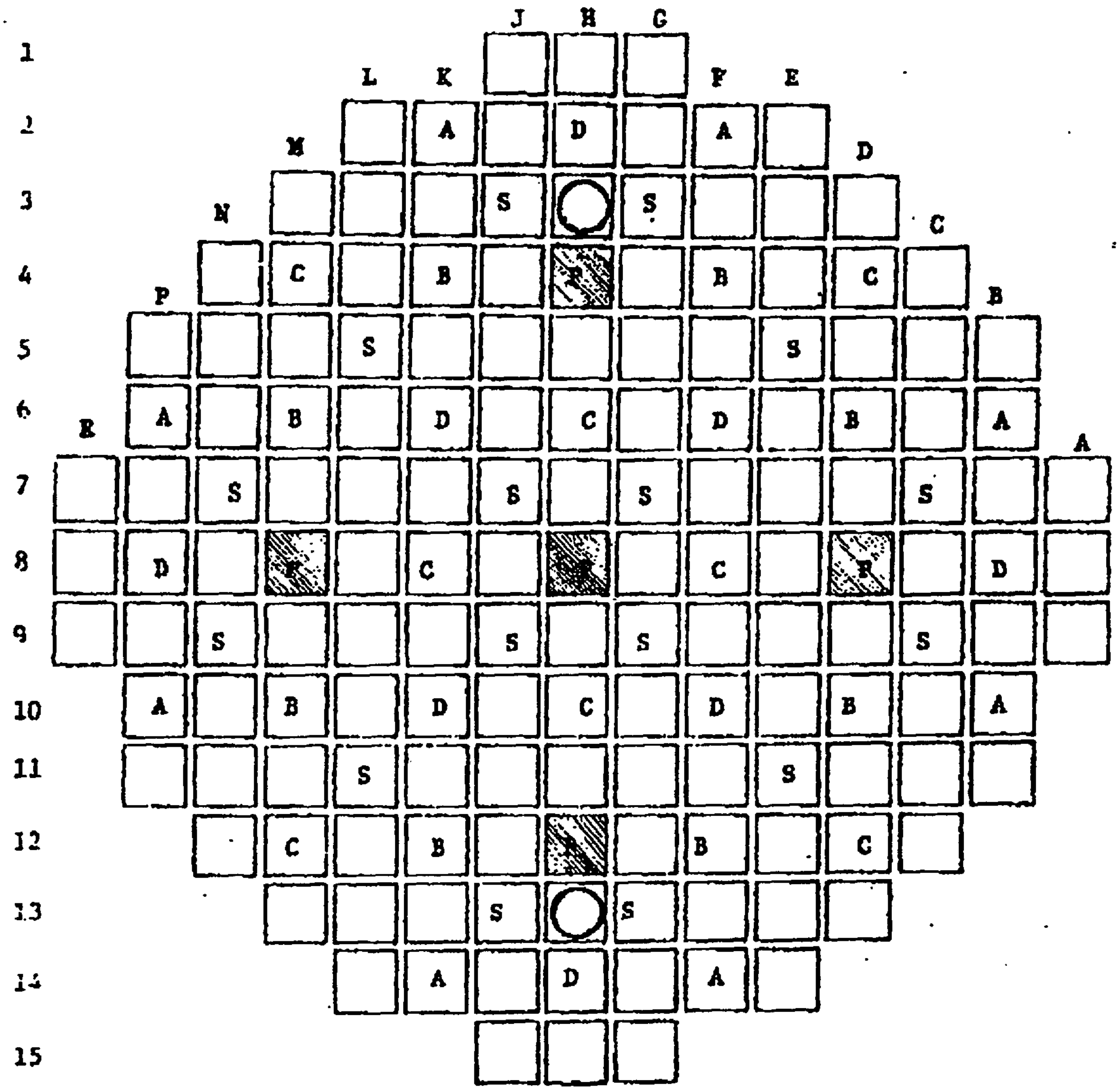
NSD

FS-78-1



PARTIAL LENGTH UP POSITION LEADSCREW RETAINER

FIGURE 4



CONTROL ROD ASSEMBLY BANKS

Function	Number of Assemblies
Control Bank D	8
Control Bank C	8
Control Bank B	8
Control Bank A	8
Shutdown (S)	16
Part Length (P)	5
	53

◯ = SOURCE ASSEMBLY LOCATIONS

FIGURE 5: LOCATIONS OF PART LENGTH CONTROL RODS

CONTROL ROD ASSEMBLY GROUPS

No. 888.19A

FINAL DESIGN IMPLEMENTATIO[N] AND TESTING
SURRY POWER STATION
VIRGINIA ELECTRIC AND POWER COMPANY

TO: 1	DESIGN CHANGE NO: 2 78-S25
DESIGN CHANGE TITLE: 3 PART LENGTH CONTROL ROD REMOVAL	UNIT NO: 4 1

DESIRED IMPLEMENTATION DATE: 5

DURING STEAM GENERATOR REPLACEMENT

FINAL DESIGN CONTROLLING PROCEDURE: 6

PROCEDURE SHALL CONSIST OF: 1. PURPOSE; 2. INITIAL CONDITIONS; 3. PRECAUTIONS; 4. INSTRUCTIONS;

☒ COPY ATTACHED

FINAL DESIGN TESTING: 7

PROCEDURE SHALL CONSIST OF: 1. PURPOSE; 2. INITIAL CONDITIONS; 3. PRECAUTIONS; 4. INSTRUCTIONS; 5. ACCEPTANCE CRITERIA.

COPY ATTACHED:
- ☐ MECHANICAL TESTING
- ☐ ELECTRICAL TESTING
- ☐ INSTRUMENT TESTING
- ☐ CHEMICAL TESTING

FINAL DESIGN CONTROLLING AND TESTING PROCEDURES: 8

SUBMITTED BY PROJECT ENGINEER: 9 Lawrence Lobo	DATE: 10 7-18-80
REVIEWED BY DESIGN CONTROL ENGINEER: 11 Richard Coupe	DATE: 12 7-18-80
RECOMMENDED APPROVED BY SUPERVISOR-ENGINEERING SERVICES: 13 David Fortin	DATE: 14 7-21-80
REVIEWED BY QUALITY CONTROL: 15 Frank Rentz	DATE: 16 7-21-81
APPROVED BY STATION NUCLEAR SAFETY AND OPERATING COMMITTEE: 17 CHAIRMAN'S SIGNATURE:	DATE: 18 8/1/80

REMARKS: 19

This procedure addendum inserted as Field Change #2

51-5015197-00 Pg. 10

888.9A (SURRY)

DESIGN CHANGE REQUEST
SURRY POWER STATION
VIRGINIA ELECTRIC AND POWER COMPANY

TO: SUPERVISOR - ENGINEERING SERVICES 1 | DESIGN CHANGE NO.: 78-525 2

SYSTEM: Reactor Control 3 | COMPONENT TAG NO.: Part Length Control Rods 4 | UNIT NO. 1 & 2 5

REFERENCE: Letter (W) to VEPCO (Sylvia) 4/25/78 – "Removal of Part Length Control Rods – Surry Units One & Two" 6

BRIEF DESCRIPTION OF CHANGE REQUESTED (ATTACH ADDITIONAL PAGES, IF REQUIRED): 7
Remove P/L RCC from core – replace with "thimble plug" inserts. Install anti-rotation device to hold lead screw up in head.

REASON FOR CHANGE: 8
1) Decreased outage time during refueling outage – 2) Decreased radiation exposure – 3) Operation not allowed by T/S.

CHANGE REQUESTED BY: G. Kane 9 | DATE: 7/13/78 10

REVIEWED BY: COGNIZANT SUPERVISOR: J. Wilson 11 | DATE: 7-20-78 12

RECOMMENDED ACTION: 13
[X] APPROVED [ ] DISAPPROVED [ ] APPROVED AS MODIFIED

PROJECT ENGINEER: L. LOBO 14 | DATE ASSIGNED: 11/1/78 15 | DATE REQUIRED: 16

17
[X] ENGINEERING REVIEW ATTACHED

QUALITY GROUP CLASSIFICATION: [X] A [ ] B [ ] C [ ] IE [ ] I [ ] NC [ ] D [ ] E [ ] OTHER 18

19 TECH SPEC. ITEMS: [ ] NO [X] YES SECT. NO. 3.12 20

21
IMPLEMENTATION METHOD: [X] DESIGN CHANGE PROGRAM [ ] MAINTENANCE PROGRAM MAINTENANCE REPORT NO.

PROJECT ENGINEER'S SIGNATURE: Lawrence Lobo 22 | DATE: 11/1/78 23

24
[X] SAFETY ANALYSIS ATTACHED (REQ'D FOR SAFETY-RELATED ITEMS)

25 TECH SPEC. CHANGE REQUIRED [X] YES [ ] NO 26

27
UNREVIEWED SAFETY QUESTION [ ] YES [X] NO

PROJECT ENGINEER'S SIGNATURE: Lawrence Lobo 28 | DATE: 11/1/78 29

30
DESIGN CONTROL ENGINEER'S RECOMMENDED ACTION: [X] APPROVE [ ] DISAPPROVED

APPROVAL LEVEL [X] NRC LEVEL [ ] SYSTEM LEVEL [ ] STATION LEVEL 31

METHOD OF IMPLEMENTATION [X] DESIGN CHANGE PROGRAM [ ] MAINTENANCE PROGRAM

DESIGN CONTROL ENGINEER'S SIGNATURE: D.H. Koupl 32 | DATE: 11/29/78 33

SUPERVISOR - ENGINEERING SERVICES' REVIEW: 34
Tech. Spec revision to be handled as a portion of the core reload package.

[X] APPROVED [ ] DISAPPROVED [X] APPROVAL LEVEL VERIFIED

[X] STATION TO COMPLETE FINAL DESIGN [ ] PRODUCTION SERVICES RESPONSIBLE FOR FINAL DESIGN

PROJECT AUTHORIZATION ATTACHED (IF REQUIRED): 35

NOT REQ'D. [X] REQ'D PRIOR TO FINAL DESIGN REQ'D POST FINAL DESIGN

IR 99-0457

SUPERVISOR ENGINEERING SERVICES' SIGNATURE: [signature] 36 | DATE: 11/30/78 37

38
STATION NUCLEAR SAFETY AND OPERATING COMMITTEE REVIEW:

[X] APPROVED [ ] DISAPPROVED [ ] APPROVED AS MODIFIED

#580.10

DESIGN CHANGE REQUE
SURRY POWER STATION
VIRGINIA ELECTRIC AND POWER COMPANY

REMARKS: 39	DESIGN CHANGE NO.: 78-525
CHAIRMAN'S SIGNATURE: [signature] 41	DATE: 2/7/79 42

NUCLEAR ENGR. SERVICES' REVIEW: 43
ORGANIZATION TO CONDUCT REVIEW ~~OR FINAL DESIGN:~~

☒ NUCLEAR ENGR. SERVICES STAFF ☐ CONTRACTOR ☐ OTHER

PROJECT ENGINEER: S.W. Bristow, Jr. 44	DATE ASSIGNED: 2-6-79 45
AFFILIATION: Engineer - NES 46	

NUCLEAR ENGR. SERVICES' REVIEW: 47

UNREVIEWED SAFETY QUESTION ☒ NO ☐ YES COMMENT:

SUPERVISOR NUCLEAR ENGR. SERVICES' SIGNATURE: R. M. Berryman 48	DATE: 3/6/79 49

SYSTEM NUCLEAR SAFETY AND OPERATING COMMITTEE REVIEW: 50

UNREVIEWED SAFETY QUESTION: ☐ YES ☒ NO

☒ APPROVED ☐ DISAPPROVED ☐ APPROVED AS MODIFIED

COMMENTS: 51

CHAIRMAN'S SIGNATURE: W. L. Dilzy 52	DATE: 3/12/79 53
FINAL DESIGN COMPLETED: L. LOBO 54	DATE: 3-30-79 55
TITLE: ASSISTANT ENGINEER 56	AFFILIATION: VEPCO 57
FINAL DESIGN REVIEWED BY STATION NUCLEAR SAFETY AND OPERATING COMMITTEE: CHAIRMAN'S SIGNATURE: J. L. WILSON 58	DATE: APR 9 1980 59
FINAL DESIGN IMPLEMENTATION CONTROLLING AND TESTING PROCEDURES COMPLETED BY: L. LOBO 60	DATE: 3-20-80 61
REVIEWED BY STATION NUCLEAR SAFETY AND OPERATING COMMITTEE: CHAIRMAN'S SIGNATURE: J. L. WILSON 62	DATE: 4-9-80 63
DATE DESIGN CHANGE COMPLETED ON UNIT NO. 1: 9-27-80 64	DATE DESIGN CHANGE COMPLETED ON UNIT NO. 2: 6-24-80 65
CONTROLLED DOCUMENT REVIEW AND REVISION COMPLETED BY PROJECT ENGINEER: Lawrence Lobo 66	DATE: 3-29-82 67
COMPLETED DESIGN CHANGE REVIEWED BY DESIGN CONTROL ENGINEER: [signature] 68	DATE: 3-29-82 69
COMPLETED DESIGN CHANGE AUDITED BY QUALITY ASSURANCE ENGINEER: [signature] 70	DATE: 4-1-82 71

FORWARD TO STATION RECORDS

880.11 A

ENGINEERING REVIEW
SURRY POWER STATION
VIRGINIA ELECTRIC AND POWER COMPANY

ATTACH TO: DESIGN CHANGE REQUEST	DESIGN CHANGE NO: 78-S25
DESIGN CHANGE TITLE: Removal of Part Length Control Rods	
PROJECT ENGINEER PERFORMING REVIEW: Lawrence Lobo (signed) Lawrence Lobo	DATE: 11/27/78
REVIEWED BY DESIGN CONTROL ENGINEER: R. H. Coupe (signed)	DATE: 11/29/78
REVIEWED BY SUPERVISOR – ENGINEERING SERVICES: T. A. Peebles (signed) T A Peebles	DATE: 11/30/78

ENGINEERING REVIEW: (THE REVIEW SHALL CONSIST OF: (1) ANALYSIS OF THE REQUEST: (2) PROPOSED RESOLUTION: (3) APPROVAL LEVEL:)

(1) ANALYSIS OF THE REQUEST:

1.) This design change request consists of the removal of part length control rods from Surry #1 and #2 Units. There are five part length control rod assemblies in each unit. After removing the part length control rods from the core, thimble plugs are to be inserted in the fuel assembly from which the part length rods are removed.

The intent of the part length control rods was to control axial power distribution and to suppress Xenon oscillations.

The utilization of part length control rod for axial power distribution control is not desirable. The insertion of the part length control rods would cause the lowering of power in the axial region.surrounding neutron absorbing material. At the same time causing a higher power in the axial region just below and above the neutron absorbing material of the part length rod.

At the time Surry units were designed, there was no stringent restriction on $\Delta\phi$ band. At the present time, there is a restriction on maintaining a narrow $\Delta\phi$ band of ± 5% which reduces the Xenon oscillations to a very low level.

2.) Westinghouse has evaluated and analyzed the removal of the part length control rods while leaving the lead screw in the fully withdrawn position (Details are discussed by Westinghouse in a letter to B. R. Sylvia) and found:

(1) There are no thermal or hydraulic problems including no change in T_H in the upper head provided the part length rods are replaced by thimble plugs.

(2) There are no problems with replacing the part length rod with a thimble plug.

(3) There are no mechanical problems including vibrations, provided the lead screw is adequately supported at the top end. This can be done using an Anti-rotation Device. When the part length rod is unlatched, the lead screw is free to rotate. So when the screw is moved to the top of its housing, its own weight and/or vibration can cause it to rotate in the direction which would lower it. Westinghouse has designed a 40 year anti-rotation device that can be utilized to prevent the lead screw from rotating. The device has a pin which fits into holes drilled into both the anti-rotation device housing and the cap of the conoseal. The cap cannot rotate

4 888.12

ENGINEERING REVIEW (SUPPL NT)
SURRY POWER STATION
VIRGINIA ELECTRIC AND POWER COMPANY

ATTACH TO: ENGINEERING REVIEW

DESIGN CHANGE NO. 78-S-25

ENGINEERING REVIEW (CONTINUED):

(1) ANALYSIS OF THE REQUEST: (CONTINUED)

therefore the device cannot. The anti-rotation device can be installed while the head is in its laydown area.

The removal of the part length control rods provides the following benefits.

(1) Decreased outage time.

The design of the part length control rod drive mechanism is such that the lead screw, which is used to raise and lower the rod, cannot be removed from the mechanism. This results in the requirement for a removable seal at the top of the part length control rod drive mechanism, as well as a long tool for extending down into CRDM to unlatch the screw from the part length rod. This unlatching and relatching process can require as much as two 10-hour shifts during each refueling outage, all of which can be critical path time. Removal of the part length control rods can therefore save as much as a full day of outage time.

In addition, after the part length control rods are removed, the seals at the top of part length lead screw travel housing need never be opened during a refueling. Because the seal is never broken, this virtually eliminates any possibility of leakage during plant startup, following an outage. Therefore, the risk of significantly extending the outage while cooling down, depressurizing, and repairing a leak at this location, is reduced essentially to zero.

(2) Decreased radiation exposure

The latching/unlatching process requires two individuals at a time working for as much as a total of 20 hours in a high radiation field. After the part length rods are removed, none of this is necessary. This makes a significant contribution to the ALARA program.

(2) PROPOSED RESOLUTION:

Based on the Westinghouse study, and operational experience at Surry, it is recommended that the following be accomplished: (1) Remove part length control rods from the core, (2) Insert thimble plugs in the fuel assemblies, which contain part length control rods, (3) Install Anti-rotation Device to keep the lead screw in the raised position.

During the fuel shuffle, the part length control rods may be inserted into spent fuel assemblies and taken to the spent fuel pit while thimble plugs are inserted into the locations formerly occupied by the Part Length Control Rods.

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1. GENERAL INFORMATION.

1.1 General data.

1.1.1 General description.

The 157-inch reactor vessel consists of a vessel shell and a closure head. The vessel shell is a cylindrical section with a 12-feet 11-7/8-inch I.D. and a 14-feet 5-7/32-inch O.D. at the primary inlet and outlet connections. Below these connections it has a 13-feet 1-5/16-inch I.D. and a 14-feet 5-7/16-inch O.D.
The dimension from the centerline of the vessel to the outer face of the inlet nozzle is 10-feet 5-½-inches. The dimension from the centerline of the vessel to the outer face of the outlet nozzle is 10 feet 2-3/8 inches.
The bottom hemispherical head is machined to receive 50 instrumentation nozzles. The closure head is machined to receive the 65 control rod mechanism housings.
The vessel stands 42 feet 7-3/16 inches high from the bottom hemispherical head to the top of the control rod mechanism housings. (see also figure 1-1).

1.1.2 Design conditions.

Design pressure	2485 psig
Design temperature	650° F.
Hydrotest pressure	3107 psig
Hydrotest temperature	NDTT + 60°F minimum
Hydrotest temperature at manufacture	110° F

1.1.3 Operating conditions.

Coolant fluid	Pressurized water
Operating pressure	2235 psig
Normal operating temperature	543° F
Inlet temperature	543° F
Outlet temperature at normal power	605,8° F

ONLY THIS INFORMATION IS PERTINENT ON THIS PAGE.
[illegible signature]

1.1.4 Initial operating limitations.

The heating and cooling rate is limited to maximum 100°F per hour. These rates will be safe for 200 occurances each. Thus, when starting at an isothermal condition at 100°F, the maximum heating rate is not to exceed 100°F per hour up to operating temperature and, when starting at an isothermal condition at operating temperature, the maximum cooling rate is not to exceed 100° F per hour returning to 100° F.

1.1.5 Basic Dimensions.

1.1.5.1 Vessel Shell Assembly.

Flange Forging	15-feet 4-inch O.D. x 2-feet 11-½ inch length
Cylindrical Section Nozzles	12-feet 11-7/8-inch I.D. x 9-inch minimum thick manganese-molybdenum steel plus 0.156-inch austenitic stainless steel cladding.

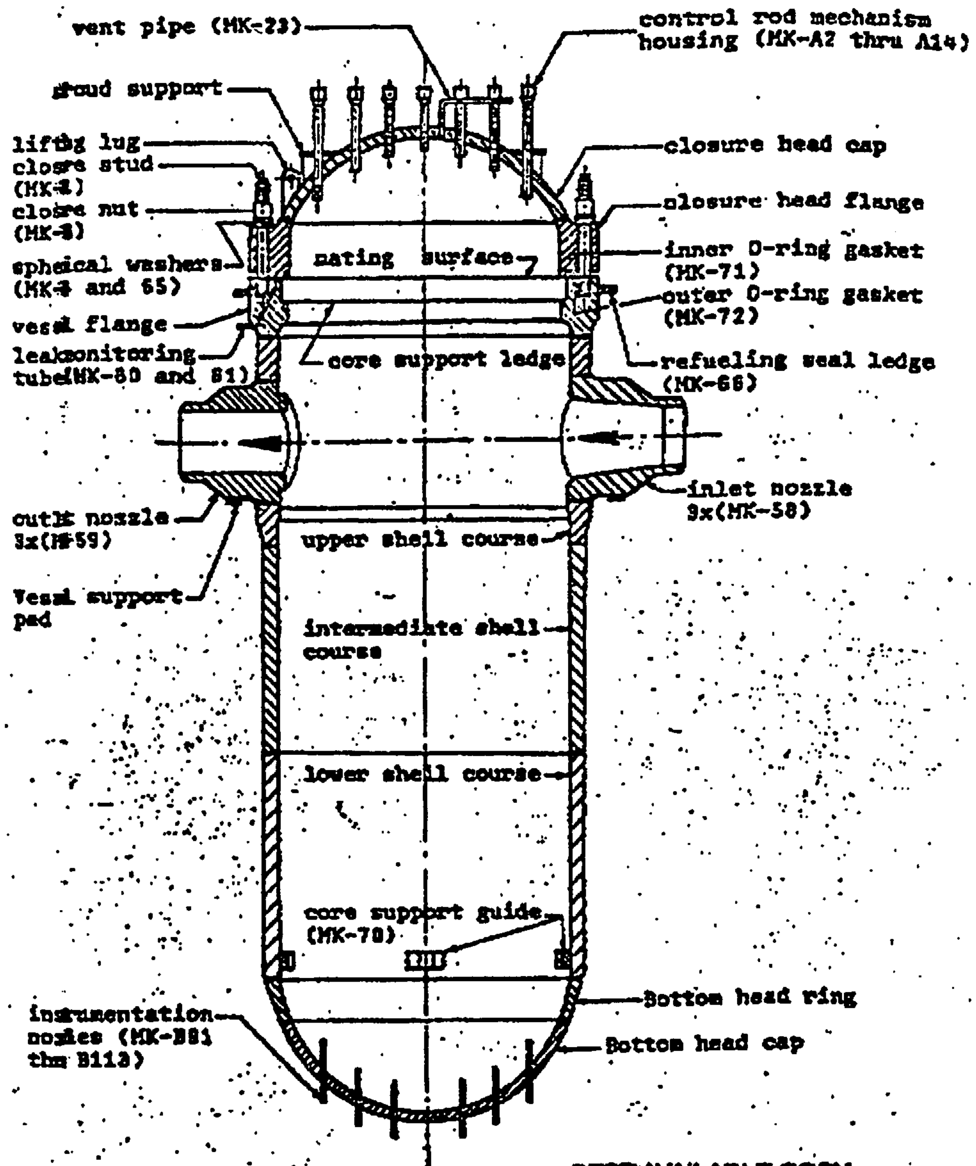

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Figure 1-1 Reactor vessel

This page is non-pertinent
WJ Comm

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PAGE 16

Cylindrical Section	13-feet 1-5/16 inch I.D. x 8- inch minimum thick manganese-molybdenum steel plus 1/8-inch uastenitic stainless steel cladding.
Hemispherical Head	6-feet 7-½ inch spherical radius x 5 inch minimum thick manganese-molybdenum steel plus 1/8-inch austenitic stainless steel cladding

1.1.5.2. Closure Head Assembly.

ONLY THIS INFORMATION IS PERTINENT
W[signature]

Closure Head Forging	15-feet 4-inch O.D. x 2-feet 11-11/32 inch length.
Closure Head Plate	6-feet 7-½ inch spherical radius x 6-3/16 inch minimum thick manganese-molybdenum steel plus 1/8-inch austenitic stainless steel cladding.
Studs	6 inch nominal diameter x 5-feet length.

1.1.6 General Dimensions.

Overall Height of Reactor Vessel Assembly	
Including Control Rod Housings	42 feet 7-13/64 inches
Excluding Control Rod Housings and Instrumentation Nozzles	40 feet 6- 3/32 inches
Overall Height of Reactor Vessel Excluding Closure Assembly and Instrumentation Nozzles	33 feet 10-49/64 inches
Outside Dimension from Certerline of Shell to Face of Outlet Nozzles	10 feet 2-3/8 inches
Outside Dimension from Centerline of Shell to Face of Inlet Nozzles	10 feet 5-½ inches
Outside Diameter of Shell at Nozzles	174-7/32 inches
Outside Diameter of Shell Below Nozzle Section	173-7/16 inches
Outside Diameter of Refueling Seal Ledge	197.000 inches
Outside Dimension from Centerline of Shell to Lifting Lugs	6 feet 3-½ inches
Dimension from Centerline of Shell to Lifting Lug Hole Centerline	5 feet 11 inches
Shell Thickness Including Cladding:	
Flange, Maximum (Pressure Boundary)	1- foot 5-7/32 inches
Flange, Minimum (Pressure Boundary)	1- foot 5-3/16 inches
Upper Shell Course, Minimum	9- 1/8 inches
Intermediate Shell Course, Minimum	8- inches
Lower Shell Course, Minimum	8- inches
Lower Head Ring, Minimum	5- 1/8 inches
Bottom Hemispherical Head, Minimum	5- 1/8 inches
Hemispherical Closure Head, Minimum	6-5/16 inches

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1.1.7. Dry Weights.

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Reactor vessel	559,082	lb.
Reactor Closure Head	111,347	lb.
Studs, Nuts & Washers	31,563	lb.
Total Assembled Reactor Vessel Weight	701,992	lb.
Closure Stud Assembly		
Stud (MK-62) (Includes Inserts MK-78 & MK-79)	450.38	Lb. each
Nut (MK-63)	64.7	lb. each
Spherical Washer Set (MK-64 & MK-65)	29	lb. each
Total per Set	544.18	lb. each set
Total for 58 sets	31,563	lb.
Vessel Shipping Arrangement		
Reactor Vessel	559,082	lb.
Roll-on/Roll-off skid	26,455	lb.
Miscellaneous Shipping parts	6,614	lb.
Total Reactor Vessel Shipping Weight	592,151	lb.
Closure Head Shipping Arrangement		
Closure Head	111,347	lb.
Shipping Skid and Cover	7,496	lb.
Mechanism Housing Cover	3,527	lb.
Total Closure Head Shipping Weight	122,370	lb.

1.1.8. Design Considerations.

The materials produced and used in fabrication of the reactor vessel (under this contract) are in accordance with the qualifications indentified in Paragraphs 1.1.8.1 and 1.1.8.2.

1.1.8.1. Governing Specifications.

1. A.S.M.E. - Code Section III.

2. A.S.M.E. - Code Section IX.

3. Westinghouse P.W.R. Equipment Specification 676413 and 677026.

1.1.8.2. Material Specifications.

The material specification for each Mark Number is listed in Figure 7.26.

1.1.9. Safety Notices and Warnings.

The internal surfaces of the reactor vessel come in contact with radioactive primary coolant of the nuclear power plant; therefore, radioactive materials will be present during operatio and may be present for long periods after shutdown. Personnel working at or near this vessel should be thoroughly familiar with the hazards involved.

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The reactor vessel is designed to operate at temperatures up to 650°F and fluid pressures up to 2485 psig. It has a high hydrostatic test pressure (3107 psig). Due regard must be made for these conditions to minimize the danger of injury to personnel.

The minimum temperature for pressurization is NDTT +60°F (110°F minimum) at time of manufacture.

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The reactor vessel shell is fabricated of ASTM A-508, Class 2, manganese-molybdenum steel. Since this material has a high brittle fracture transition temperature, extreme care must be taken by all persons working on and/or handling this equipment. No welding, striking of arcs, notches, grooves, or other stress concentrations shall be allowed on the surface of the vessel at any time during handling, installation, or operation. In the event such an incident occurs the matter shall be immediately reported to the Plant Operations Engineer. No remedial action shall be initiated except as directed by the Plant Operations Engineer.

1.2. Installation and Maintenance Operations.

1.2.1. Cleaning.

WARNING

Improper mechanical or chemical cleaning of surfaces may result in excessive local corrosion of those surfaces when placed in contact with primary coolant. The resultant corrosion products taken into solution in the primary coolant could become highly radioactive, thus complicating the maintenance of any component due to the hazards of exposing men to high levels of radioactivity.

CAUTION

Use extreme care at all times to prevent dirt, foreign particles, etc., from entering the reactor system and lodging between bearing surfaces of parts operating with extremely small clearances and causing excessive wear or seizure.

NOTES

1. Components shall be cleaned to the extent that no contamination is visible. Areas which cannot be visually inspected due to inaccessibility or geometry shall be evaluated by wiping the surface with a wet or dry, lint-free cloth until all traces of foreign material are removed and the cloth remains clean after use.

2. Rust of any type or amount shall not be allowed. If rusting does occur, the surface shall be cleaned to remove the rust or rust-producing condition and any visible surface contamination.

3. Cleanliness shall be maintained by packaging components or subassemblies in polyethylene bags for storage.

All instructions for the cleaning of surfaces in this instruction manual refer to a condition of maximum cleanliness. The cleaning is to be performed as follows :

1. Clean all metal surfaces as necessary by swabbing with clean, lint-free cloths saturated with acetone followed by swabbing with clean, lint-free cloths saturated with destilled water. Dry with clean, lint-free cloths. The cleaning must be such that no foreign matter can be seen after cleaning, particulary in the root area of the threads.

2. Clean Buna-N Rubber as necessary by swabbing with clean, lint-free cloths saturated with chloride-free naphta gas followed by swabbing with clean, lint-free cloths saturated with destilled water. Dry with clean, lint-free cloths. The cleaning must be such that no foreign matter can be seen after cleaning.

3. Pressure sensitive tape may be used occasionally on components (that is, over the top of closure studs). Any time the pressure sensitive tape is removed from a component, use acetone to remove any residue. Clean the area as described above in Step 1.

1.2.2. Lubrication.

As the following tabulated parts are assembled, they shall be lubricated as indicated below.

Mark No.	Nomenclature	Lubricant	Apply to
MK-62	Stud	Neolube	Male threads
MK-63	Nut	Neolube	Bearing surface
MK-64	Convex Spherical Washer	Neolube	Both faces
MK-65	Concave Spherical Washer	Neolube	Both faces
MK-78	Top Insert	Neolube	Male threads
MK-79	Bottom Insert	Neolube	Male threads
MK-80	Eyebolt	Neolube	Male threads
	Plug (Westinghouse)	Neolube	Male threads
MK-32	Sleeve	Neolube	Male threads
MK-28	Guide Stud	Neolube	Bottom 8-inches
MK-31	Eyebolt	Neolube	Male threads

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3 DESCRIPTION.

3.1 Detailed Description.

(See figures 1.1, 7.8, 7.9, 7.10, 7.11, 7.15, 7.20 and 7.26)

3.1.1 Introduction.

The Virginia Electric and Power Company reactor pressure vessel equipment described in this manual include: the vessel, the closure head assembly, closure stud assembly, special tools, and shipping arrangements. Discussions of the equipment with detailed description of their features are presented in subsequent paragraphs. Material and material specifications for all parts or segments are presented in Figure 7.26 by mark numbers.

3.1.2 Vessel Shell Assembly.

The reactor vessel (see figures 7.11, 7.2, 7.3, 7.4 and 7.5) is built up from :

(1) A flange forging.

(2) A refueling seal ledge.

(3) An upper shell course containing the inlet and outlet nozzles.

(4) An intermediate shell course.

(5) A lower shell course containing the core support guides.

(6) A lower head ring.

(7) A bottom hemispherical head having the instrumentation nozzles.

The vessel segments are discussed in subsequent paragraphs.

3.1.2.1 Reactor Vessel Flange.

The reactor vessel flange is a machined forging welded to the upper shell course. (See figure 7.3).
A refueling seal ledge is welded to the vessel flange. The flange is fabricated of ASTM A-508, Class 2, manganese-molybdenum steel and is clad internally and on the gasket face with weld deposited austenitic stainless steel.

The flange is designed with a ledge for the support of the core, a gasket face for sealing of the vessel, 2 monitoring taps on 98°33' and 133°27' degrees angular location for detection of water leakage through the gasket closure, irradiation tube slots on 45°, 55°, 65°, 165°, 245°, 285°, 295°, 305° degrees angular location for holding of irradiation specimen baskets, key slots on 0, 90, 180 and 270 degrees angular location for aligning the closure head and vessel assembly and 58 stud holes for tightening the head to the vessel.

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Of these stud holes 3 holes are used for holding the guide studs which are used for refueling. The stud holes are threaded and receive the 6 inch diameter closure studs.

3.1.2.2. Refueling Seal Ring Ledge.

The refueling seal ring ledge (See figure 7.5) is a machined weldment fabricated of ASME SA-533, Grade A, manganese-molybdenum steel. The refueling seal ledge is a 2-½-inch thick ring welded to the reactor vessel flange.

3.1.2.3. Upper Shell Course.

The upper shell course of the vessel (see figure 7.3) is a machined forging welded to the reactor vessel flange and to the intermediate shell course. The upper shell course is fabricated of ASTM A-508, Class 2, manganese-molybdenum steel and is clad internally with weld deposited stainless steel. The upper shell course contains the six primary coolant nozzles.

The six primary coolant nozzle forgings are welded to the upper shell course for entry and discharge of the primary coolant. The nozzle centerlines are 6 feet 10-7/16 inches below the mating surface of the vessel flange.

The three 27.469-inch I.D. inlet nozzles are located 120 degrees apart, (their centerlines are located respectively on 95, 215 and 335 degrees).

The three 28.969-inch I.D. outlet nozzles are located 120 degrees apart (their centerlines are located respectively 25, 145 and 265 degrees). Vessel support weld pads are located on the bottom of each of the six nozzles. The machined pads are 9 feet 2-15/16 inches below the mating surface of the vessel flange.

The primary coolant nozzle forgings are also fabricated of ASTM A-508, Class 2, manganese-molybdenum steel and are clad with weld deposited austenitic stainless steel internally. The nozzle and connections are clad with weld deposited austenitic stainless steel and are machined for field welding to the main coolant piping.

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3.1.2.4. Intermediate Shell Course.

The intermediate shell course (see figure 7.2) is a cylindrical shell formed from two plates of ASTM A-533 Gr.B, Cl.1, manganese-molybdenum steel and is clad internally with weld deposited austenitic stainless steel. The intermediate shell course is welded to the upper and lower shell courses. The two longitudinal weld seams are located on 45 and 225 degrees.

3.1.2.5. Lower Shell Course.

The lower shell course (see fig.7.2) is a cylindrical shell formed from two plates of ASTM A-533 Gr.B Cl1, manganese-molybdenum steel and is clad internally with weld deposited austenitic stainless steel except for the weld deposited Inconel cladding on the bottom 11-3/16 inches. Four core support guides which have a 8-1/16 inch wide x 4.040 inch deep x 5-½ inch long machined slot at the bottom of the shell course are located on 0, 90, 180 and 270 degrees. The core support guides are fabricated of ASME SB-166-68 Inconel.

The lower shell course is welded to the intermediate shell course and to the lower head ring.

The two longitudinal weld seams are located on 135 and 215 degrees.

3.1.2.6. Lower Head Ring.

The lower head ring (see figure 7.2) is welded to and joins the lower shell course and the bottom hemispherical head. It is fabricated of ASTM A-508, Class 2, manganese-molybdenum steel and is clad internally with weld deposited austenitic stainless steel.

3.1.2.7. Bottom Hemispherical Head.

The bottom hemispherical head (see figures 7.1 and 7.2) is welded to the lower head ring of the vessel The hemispherical head is formed from a single plate of ASTM A-533, manganese-molybdenum steel and is internally clad with 0.125-inch thick weld deposited austenitic stainless steel. The head is penetrated by 50 instrumentation nozzles fabricated from ASME SB-166-68 Inconel.

Each 1-½ inch O.D. (0.607 inch I.D.) instrumentation nozzle is Inconel welded into place. A safe end of ASME SA-475, Type 304, stainless steel is welded to the exterior end of each instrumentation nozzle.

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3.1.3. Closure Head Assembly.

The closure head assembly (see figures 7.6, 7.7, 7.8, 7.9, 7.10 and 7.12) is a weldment consisting of a hemispherically dished plate and a flange forging. The hemisph. dished plate is fabricated of ASTM A-533 Gr.B Cl.1, manganese-molybdenum steel and is clad internally with weld deposited austenitic stainless steel 0.125 inch thick.

The flange forging is ASTM A-508, Class 2, manganese-molybdenum steel and is clad with weld deposited austenitic stainless steel internally and on the gasket face. The closure head forging gasket face is machined to accommodate two silver plated self-energizing stainless steel O-ring gaskets and the 24 sets of wire clips, backing plates, and screws.
The flange of the forging is bored through to receive the 58 closure head studs. An indicator arrow is welded to the head to indicate the number one stud hole.

The dished segment of the closure head contains 65 penetrations, positioned in a square pattern on 8.486 inch centers, to accommodate the control rod mechanism housings. A nominal one-inch diameter penetration in the closure head accommodates the vent pipe.

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The closure head has three lifting lugs. Three vent shroud support lugs are also attached to the closure head.

3.1.3.1. Control Rod Mechanism Housings.

Each of the 65 control rod mechanism housings (see figure 7.13) penetrating the closure head is a weldment consisting of a threaded, 6-inch O.D. adapter and a 4-inch O.D. body. The adapter is fabricated of ASME SA-182, Type 304, stainless steel, and the body is fabricated of ASME SB-167 Inconel.

The mechanism housing weldments are inserted with an interference fit into the penetrations of the closure head. The bodies are welded into the inside of the closure head with weld deposited Inconel.

3.1.3.2. Vent Shroud Support Assembly.

The vent shroud support assembly (see figure 7.9) is attached to the closure head at three places. Each pair of support lugs on the vent support ring is mated with a vent shroud support lug on the closure head assembly and is fastened to it by a 3/4-inch hex head bolt with nut.

The shroud support flange has 18 holes of 11/16-inch diameter, equally spaced on a 128-inch diameter bolt circle. The flange is welded to the support ring; and the assembly is stiffened by 15 support gussets welded to the ring and flange at equal distances.

The 24 shroud insulation support angles are equally spaced on and welded to the support ring. In addition, the support ring has 24 saw cuts, each terminating in a 1/2-inch diameter hole. The saw cuts and holes are equally spaced between the support angles. The saw cuts enable the support ring to compensate for temperature caused variations in dimensions; this will allow the support lug attachments to remain secure.

3.1.3.3. Closure Stud Assembly.

The closure head is secured to the vessel flange by 58 closure stud assemblies. (see figure 7.20) Each assembly consists of a threaded, hex head stud with a nominal 6-inch diameter, a nut having eight castellations at the top, a set of spherical washers, and top and bottom inserts.

Each stud has a one-inch diameter center hole through the length of the stud to receive a stud elongation measuring rod. The bottom insert is used to close the bottom of the stud and serves as a seat for the stud elongation measuring rod. The top insert is used to close the top of the stud and prevents the entry of any foreign matter. Each stud has a threaded length sufficient to accommodate a hydraulic stud tensioner. For handling purposes an eyebolt is supplied for each stud. The studs, nuts and spherical washers (marked in matched sets) are fabricated of ASTM A-540, Gr. B 24, nickel-chrome-molybdenum steel. The studs and washers are "phosphated".

3.1.4. Special Tools.

The special tools for mounting and measuring supplied by The Rotterdam Dockyard Company are listed in table 6.2. The identification and function of each tool are given in the table.

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APPENDIX D
Doc Id 51-5015197-00

Westinghouse Electric Company
Box 355
Pittsburgh Pennsylvania 15230-0355
Fax Number: (412) 374- 6647

TO: DEAN PRICE

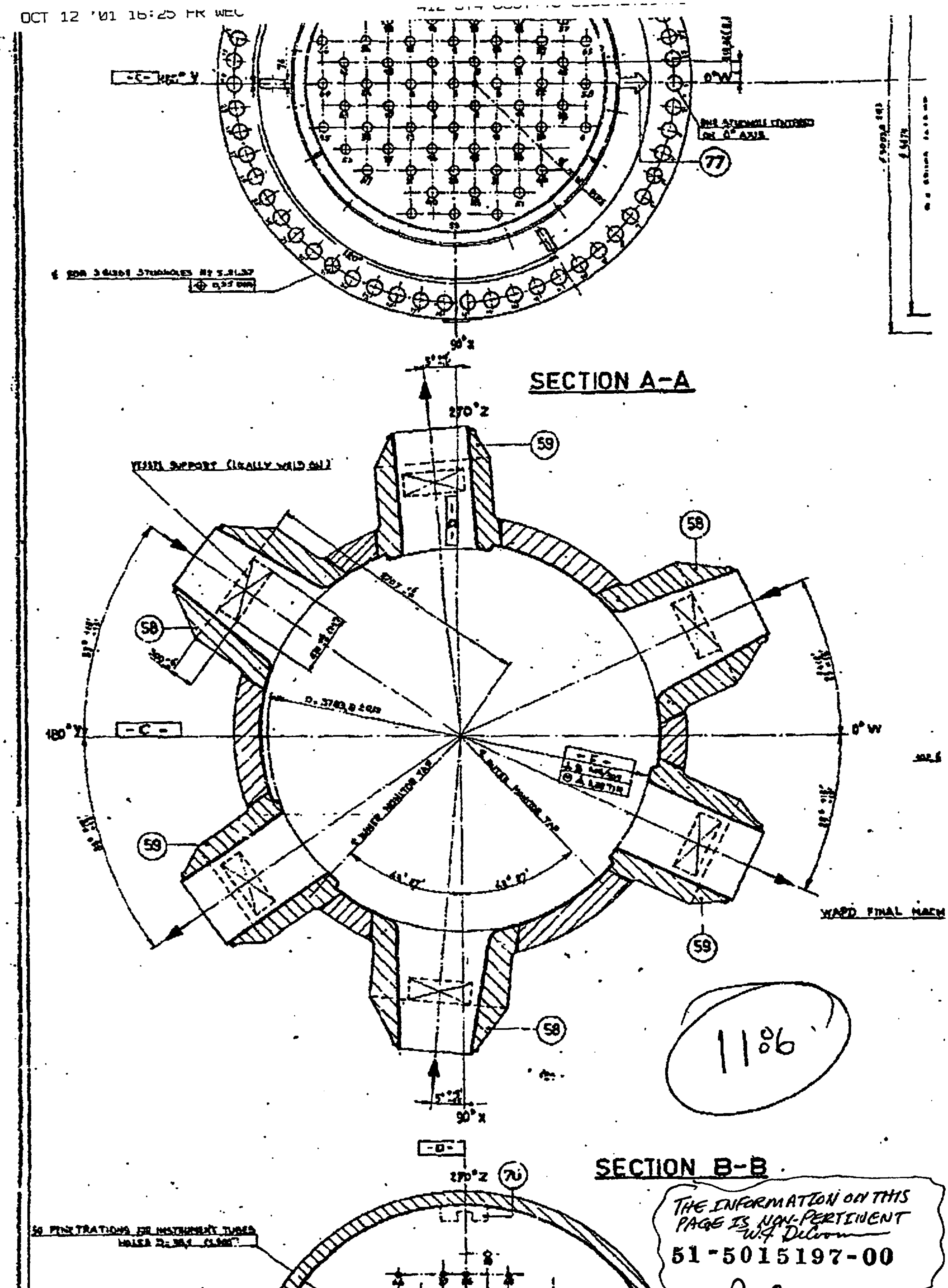
FROM: JUSTIN LEDGER DATE: 10/12/01

MESSAGE:
DEAN,

PLEASE FIND ATTACHED THE SECTIONS OF THE DRAWINGS YOU REQUESTED. IF YOU NEED FURTHER CLEARIFICATION, DO NOT HESITATE TO CALL ME,

(412) 374-3898

Number of pages 15 INCLUDING COVER



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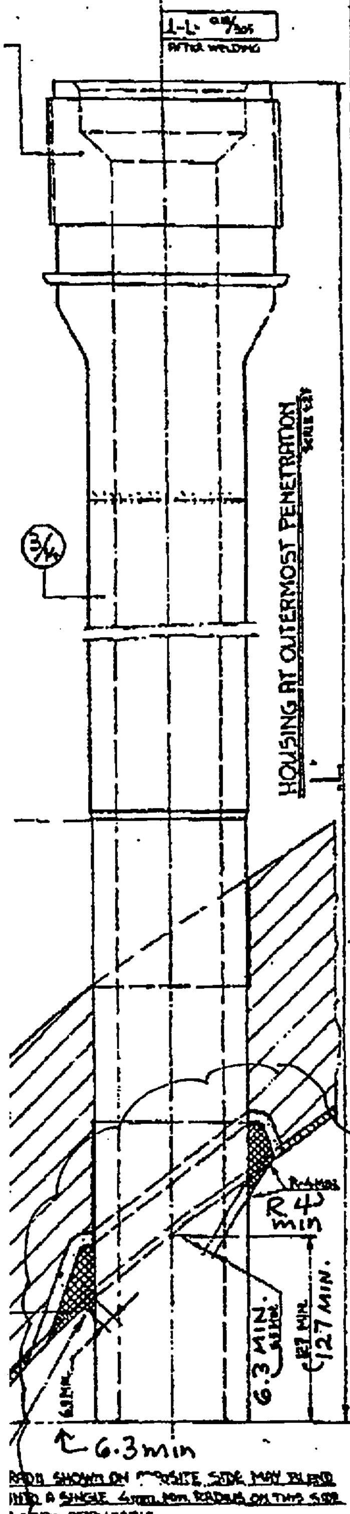

PENETRATION Nº:	HOUSING ASSY. Nº:	"L" (REF)	"G" (REF)
1	A2-137-1	965.20	328.61
2	A3-137-1	988.22	337.36
3	A3-137-2		
4	A3-137-3		
5	A3-137-4	988.22	337.36
6	A4-137-1	1012.09	342.90
7	A4-137-2		
8	A4-137-3		
9	A4-137-4	1012.09	342.90
10	A5-137-1	1059.66	351.63
11	A5-137-2		
12	A5-137-3		
13	A5-137-4	1059.66	351.63
14	A6-137-1	1084.26	355.60
15	A6-137-2		
16	A6-137-3		
17	A6-137-4		
18	A6-137-5		
19	A6-137-6		
20	A6-137-7		
21	A6-137-8	1084.26	355.60
22	A7-137-1	1158.08	366.71
23	A7-137-2		
24	A7-137-3		
25	A7-137-4	1158.08	366.71
26	A8-137-1	1185.07	371.48
27	A8-137-2		
28	A8-137-3		
29	A8-137-4	1185.07	371.48
30	A9-137-1	1210.47	375.44
31	A9-137-2		
32	A9-137-3		
33	A9-137-4		
34	A9-137-5		
35	A9-137-6		
36	A9-137-7		
37	A9-137-8	1210.47	375.44
38	A10-137-1	1291.43	388.94
39	A10-137-2		
40	A10-137-3		
41	A10-137-4		
42	A10-137-5		
43	A10-137-6		
44	A10-137-7		
45	A10-137-8	1291.43	388.94
46	A11-137-1	1375.57	402.43
47	A11-137-2		
48	A11-137-3		
48	A11-137-4	1375.57	402.43
51	A12-137-1	1404.94	407.99
53	A12-137-2	1404.94	407.99
55	A12-137-3	1404.94	407.99
57	A12-137-4	1404.94	407.99
58	A13-137-1	1435.10	413.54
59	A13-137-2		
60	A13-137-3		
61	A13-137-4	1435.10	413.54
62	A14-137-1	1496.22	423.86
63	A14-137-2		
64	A14-137-3		
65	A14-137-4		
66	A14-137-5		
67	A14-137-6		
68	A14-137-7		
69	A14-137-8	1496.22	423.86

LETTER	DATUM	OMSCHRIJVING VAN DE WIJZIGING
A	3-11-'69	CHANGED ACCORDING PAR 36, HOUSING ASSY Nº CHANGED

AFGEGEVEN AAN	DATUM
W.E.C.	
LLOYD'S	
APP. BOUW	
EMBDERS	
MACH.FABR.	
COÖRD. BUR. W.	
LAB.	
UNSERV. ADV.	
MR. HERBERT	
REISEKAFD. K.E.	
K.E.	
MR. RUTHERFORD	
W4Z.	

1185 SHEET 1 OF 3

NOTE:

ALL CONTROL ROD, MECH. HOUSING CENTERLINES MUST BE PERPENDICULAR TO THE MATING SURFACE WITHIN 0.13mm./600mm.

REFERENCE DRAWINGS

CLOSURE HEAD SUB-ASSY.	30678 - 1184 (2 SHEETS)
CRD. HOUSING	30678 - 1188
GENERAL ARRANGEMENT	30678 - 1186

FOR SHROUD SUPPORT ASSY. SEE SHEET Nº2

FOR VENT PIPE ASSY. SEE SHEET Nº3

VPA-RCPCRV1

POS NR	AANT.	BENAMING	NORM.	MATERIAAL		BESTELNR.	GEW. IN KG.
49	4	RND HEAD MACH SCREW		BRASS			
48	1	NAME PLATE		CAST BRONZE			
25	3	BOLT WITH NUT 3/4" x 76		B307			
3÷14	64	CRD. HOUSING BODY		INCONEL SB-167			
2	1	CRD. HOUSING BODY		INCONEL SB-167			
1	65	CRD HOUSING ADAPTER		SA-182 TYPE 304			

STUKLIJST PER | VOOR

DE ROTTERDAMSCHE DROOGDOK MIJ. N.V.

AFD. KERNENERGIE

187" DWD VESSEL WESTINGHOUSE

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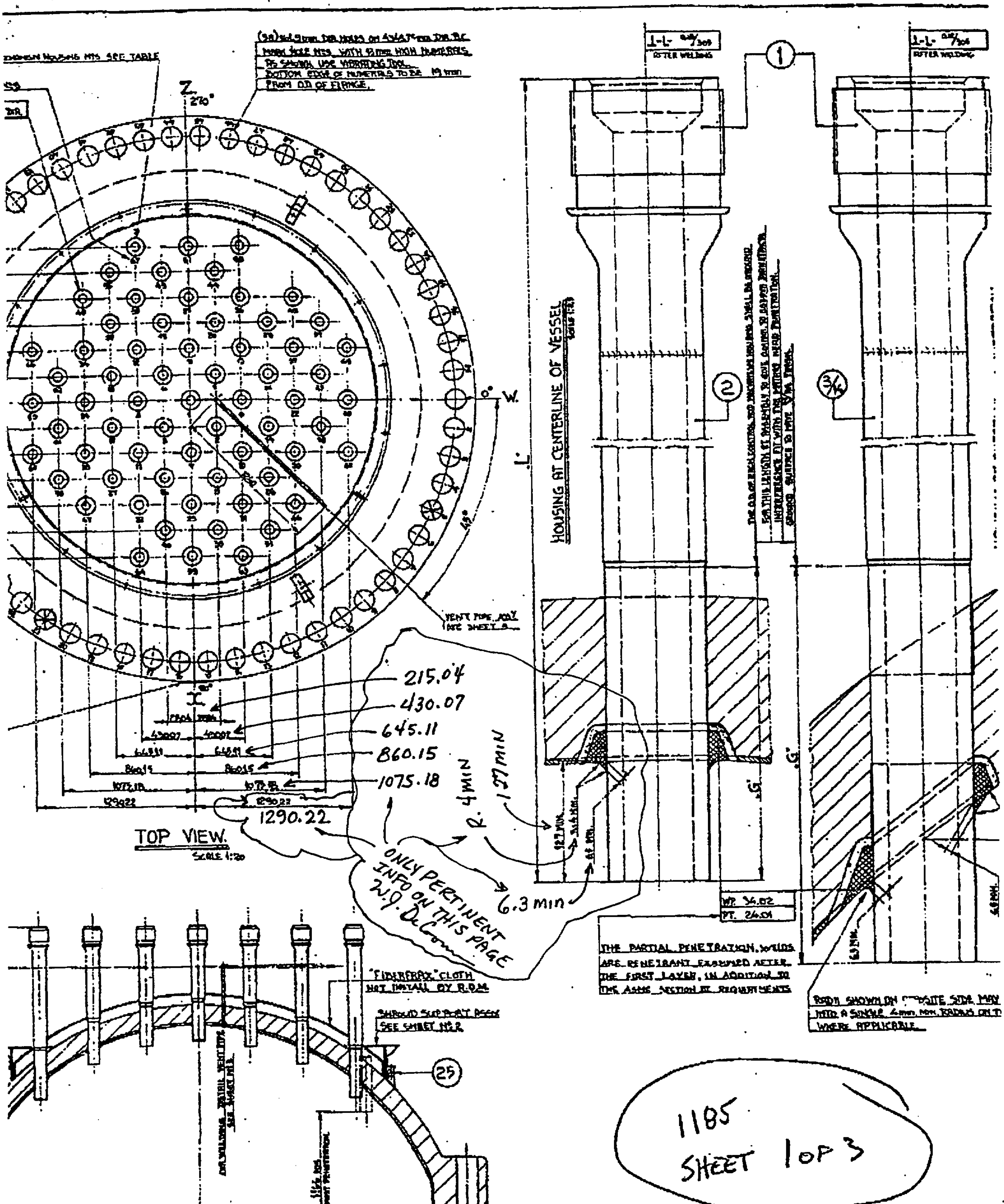

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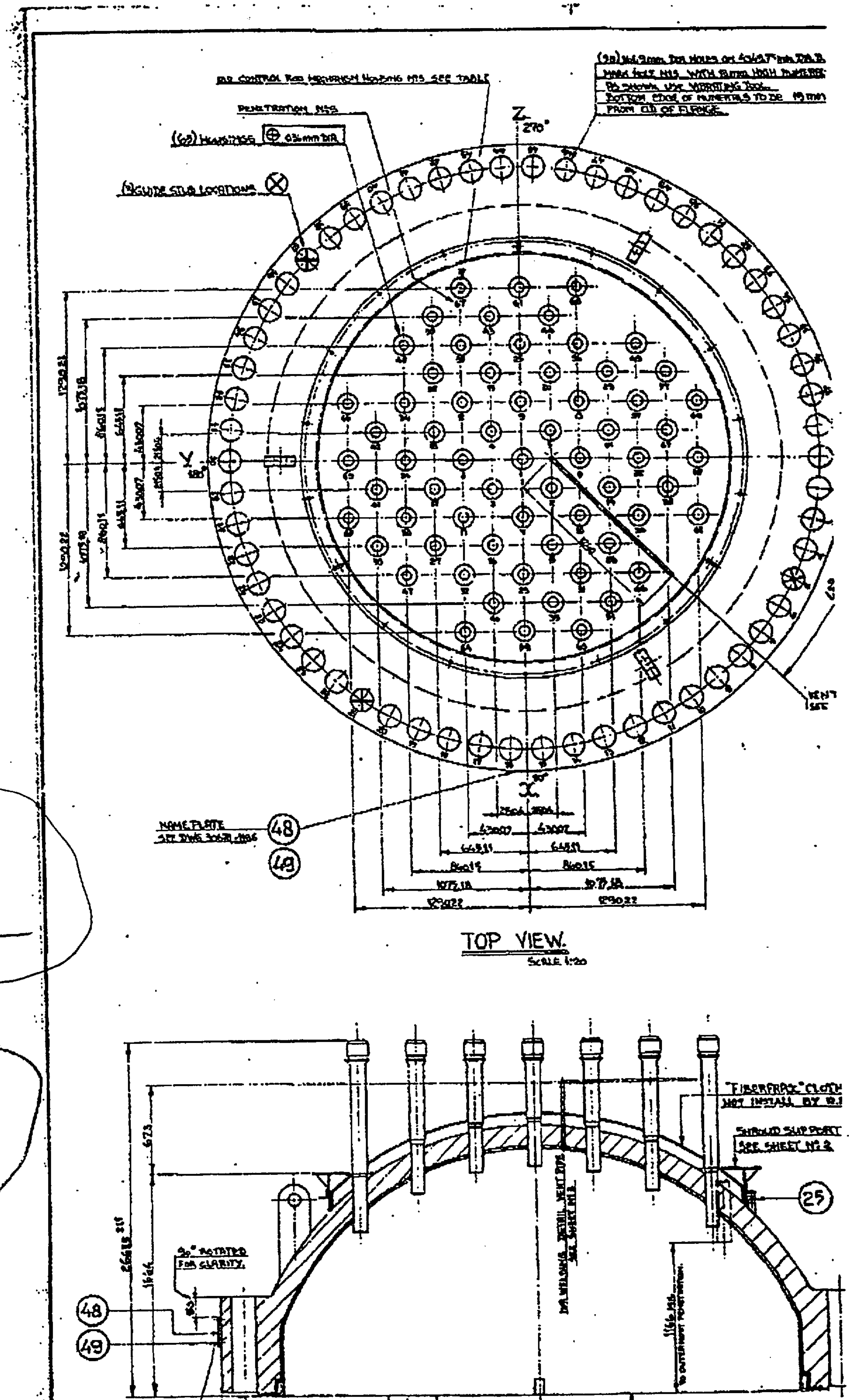

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SHEET 1 OF 3

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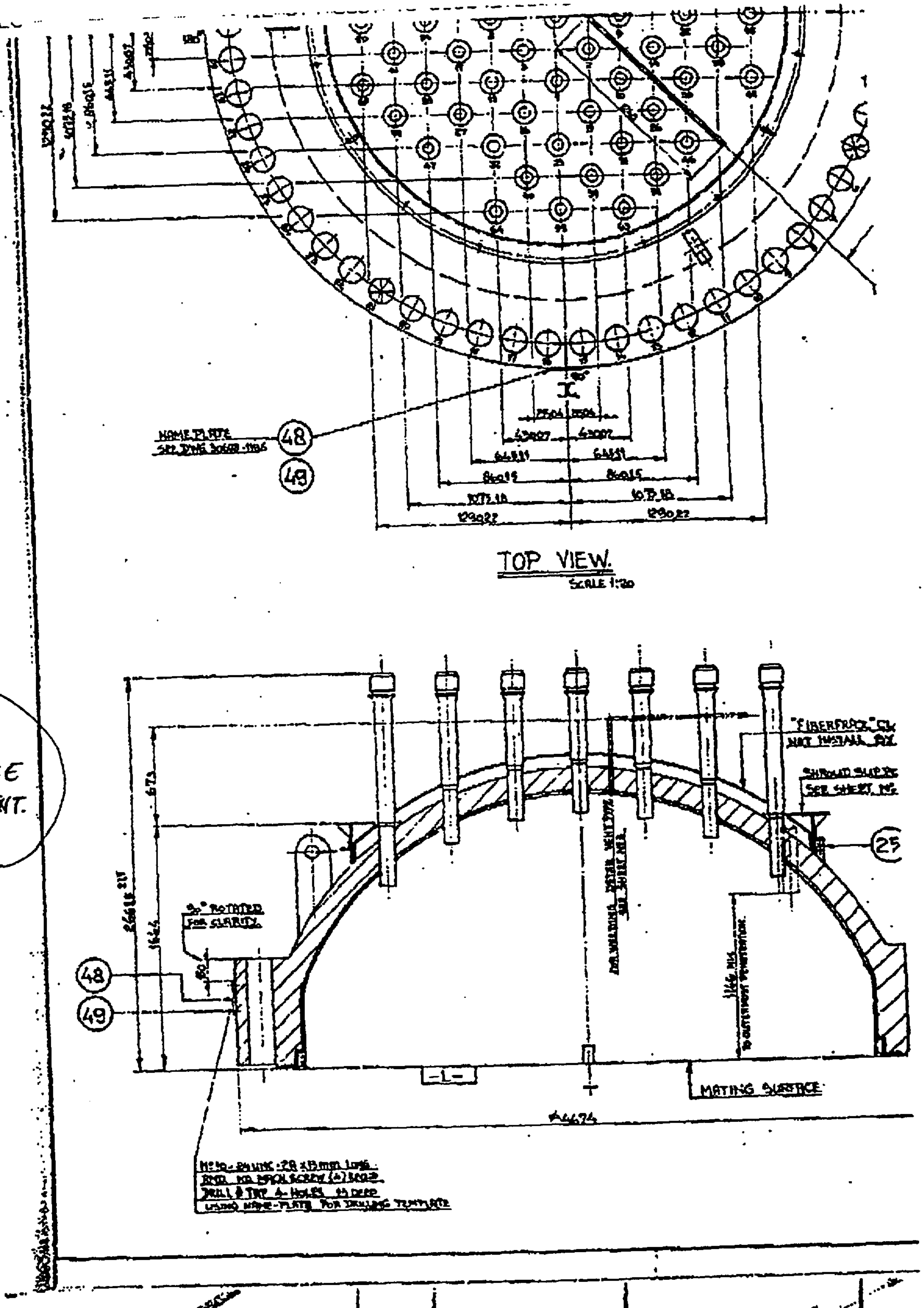

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1185 SHEET 1 OF 3

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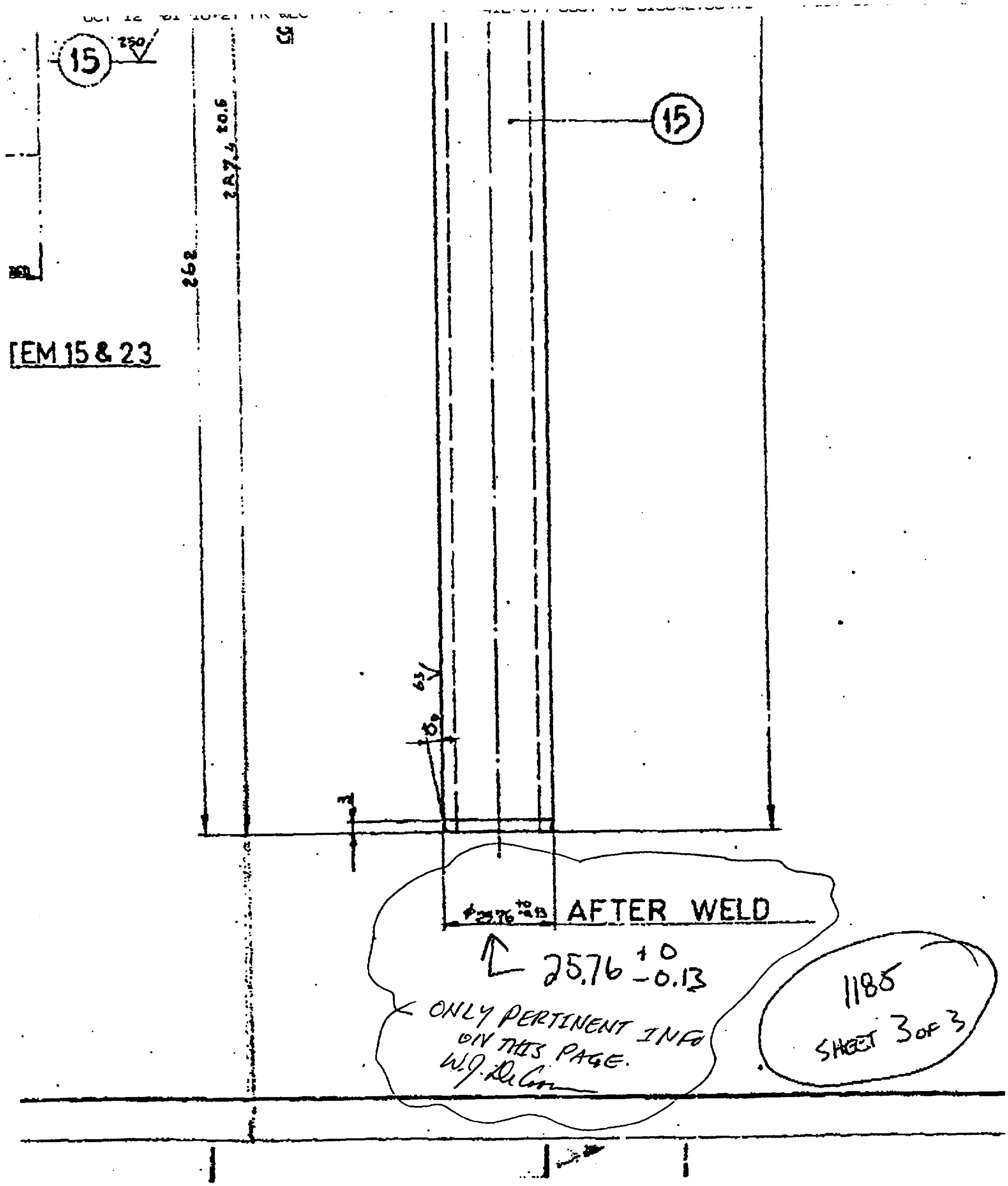

15
250
15
ITEM 15 & 23
262
287.6 ±0.6
63
AFTER WELD
℄ 25.76 +0 −0.13
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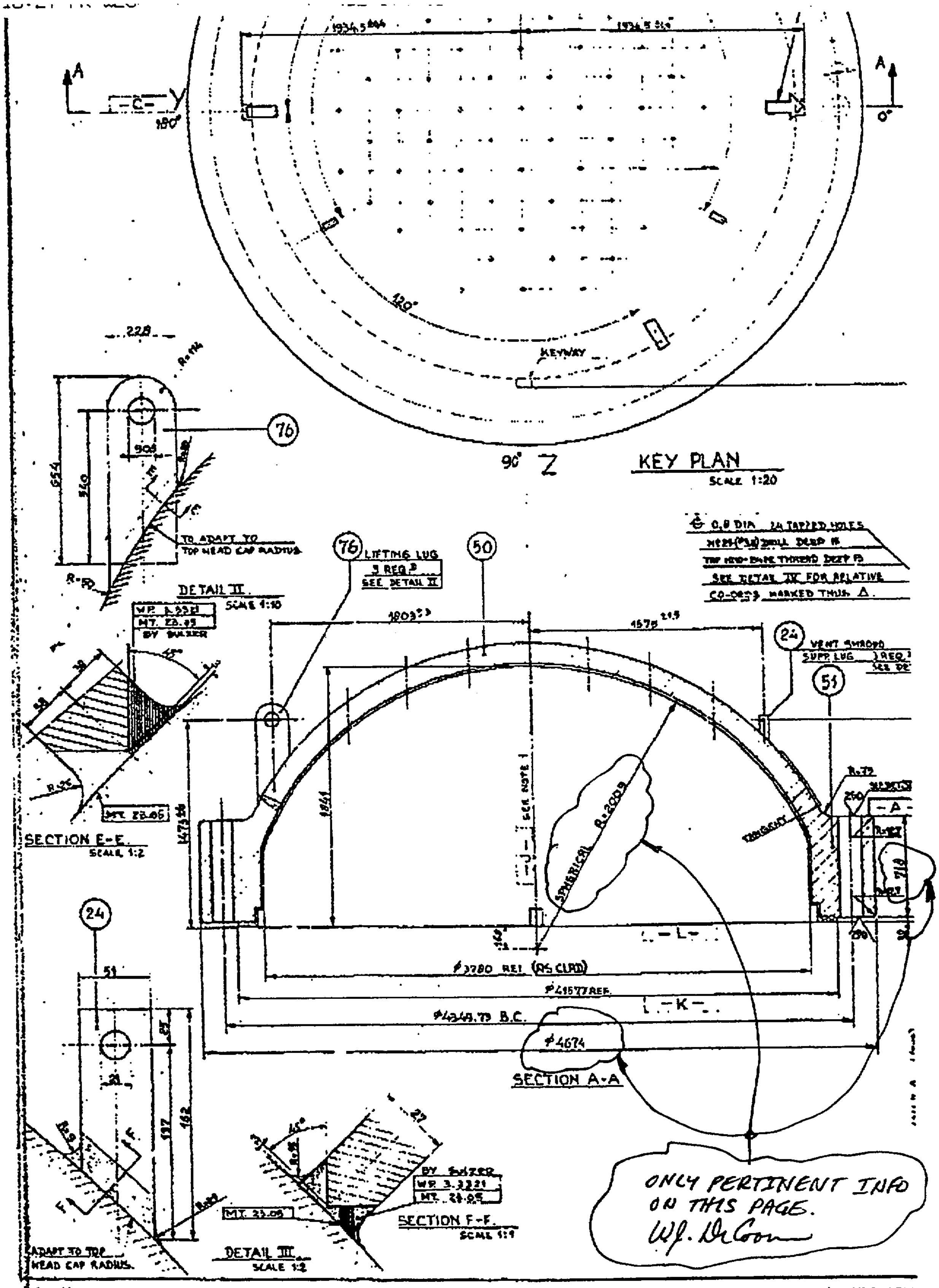
W.J. DeCon
1185
SHEET 3 OF 3



1184 FIG 7-7

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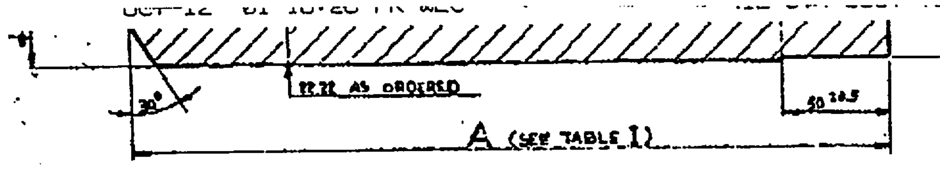
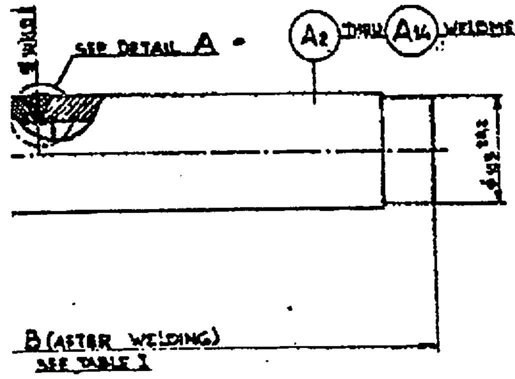
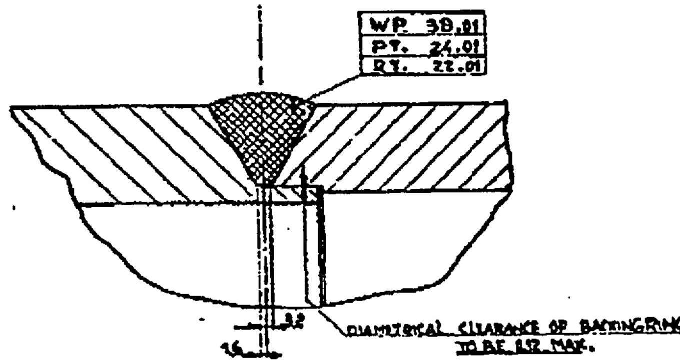


A10	1	40	1018	1304
A11	1	41	1074	1380
A12	1	42	1129	1418
A13	1	43	1153	1418
A14	1	44	1220	1509



DETAIL A



ROL ROD MECHANISM HOUSING

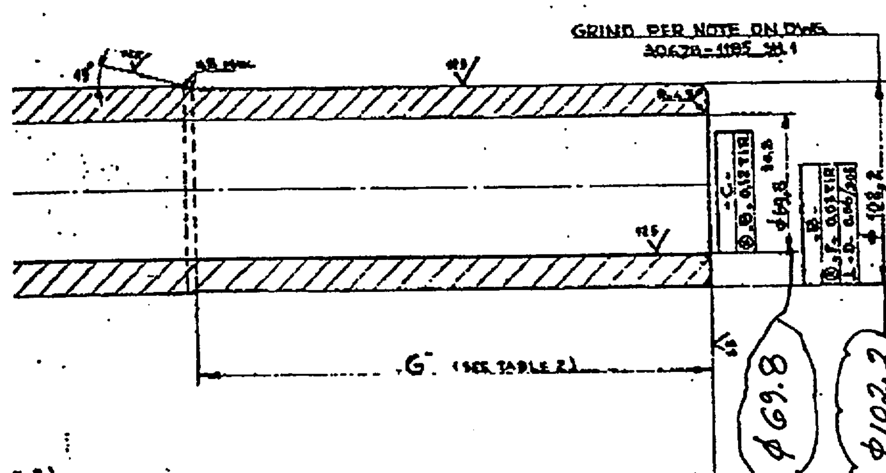


TABLE II				
HOUSING ASSY Nº	PENETRATION Nº	"L"	"G"	Nº REQ'D
A2	1	965	329	1
A3	2,3,4,5	988	337	4
A4	6,7,8,9	1012	343	4
A5	10,11,12,13	1059	352	4
A6	14,15,16,17 18,19,20,21	1084	356	8
A7	22,23,24,25	1158	367	4
A8	26,27,28,29	1188	372	4
A9	30,31,32,33 34,35,36,37	1240	375	8
A10	38,39,40,41 42,43,44,45	1291	389	8
A11	46,47,48,49	1375	402	4
A12	51,53,55,57	1463	408	4
A13	58,59,60,61	1485	414	4
A14	62,63,64,65 66,67,68,69	1486	424	8

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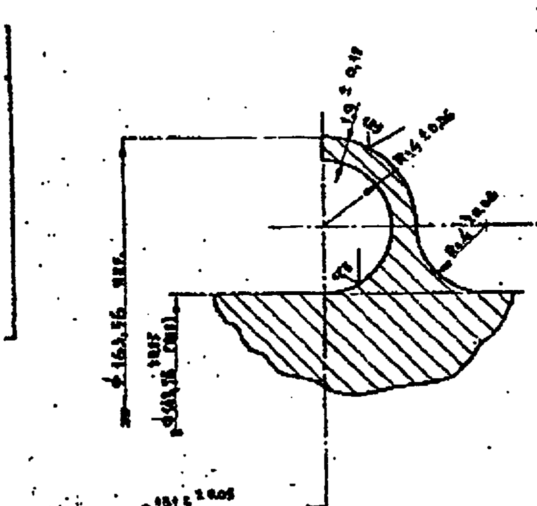
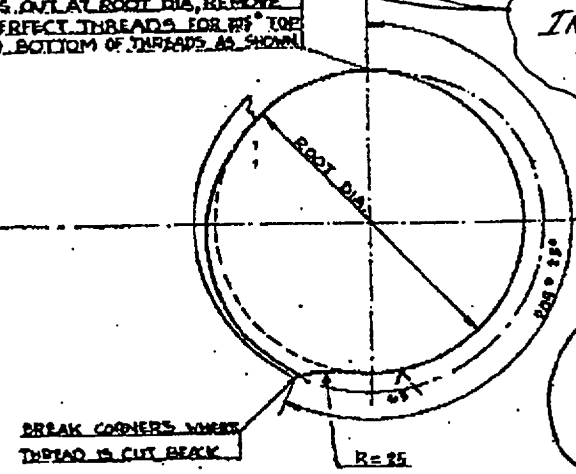
BEGINNING AT POINT WHERE THREAD RUNS OUT AT ROOT DIA, REMOVE IMPERFECT THREADS FOR 275° TOP AND BOTTOM OF THREADS AS SHOWN





THREAD REMOVAL

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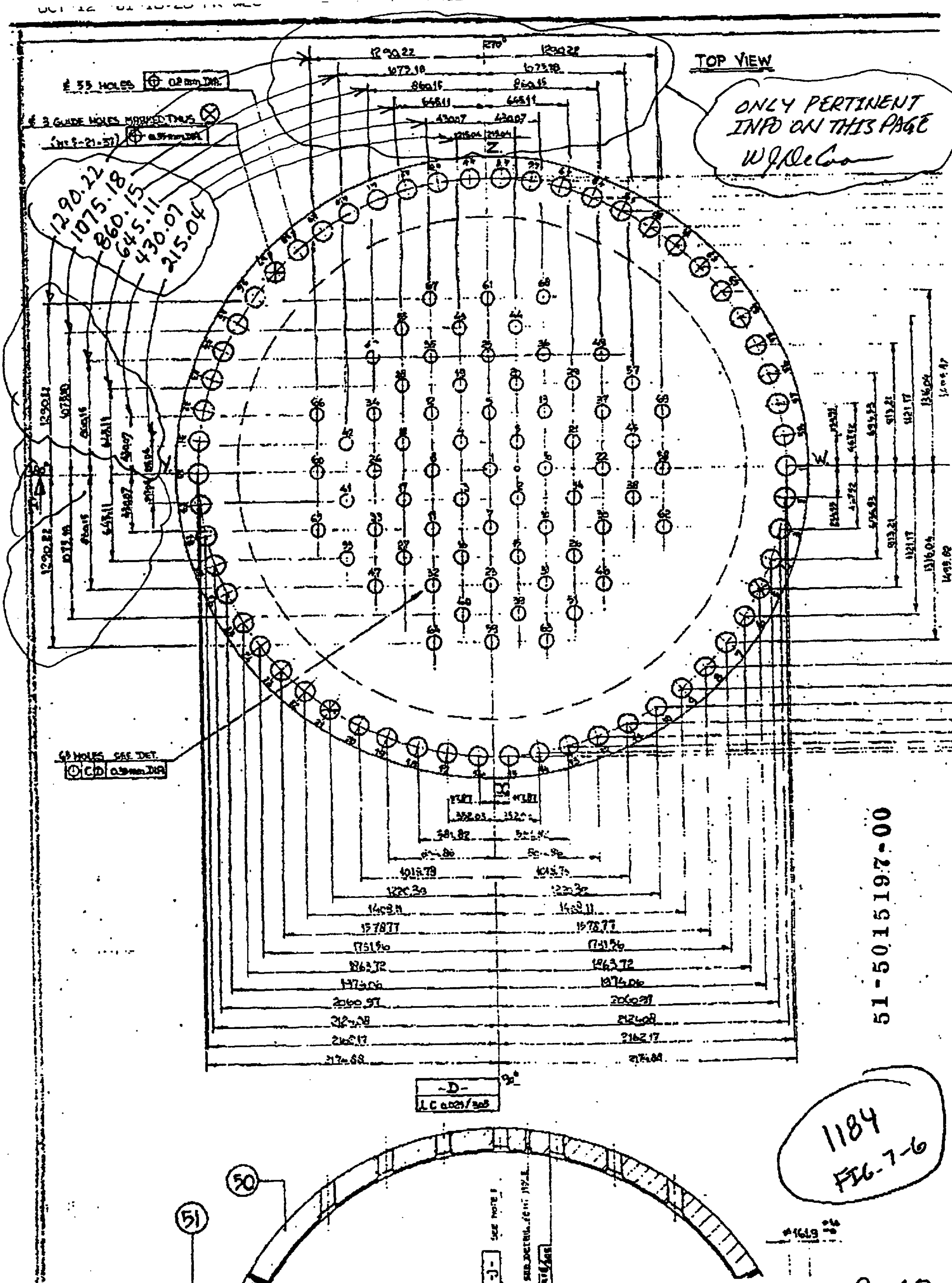
Pg. 9



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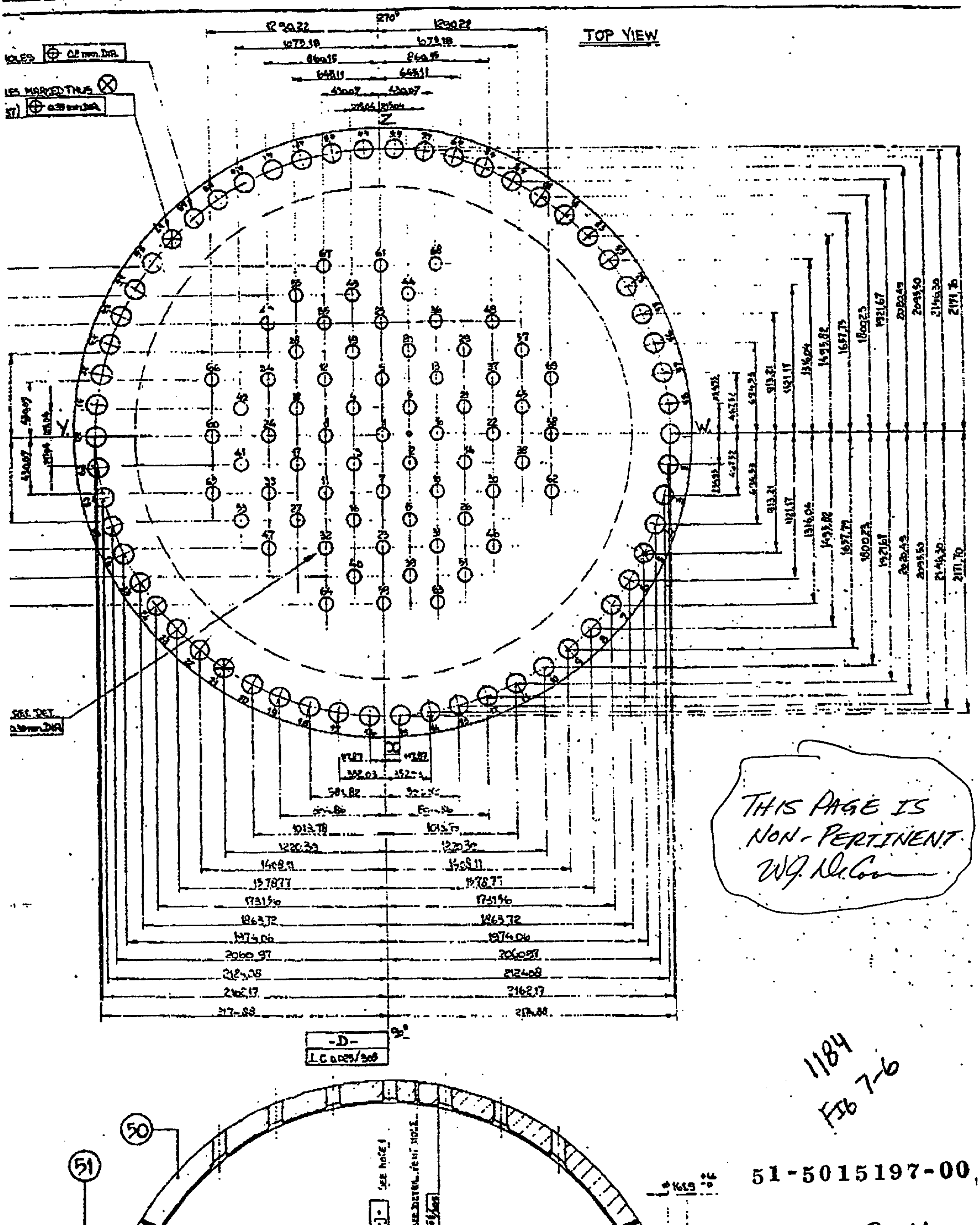

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FIG 7-6

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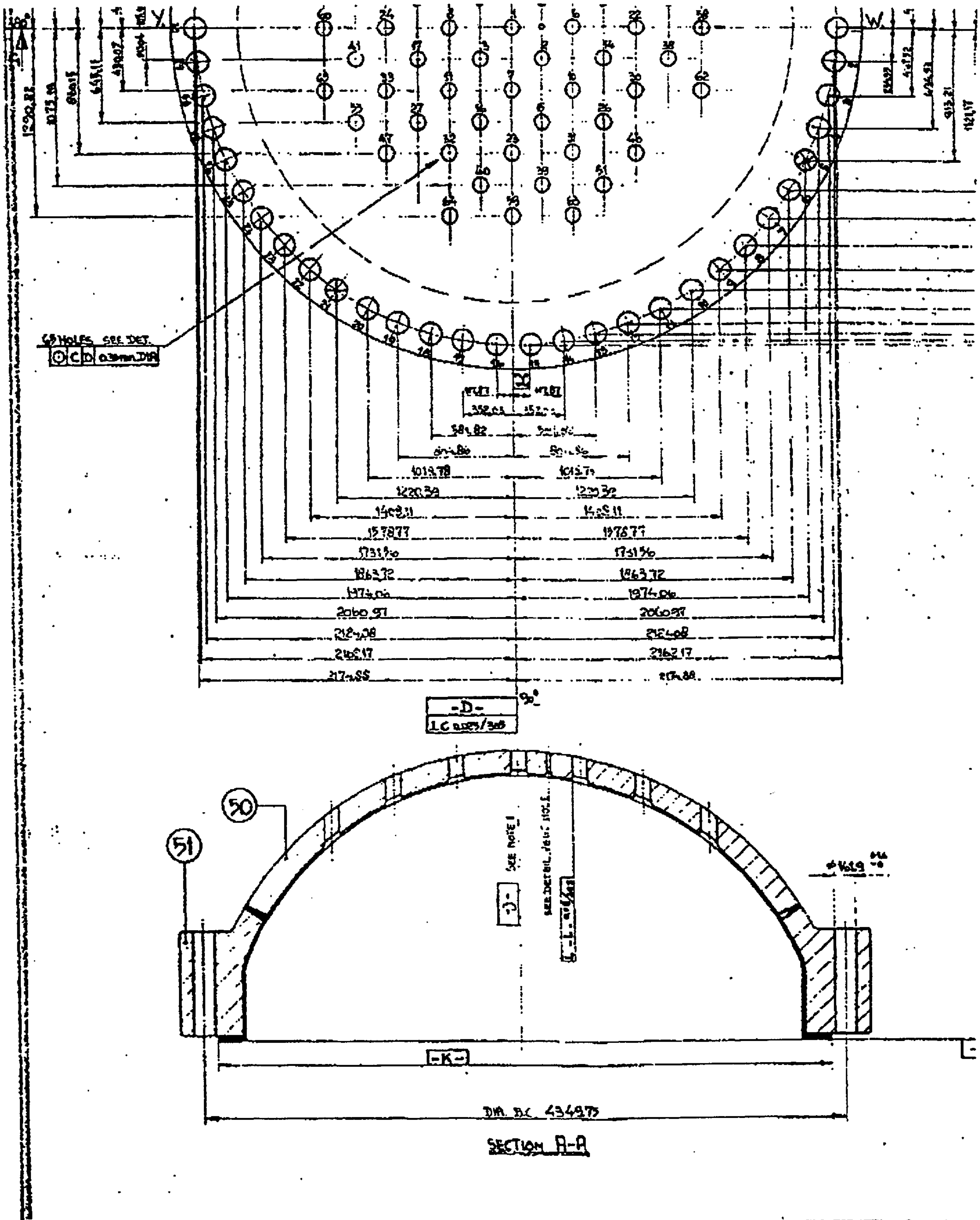
Pg. 11



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Pg. 12

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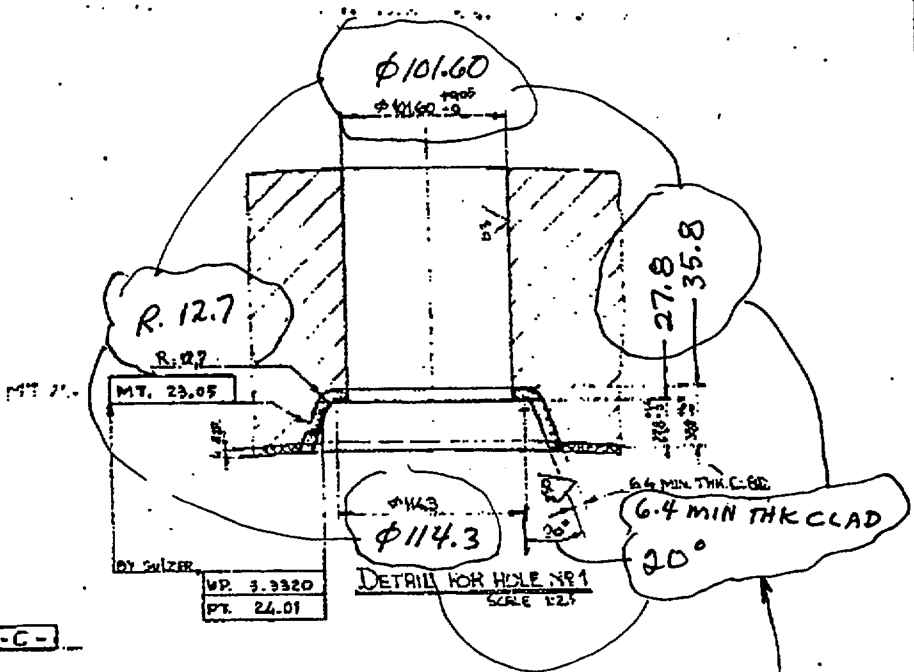
W.E.C.						
LLOYD'S						
APP. BOUW						
SMEDERY						
MACH. FABR.						
COÖRD. BUR. W.						
LAB.						
LEASERY STN.						
Mr. HERBERT						
BEKEMAED K.E.						
K.E.						
Mr. RUTHERFORD						
WYZ						



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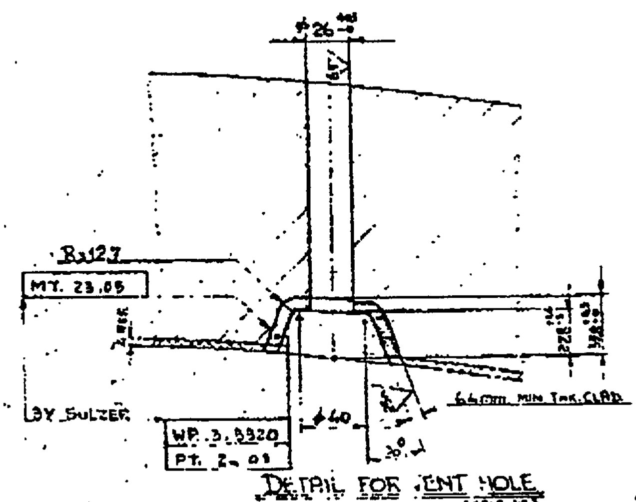

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NOTES:

1/ CENTERLINE -J- IS DEFINED AS A VERTICAL OF DIR -K- ⊥ 0.025/305.

2/ ALL INTERNAL MACHINED & CLAD SURFACES UNLESS OTHERWISE NOTED. ALL EXTERNAL SURFACES TO HAVE 500 RMS OTHERWISE NOTED.

3/ CLOSURE HEAD MANUFACTERED BY SULZER. ACC. TO SULZER DWG. 0.103.080.218

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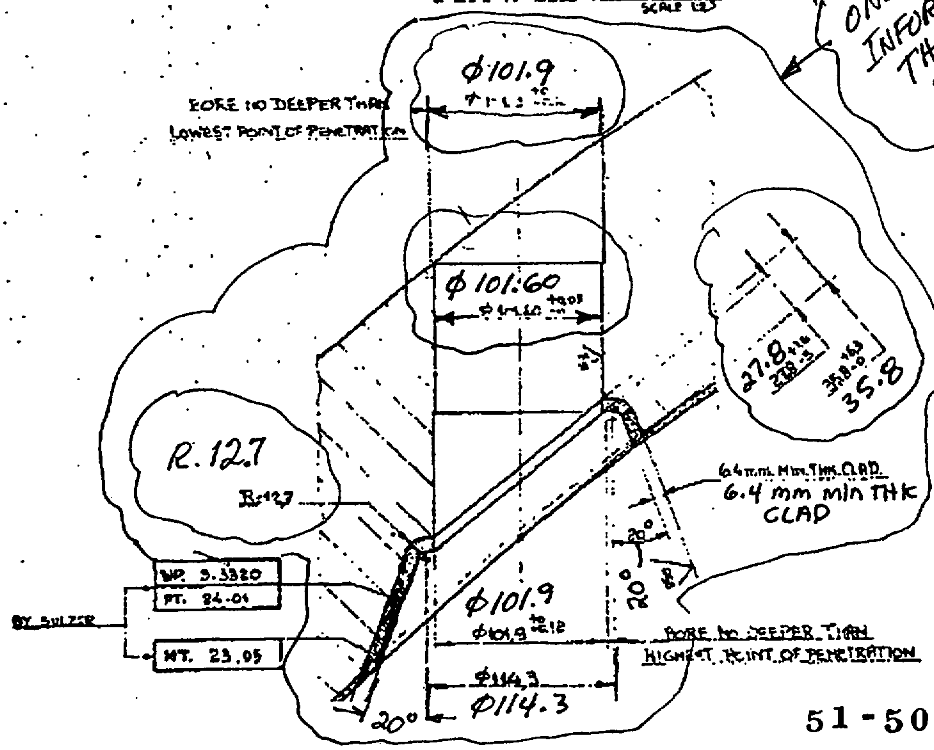
FIG 7-6



FOR MACH. DIMENSIONS AND ATTACHMENTS SEE SHEET Nº2

VPA-RCPCRV-01

51	1	CLOSURE HEAD FLANGE	
50	1	CLOSURE HEAD CENTR. DISC.	

51-5015197-00 Pg. 13

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Mr. HERBERT				
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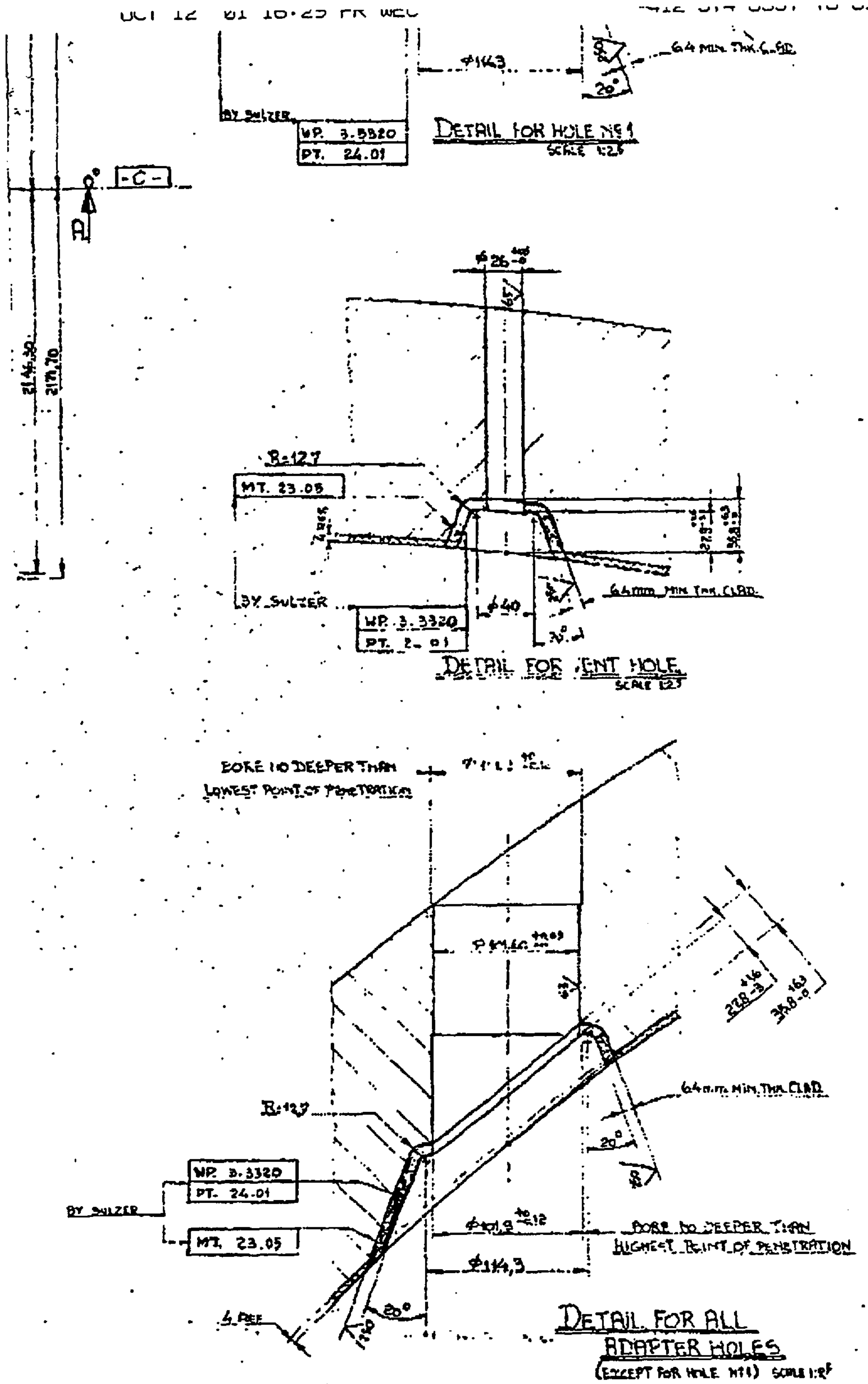
K.E.				
Mr. RUTHERFORD				
WMZ.				



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3/ CLOSURE HEAD MANUFACTERED BY SULZE[R] ACC. TO SULZER DWG. 0.103.080.218

FOR MACH. DIMENSIONS AND ATTACHMENTS SEE SHEET

VPA-RCPLRV-01

POS NR	AANT.	BENAMING	NORM
51	1	CLOSURE HEAD FLANGE	
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CLOSURE HEAD SUB

DRILLING OF ADAPTER HOLES

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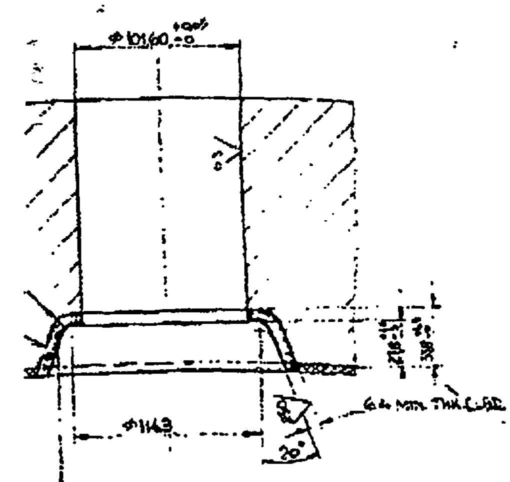

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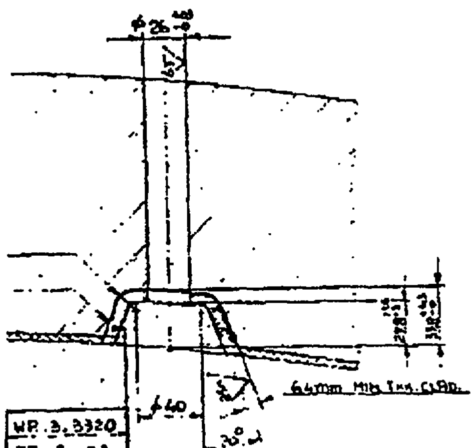

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DETAIL FOR VENT HOLE
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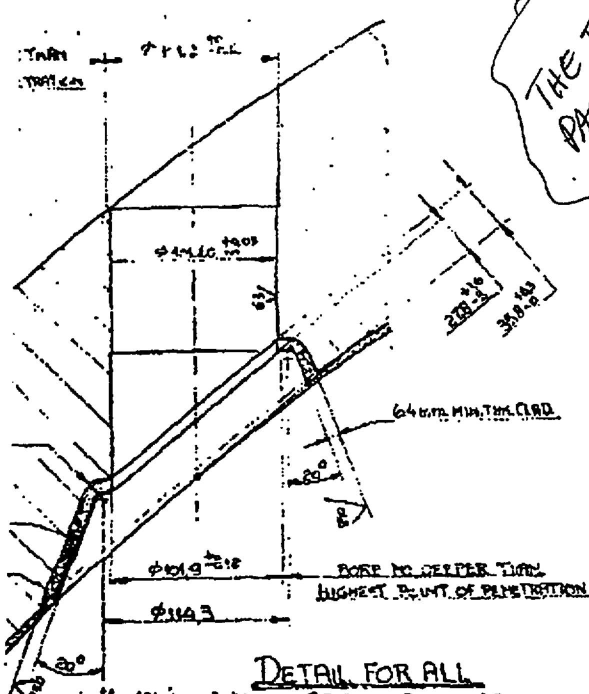

DETAIL FOR ALL ADAPTER HOLES

AFGEGEVEN AAN	DATUM									
W.Z.C.										
LLOYD'S										
APP. BOUW										
AMEDERH										
MACH FABR										
COORD. BUR. W										
LBA										
LASSERIJ. STV.										
Mr. HERBERT										
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2/ ALL INTERNAL MACHINED & CLAD SURFACES TO HAVE 250 √AR FINISH UNLESS OTHERWISE NOTED.
ALL EXTERNAL SURFACES TO HAVE 500 √RMS FINISH UNLESS OTHERWISE NOTED.

3/ CLOSURE HEAD MANUFACTERED BY SULZER.
ACC. TO SULZER DWG. 0.103.080.218

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FIG 7-6

FOR MACH. DIMENSIONS AND ATTACHMENTS SEE SHEET No 2

VPA-RCPCRV-01

POS NR	AANT.	BENAMING	NORM.	MATERIAAL		BESTELNR.	GEW. IN KG.
51	1	CLOSURE HEAD FLANGE		ASTM A-508 CL2			
50	1	CLOSURE HEAD CENTR. DISC.		ASTM A-533			
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51-5015197-00 Pg. 15 of 15 Surry

** TOTAL PAGE. 15 **

Enclosure 1-3
(Non-Proprietary)

Framatome-ANP Document No. 32-5015624-01, "Surry CRDMH Temperbead Weld Seismic Analysis"

FRAMATOME ANP

CALCULATION SUMMARY SHEET (CSS)

Document Identifier 32 - 5015624 - 01

Title SURRY CRDMH TEMPERBEAD WELD SEISMIC ANALYSIS

PREPARED BY:

NAME DONG KIM

SIGNATURE [signature]

TITLE ENGINEER III DATE 11/28/01

COST CENTER 4160048 REF. PAGE(S) 4

REVIEWED BY:

METHOD: ☒ DETAILED CHECK ☐ INDEPENDENT CALCULATION

NAME J. F. SHEPARD

SIGNATURE JFShepard

TITLE SUPERVISORY ENG DATE 11/28/01

TM STATEMENT: REVIEWER INDEPENDENCE ADM

PURPOSE AND SUMMARY OF RESULTS:

THIS IS THE NON-PROPRIETARY VERSION OF 32-5015624-00.

PURPOSE

The purpose of this document is to check the structural integrity on the Surry CRDMH temperbead weld under seismic condition.

RESULTS

The Surry CRDMH temperbead weld is structurally acceptable under the seismic condition, which is described in Appendix section of Ref. 1.

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

☐ YES ☒ NO

1. PURPOSE

The purpose of this document is to check the structural integrity on the Surry CRDMH temperbead weld under seismic condition.

2. CALCULATION

The following is a calculation of the stresses on the repair weld resulting from OBE and SSE loads. The loads are found at Appendix section of Reference 1. Since a small gap (1 or 2 mils) could exist at operating conditions, no credit is taken for restraint of the Closure head. The bending moments obtained from Reference 1 at the CRDM penetration are:

OBE: M = 29,580 in-lbs
SSE: M = 58,000 in-lbs

The internal pressure is assumed to be equal to 2500 psi.

<u>SSE</u>

Nozzle OD = 4.075 in (Ref. 2)
Nozzle ID = 2.818 in (Ref. 2)

$$t = \frac{1}{2}*(4.075 - 2.818) = 0.6285 \text{ in}$$

$$A = \frac{\pi}{4}*(4.075^2 - 2.818^2) = 6.81 \text{ in}^2$$

$$I = \frac{\pi}{64}*(4.075^4 - 2.818^4) = 10.4 \text{ in}^4$$

$$\sigma_{Bend} = \frac{MR_o}{I} = \frac{58000*2.038}{10.4} = 11.4 \text{ ksi}$$

Pressure Stresses in nozzle:

$$\sigma^P_{Axial} = \frac{PR_i}{2t} = \frac{2500*1.409}{2*0.6285} = 2.8 \text{ ksi}$$

$$\sigma^P_{Hoop} = 2*2.8 = 5.6 \text{ ksi}$$

$$\sigma^P_{Radial} = -P/2 = -1.25 \text{ ksi}$$

$\sigma_L = \sigma_{Bend} + \sigma^P_{Axial} = 11.4 + 2.8 = 14.2$ ksi

$\sigma_{Hoop} = 5.6$ ksi

$\sigma_{Radial} = -1.25$ ksi

Stress Intensity = 14.2 – (-1.25) = 15.45 ksi

Allowable Stress Intensity (Section III, Appendix of Ref. 3)

= Lesser of 2.4 S_m or 0.7 S_u
= 2.4*23.3 = 55.9 ksi or =0.7*80 = 56.0 ksi
= 55.9 ksi

Therefore, comparing SI and the allowable, the SSE load is acceptable.

<u>OBE</u>

The bending stress is 0.51*SSE stress

$\sigma_{Bend} = 0.51*11.4 = 5.81$ ksi

$\sigma_L = \sigma_{Bend} + \sigma^P_{Axial} = 5.81 + 2.8 = 8.6$ ksi

$\sigma_{Hoop} = 5.6$ ksi

$\sigma_{Radial} = -1.25$ ksi

Stress Intensity = 8.6 – (-1.25) = 9.85 ksi

Allowable Stress Intensity = 1.5 S_m = 1.5*23.3 = 35 ksi (assume Level B)

Thus, the OBE load is acceptable.

3. CONCLUSION

The Surry CRDMH temperbead weld is structurally acceptable under the seismic condition, which is described in Appendix section of Ref. 1.

4. REFERENCES

1) FRA-ANP Doc. 51-5015050-02, "Surry CRDM Nozzle ID Temper Bead Weld Repair Requirements"

2) FRA-ANP Dwg. 02-5015149E-00, "Surry 1&2 CRDM Nozzle ID Temper Bead Weld Repair"

3) 1989 ASME BOILER AND PRESSURE VESSEL CODE with no addenda

Enclosure 2-1
(Redacted)

Framatome ANP, Document No. 32-5015219-01,
"SURRY CRDM NOZZLE IDTB WELD ANOMALY FLAW EVALUATIONS"

FRAMATOME ANP

CALCULATION SUMMARY SHEET (CSS)

Document Identifier 32 - 5015219 - 01

Title SURRY CRDM NOZZLE IDTB WELD ANOMALY FLAW EVALUATIONS

PREPARED BY:		REVIEWED BY:	
		METHOD: ☒ DETAILED CHECK ☐ INDEPENDENT CALCULATION	
NAME D.E. KILLIAN		NAME A.D. NANA	
SIGNATURE		SIGNATURE	
TITLE PRINCIPAL ENGR.	DATE 11/29/01	TITLE PRINCIPAL ENGR.	DATE 11/29/01
COST CENTER 41026	REF. PAGE(S) 36	TM STATEMENT: REVIEWER INDEPENDENCE	ADN

PURPOSE AND SUMMARY OF RESULTS:

Revision 1: This revision is a non-proprietary version of Revision 0.

The purpose of this analysis is to perform a fracture mechanics evaluation of a postulated weld anomaly in the CRDM nozzle ID temper bead weld repair design. The postulated anomaly is a [ ] inch semi-circular flaw extending 360 degrees around the circumference at the "triple point" location where there is a confluence of three materials; the Alloy 600 nozzle, the Alloy 52 weld, and the low alloy steel head. Two potential flaw propagation paths are considered in the flaw evaluations. The analysis includes prediction of fatigue crack growth in air environment since the anomaly is located on the outside surface of the new weld, just below the bottom of the severed CRDM tube. Flaw acceptance is based on the 1989 ASME Code Section XI criteria for applied stress intensity factor (IWB-3612) and limit load (IWB-3642).

The results of the analysis demonstrate that a [ ] inch weld anomaly is acceptable for a 25 year design life for the CRDM nozzle ID temper bead weld repair, considering the following transient frequencies:

Transient	Frequency (cycles/year)
Heatup/Cooldown	[ ]
Plant Loading/Unloading	[ ]
Remaining Transients (Rapid Transient)	[ ]

Significant fracture toughness margins have been demonstrated for each of the two flaw propagation paths considered in the analysis. The minimum fracture toughness margin is 11.4, compared to the required margin of $\sqrt{10}$ per IWB-3612. Fatigue crack growth is minimal. The maximum final flaw size is [ ] inch. The margin on limit load is 6.25, compared to the required margin of 3.0 per IWB-3642.

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

RECORD OF REVISIONS

Revision	Description	Date
0	Original release	10/01
1	Revision 1 is a non-proprietary version of Revision 0.	11/01

TABLE OF CONTENTS

1.0 INTRODUCTION

The CRDM nozzle ID temper bead weld repair design is illustrated by the drawing of Reference 1. The repair is a welded design, which establishes a new pressure boundary away from the original J-groove weld. The seven steps involved in the repair design are depicted in Reference 1. The steps involved are:

1) [ ]
2) [ ]
3) [ ]
4) [ ]
5) [ ]
6) [ ]
7) [ ]

During the welding process (step 4), a maximum [ ] inch weld anomaly may be formed due to lack of fusion at the "triple point", as shown in Figure 1. The anomaly is assumed to be a "crack-like" defect, 360 degrees around the circumference at the "triple point" location. The technical requirements document (Reference 2) provides additional details of the ID temper bead weld repair procedure. The purpose of the present fracture mechanics analysis is to provide justification, in accordance with Section XI of the ASME Code (Reference 3), for operating with the postulated weld anomaly at the triple point. Predictions of fatigue crack growth are based on a design life of 25 years.

2.0 ASSUMPTIONS

Listed below are assumptions that are pertinent to the present fracture mechanics evaluation.

1) The anomaly is assumed to include a "crack-like" defect, located at the triple-point location and extending all the way around the circumference.

2) Other "crack-like" defects are assumed to be of a semi-elliptical shape with a 2:1 aspect ratio (semi-circular flaw).

3) A 25 year design life is assumed for the fatigue crack growth analysis.

4) It is assumed that the weld residual stresses due to the new repair weld are negligible and therefore can be neglected in the present analysis, as discussed in Reference 17.

5) A final flaw size of [ ] inch will be used as a design limit on fatigue crack growth.

6) An RT_{NDT} value of 60 °F is conservatively assumed for the SA-533, Grade B low alloy reactor vessel head material. This is based on a highest measured value of 40 °F for 13 heats of SA-533 Grade B plate material (Reference 4).

3.0 WELD ANOMALY

The anomaly is located in the triple point region as shown in Figure 1 below.

Figure 1. Weld Anomaly in Temper Bead Weld Repair

The region is called a "triple point" since three materials intersect at this location. The materials are:

a) the Alloy 600 CRDM nozzle material,

b) [ ],* and

c) the low alloy steel RV head material.

* [ ]

3.1 Postulated Flaw

The triple point weld anomaly is assumed to be semi-circular in shape with an initial radius of [ ]", as indicated in Figure 1. It is further assumed that the anomaly extends 360° around the nozzle. Three flaws are postulated to simulate various orientations and propagation directions for the anomaly. A circumferential and an axial flaw on the outside surface of nozzle would both propagate in a horizontal direction toward the inside surface. A cylindrically oriented flaw along the interface between the weld and head would propagate downward between the two components. The horizontal and vertical flaw propagation directions are represented in Figure 2 by separate paths for the downhill and uphill sides of the nozzle, as discussed below. For both these directions, fatigue crack growth will be calculated considering the most susceptible material for flaw propagation.

Horizontal Direction (Paths 1 and 2):

Flaw propagation is across the CRDM tube wall thickness from the OD of the tube to the ID of the tube. This is the shortest path through the component wall, passing through the new Alloy 690 weld material. However, Alloy 600 tube material properties or equivalent are used to ensure that another potential path through the HAZ between the new repair weld and the Alloy 600 tube material is bounded.

For completeness, two types of flaws are postulated at the outside surface of the tube. A 360° continuous circumferential flaw, lying in a horizontal plane, is considered to be a conservative representation of crack-like defects that may exist in the weld anomaly. This flaw would be subjected to axial stresses in the tube. An axially oriented semi-circular outside surface flaw is also considered since it would lie in a plane that is normal to the higher circumferential stresses. Both of these flaws would propagate toward the inside surface of the tube.

Vertical Direction (Paths 3 and 4):

Flaw propagation is down the outside surface of the repair weld between the weld and RV head. A semi-circular cylindrically oriented flaw is postulated to lie along this interface, subjected to radial stresses with respect to the tube. This flaw may propagate through either the new Alloy 690 weld material or the low alloy steel RV head material.

4.0 MATERIAL PROPERTIES

The region of interest for the present flaw evaluation is near the triple point location. As stated in Section 3.0, at this location three different materials intersect. The three materials are the CRDM nozzle material, the new weld material and the reactor vessel (RV) head material.

Surry Units 1 & 2 CRDM nozzles are made from Alloy 600 material to ASME specification SB-167 for tubular products (Reference 2). The new weld material, as noted in Section 3.0, is made from Alloy 690 type material. The RV head (closure head center disk) is made from SA-533 Grade B Class 1 material (Reference 2).

4.1 Yield Strength

Values of yield strength, S_y, are obtained from the 1989 Edition of the ASME Code (Reference 9), as listed below.

SA-533 Grade B Class 1 Low Alloy Steel Plate Material (RV Head)

Room temperature	50.0 ksi
Operating temperature of 600 °F	43.8 ksi

SB-163 Material N06690 (used for Alloy 52 Weld Metal)

Room temperature	40.0 ksi
Operating temperature of 600 °F	31.1 ksi

SB-167 Material N06600 (Alloy 600 Material)

Room temperature	35.0 ksi
Operating temperature of 600 °F	27.9 ksi

4.2 Fracture Toughness

4.2.1. Low Alloy Steel RV Head Material

Fracture toughness curves for SA-533 Grade B, Class 1 material are illustrated in Figure A-4200-1 of Reference 3. At an operating temperature of 600 F, the K_{Ia} fracture toughness value for this material is above 200 ksi$\sqrt{in}$ for the assumed RT_{NDT} of 60 °F. An upper-shelf value of 200 ksi$\sqrt{in}$ will be conservatively used for the present flaw evaluations.

4.2.2. Alloy 600 and Alloy 690 Materials

In Table 7 of Reference 12, Mills provides fracture toughness data for unirradiated Alloy 600 material at 24 °C (75 °F) and 427 °C (800 °F) in the form of crack initiation values for the J-integral, J_c. Using linear interpolation and the LEFM plane strain relationship between J_c and fracture toughness, K_{Jc},

$$K_{Jc} = \sqrt{\frac{J_c E}{1-\nu^2}} ,$$

the fracture toughness at an operating temperature of 600 °F is derived as follows:

Note: $\nu = 0.3$
1 kN/m = 1 kN/m ÷ 4.448 N/lb × 0.0254 m/in = 0.00571 kip/in

Temp. (F)	Mills [12] J_c (kN/m)	J_c (kip/in)	Code [9] E (ksi)	K_{Jc} (ksi√in)
75	382	2.18	31000	273
600	522	2.98	28700	307
800	575	3.28	27600	316

Since brittle fracture is not a credible failure mechanism for ductile materials like Alloy 600 or Alloy 690, these fracture toughness measures, provided for information only, are not considered in the present flaw evaluations. However it should be noted that the fracture toughness measures of these ductile materials is significantly greater than the fracture toughness measure of the low alloy RV head material reported in Section 4.2.1.

4.3 Fatigue Crack Growth

Flaw growth due to fatigue is characterized by

$$\frac{da}{dN} = C_o(\Delta K_I)^n ,$$

where C_o and n are constants that depend on the material and environmental conditions, ΔK_I is the range of applied stress intensity factor in terms of ksi√in, and da/dN is the incremental flaw growth in terms of inches/cycle. For the embedded weld anomaly considered in the present analysis, it is appropriate to use crack growth rates for an air environment. Fatigue crack growth is also dependent on the ratio of the minimum to the maximum stress intensity factor; i.e.,

$$R = (K_I)_{min} / (K_I)_{max}$$

SA-533 Grade B Class 1 Low Alloy Steel Plate Material (RV Head)

From Article A-4300 of Section XI (Reference 3), the fatigue crack growth constants for subsurface flaws in an air environment are:

$$n = 3.726$$

$$C_o = 2.67 \times 10^{-11}$$

Alloy 600 and Alloy 690 (used for Alloy 52 Weld Metal)

Fatigue crack growth rates for austenitic stainless steels are used to conservatively predict flaw growth in the new Alloy 52 repair weld. Using crack growth rates from Article C-3210 of Section XI (Reference 3) for austenitic stainless steels in an air environment,

$$n = 3.3$$

$$C_o = C \times S$$

where

$$C = 10^{[-10.009 + 8.12E\text{-}4 \times T - 1.13E\text{-}6 \times T^2 + 1.02E\text{-}9 \times T^3]}$$

$$S = 1.0 \quad \text{for} \quad R \leq 0$$

$$= 1.0 + 1.8R \quad \text{for} \quad 0 < R \leq 0.79$$

$$= -43.35 + 57.97R \quad \text{for} \quad 0.79 < R < 1.0$$

5.0 APPLIED STRESSES

The applied stresses are the cyclic stresses that contribute to fatigue crack growth. Fatigue stresses are obtained from the stress analysis of the CRDM temperbead design contained in Reference 10[1]. The stresses for the controlling transient are combined with a zero stress at shutdown to produce a conservative stress range, since the triple point stresses are always positive due to the dominating effect of pressure. Incremental crack growth is conservatively calculated using the maximum stress range and a total of 300 cycles per year, based on the following transient frequencies:

Transient	Frequency
Heatup/Cooldown	[ ] cycles/60 years
Plant Loading/Unloading	[ ] cycles/60 years
Remaining Transients (Rapid Transient)	[ ] cycles/60 years
Total	[ ] cycles/60 years
or about	[ ] cycles/year

Stresses are available from Reference 10 for the four crack propagation paths illustrated in Figure 2. Paths 1 and 3 are located on the downhill (0°) side of the nozzle and Paths 2 and 4 are on the uphill (180°) side. Stresses are reported in a cylindrical coordinate system relative to the CRDM nozzle and include the three component directions (axial, hoop and radial) needed to calculate mode I stress intensity factors for the various postulated flaws. From Reference 10, the length of Paths 1 and 2 is [ ]" and the length of Paths 3 and 4 is [ ]". Stresses are provided at four uniform increments along each path.

Stresses are presented for the heatup/cooldown transient in Table 1, for plant loading/unloading in Table 2, and for the rapid transient in Table 3. Since stresses are higher on the uphill side of the nozzle, the stresses for Paths 2 and 4 will be used to evaluate the postulated flaws at the triple point weld anomaly.

Since the stresses in Reference 10 apply directly to a weld thickness of 0.505", they will be adjusted to account for the minimum weld thickness specified on the design drawing. When the inside surface of the weld is finished by grinding, the thickness of the weld is

[ ] (Reference 1)

Conservatively assuming that all the stress along Path 2 is due to bending, the stresses from Reference 10 are increased by the ratio

[ ]

This adjustment to stress is made as part of the flaw evaluations in Tables 3 and 5.

---

[1] The stress analysis documented in Reference 10 was performed for Turkey Point Unit 3. Differences between Turkey Point Unit 3 and Surry Units 1 & 2 are minor, as discussed in Reference 5. Stresses from Reference 10 are therefore also considered to be applicable to Surry Units 1 & 2.

This figure is not pertinent to this document.
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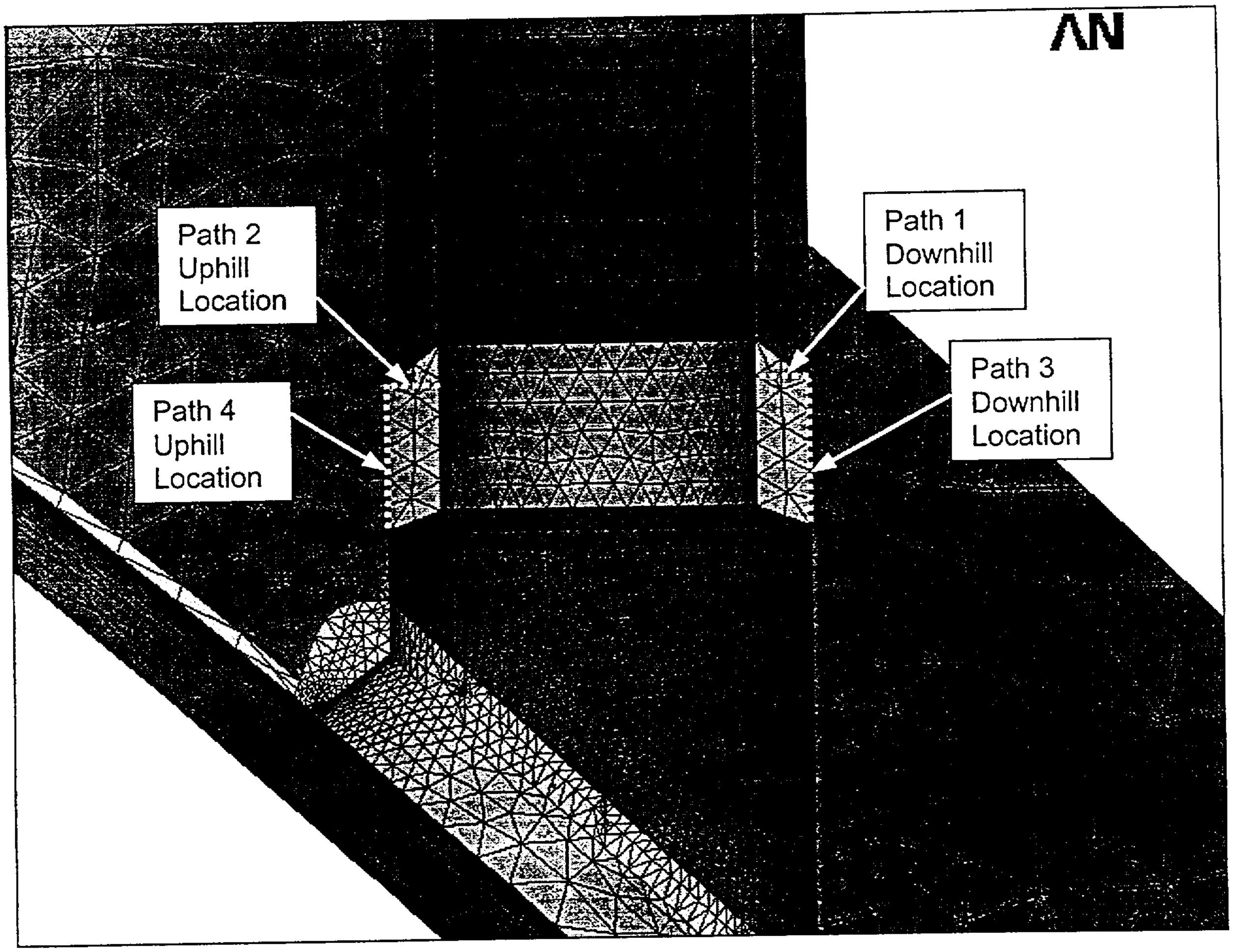


Figure 2. Illustration of Crack Propagation Paths on the Finite Element Stress Model

Table 1. Stresses for Heatup/Cooldown Transient (from Reference 10)

Triple Point Location

Legend for stress indicators: SX = radial stress
SY = hoop stress
SZ = axial stress

Table 2. Stresses for Plant Loading/Unloading Transient (from Reference 10)

Triple Point Location

[ ]

Legend for stress indicators: SX = radial stress
SY = hoop stress
SZ = axial stress

Table 3. Stresses for Rapid Transient (from Reference 10)

Triple Point Location

[ ]

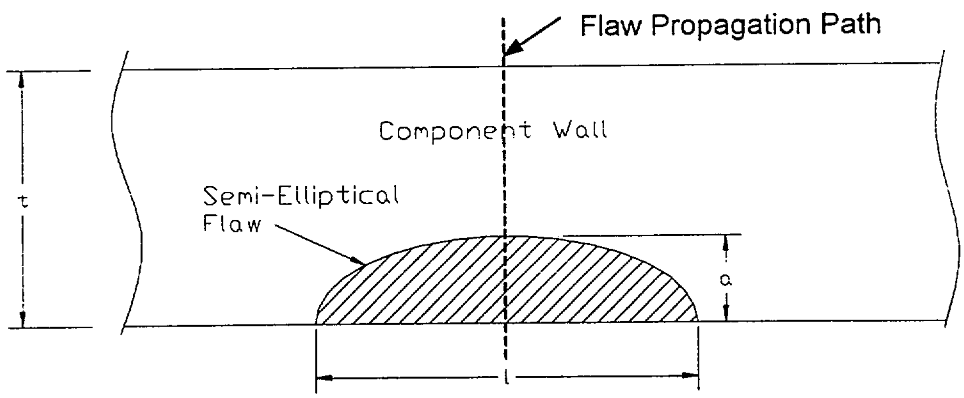
Legend for stress indicators: SX = radial stress
SY = hoop stress
SZ = axial stress

6.0 FRACTURE MECHANICS METHODOLOGY

This section presents several aspects of linear elastic fracture mechanics (LEFM) and limit load analysis (to address the ductile Alloy 600 and Alloy 690 materials) that form the basis of the present flaw evaluations. As discussed in Section 3.1, flaw evaluations are performed for flaw propagation Paths 2 and 4 in Figure 2.

Path 2 represents a section across the new Alloy 52 weld metal which is equivalent to the thickness of the CRDM tube wall. Since the weld anomaly is located at the base of the OD of the CRDM tube and is assumed to be all the way around the circumference, a stress intensity factor (SIF) solution for a 360 degree circumferential crack on the OD of a circular tube is deemed appropriate. Therefore, the SIF solution of Buchalet and Bamford (Reference 13) is used in the analysis. However, this solution is applicable for a 360-degree part-through ID flaw. To develop an SIF solution for a 360 degree part-through OD flaw, an F function is determined based on SIF solutions of Kumar (References 14 and 15). The appropriate F function for an internal as well as an external circumferential flaw in a cylinder subjected to remote tension are determined first. The ratio of the F functions of the external flaw to the internal flaw is considered to be the appropriate multiplication factor for the Buchalet and Bamford SIF solution, to extend its application to an external crack. The materials to be considered for this path are the Alloy 600 tube material or the Alloy 52 weld metal. The fatigue crack growth rate properties for austenitic stainless steel as given in Appendix C of Reference 3 will be conservatively used in the analysis. A limit load analysis for an external circumferential flaw in a cylinder subjected to remote tension per Reference 15 is also performed to demonstrate the margins against the applied loads on the CRDM tube.

An axially oriented semi-circular OD surface flaw is also considered in the evaluation, as illustrated by the schematic below.



where, a = initial flaw depth = [ ] inch

$l = 2c$ = flaw length = [ ] inch

t = wall thickness = [ ] inch

An axial flaw is considered since the stresses in the CRDM penetration region are primarily due to pressure and therefore the hoop stresses are more significant. The SIF solution by Raju & Newman (Reference 16) for an external surface crack in a cylindrical vessel is used in the evaluation. The fatigue flaw growth analysis for the axial crack is also performed using the austenitic stainless steel properties.

Path 4 represents the interface between the new repair weld and the RV head material. The potential for flaw propagation along this interface is likely if the radial stresses are significant between the weld and head. This assessment utilizes an SIF solution (Reference 11, Table 12.23) for a semi-circular surface crack in a flat plate subjected to radial stresses. Crack growth analysis is performed considering propagation through the Alloy 52 weld metal or the low alloy carbon steel material, whichever is limiting.

The Irwin plasticity correction is also considered in the SIF solutions discussed above. This plastic zone correction is discussed in detail in Section 2.8.1 of Reference 11. The effective crack length is defined as the sum of the actual crack size and the plastic zone correction:

$$a_e = a + r_y$$

where r_y for plane strain conditions (applicable for this analysis) is given by:

$$r_y = \frac{1}{6\pi}\left(\frac{K_I}{\sigma_{YS}}\right)^2$$

7.0 ANALYTICAL CONSIDERATIONS

For low alloy steel materials such as the RV head material, the evaluation will be performed to the IWB-3612 acceptance criteria of Section XI of the Code (Reference 3). The following considerations are made to address the flaw acceptance criteria for highly ductile materials such as Alloy 600 and Alloy 690 type materials. The assumed initial flaw size to thickness ratio in this analysis is about 20%. Fatigue crack growth under normal operating loads is minimal for Alloy 600 or Alloy 690 materials in an air environment. The only acceptance criterion on flaw size is the industry developed 75% through-wall limit on depth (Reference 8):

$$\frac{a}{t} \leq 0.75$$

For the shallow cracks considered in the present analysis, this criterion is easily met. Another acceptance criteria for ductile materials is demonstration of sufficient limit load margin. From IWB-3642 (Reference 3), the required safety margin, based on load, is a factor of 3 for normal operating conditions.

The calculated stress intensity factors are also compared against the required fracture toughness margins of $\sqrt{10}$ for normal operating conditions. As noted in the Section 2.0, the final flaw size of the anomaly after fatigue crack growth is not to exceed [ ] inch.

From Reference 17, residual stresses due to the repair weld need not be considered in the present flaw evaluations.

8.0 FLAW EVALUATIONS

The flaw evaluations for flaw propagation Path 2 are contained in Tables 4 through 6. The fatigue crack growth (FCG) analysis of the continuous external circumferential flaw in a CRDM tube is provided in Table 4. A limit load analysis, for this type of postulated flaw, is summarized in Table 5. Finally, the fatigue crack growth analysis for an external axial flaw in a CRDM tube is documented in Table 6.

The FCG evaluations for flaw propagation Path 4 are contained in Table 7.

Table 4. **Evaluation of Continuous External Circumferential Flaw for Fatigue Crack Growth Along Path 2**

INPUT DATA

Pipe Geometry:	Outside diameter,	Do =	[ ]	in.
	Inside diameter,	Di =	[ ]	in.
	Mean radius,	R =	[ ]	in.
	Thickness,	t =	[ ]	in.
		Ri/t =	3.098	
Flaw Size:	Flaw depth,	a =	[ ]	in.
		a/t =	0.205	
Environment:	Temperature,	T =	600	F
Material Strength:	Yield strength,	y.s. =	27.9	ksi

Table 4. Evaluation of Continuous External Circumferential Flaw for Fatigue Crack Growth Along Path 2 (Cont'd)

CRACK GROWTH RATES IN AUSTENITIC PIPING

Fatigue crack growth rate, 1989 ASME Code, Section XI, Appendix C (Reference 3):

$$da/dN = C_o*(\Delta KI)^n$$

where: da = change in crack depth, in.
ΔKI = change in stress intensity factor, ksi√in

In air:

$n = 3.3$

$C_o = C*S$

$C = 10^{[-10.009 + (8.12E-4)*T - (1.13E-6)*T\text{^}2 + (1.02E-9)*T\text{^}3]}$

$= 1.96E-10$

$R = KImin / KImax$

$S = 1.0$	when	$R \leq 0$
$= 1.0 + 1.8R$	when	$0 < R \leq 0.79$
$= -43.35 + 57.97R$	when	$0.79 < R < 1.0$

Table 4. **Evaluation of Continuous External Circumferential Flaw for Fatigue Crack Growth Along Path 2 (Cont'd)**

STRESS INTENSITY FACTOR FOR CIRCUMFERENTIAL FLAW

Basis: Buchalet and Bamford solution for continuous circumferential flaws on the inside surface of cylinders (Ref. 13)

$$KI = \sqrt{(\pi * a)} * [A_0 F_1 + (2a/\pi) A_1 F_2 + (a^2/2) A_2 F_3 + (4a^3)/(3\pi) A_3 F_4]$$

where,

$$F1 = 1.1259 + 0.2344(a/t) + 2.2018(a/t)^2 - 0.2083(a/t)^3$$
$$F2 = 1.0732 + 0.2677(a/t) + 0.6661(a/t)^2 + 0.6354(a/t)^3$$
$$F3 = 1.0528 + 0.1065(a/t) + 0.4429(a/t)^2 + 0.6042(a/t)^3$$
$$F4 = 1.0387 - 0.0939(a/t) + 0.6018(a/t)^2 + 0.3750(a/t)^3$$

and the through-wall stress distribution is described by the third order polynomial,

$$S(x) = A_0 + A_1x + A_2x^2 + A_3x^3.$$

Applicablility: $Ri/t = 10$
$a/t \le 0.8$

Axial Stresses:

Wall Position x	Normal/Upset Cond. Stresses [10]		Ratioed Stresses Factor = 1.071	
	NU1	NU2	NU1	NU2
(in.)	(ksi)	(ksi)	(ksi)	(ksi)
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]

Stress Coefficients:

Stress Coeff.	Normal/Upset Loading Conditions	
	NU1	NU2
	(ksi)	(ksi)
A_0	[ ]	[ ]
A_1	[ ]	[ ]
A_2	[ ]	[ ]
A_3	[ ]	[ ]

Table 4. Evaluation of Continuous External Circumferential Flaw for Fatigue Crack Growth Along Path 2 (Cont'd)

3rd Order Polynomial Stress Fit for Loading Condition NU1:

S = A0 + A1*x + A2*x^2 + A3*x^3

[B]{A} = {S}
{A} = [B^T B]^(-1) [B]^T{S}

x	{S}
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]

[B]			
1	x	x^2	x^3
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

[B]^T				
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]

[B^T B]			
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

[B^T B]^(-1)			
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

[B]^T{S}	{A}
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]

Table 4. Evaluation of Continuous External Circumferential Flaw for Fatigue Crack Growth Along Path 2 (Cont'd)

Variation of F Function between Continuous External and Continuous Internal Circumferential Flaws Using Solutions by V. Kumar et al.

Source: EPRI NP-1931 Topical Report, Section 4.3 for F Function for An Internal Circumferential Crack Under Remote Tension (Ref. 14).

The applied KI equation is given by the expression:

$$KI = \sigma*\sqrt{(\pi*a)}*F(a/b, Ri/Ro)$$

where

$$\sigma = P/(\pi*(Ro^2 - Ri^2)$$

and F is a function of a/b and Ri/Ro or b/Ri.

For this application:

a/b =	0.205
Ri/Ro =	0.756
b/Ri =	0.323

By extrapolation from Table 4-5 of EPRI-1931, F is estimated to be:

F = 1.16

Source: GE Report SRD-82-048, Prepared for EPRI Contract RP-1237-1, Fifth & Sixth Semi-Annual Report, Section 3.5 for F Function (Ref. 15).

For the external circumferenital crack, the expressions for KI and σ are as defined above for the internal circumferential crack.

From Figure 3-11, the F function for:

a/b =	0.205
Ri/Ro =	0.756

is estimated to be,

F = 1.25

Multiplying Factor:

To estimate the stress intensity factor for an external cicumferential crack from the solution for an internal circumferenital crack under remote tension, the appropriate multiplying factor is: 1.08

Table 4. Evaluation of Continuous External Circumferential Flaw for Fatigue Crack Growth Along Path 2 (Cont'd)

CRACK GROWTH FOR CIRCUMFERENTIAL FLAW

Basis: $\Delta a = \Delta N * C_o(\Delta KI)^n$

Let:
ΔN = [ ] fatigue cycles / year
Duration = 25 years
N = [ ] total number of fatigue cycles

Cycle	a (in.)	NU1 KI(a)max (ksi√in)	NU2 KI(a)min (ksi√in)	ΔKI (ksi√in)	R	S	C_o	Δa (in.)	r_y	a_e	NU1 KI(a_e)max (ksi√in)
[											]

Table 5. Limit Load Analysis for a Continuous External Circumferenital Flaw

LIMIT LOAD

Basis: GE Report SRD-82-048, Combined Fifth and Sixth Semi-Annual Report by V. Kumar et al, Section 3.5 (Ref. 15).

For remote tension loading,

$$Po = 2/\sqrt{3}*\sigma_o*\pi*(Rc^2-Ri^2)$$

where

$Rc = Ro - a$

and

$\sigma_o =$ 30000 psi (conservatively using the minimum yield strength)

Ro = [ ] in.

a = [ ] in.

Rc = [ ] in.

Ri = [ ] in.

Then

Po = 139620 lbs

A bounding axial tube load on the CRDM tube is the hydrostatic test load:

$$P = (\pi Ri^2)*(3110 \text{ psig})$$

= 22336 lbs

The limit load safety margin is:

Po/P = 6.25

This safety margin is greater than the value of 3 required by Article IWB-3642 of Section XI (Reference 3).

Table 6. Evaluation of an External Axial Flaw for Fatigue Crack Growth Along Path 2

STRESS INTENSITY FACTOR FOR AXIAL FLAW

Basis: Raju & Newman, "Stress Intensity Factors for Internal & External Surface Cracks in Cylindrical Vessels (Ref. 17)

$$KI = \sqrt{(\pi/Q)} * [G_0 A_0 a^{0.5} + G_1 A_1 a^{1.5} + G_2 A_2 a^{2.5} + G_3 A_3 a^{3.5}]$$

where, per Table 4, for an external surface crack and for t/R = 0.25, a/t = 0.2, $2\phi/\pi$ = 1, and a/c = 1.0

Go = 1.030
G_1 = 0.720
G_2 = 0.591
G_3 = 0.513

and **Q =** 2.464 = (1 + 1.464*(a/c)^1.65)

and the through-wall stress distribution is described by the third order polynomial,

$$S(x) = A_0 + A_1x + A_2x^2 + A_3x^3.$$

Hoop Stresses:

Wall Position x	Normal/Upset Cond. Stresses [10]		Ratioed Stresses Factor = 1.071	
	NU1	NU2	NU1	NU2
(in.)	(ksi)	(ksi)	(ksi)	(ksi)
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]

Stress Coefficients:

Stress Coeff.	Normal/Upset Loading Conditions	
	NU1	NU2
	(ksi)	(ksi)
A_0	[ ]	[ ]
A_1	[ ]	[ ]
A_2	[ ]	[ ]
A_3	[ ]	[ ]

Table 6. Evaluation of an External Axial Flaw for Fatigue Crack Growth Along Path 2 (Cont'd)

3rd Order Polynomial Stress Fit for Loading Condition NU1:

S = A0 + A1*x + A2*x^2 + A3*x^3

[B]{A} = {S}
{A} = [B^T B]^(-1) [B]^T{S}

x
[ ]
[ ]
[ ]
[ ]
[ ]

{S}
[ ]
[ ]
[ ]
[ ]
[ ]

[B]			
1	x	x^2	x^3
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

[B]^T				
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]

[B^T B]			
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

[B^T B]^(-1)			
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

[B]^T{S}
[ ]
[ ]
[ ]
[ ]

{A}
[ ]
[ ]
[ ]
[ ]

Table 6. Evaluation of an External Axial Flaw for Fatigue Crack Growth Along Path 2 (Cont'd)

CRACK GROWTH FOR AXIAL FLAW

Basis: $\Delta a = \Delta N * C_o(\Delta KI)^n$

Let:
ΔN = [ ] fatigue cycles / year
Duration = 25 years
N = [ ] total number of fatigue cycles

Cycle	a (in.)	NU1 KI(a)max (ksi√in)	NU2 KI(a)min (ksi√in)	ΔKI (ksi√in)	R	S	C_o	Δa (in.)	r_y	a_e	NU1 KI(a_e)max (ksi√in)
[											]

Table 7. Evaluation of a Semi-Elliptical Surface Crack for Fatigue Crack Growth Along Path 4

INPUT DATA

Repair Geometry:	Thickness of section,	t =	[ ]	in.
	OD of weld,	Do =	[ ]	in.
	Half width of section,	W =	[ ]	in.
Flaw Size:	Flaw depth,	a =	[ ]	in.
		a/t =	0.074	
Environment:	Temperature,	T =	600	F
Material Strength:	Yield Strength,	y.s. =	27.9	ksi

Table 7. Evaluation of a Semi-Elliptical Surface Crack for Fatigue Crack Growth Along Path 4 (Cont'd)

STRESS INTENSITY FACTOR FOR SEMI-ELLIPTICAL SURFACE CRACK

Basis: Anderson T.L., "Fracture Mechanics: Fundamentals and Applications", Table 12.23, Semi-elliptical Surface Crack in a Flat Plate.

$$KI = \sqrt{(\pi a/Q)} * (G_0 A_0 + G_1 A_1 a + G_2 A_2 a^2 + G_3 A_3 a^3) f_w$$

For $a/c = 1.0$, $a/t <= 0.2$, $2\phi/\pi = 1$,

and c = a = [ ] in.

Go = 1.021
G_1 = 0.717
G_2 = 0.589
G_3 = 0.513

Q = 2.464 = (1 + 1.464*(a/c)^1.65)

f_w = [ ] = [sec((π*c)/(2*W)*sqrt(a/t))]^0.5

The through-wall stress distribution is described by the third order polynomial,

$$S(x) = A_0 + A_1 x + A_2 x^2 + A_3 x^3$$

Radial Stresses:

Wall Position x	Normal/Upset Cond. Stresses [10]		Ratioed Stresses Factor = 1.071	
	NU1	NU2	NU1	NU2
(in.)	(ksi)	(ksi)	(ksi)	(ksi)
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]

Stress Coefficients:

Stress Coeff.	Normal/Upset Loading Conditions	
	NU1	NU2
	(ksi)	(ksi)
A_0	[ ]	[ ]
A_1	[ ]	[ ]
A_2	[ ]	[ ]
A_3	[ ]	[ ]

Table 7. Evaluation of a Semi-Elliptical Surface Crack for Fatigue Crack Growth Along Path 4 (Cont'd)

3rd Order Polynomial Stress Fit for Loading Condition NU1:

S = A0 + A1*x + A2*x^2 + A3*x^3

[B]{A} = {S}
{A} = [B^T B]^(-1) [B]^T{S}

x	{S}
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]

[B]			
1	x	x^2	x^3
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

[B]^T				
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]

[B^T B]			
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

[B^T B]^(-1)			
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]

[B]^T{S}	{A}
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]

Table 7. Evaluation of a Semi-Elliptical Surface Crack for Fatigue Crack Growth Along Path 4 (Cont'd)

CRACK GROWTH FOR SEMI-ELLIPTICAL SURFACE CRACK

Basis: $\Delta a = \Delta N * C_o(\Delta KI)^n$

Let:
ΔN = [ ] fatigue cycles / year
Duration = 25 years
N = [ ] total number of fatigue cycles

Cycle	a (in.)	NU1 KI(a)max (ksi√in)	NU2 KI(a)min (ksi√in)	ΔKI (ksi√in)	R	S	C_o	Δa (in.)	r_y	a_e	$KI(a_e)max$ (ksi√in)
[											]

9.0 SUMMARY OF RESULTS

The flaw evaluation results for 25 years of fatigue crack growth (FCG) are as follows.

9.1 Flaw Propagation Path 2

a) FCG analysis of a continuous external circumferential flaw in weld:

Initial flaw size, a_i = [ ] in.
Final flaw size, a_f = [ ] in. < [ ] in.

Stress intensity factor at final flaw size, $K_I (a_{ef})$ = 15.7 ksi√in
Fracture toughness K_{Ia} = 200 ksi√in
Fracture toughness margin, K_I / K_{Ia} = 12.7 > √10

b) Limit load analysis for a continuous external circumferential flaw in weld:

Bounding axial tube load, P(appl) = 22,336 lbs
Limit load, P_O = 139,620 lbs

Limit load margins, P_O / P(appl) = 6.25 > 3.0

c) FCG analysis of a semi-circular external axial flaw in weld:

Initial flaw size, a_i = [ ] in.
Final flaw size, a_f = [ ] in. < [ ] in.

Stress intensity factor at final flaw size, $K_I (a_{ef})$ = 17.5 ksi√in
Fracture toughness K_{Ia} = 200 ksi√in
Fracture toughness margin, K_I / K_{Ia} = 11.4 > √10

9.2 Flaw Propagation Path 4

FCG analysis of a semi-circular surface flaw at weld/head interface:

Initial flaw size, a_i = [ ] in.
Final flaw size, a_f = [ ] in. < [ ] in.

Stress intensity factor at final flaw size, $K_I (a_{ef})$ = 9.0 ksi√in
Fracture toughness K_{Ia} = 200 ksi√in
Fracture toughness margin, K_I / K_{Ia} = 22.2 > √10

10.0 CONCLUSION

The results of the analysis demonstrate that the [ ] inch weld anomaly is acceptable for a 25 year design life of the CRDM ID temper bead weld repair. Significant fracture toughness margins have been demonstrated for both of the flaw propagation paths considered in the analysis. The minimum fracture toughness margins for flaw propagation Paths 2 and 4 have been shown to be 11.4 and 22.2, respectively, as compared to the required margin of $\sqrt{10}$ for normal operating conditions per Section XI, IWB-3612 (Reference 3). Fatigue crack growth is minimal. The maximum final flaw size is [ ] inches (considering both flaw propagation paths). A limit load analysis was also performed considering the ductile Alloy 600/Alloy 690 materials along flaw propagation Path 2. The analysis showed limit load margin of 6.25 for normal operating conditions, as compared to the required margin of 3.0 per Section XI, IWB-3642 (Reference 3).

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Enclosure 3-1
(Redacted)

Framatome ANP Document No. 32-5015650-01,
"SURRY CRDM NOZZLE 1.0" J-GROOVE WELD FLAW EVALUATION"

FRAMATOME ANP

CALCULATION SUMMARY SHEET (CSS)

Document Identifier 32 – 5015650 - 01

Title SURRY CRDM NOZZLE 1.0" J-GROOVE WELD FLAW EVALUATION

PREPARED BY:	REVIEWED BY:
	METHOD: ☒ DETAILED CHECK ☐ INDEPENDENT CALCULATION
NAME D.E. KILLIAN	NAME K.K. YOON
SIGNATURE [signature]	SIGNATURE [signature]
TITLE PRIN. ENGR. DATE 11/29/01	TITLE TECH. CONSULT. DATE 11/29/01
COST CENTER 41026 REF. PAGE(S) 47	TM STATEMENT: REVIEWER INDEPENDENCE [initials]

PURPOSE AND SUMMARY OF RESULTS:

Revision 1: This revision is a non-proprietary version of Revision 0.

The purpose of the present analysis is to assess the suitability of leaving 1.000" of degraded J-groove weld material in the Surry Units 1 & 2 reactor vessel heads following the repair of a CRDM nozzle by the ID temper bead weld procedure. It is postulated that a small flaw in the head would combine with a large stress corrosion crack in the weld to form a radial corner flaw that would propagate into the low alloy steel head by fatigue crack growth under cyclic loading conditions.

Based on an evaluation of fatigue crack growth into the low alloy steel head and considering the Section XI requirements of the ASME Code for fracture toughness, a 1.000" J-groove weld remnant would be acceptable for at least 5 years of operation, considering the following transient frequencies:

Transient	Frequency (cycles/year)
Heatup and Cooldown	[ ]
Plant Loading and Unloading	[ ]
Large Step Decrease	[ ]
Loss of Load	[ ]
Loss of Flow	[ ]
Reactor Trip	[ ]
Remaining Transient	[ ]

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE/VERSION/REV	CODE/VERSION/REV

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

☐ YES ☐ NO

RECORD OF REVISIONS

Revision	Pages	Description of Revision	Date
0	All	Original release	11/01
1	All	Revision 1 is a non-proprietary version of Revision 0.	11/01

CONTENTS

1.0 Introduction

Due to the susceptibility of Alloy 600 reactor vessel head partial penetration nozzles to primary water stress corrosion cracking (PWSCC), a repair procedure has been developed for Surry Units 1 & 2 wherein the lower portion of the CRDM nozzle is removed by a boring procedure and the remaining portion of the nozzle is welded to the low alloy steel reactor vessel head above the original Alloy 182 J-groove attachment weld, as shown in Figure 1. This repair design is more fully described by the design drawing [1] and the technical requirements document [2]. Except for a chamfer at the corner, the original J-groove weld will not be removed. Since a potential flaw in the J-groove weld can not be sized by currently available non-destructive examination techniques, it must be assumed that the "as-left" condition of the remaining J-groove weld includes degraded or cracked weld material extending through the entire J-groove weld and Alloy 182 butter material. The purpose of the present analysis is to determine from a fracture mechanics viewpoint the suitability of leaving degraded J-groove weld material in the vessel following repair of the nozzle.

Since it is known from analysis of the Surry CRDM reactor vessel head nozzle penetrations [12] that the hoop stress in the J-groove weld is greater than the axial stress at the same location, by as much as a factor of two, the preferential direction for cracking would be axial, or radial relative to the nozzle. It is postulated that a radial crack in the Alloy 182 weld metal would propagate by PWSCC, through the weld and butter, to the interface with the low alloy steel head. It is fully expected that such a crack would then blunt and arrest at the butter-to-head interface [4]. Since the height of the original weld along the bored surface is about 1.7", a radial crack depth extending from the corner of the weld to the low alloy steel head would be very deep. Ductile crack growth through the Alloy 182 material would tend to relieve the residual stresses in the weld as the crack grew to its final size and blunted. Although residual stresses in the head material are low (and even compressive) [12], it is assumed that a small flaw could initiate in the low alloy steel material and grow by fatigue. For the present analysis of the remaining J-groove weld, it is postulated that a small flaw in the head would combine with the stress corrosion crack in the weld to form a large radial corner flaw that would propagate into the low alloy steel head by fatigue crack growth.

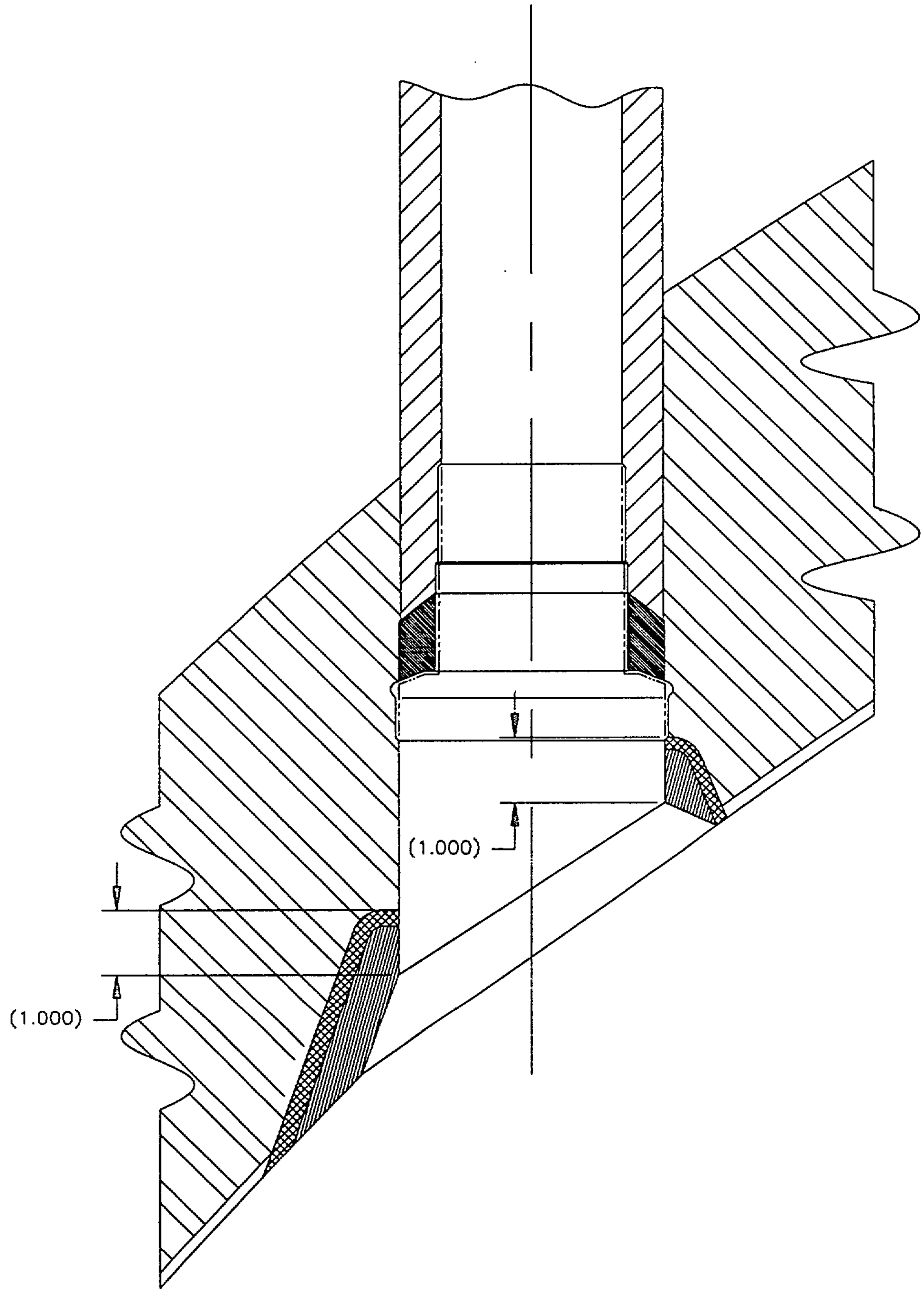


Figure 1. ID Temper Bead Weld Repair

2.0 Geometry and Flaw Model

It is postulated that a radial flaw is present in the low alloy steel head, extending from the chamfered corner of the remaining J-groove weld to the interface between the butter and head. Analytically, this flaw is crudely simulated using the corner flaw model shown below in Figure 2.

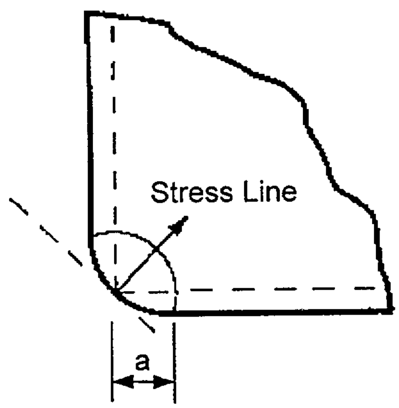


Figure 2. Corner Flaw Model

The flaw depth, "a", is the radius to the crack front. The stress line shown in the figure above depicts a typical direction for consideration of a one-dimensional variation of stress through the area represented by the corner flaw model.

Since a large flaw would have to be postulated if the J-groove weld was left in its original configuration after removal of the nozzle in the ID temper bead repair procedure, the design drawing [1] specifies a chamfer at the inside corner of the remaining weld to limit the height of the weld along the bored surface, from the inside corner to the low alloy steel head, to 1.000". This configuration was modeled in a three-dimensional finite element structural analysis [6] to determine operating stresses throughout the remaining weld, nozzle, and head. The finite element model of the outermost nozzle location includes a detailed geometrical representation of the remaining J-groove weld prep around the penetration. Stresses are reported along a line originating at the inside corner (Point 0) and oriented about 45° relative to the vertical bored surface, as shown in Figure 3 at the uphill location where the hoop stresses are the highest. The distance along the line, from Point 0 to the interface between the butter and head, is used for the depth of the postulated corner flaw. From Reference 6, the distance from the origin of the stress line at the uphill location to the butter/head interface is 1.0532", so that the initial flaw depth is

$$a = 1.053 \text{ in.}$$

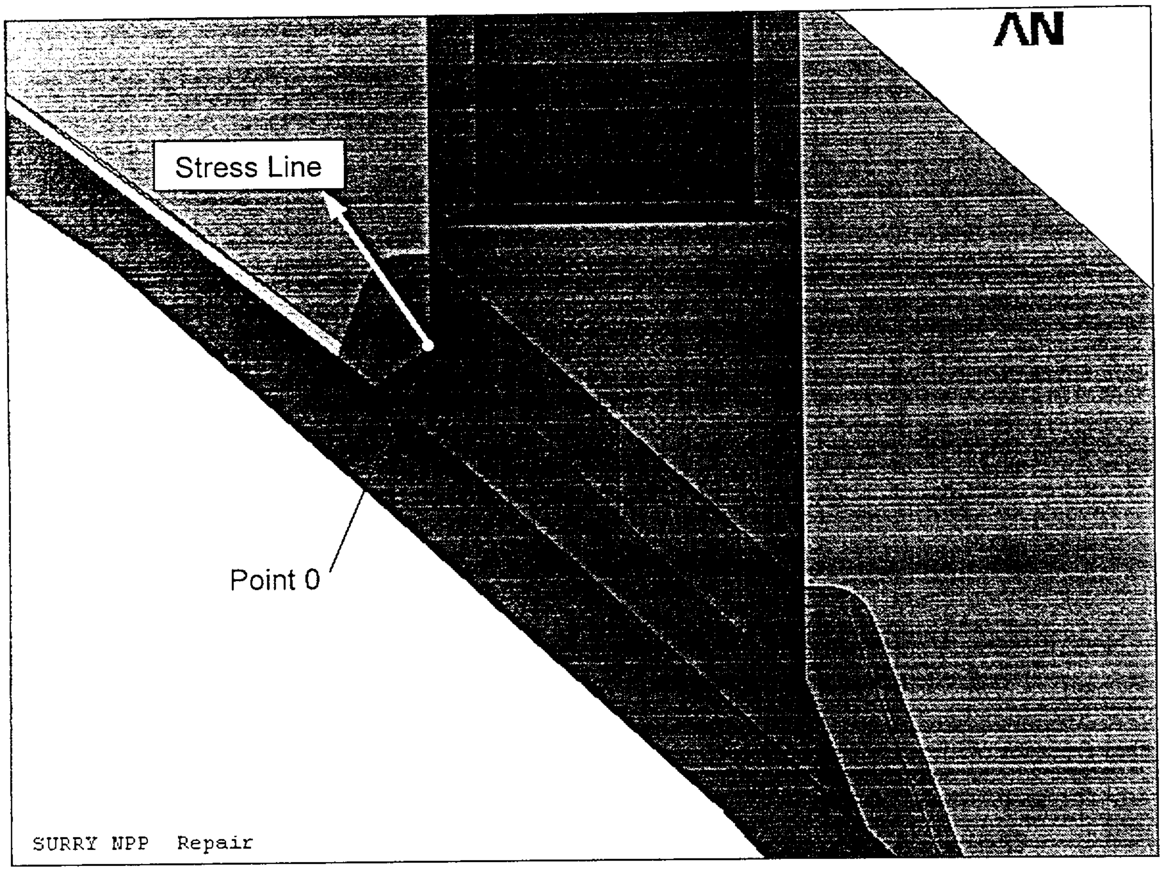


Figure 3. Orientation of Stress Line

3.0 Material Properties

The material used for the center portion of the reactor vessel head (closure head center disc) is SA-533, Grade B, Class 1 Mn-Mo low alloy steel plate [2].

Yield Strength

From the ASME Code, Section III, Appendix I [8], the specified minimum yield strength for the head material is 50.0 ksi below 100 °F and 43.8 ksi at 600 °F. The value at 600 °F is used as a conservative lower bound for yield strengths at operating temperatures less than 600 °F.

Reference Temperature

The RT_{NDT} of the SA-533, Grade B low alloy reactor vessel head material is conservatively taken as 60 °F. This is based on a highest measured value of 40 °F for 13 heats of SA-533 Grade B plate material [5].

Fracture Toughness

The lower bound K_{Ia} curve of Section XI, Appendix A, Figure A-4200-1 [10], which can be expressed as

$$K_{Ia} = 26.8 + 1.233 \exp [0.0145 (T - RT_{NDT} + 160)] , \qquad [11]$$

represents the fracture toughness for crack arrest, where T is the crack tip temperature and RT_{NDT} is the reference nil-ductility temperature of the material. K_{Ia} is in ksi√in, and T and RT_{NDT} are in °F. In the present flaw evaluations, K_{Ia} is limited to a maximum value of 200 ksi√in (upper-shelf fracture toughness). Using the above equation with an RT_{NDT} of 60 °F, K_{Ia} equals 200 ksi√in at a crack tip temperature of 242 °F.

Fatigue Crack Growth

Flaw growth due to cyclic loading is calculated using the fatigue crack growth rate model from Article A-4300 of Section XI [10],

$$\frac{da}{dN} = C_o(\Delta K_I)^n,$$

where ΔK_I is the stress intensity factor range in ksi√in and da/dN is in inches/cycle. The crack growth rates for a surface flaw will be used for the evaluation of the corner crack since it is assumed that the degraded condition of the J-groove weld and butter exposes the low alloy steel head material to the primary water environment.

Fatigue Crack Growth Rates for Low Alloy Ferritic Steels in a Primary Water Environment

Source: ASME Code, Section XI, 1989 Edition with No Addenda [10]

$$\Delta KI = KI_{max} - KI_{min}$$
$$R = KI_{min} / KI_{max}$$

Accounting for the maximum effect of mean stress ($R \geq 0.65$),

For $\Delta K_I < 12$ ksi√in,

$$n = 5.95$$
$$C_o = 1.20 \times 10^{-11}$$

For $\Delta K_I \geq 12$ ksi√in,

$$n = 1.95$$
$$C_o = 2.52 \times 10^{-7}$$

4.0 Fracture Mechanics Methodology

The corner crack is analyzed using the following stress intensity factor solution:

$$K_I = \sqrt{\pi a}\left[0.706(A_0 + A_p) + 0.537\left(\frac{2a}{\pi}\right)A_1 + 0.448\left(\frac{a^2}{2}\right)A_2 + 0.393\left(\frac{4a^3}{3\pi}\right)A_3\right],$$

[Ref. 11, Eqn. (G-2.2)]

where a is the depth of the crack and A_p is a term added to the Reference 11 solution to account for pressure on the crack face.

The stress distribution in the radial direction is described by the third-order polynomial,

$$\sigma = A_0 + A_1x + A_2x^2 + A_3x^3,$$ [Ref. 11, Eqn. (G-2.1)]

where x is measured from the inside corner.

<u>Irwin Plasticity Correction</u>

The Irwin plasticity correction is used to account for a moderate amount of yielding at the crack tip. For plane strain conditions, this correction is defined by

$$r_y = \frac{1}{6\pi}\left(\frac{K_I(a)}{\sigma_y}\right)^2,$$

where,

$K_I(a)$ = stress intensity factor based on the actual crack length, a,
σ_y = material yield strength.

A stress intensity factor, $K_I(a_e)$, is then calculated based on the effective crack length,

$$a_e = a + r_y.$$

5.0 Applied Stresses

Operational stresses are obtained from the results of a three-dimensional linear finite element analysis of the outermost CRDM nozzle head penetration that addresses the configuration after repair by the ID temper bead weld procedure of Reference 1. Stresses are available from Reference 6 at the 0° (downhill) and 180° (uphill) sides of the nozzle bore for 7 transients: plant heatup and cooldown, plant loading and unloading, large step decrease, loss of load, loss of flow, reactor trip, and a composite transient that bounds the remaining transients. Stresses were reported in a cylindrical coordinate system relative to the nozzle so that the stress directions remain constant around the nozzle. The largest hoop stresses are found at the uphill side of the nozzle bore, or at the 180° location. These stresses are perpendicular to the crack face and tend to open the corner crack. The operational stresses from Reference 6, calculated for the outermost CRDM nozzle location, conservatively bound the stresses at all other nozzle locations.

The maximum and minimum hoop stresses are listed in Table 1 for each transient. Due to the dominating influence of pressure on stress, stresses remain positive for all transient conditions. The highest stresses occur during plant unloading, a large step decrease, and a reactor trip. The plant loading transient is used to recover from the loss of load, loss of flow, and reactor trip "down ramp" transients. A zero stress state at shutdown is paired with the large step decrease stresses to form the largest stress intensity factor range that need be considered for fatigue crack growth. Hoop stresses are listed in Table 1 for the uphill (180°) location, as a function of the radial position along the stress line shown in Figures 2 and 3. Stresses are reported for 9 positions along the stress line as follows: the first 4 positions are within the weld material, the fifth position is at the butter/head interface, and the last 4 positions are located in the reactor vessel head base metal.

Table 1. Operational Hoop Stresses on Uphill Side [6]

Parameter	Loading Condition							
Transient	Heatup/Cooldown		Plant Loading/Unloading		Large Step Decrease		Loss of Load	
Time	4.77 hr.	12.94 hr.	0.333 hr.	3.333 hr.	Shutdown	0.226 hr.	Plant Load.	3.021 hr.
Temperature	[ ] °F	[ ] °F	[ ] °F	[ ] °F	70 °F	[ ] °F	[ ] °F	[ ] °F
Pressure	[ ] psig	[ ] psig	[ ] psig	[ ] psig	0 psig	[ ] psig	[ ] psig	[ ] psig
x (in.)*	SY (psi)	SY (psi)	SY (psi)	SY (psi)	SY (psi)	SY (psi)	SY (psi)	SY (psi)
0.0000	[ ]	[ ]	[ ]	[ ]	0	[ ]	[ ]	[ ]
0.2633	[ ]	[ ]	[ ]	[ ]	0	[ ]	[ ]	[ ]
0.5266	[ ]	[ ]	[ ]	[ ]	0	[ ]	[ ]	[ ]
0.7899	[ ]	[ ]	[ ]	[ ]	0	[ ]	[ ]	[ ]
1.0532	[ ]	[ ]	[ ]	[ ]	0	[ ]	[ ]	[ ]
1.4448	[ ]	[ ]	[ ]	[ ]	0	[ ]	[ ]	[ ]
1.8364	[ ]	[ ]	[ ]	[ ]	0	[ ]	[ ]	[ ]
2.2280	[ ]	[ ]	[ ]	[ ]	0	[ ]	[ ]	[ ]
2.6195	[ ]	[ ]	[ ]	[ ]	0	[ ]	[ ]	[ ]

* Location along path line PW_180 in Reference 6.

Table 1. Operational Hoop Stresses on Uphill Side [6] (Cont'd)

Parameter	Loading Condition					
Transient	Loss of Flow		Reactor Trip		Remaining Transient	
Time	Plant Load.	3.025 hr.	Plant Load.	0.143 hr.	0.144 hr.	3.152 hr.
Temperature	[ ] °F	[ ] °F	[ ] °F	[ ] °F	[ ] °F	[ ] °F
Pressure	[ ] psig	[ ] psig	[ ] psig	[ ] psig	[ ] psig	[ ] psig
x (in.)*	SY (psi)	SY (psi)	SY (psi)	SY (psi)	SY (psi)	SY (psi)
0.0000	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
0.2633	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
0.5266	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
0.7899	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1.0532	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1.4448	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1.8364	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
2.2280	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
2.6195	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

* Location along path line PW_180 in Reference 6.

Residual stresses are not considered in the present flaw evaluations since a crack that has propagated all the way through the weld and butter would tend to relieve these stresses. A three-dimensional elastic-plastic finite element analysis was performed by Dominion Engineering, Inc. [12] to simulate the sequence of steps involved in arriving at the configuration of the CRDM nozzle and RV head after completion of the ID temper bead repair. This analysis simulated the heatup of the weld, butter, and adjacent material during the welding process and the subsequent cooldown to ambient temperature, a pre-service hydro test, and operation at steady state conditions. After the steady state loads were removed, and the structure was again at ambient conditions, the lower portion of the CRDM nozzle was deleted from the model below the temper bead weld. The stresses associated with this repair configuration are the residual stresses corresponding to an unflawed structure.

The residual stresses from the Dominion Engineering analysis are listed in Table 2 and plotted in Figure 4. These stresses are in the original weld, before the weld is chamfered. The Dominion Engineering analysis [12] also showed that chamfering has only a small effect on the residual stress in the remaining material, less than 5 ksi. Although the residual hoop stress in the weld region is high, up to about 60,000 psi, the stress decreases to zero at the butter-to-head interface (the postulated crack tip), and is compressive in the head. These stresses would be relieved as the crack propagates through the weld, and a crack at the butter-to-head interface would experience only compressive stress ahead of the crack.

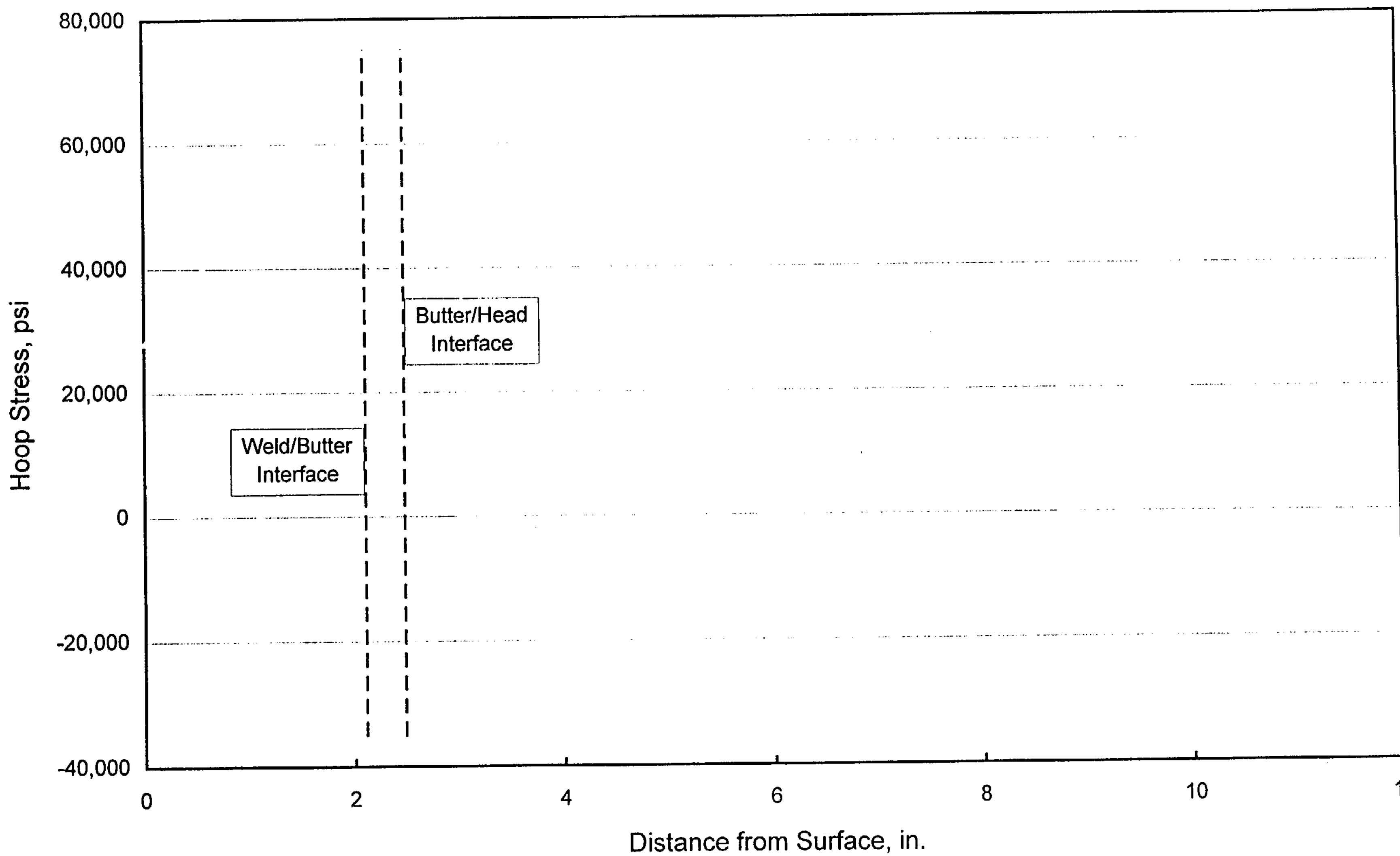
Table 2.
Residual Hoop Stresses in the Unflawed Structure After Nozzle Removal [12]

Note: Nozzle yield strength = 48.5 ksi
Penetration angle = 42.9 degrees

Node	Global Coordinates X (in.)	Global Coordinates Z (in.)	ΔS(1) (in.)	Location	Hoop Stress (psi)
80605	2.0000	59.075	0.000	Inside Surface of Weld	[ ]
80807	2.1764	59.886	0.830	Weld	[ ]
81008	2.3189	60.498	1.458	Weld	[ ]
81209	2.4274	60.884	1.859	Weld	[ ]
81410	2.5021	61.126	2.112	Weld/Butter Interface	[ ]
81511	2.6358	61.472	2.480	Butter/Head Interface	[ ]
81611	2.6862	61.795	2.805	Head	[ ]
81711	2.7569	62.249	3.263	Head	[ ]
81811	2.8563	62.886	3.906	Head	[ ]
81911	2.9959	63.782	4.811	Head	[ ]
82011	3.1920	65.040	6.083	Head	[ ]
82111	3.4674	66.808	7.871	Head	[ ]
82211	3.8544	69.291	10.383	Head	[ ]

(1) Distance along a stress line, originating at the inside corner of the original weld, and oriented about 15 degrees off the vertical bored surface (similar to Figure 3).

Figure 4. Residual Hoop Stresses in Unflawed Structure After Nozzle Removal



6.0 Flaw Evaluations

A fracture mechanics analysis is performed by calculating stress intensity factors at increments of fatigue crack growth for comparison with the fracture toughness requirements of Section XI. Article IWB-3612 [10] requires that a safety factor of √10 be used is applied when comparing the applied stress intensity factor to the material fracture toughness. Calculations are performed for a postulated radial corner crack on the uphill side of the outermost CRDM nozzle head penetration.

The actual fracture mechanics calculations are presented in Tables 3 through 9. The applied hoop stresses (perpendicular to the plane of the postulated crack) are listed in Table 1 for seven transients. Since temperature for each transient condition is above 242 °F (from Section 3), the fracture toughness is limited to an upper-shelf value of 200 ksi√in for all flaw evaluations. Fatigue crack growth is calculated on a yearly basis using the following pattern for accumulating cycles:

Transient	Cycles / 60 Years	Cycles / Year
Heatup and Cooldown		
Plant Loading and Unloading		
Large Step Decrease		
Loss of Load		
Loss of Flow		
Reactor Trip		
Remaining Transient*		

* The remaining transient includes 2000 cycles of the 10% step changes and 40 cycles of the loss of power transient.

These cycles are distributed uniformly over the service life by linking the incremental crack growth between Tables 3 through 9.

Table 3. Evaluation of CRDM Nozzle Corner Crack for Heatup/Cooldown

INPUT DATA

Initial Flaw Size:	Depth,	a =	1.0532	in.
Material Data:	Temperature,	T =	353	F
	Yield strength,	S_y =	43.8	ksi
	Reference temp.,	RTndt =	20	F
	Upper shelf tough.	=	200	ksi√in

Kla = 26.8 + 1.233 exp [0.0145 (T - RTndt + 160)]

Kla is limited to the upper shelf toughness.

Arrest toughness, Kla = 200 ksi√in

Applied Loads:

	Loading Conditions	
	CD*	HU**
Position x	Pressure, p (ksi)	
	1.483	2.235
	Hoop Stress	
(in.)	(ksi)	(ksi)
0.0000		
0.2633		
0.5266		
0.7899		
1.0532		
1.4448		
1.8364		
2.2280		
2.6195		

* Heatup/Cooldown Transient at 12.94 hours
** Heatup/Cooldown Transient at 4.77 hours

Table 3. Evaluation of CRDM Nozzle Corner Crack for Heatup/Cooldown (Cont'd)

STRESS INTENSITY FACTOR

$$KI(a) = \sqrt{(\pi a)}\ [\ 0.706(A_0+A_p) + 0.537(2a/\pi)A_1 + 0.448(a^2/2)A_2 + 0.393(4a^3/3\pi)A_3\ ]$$

where the through-wall stress distribution is described by the third order polynomial,

$$S(x) = A_0 + A_1x + A_2x^2 + A_3x^3,$$

defined by:

Stress Coeff.	Loading Conditions	
	CD (ksi)	HU (ksi)
A_0		
A_1		
A_2		
A_3		

Irwin's plastic zone correction:

$$a_e = a + 1/(6\pi)*[KI(a)/S_y]^2$$

Effective stress intensity factor:

$$KI(a_e) = \sqrt{(\pi a_e)}\ [\ 0.706(A_0+A_p) + 0.537(2a_e/\pi)A_1 + 0.448(a_e^2/2)A_2 + 0.393(4a_e^3/3\pi)A_3\ ]$$

Table 3. Evaluation of CRDM Nozzle Corner Crack for Heatup/Cooldown (Cont'd)

FATIGUE CRACK GROWTH

Let: ΔN = [ ] cycles/year

Operating Time (yr.)	Cycle	a (in.)	CD KI(a) (ksi√in)	HU KI(a) (ksi√in)	ΔKI (ksi√in)	Δa (in.)	CD a_e (in.)	HU a_e (in.)	CD KI(a_e) (ksi√in)	HU KI(a_e) (ksi√in)	CD Margin = KIa / KI(a_e)	HU Margin = KIa / KI(a_e)
0.00		1.0532	46.39	28.21	18.18	0.00024	1.1127	1.0752	47.05	28.42	4.25	7.04
1.00		1.0648	46.53	28.32	18.20	0.00024	1.1246	1.0870	47.18	28.54	4.24	7.01
2.00		1.0764	46.66	28.43	18.22	0.00024	1.1366	1.0987	47.30	28.65	4.23	6.98
3.00		1.0880	46.78	28.55	18.24	0.00024	1.1486	1.1106	47.42	28.76	4.22	6.95
4.00		1.0997	46.91	28.66	18.26	0.00024	1.1606	1.1224	47.55	28.87	4.21	6.93
5.00		1.1115	47.04	28.77	18.27	0.00024	1.1727	1.1344	47.67	28.98	4.20	6.90
6.00		1.1233	47.16	28.88	18.29	0.00024	1.1848	1.1463	47.78	29.09	4.19	6.88
7.00		1.1351	47.29	28.98	18.30	0.00024	1.1969	1.1583	47.90	29.20	4.18	6.85
8.00		1.1469	47.41	29.09	18.31	0.00024	1.2091	1.1703	48.02	29.30	4.16	6.82
9.00		1.1588	47.53	29.20	18.33	0.00024	1.2213	1.1824	48.13	29.41	4.16	6.80
10.00		1.1708	47.65	29.31	18.34	0.00024	1.2336	1.1945	48.25	29.52	4.15	6.78
11.00		1.1828	47.77	29.42	18.35	0.00024	1.2459	1.2067	48.36	29.63	4.14	6.75
12.00		1.1948	47.88	29.52	18.36	0.00024	1.2582	1.2189	48.47	29.73	4.13	6.73
13.00		1.2068	48.00	29.63	18.37	0.00025	1.2705	1.2311	48.58	29.84	4.12	6.70
14.00		1.2189	48.11	29.73	18.38	0.00025	1.2829	1.2434	48.69	29.94	4.11	6.68
15.00		1.2310	48.23	29.84	18.39	0.00025	1.2954	1.2557	48.80	30.05	4.10	6.66
16.00		1.2432	48.34	29.94	18.40	0.00025	1.3078	1.2680	48.91	30.15	4.09	6.63
17.00		1.2554	48.45	30.05	18.40	0.00025	1.3203	1.2804	49.01	30.26	4.08	6.61
18.00		1.2676	48.56	30.15	18.41	0.00025	1.3328	1.2927	49.12	30.36	4.07	6.59
19.00		1.2799	48.67	30.25	18.41	0.00025	1.3454	1.3052	49.22	30.46	4.06	6.57
20.00		1.2922	48.77	30.35	18.42	0.00025	1.3579	1.3176	49.32	30.56	4.05	6.54
21.00		1.3045	48.88	30.46	18.42	0.00025	1.3705	1.3301	49.43	30.67	4.05	6.52
22.00		1.3168	48.98	30.56	18.43	0.00025	1.3832	1.3426	49.53	30.77	4.04	6.50
23.00		1.3292	49.09	30.66	18.43	0.00025	1.3958	1.3552	49.63	30.87	4.03	6.48
24.00		1.3416	49.19	30.76	18.43	0.00025	1.4085	1.3678	49.72	30.97	4.02	6.46
25.00		1.3540	49.29	30.86	18.43	0.00025	1.4212	1.3804	49.82	31.07	4.01	6.44

Table 3. Evaluation of CRDM Nozzle Corner Crack for Heatup/Cooldown (Cont'd)

FRACTURE TOUGHNESS MARGINS

Period of Operation: Time = 5.00 years

Final Flaw Size: a = 1.1115 in.

Margin = KIa / KI(a_e)

	Loading Conditions		
	CD	HU	
Fracture Toughness, KIa	200.0	200.0	ksi√in
KI(a_e)	47.67	28.98	ksi√in
Actual Margin	4.20	6.90	
Required Margin	3.16	3.16	

Table 4. Evaluation of CRDM Nozzle Corner Crack for Plant Loading/Unloading

INPUT DATA

Initial Flaw Size: Depth, a = 1.0534 in.

Material Data:

Temperature, T = 547 F
Yield strength, S_y = 43.8 ksi

Reference temp., RTndt = 20 F
Upper shelf tough. = 200 ksi√in

Kla = 26.8 + 1.233 exp [0.0145 (T - RTndt + 160)]

Kla is limited to the upper shelf toughness.

Arrest toughness, Kla = 200 ksi√in

Applied Loads:

Position x	Loading Conditions PU*	Loading Conditions PL**
	Pressure, p (ksi)	
	2.235	2.235
	Hoop Stress	
(in.)	(ksi)	(ksi)
0.0000		
0.2633		
0.5266		
0.7899		
1.0532		
1.4448		
1.8364		
2.2280		
2.6195		

* Plant Loading/Unloading Transient at 3.333 hours
** Plant Loading/Unloading Transient at 0.333 hours

Table 4. Evaluation of CRDM Nozzle Corner Crack for Plant Loading/Unloading (Cont'd)

STRESS INTENSITY FACTOR

$$KI(a) = \sqrt{(\pi a)}\ [\ 0.706(A_0+A_p) + 0.537(2a/\pi)A_1 + 0.448(a^2/2)A_2 + 0.393(4a^3/3\pi)A_3\ ]$$

where the through-wall stress distribution is described by the third order polynomial,

$$S(x) = A_0 + A_1x + A_2x^2 + A_3x^3,$$

defined by:

Stress Coeff.	Loading Conditions	
	PU (ksi)	PL (ksi)
A_0		
A_1		
A_2		
A_3		

Irwin's plastic zone correction:

$$a_e = a + 1/(6\pi)*[KI(a)/S_y]^2$$

Effective stress intensity factor:

$$KI(a_e) = \sqrt{(\pi a_e)}\ [\ 0.706(A_0+A_p) + 0.537(2a_e/\pi)A_1 + 0.448(a_e^2/2)A_2 + 0.393(4a_e^3/3\pi)A_3\ ]$$

Table 4. Evaluation of CRDM Nozzle Corner Crack for Plant Loading/Unloading (Cont'd)

FATIGUE CRACK GROWTH

Let: ΔN = [ ] cycles/year

Operating Time (yr.)	Cycle	a (in.)	PU KI(a) (ksi√in)	PL KI(a) (ksi√in)	ΔKI (ksi√in)	Δa (in.)	PU a_e (in.)	PL a_e (in.)	PU KI(a_e) (ksi√in)	PL KI(a_e) (ksi√in)	PU Margin = KIa / KI(a_e)	PL Margin = KIa / KI(a_e)
0.00	[	1.0534	60.48	36.03	24.44	0.00642	1.1546	1.0893	61.88	36.40	3.23	5.49
1.00		1.0650	60.65	36.15	24.49	0.00644	1.1667	1.1012	62.04	36.52	3.22	5.48
2.00		1.0766	60.81	36.27	24.54	0.00647	1.1789	1.1130	62.19	36.64	3.22	5.46
3.00		1.0883	60.98	36.39	24.59	0.00649	1.1911	1.1249	62.35	36.76	3.21	5.44
4.00		1.1000	61.14	36.51	24.63	0.00651	1.2034	1.1368	62.50	36.88	3.20	5.42
5.00		1.1117	61.31	36.63	24.68	0.00654	1.2157	1.1488	62.65	36.99	3.19	5.41
6.00		1.1235	61.47	36.75	24.72	0.00656	1.2280	1.1608	62.80	37.11	3.18	5.39
7.00		1.1353	61.63	36.86	24.76	0.00658	1.2403	1.1729	62.95	37.22	3.18	5.37
8.00		1.1472	61.78	36.98	24.81	0.00660	1.2527	1.1850	63.09	37.34	3.17	5.36
9.00		1.1591	61.94	37.09	24.85	0.00662	1.2652	1.1971	63.24	37.45	3.16	5.34
10.00		1.1710	62.09	37.21	24.89	0.00665	1.2777	1.2093	63.38	37.56	3.16	5.32
11.00		1.1830	62.25	37.32	24.93	0.00667	1.2902	1.2215	63.52	37.67	3.15	5.31
12.00		1.1950	62.40	37.43	24.97	0.00669	1.3027	1.2338	63.66	37.78	3.14	5.29
13.00		1.2071	62.55	37.54	25.00	0.00671	1.3153	1.2460	63.80	37.89	3.13	5.28
14.00		1.2192	62.69	37.65	25.04	0.00673	1.3279	1.2584	63.93	38.00	3.13	5.26
15.00		1.2313	62.84	37.76	25.08	0.00674	1.3405	1.2707	64.07	38.11	3.12	5.25
16.00		1.2434	62.98	37.87	25.11	0.00676	1.3531	1.2831	64.20	38.22	3.12	5.23
17.00		1.2556	63.12	37.98	25.15	0.00678	1.3658	1.2955	64.33	38.32	3.11	5.22
18.00		1.2679	63.27	38.08	25.18	0.00680	1.3785	1.3080	64.46	38.43	3.10	5.20
19.00		1.2801	63.41	38.19	25.22	0.00682	1.3913	1.3204	64.59	38.53	3.10	5.19
20.00		1.2924	63.54	38.30	25.25	0.00683	1.4041	1.3330	64.72	38.64	3.09	5.18
21.00		1.3047	63.68	38.40	25.28	0.00685	1.4169	1.3455	64.85	38.74	3.08	5.16
22.00		1.3171	63.82	38.50	25.31	0.00687	1.4297	1.3581	64.97	38.84	3.08	5.15
23.00		1.3294	63.95	38.61	25.34	0.00688	1.4425	1.3707	65.10	38.95	3.07	5.14
24.00		1.3418	64.08	38.71	25.37	0.00690	1.4554	1.3833	65.22	39.05	3.07	5.12
25.00	]	1.3543	64.21	38.81	25.40	0.00692	1.4683	1.3959	65.34	39.15	3.06	5.11

Table 4. Evaluation of CRDM Nozzle Corner Crack for Plant Loading/Unloading (Cont'd)

FRACTURE TOUGHNESS MARGINS

Period of Operation: Time = 5.00 years

Final Flaw Size: a = 1.1117 in.

Margin = KIa / $KI(a_e)$

	Loading Conditions		
	PU	PL	
Fracture Toughness, KIa	200.0	200.0	ksi√in
$KI(a_e)$	62.65	36.99	ksi√in
Actual Margin	3.19	5.41	
Required Margin	3.16	3.16	

Table 5. Evaluation of CRDM Nozzle Corner Crack for Large Step Decrease

INPUT DATA

Initial Flaw Size:	Depth,	a =	1.0599	in.
Material Data:	Temperature,	T =	528	F
	Yield strength,	S_y =	43.8	ksi
	Reference temp.,	RTndt =	20	F
	Upper shelf tough.	=	200	ksi√in

$K_{Ia} = 26.8 + 1.233 \exp [0.0145 (T - RT_{ndt} + 160)]$

KIa is limited to the upper shelf toughness.

Arrest toughness, KIa = 200 ksi√in

Applied Loads:

	Loading Conditions	
	LSD*	SD**
Position x	Pressure, p (ksi)	
	1.960	0.000
	Hoop Stress	
(in.)	(ksi)	(ksi)
0.0000		
0.2633		
0.5266		
0.7899		
1.0532		
1.4448		
1.8364		
2.2280		
2.6195		

* Large Step Decrease at 0.226 hours
** Shutdown

Table 5. Evaluation of CRDM Nozzle Corner Crack for Large Step Decrease (Cont'd)

STRESS INTENSITY FACTOR

$$KI(a) = \sqrt{(\pi a)}\ [\ 0.706(A_0+A_p) + 0.537(2a/\pi)A_1 + 0.448(a^2/2)A_2 + 0.393(4a^3/3\pi)A_3\ ]$$

where the through-wall stress distribution is described by the third order polynomial,

$$S(x) = A_0 + A_1x + A_2x^2 + A_3x^3,$$

defined by:

Stress Coeff.	Loading Conditions	
	RT	SD
	(ksi)	(ksi)
A_0	[	]
A_1		
A_2		
A_3		

Irwin's plastic zone correction:

$$a_e = a + 1/(6\pi)*[KI(a)/S_y]^2$$

Effective stress intensity factor:

$$KI(a_e) = \sqrt{(\pi a_e)}\ [\ 0.706(A_0+A_p) + 0.537(2a_e/\pi)A_1 + 0.448(a_e^2/2)A_2 + 0.393(4a_e^3/3\pi)A_3\ ]$$

Table 5. Evaluation of CRDM Nozzle Corner Crack for Large Step Decrease (Cont'd)

FATIGUE CRACK GROWTH

Let: ΔN = [ ] cycles/year

Operating Time (yr.)	Cycle	a (in.)	RT KI(a) (ksi√in)	SD KI(a) (ksi√in)	ΔKI (ksi√in)	Δa (in.)	RT a_e (in.)	SD a_e (in.)	RT KI(a_e) (ksi√in)	SD KI(a_e) (ksi√in)	RT Margin = KIa / KI(a_e)	SD
0.00	[	1.0599	60.94	0.00	60.94	0.00254	1.1626	1.0599	62.30	0.00	3.21	#N/A
1.00		1.0714	61.10	0.00	61.10	0.00255	1.1747	1.0714	62.45	0.00	3.20	#N/A
2.00		1.0831	61.26	0.00	61.26	0.00257	1.1869	1.0831	62.59	0.00	3.20	#N/A
3.00		1.0948	61.42	0.00	61.42	0.00258	1.1991	1.0948	62.74	0.00	3.19	#N/A
4.00		1.1065	61.58	0.00	61.58	0.00259	1.2114	1.1065	62.88	0.00	3.18	#N/A
5.00		1.1183	61.73	0.00	61.73	0.00260	1.2236	1.1183	63.02	0.00	3.17	#N/A
6.00		1.1301	61.89	0.00	61.89	0.00262	1.2360	1.1301	63.16	0.00	3.17	#N/A
7.00		1.1419	62.04	0.00	62.04	0.00263	1.2483	1.1419	63.30	0.00	3.16	#N/A
8.00		1.1538	62.19	0.00	62.19	0.00264	1.2607	1.1538	63.44	0.00	3.15	#N/A
9.00		1.1657	62.34	0.00	62.34	0.00265	1.2732	1.1657	63.57	0.00	3.15	#N/A
10.00		1.1777	62.48	0.00	62.48	0.00267	1.2856	1.1777	63.71	0.00	3.14	#N/A
11.00		1.1897	62.63	0.00	62.63	0.00268	1.2981	1.1897	63.84	0.00	3.13	#N/A
12.00		1.2017	62.77	0.00	62.77	0.00269	1.3107	1.2017	63.97	0.00	3.13	#N/A
13.00		1.2138	62.91	0.00	62.91	0.00270	1.3232	1.2138	64.10	0.00	3.12	#N/A
14.00		1.2259	63.05	0.00	63.05	0.00271	1.3358	1.2259	64.22	0.00	3.11	#N/A
15.00		1.2380	63.19	0.00	63.19	0.00273	1.3484	1.2380	64.35	0.00	3.11	#N/A
16.00		1.2502	63.32	0.00	63.32	0.00274	1.3611	1.2502	64.47	0.00	3.10	#N/A
17.00		1.2624	63.46	0.00	63.46	0.00275	1.3738	1.2624	64.59	0.00	3.10	#N/A
18.00		1.2747	63.59	0.00	63.59	0.00276	1.3865	1.2747	64.72	0.00	3.09	#N/A
19.00		1.2869	63.72	0.00	63.72	0.00277	1.3992	1.2869	64.84	0.00	3.08	#N/A
20.00		1.2992	63.85	0.00	63.85	0.00278	1.4120	1.2992	64.95	0.00	3.08	#N/A
21.00		1.3116	63.98	0.00	63.98	0.00279	1.4248	1.3116	65.07	0.00	3.07	#N/A
22.00		1.3239	64.10	0.00	64.10	0.00280	1.4376	1.3239	65.19	0.00	3.07	#N/A
23.00		1.3363	64.23	0.00	64.23	0.00281	1.4504	1.3363	65.30	0.00	3.06	#N/A
24.00		1.3487	64.35	0.00	64.35	0.00282	1.4633	1.3487	65.41	0.00	3.06	#N/A
25.00	]	1.3612	64.47	0.00	64.47	0.00284	1.4762	1.3612	65.53	0.00	3.05	#N/A

Table 5. Evaluation of CRDM Nozzle Corner Crack for Large Step Decrease (Cont'd)

FRACTURE TOUGHNESS MARGINS

Period of Operation: Time = 5.00 years

Final Flaw Size: a = 1.1183 in.

Margin = KIa / KI(a_e)

	Loading Conditions		
	RT	SD	
Fracture Toughness, KIa	200.0	200.0	ksi√in
KI(a_e)	63.02	0.00	ksi√in
Actual Margin	3.17	#N/A	
Required Margin	3.16	#N/A	

Table 6. Evaluation of CRDM Nozzle Corner Crack for Loss of Load

INPUT DATA

Initial Flaw Size:	Depth,	a =	1.0624	in.
Material Data:	Temperature,	T =	547	F
	Yield strength,	S_y =	43.8	ksi
	Reference temp.,	RTndt =	20	F
	Upper shelf tough.	=	200	ksi√in

$$KIa = 26.8 + 1.233 \exp[0.0145 (T - RTndt + 160)]$$

KIa is limited to the upper shelf toughness.

Arrest toughness, KIa = 200 ksi√in

Applied Loads:

Position x	Loading Conditions LL*	Loading Conditions PL**
	Pressure, p (ksi)	Pressure, p (ksi)
	1.585	2.235
	Hoop Stress	Hoop Stress
(in.)	(ksi)	(ksi)
0.0000		
0.2633		
0.5266		
0.7899		
1.0532		
1.4448		
1.8364		
2.2280		
2.6195		

* Loss of Load Transient at 3.021 hours
** Plant Loading/Unloading Transient at 0.333 hours

Table 6. Evaluation of CRDM Nozzle Corner Crack for Loss of Load (Cont'd)

STRESS INTENSITY FACTOR

$$KI(a) = \sqrt{(\pi a)}\ [\ 0.706(A_0+A_p) + 0.537(2a/\pi)A_1 + 0.448(a^2/2)A_2 + 0.393(4a^3/3\pi)A_3\ ]$$

where the through-wall stress distribution is described by the third order polynomial,

$$S(x) = A_0 + A_1x + A_2x^2 + A_3x^3,$$

defined by:

Stress Coeff.	Loading Conditions	
	LL	PL
	(ksi)	(ksi)
A_0		
A_1		
A_2		
A_3		

Irwin's plastic zone correction:

$$a_e = a + 1/(6\pi)*[KI(a)/S_y]^2$$

Effective stress intensity factor:

$$KI(a_e) = \sqrt{(\pi a_e)}\ [\ 0.706(A_0+A_p) + 0.537(2a_e/\pi)A_1 + 0.448(a_e^{\ 2}/2)A_2 + 0.393(4a_e^{\ 3}/3\pi)A_3\ ]$$

Table 6. Evaluation of CRDM Nozzle Corner Crack for Loss of Load (Cont'd)

FATIGUE CRACK GROWTH

Let: ΔN = [ ] cycles/year

Operating Time (yr.)	Cycle	a (in.)	LL $K_I(a)$ (ksi√in)	PL $K_I(a)$ (ksi√in)	ΔK_I (ksi√in)	Δa (in.)	LL a_e (in.)	PL a_e (in.)	LL $K_I(a_e)$ (ksi√in)	PL $K_I(a_e)$ (ksi√in)	LL Margin = K_{Ia} / $K_I(a_e)$	PL Margin = K_{Ia} / $K_I(a_e)$
0.00		1.0624	46.67	36.13	10.55	0.00002	1.1226	1.0985	47.09	36.50	4.25	5.48
1.00		1.0740	46.76	36.25	10.51	0.00002	1.1345	1.1103	47.16	36.62	4.24	5.46
2.00		1.0857	46.84	36.37	10.47	0.00002	1.1463	1.1222	47.24	36.73	4.23	5.44
3.00		1.0973	46.92	36.49	10.43	0.00002	1.1582	1.1342	47.31	36.85	4.23	5.43
4.00		1.1091	47.00	36.60	10.39	0.00002	1.1702	1.1461	47.38	36.97	4.22	5.41
5.00		1.1209	47.08	36.72	10.35	0.00002	1.1821	1.1581	47.45	37.08	4.21	5.39
6.00		1.1327	47.15	36.84	10.31	0.00002	1.1942	1.1702	47.52	37.20	4.21	5.38
7.00		1.1445	47.23	36.95	10.27	0.00002	1.2062	1.1823	47.59	37.31	4.20	5.36
8.00		1.1564	47.30	37.07	10.23	0.00002	1.2183	1.1944	47.66	37.42	4.20	5.34
9.00		1.1684	47.37	37.18	10.19	0.00002	1.2304	1.2066	47.72	37.54	4.19	5.33
10.00		1.1803	47.44	37.29	10.15	0.00002	1.2426	1.2188	47.79	37.65	4.19	5.31
11.00		1.1924	47.51	37.41	10.11	0.00002	1.2548	1.2310	47.85	37.76	4.18	5.30
12.00		1.2044	47.58	37.52	10.06	0.00001	1.2670	1.2433	47.91	37.87	4.17	5.28
13.00		1.2165	47.65	37.63	10.02	0.00001	1.2793	1.2556	47.97	37.98	4.17	5.27
14.00		1.2286	47.71	37.74	9.98	0.00001	1.2916	1.2680	48.03	38.09	4.16	5.25
15.00		1.2408	47.78	37.85	9.93	0.00001	1.3039	1.2804	48.09	38.19	4.16	5.24
16.00		1.2529	47.84	37.95	9.89	0.00001	1.3162	1.2928	48.15	38.30	4.15	5.22
17.00		1.2652	47.90	38.06	9.84	0.00001	1.3286	1.3052	48.20	38.40	4.15	5.21
18.00		1.2774	47.96	38.17	9.80	0.00001	1.3410	1.3177	48.26	38.51	4.14	5.19
19.00		1.2897	48.02	38.27	9.75	0.00001	1.3535	1.3302	48.31	38.61	4.14	5.18
20.00		1.3020	48.08	38.38	9.70	0.00001	1.3659	1.3427	48.37	38.72	4.14	5.17
21.00		1.3144	48.14	38.48	9.66	0.00001	1.3784	1.3553	48.42	38.82	4.13	5.15
22.00		1.3267	48.19	38.59	9.61	0.00001	1.3910	1.3679	48.47	38.92	4.13	5.14
23.00		1.3391	48.25	38.69	9.56	0.00001	1.4035	1.3805	48.52	39.02	4.12	5.12
24.00		1.3516	48.30	38.79	9.51	0.00001	1.4161	1.3932	48.57	39.13	4.12	5.11
25.00		1.3640	48.36	38.89	9.47	0.00001	1.4287	1.4059	48.62	39.23	4.11	5.10

Table 6. Evaluation of CRDM Nozzle Corner Crack for Loss of Load (Cont'd)

FRACTURE TOUGHNESS MARGINS

Period of Operation: Time = 5.00 years

Final Flaw Size: a = 1.1209 in.

Margin = KIa / KI(a_e)

	Loading Conditions		
	LL	PL	
Fracture Toughness, KIa	200.0	200.0	ksi√in
KI(a_e)	47.45	37.08	ksi√in
Actual Margin	4.21	5.39	
Required Margin	3.16	3.16	

Table 7. Evaluation of CRDM Nozzle Corner Crack for Loss of Flow

INPUT DATA

Initial Flaw Size:	Depth,	a =	1.0624	in.
Material Data:	Temperature,	T =	547	F
	Yield strength,	S_y =	43.8	ksi
	Reference temp.,	RTndt =	20	F
	Upper shelf tough.	=	200	ksi√in

KIa = 26.8 + 1.233 exp [0.0145 (T - RTndt + 160)]

KIa is limited to the upper shelf toughness.

Arrest toughness, KIa = 200 ksi√in

Applied Loads:

	Loading Conditions	
	LF*	PL**
	Pressure, p (ksi)	
Position	1.860	2.235
x	Hoop Stress	
(in.)	(ksi)	(ksi)
0.0000		
0.2633		
0.5266		
0.7899		
1.0532		
1.4448		
1.8364		
2.2280		
2.6195		

* Loss of Flow Transient at 3.025 hours
** Plant Loading/Unloading Transient at 0.333 hours

Table 7. Evaluation of CRDM Nozzle Corner Crack for Loss of Flow (Cont'd)

STRESS INTENSITY FACTOR

$$KI(a) = \sqrt{(\pi a)}\ [\ 0.706(A_0+A_p) + 0.537(2a/\pi)A_1 + 0.448(a^2/2)A_2 + 0.393(4a^3/3\pi)A_3\ ]$$

where the through-wall stress distribution is described by the third order polynomial,

$$S(x) = A_0 + A_1x + A_2x^2 + A_3x^3,$$

defined by:

Stress Coeff.	Loading Conditions	
	LF	PL
	(ksi)	(ksi)
A_0		
A_1		
A_2		
A_3		

Irwin's plastic zone correction:

$$a_e = a + 1/(6\pi)*[KI(a)/S_y]^2$$

Effective stress intensity factor:

$$KI(a_e) = \sqrt{(\pi a_e)}\ [\ 0.706(A_0+A_p) + 0.537(2a_e/\pi)A_1 + 0.448(a_e^2/2)A_2 + 0.393(4a_e^3/3\pi)A_3\ ]$$

Table 7. Evaluation of CRDM Nozzle Corner Crack for Loss of Flow (Cont'd)

FATIGUE CRACK GROWTH

Let: ΔN = [ ] cycles/year

Operating Time (yr.)	Cycle	a (in.)	LF KI(a) (ksi√in)	PL KI(a) (ksi√in)	ΔKI (ksi√in)	Δa (in.)	LF a_e (in.)	PL a_e (in.)	LF KI(a_e) (ksi√in)	PL KI(a_e) (ksi√in)	LF Margin = KIa / KI(a_e)	PL Margin = KIa / KI(a_e)
0.00	[	1.0624	50.81	36.13	14.68	0.00006	1.1338	1.0985	51.45	36.50	3.89	5.48
1.00		1.0740	50.92	36.25	14.67	0.00006	1.1457	1.1104	51.54	36.62	3.88	5.46
2.00		1.0857	51.02	36.37	14.66	0.00006	1.1577	1.1222	51.64	36.73	3.87	5.44
3.00		1.0974	51.13	36.49	14.64	0.00006	1.1697	1.1342	51.74	36.85	3.87	5.43
4.00		1.1091	51.23	36.60	14.63	0.00006	1.1817	1.1462	51.83	36.97	3.86	5.41
5.00		1.1209	51.33	36.72	14.61	0.00006	1.1938	1.1582	51.93	37.08	3.85	5.39
6.00		1.1327	51.44	36.84	14.60	0.00006	1.2059	1.1702	52.02	37.20	3.84	5.38
7.00		1.1446	51.54	36.95	14.58	0.00006	1.2180	1.1823	52.11	37.31	3.84	5.36
8.00		1.1564	51.63	37.07	14.57	0.00006	1.2302	1.1944	52.20	37.42	3.83	5.34
9.00		1.1684	51.73	37.18	14.55	0.00006	1.2424	1.2066	52.29	37.54	3.82	5.33
10.00		1.1804	51.82	37.29	14.53	0.00006	1.2546	1.2188	52.38	37.65	3.82	5.31
11.00		1.1924	51.92	37.41	14.51	0.00006	1.2669	1.2311	52.46	37.76	3.81	5.30
12.00		1.2044	52.01	37.52	14.49	0.00006	1.2792	1.2433	52.55	37.87	3.81	5.28
13.00		1.2165	52.10	37.63	14.47	0.00006	1.2916	1.2557	52.63	37.98	3.80	5.27
14.00		1.2286	52.19	37.74	14.45	0.00006	1.3039	1.2680	52.71	38.09	3.79	5.25
15.00		1.2408	52.28	37.85	14.43	0.00006	1.3163	1.2804	52.79	38.19	3.79	5.24
16.00		1.2530	52.36	37.95	14.41	0.00006	1.3288	1.2928	52.87	38.30	3.78	5.22
17.00		1.2652	52.45	38.06	14.39	0.00006	1.3413	1.3052	52.95	38.40	3.78	5.21
18.00		1.2774	52.53	38.17	14.37	0.00006	1.3537	1.3177	53.03	38.51	3.77	5.19
19.00		1.2897	52.62	38.27	14.34	0.00006	1.3663	1.3302	53.10	38.61	3.77	5.18
20.00		1.3020	52.70	38.38	14.32	0.00006	1.3788	1.3428	53.18	38.72	3.76	5.17
21.00		1.3144	52.78	38.48	14.30	0.00006	1.3914	1.3553	53.25	38.82	3.76	5.15
22.00		1.3267	52.86	38.59	14.27	0.00006	1.4040	1.3679	53.32	38.92	3.75	5.14
23.00		1.3392	52.94	38.69	14.25	0.00006	1.4166	1.3805	53.40	39.02	3.75	5.12
24.00		1.3516	53.01	38.79	14.22	0.00006	1.4293	1.3932	53.47	39.13	3.74	5.11
25.00	]	1.3640	53.09	38.89	14.20	0.00006	1.4420	1.4059	53.54	39.23	3.74	5.10

Table 7. Evaluation of CRDM Nozzle Corner Crack for Loss of Flow (Cont'd)

FRACTURE TOUGHNESS MARGINS

Period of Operation: Time = 5.00 years

Final Flaw Size: a = 1.1209 in.

Margin = KIa / KI(a_e)

	Loading Conditions		
	LF	PL	
Fracture Toughness, KIa	200.0	200.0	ksi√in
KI(a_e)	51.93	37.08	ksi√in
Actual Margin	3.85	5.39	
Required Margin	3.16	3.16	

Table 8. Evaluation of CRDM Nozzle Corner Crack for Reactor Trip

INPUT DATA

Initial Flaw Size:	Depth,	a =	1.0625	in.
Material Data:	Temperature,	T =	522	F
	Yield strength,	S_y =	43.8	ksi
	Reference temp.,	RTndt =	20	F
	Upper shelf tough.	=	200	ksi√in

Kla = 26.8 + 1.233 exp [0.0145 (T - RTndt + 160)]

Kla is limited to the upper shelf toughness.

Arrest toughness, Kla = 200 ksi√in

Applied Loads:

	Loading Conditions	
	RT*	PL**
Position	Pressure, p (ksi)	
	1.855	2.235
x	Hoop Stress	
(in.)	(ksi)	(ksi)
0.0000		
0.2633		
0.5266		
0.7899		
1.0532		
1.4448		
1.8364		
2.2280		
2.6195		

* Reactor Trip Transient at 0.143 hours
** Plant Loading/Unloading Transient at 0.333 hours

Table 8. Evaluation of CRDM Nozzle Corner Crack for Reactor Trip (Cont'd)

STRESS INTENSITY FACTOR

$$KI(a) = \sqrt{(\pi a)}\ [\ 0.706(A_0+A_p) + 0.537(2a/\pi)A_1 + 0.448(a^2/2)A_2 + 0.393(4a^3/3\pi)A_3\ ]$$

where the through-wall stress distribution is described by the third order polynomial,

$$S(x) = A_0 + A_1x + A_2x^2 + A_3x^3,$$

defined by:

Stress Coeff.	Loading Conditions	
	RT	PL
	(ksi)	(ksi)
A_0		
A_1		
A_2		
A_3		

Irwin's plastic zone correction:

$$a_e = a + 1/(6\pi)*[KI(a)/S_y]^2$$

Effective stress intensity factor:

$$KI(a_e) = \sqrt{(\pi a_e)}\ [\ 0.706(A_0+A_p) + 0.537(2a_e/\pi)A_1 + 0.448(a_e^{\,2}/2)A_2 + 0.393(4a_e^{\,3}/3\pi)A_3\ ]$$

Table 8. Evaluation of CRDM Nozzle Corner Crack for Reactor Trip (Cont'd)

FATIGUE CRACK GROWTH

Let: ΔN = [ ] cycles/year

Operating Time (yr.)	Cycle	a (in.)	RT KI(a) (ksi√in)	PL KI(a) (ksi√in)	ΔKI (ksi√in)	Δa (in.)	RT a_e (in.)	PL a_e (in.)	RT KI(a_e) (ksi√in)	PL KI(a_e) (ksi√in)	RT Margin = KIa / KI(a_e)	PL Margin = KIa / KI(a_e)
0.00		1.0625	60.17	36.13	24.05	0.00083	1.1626	1.0986	61.45	36.50	3.25	5.48
1.00		1.0741	60.33	36.25	24.08	0.00083	1.1747	1.1104	61.59	36.62	3.25	5.46
2.00		1.0857	60.48	36.37	24.12	0.00083	1.1869	1.1223	61.73	36.74	3.24	5.44
3.00		1.0974	60.64	36.49	24.15	0.00084	1.1991	1.1342	61.87	36.85	3.23	5.43
4.00		1.1092	60.79	36.60	24.18	0.00084	1.2114	1.1462	62.01	36.97	3.23	5.41
5.00		1.1209	60.94	36.72	24.22	0.00084	1.2236	1.1582	62.15	37.08	3.22	5.39
6.00		1.1328	61.09	36.84	24.25	0.00084	1.2359	1.1703	62.28	37.20	3.21	5.38
7.00		1.1446	61.23	36.95	24.28	0.00084	1.2483	1.1824	62.42	37.31	3.20	5.36
8.00		1.1565	61.38	37.07	24.31	0.00085	1.2607	1.1945	62.55	37.43	3.20	5.34
9.00		1.1684	61.52	37.18	24.34	0.00085	1.2731	1.2067	62.68	37.54	3.19	5.33
10.00		1.1804	61.66	37.29	24.36	0.00085	1.2856	1.2189	62.80	37.65	3.18	5.31
11.00		1.1924	61.80	37.41	24.39	0.00085	1.2980	1.2311	62.93	37.76	3.18	5.30
12.00		1.2045	61.93	37.52	24.42	0.00085	1.3106	1.2434	63.06	37.87	3.17	5.28
13.00		1.2166	62.07	37.63	24.44	0.00086	1.3231	1.2557	63.18	37.98	3.17	5.27
14.00		1.2287	62.20	37.74	24.47	0.00086	1.3357	1.2681	63.30	38.09	3.16	5.25
15.00		1.2408	62.34	37.85	24.49	0.00086	1.3483	1.2804	63.42	38.19	3.15	5.24
16.00		1.2530	62.47	37.95	24.51	0.00086	1.3609	1.2929	63.54	38.30	3.15	5.22
17.00		1.2652	62.59	38.06	24.53	0.00086	1.3736	1.3053	63.66	38.41	3.14	5.21
18.00		1.2775	62.72	38.17	24.55	0.00086	1.3863	1.3178	63.77	38.51	3.14	5.19
19.00		1.2898	62.85	38.27	24.57	0.00086	1.3990	1.3303	63.89	38.61	3.13	5.18
20.00		1.3021	62.97	38.38	24.59	0.00087	1.4117	1.3428	64.00	38.72	3.12	5.17
21.00		1.3144	63.09	38.48	24.61	0.00087	1.4245	1.3554	64.11	38.82	3.12	5.15
22.00		1.3268	63.22	38.59	24.63	0.00087	1.4373	1.3680	64.22	38.92	3.11	5.14
23.00		1.3392	63.33	38.69	24.65	0.00087	1.4501	1.3806	64.33	39.03	3.11	5.12
24.00		1.3516	63.45	38.79	24.66	0.00087	1.4630	1.3933	64.44	39.13	3.10	5.11
25.00		1.3641	63.57	38.89	24.68	0.00087	1.4759	1.4059	64.55	39.23	3.10	5.10

Table 8. Evaluation of CRDM Nozzle Corner Crack for Reactor Trip (Cont'd)

FRACTURE TOUGHNESS MARGINS

Period of Operation: Time = 5.00 years

Final Flaw Size: a = 1.1209 in.

Margin = $K_{Ia} / K_I(a_e)$

	Loading Conditions		
	RT	PL	
Fracture Toughness, KIa	200.0	200.0	ksi√in
$K_I(a_e)$	62.15	37.08	ksi√in
Actual Margin	3.22	5.39	
Required Margin	3.16	3.16	

Table 9. Evaluation of CRDM Nozzle Corner Crack for Remaining Transients

INPUT DATA

Initial Flaw Size:	Depth,	a =	1.0633	in.
Material Data:	Temperature,	T =	595	F
	Yield strength,	S_y =	43.8	ksi
	Reference temp.,	RTndt =	20	F
	Upper shelf tough.	=	200	ksi√in

Kla = 26.8 + 1.233 exp [0.0145 (T - RTndt + 160)]

Kla is limited to the upper shelf toughness.

Arrest toughness, Kla = 200 ksi√in

Applied Loads:

	Loading Conditions	
	RemDn*	RemUp**
Position	Pressure, p (ksi)	
	2.235	2.485
x	Hoop Stress	
(in.)	(ksi)	(ksi)
0.0000		
0.2633		
0.5266		
0.7899		
1.0532		
1.4448		
1.8364		
2.2280		
2.6195		

* Remaining Transient at 3.152 hours (down ramp)
** Remaining Transient at 0.144 hours (up ramp)

Table 9. Evaluation of CRDM Nozzle Corner Crack for Remaining Transients (Cont'd)

STRESS INTENSITY FACTOR

$$KI(a) = \sqrt{(\pi a)}\ [\ 0.706(A_0+A_p) + 0.537(2a/\pi)A_1 + 0.448(a^2/2)A_2 + 0.393(4a^3/3\pi)A_3\ ]$$

where the through-wall stress distribution is described by the third order polynomial,

$$S(x) = A_0 + A_1x + A_2x^2 + A_3x^3,$$

defined by:

Stress Coeff.	Loading Conditions	
	RemDn	RemUp
	(ksi)	(ksi)
A_0	[	]
A_1		
A_2		
A_3	[	]

Irwin's plastic zone correction:

$$a_e = a + 1/(6\pi)*[KI(a)/S_y]^2$$

Effective stress intensity factor:

$$KI(a_e) = \sqrt{(\pi a_e)}\ [\ 0.706(A_0+A_p) + 0.537(2a_e/\pi)A_1 + 0.448(a_e^{\,2}/2)A_2 + 0.393(4a_e^{\,3}/3\pi)A_3\ ]$$

Table 9. Evaluation of CRDM Nozzle Corner Crack for Remaining Transients (Cont'd)

FATIGUE CRACK GROWTH

Let: ΔN = [ ] cycles/year

Operating Time (yr.)	Cycle	a (in.)	RemDn KI(a) (ksi√in)	RemUp KI(a) (ksi√in)	ΔKI (ksi√in)	Δa (in.)	RemDn a_e (in.)	RemUp a_e (in.)	RemDn $KI(a_e)$ (ksi√in)	RemUp $KI(a_e)$ (ksi√in)	RemDn Margin = KIa / $KI(a_e)$	RemUp Margin = KIa / $KI(a_e)$
0.00	[ ]	1.0633	53.93	39.99	13.94	0.00146	1.1437	1.1075	54.95	40.49	3.64	4.94
1.00		1.0749	54.08	40.12	13.96	0.00146	1.1558	1.1194	55.09	40.62	3.63	4.92
2.00		1.0866	54.23	40.25	13.98	0.00147	1.1679	1.1314	55.24	40.75	3.62	4.91
3.00		1.0983	54.38	40.39	14.00	0.00147	1.1800	1.1434	55.38	40.88	3.61	4.89
4.00		1.1100	54.53	40.52	14.01	0.00147	1.1922	1.1554	55.52	41.01	3.60	4.88
5.00		1.1218	54.68	40.65	14.03	0.00148	1.2045	1.1675	55.66	41.14	3.59	4.86
6.00		1.1336	54.83	40.78	14.05	0.00148	1.2167	1.1796	55.80	41.27	3.58	4.85
7.00		1.1455	54.97	40.91	14.06	0.00148	1.2290	1.1917	55.93	41.39	3.58	4.83
8.00		1.1574	55.11	41.03	14.08	0.00149	1.2414	1.2039	56.07	41.52	3.57	4.82
9.00		1.1693	55.25	41.16	14.09	0.00149	1.2537	1.2161	56.20	41.64	3.56	4.80
10.00		1.1813	55.39	41.29	14.11	0.00149	1.2661	1.2284	56.33	41.77	3.55	4.79
11.00		1.1933	55.53	41.41	14.12	0.00150	1.2786	1.2407	56.46	41.89	3.54	4.77
12.00		1.2053	55.67	41.53	14.13	0.00150	1.2910	1.2530	56.59	42.01	3.53	4.76
13.00		1.2174	55.80	41.66	14.15	0.00150	1.3035	1.2654	56.72	42.13	3.53	4.75
14.00		1.2295	55.94	41.78	14.16	0.00150	1.3161	1.2778	56.85	42.25	3.52	4.73
15.00		1.2417	56.07	41.90	14.17	0.00151	1.3286	1.2902	56.97	42.37	3.51	4.72
16.00		1.2539	56.20	42.02	14.18	0.00151	1.3412	1.3027	57.10	42.49	3.50	4.71
17.00		1.2661	56.33	42.14	14.19	0.00151	1.3539	1.3152	57.22	42.61	3.50	4.69
18.00		1.2784	56.46	42.26	14.20	0.00151	1.3665	1.3277	57.34	42.73	3.49	4.68
19.00		1.2906	56.59	42.38	14.21	0.00152	1.3792	1.3403	57.46	42.84	3.48	4.67
20.00		1.3030	56.71	42.50	14.22	0.00152	1.3919	1.3529	57.58	42.96	3.47	4.66
21.00		1.3153	56.84	42.61	14.23	0.00152	1.4046	1.3655	57.70	43.07	3.47	4.64
22.00		1.3277	56.96	42.73	14.24	0.00152	1.4174	1.3782	57.81	43.19	3.46	4.63
23.00		1.3401	57.08	42.84	14.24	0.00152	1.4302	1.3908	57.93	43.30	3.45	4.62
24.00		1.3525	57.21	42.96	14.25	0.00152	1.4430	1.4035	58.04	43.41	3.45	4.61
25.00		1.3650	57.33	43.07	14.26	0.00152	1.4559	1.4163	58.16	43.53	3.44	4.60

Table 9. Evaluation of CRDM Nozzle Corner Crack for Remaining Transients (Cont'd)

FRACTURE TOUGHNESS MARGINS

Period of Operation: Time = 5.00 years

Final Flaw Size: a = 1.1218 in.

Margin = KIa / $KI(a_e)$

	Loading Conditions		
	RemDn	RemUp	
Fracture Toughness, KIa	200.0	200.0	ksi√in
$KI(a_e)$	55.66	41.14	ksi√in
Actual Margin	3.59	4.86	
Required Margin	3.16	3.16	

7.0 Summary of Results

A fracture mechanics analysis has been performed to evaluate a postulated large radial crack in the remnants of the original J-groove weld (and butter) at the CRDM nozzle reactor vessel head penetration. Results of this analysis are summarized below for the controlling transient.

<u>Large Step Decrease</u>

Temperature,	$T = 528\ ^\circ F$
Initial flaw size,	$a_i = 1.053$ in.
Final flaw size after 5 years,	$a_f = 1.118$ in.
Flaw growth,	$a_f - a_i = 0.065$ in.
Stress intensity factor at final flaw size,	$K_I = 63.02\ ksi\sqrt{in}$
Fracture toughness at 528 °F,	$K_{Ia} = 200.0\ ksi\sqrt{in}$
Safety margin:	$K_{Ia} / KI = 3.17 > \sqrt{10} = 3.16$

<u>Conclusion</u>

Based on an evaluation of fatigue crack growth into the low alloy steel head, the above results demonstrate that a postulated radial crack in the Alloy 182 J-groove weld would be acceptable for at least 5 years of operation, considering the following transient frequencies:

Transient	Frequency (cycles/year)
Heatup and Cooldown	
Plant Loading and Unloading	
Large Step Decrease	
Loss of Load	
Loss of Flow	
Reactor Trip	
Remaining Transient	

8.0 References

1. Framatome ANP Drawing 02-5015149E-2, "Surry 1 & 2 CRDM Nozzle ID Temper Bead Weld Repair."

2. Framatome ANP Document 51-5015050-02, "Surry CRDM Nozzle ID Temper Bead Weld Repair Requirements," October 2001.

3. Not used.

4. Framatome ANP Document 51-5012047-00, "Stress Corrosion Cracking of Low Alloy Steel," March 2001.

5. BAW-10046A, Rev. 2, "Methods of Compliance With Fracture Toughness and Operational Requirements of 10 CFR 50, Appendix G," B&W Owners Group Materials Committee Topical Report, June 1986.

6. Framatome ANP Document 32-5015651-00, "Surry – CRDMH J-Groove Weld Stress for Flaw Growth (1" Chamfer)," November 2001.

7. Not used.

8. ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Power Plant Components, Division 1 - Appendices, 1989 Edition with No Addenda.

9. Not used.

10. ASME Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, 1989 Edition with No Addenda.

11. Marston, T.U., "Flaw Evaluation Procedures – Background and Application of ASME Section XI, Appendix A," EPRI Report NP-719-SR, August 1978.

12. Framatome ANP Document 38-1288530-00, "Dominion Engineering Calculations C-4512-00-1, Revision 0, and C-4512-00-2, Revision 0 - 10/22/01," October 2001.

Enclosure 3-2
(Redacted)

Framatome ANP Document No. 32-5015651-01,
" SURRY CRDM J-GROOVE WELD STRESS FOR FLAW GROWTH,
(1" CHAMFER)"

FRAMATOME ANP

CALCULATION SUMMARY SHEET (CSS)

Document Identifier 32 - 5015651 - 01

Title SURRY - CRDMH J-GROOVE WELD STRESS FOR FLAW GROWTH (1" CHAMFER)

PREPARED BY:		REVIEWED BY:	
		METHOD: ☒ DETAILED CHECK ☐ INDEPENDENT CALCULATION	
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PURPOSE AND SUMMARY OF RESULTS:

THIS IS THE NON-PROPRIETARY VERSION OF 32-5015651-00.

PURPOSE

The purpose of this document is to provide supplemental stress results of the operating transient analyses for flaw growth assessments on SURRY CRDMH J-groove weld and its adjacent base metal area.

RESULTS

Linearized stresses on J-groove weld and its adjacent base metal area are calculated from a 3-D model based on geometry, materials and boundary conditions from References 3 and 4. The table of stresses are shown in Section 5.0 of this document.

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

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RECORD OF REVISIONS		
REVISION	DESCRIPTION	DATE
00	ORIGINAL RELEASE	11/01
01	NON-PROPRIETARY VERSION OF ORIGINAL DOC	11/01

1.0 Purpose

The purpose of this document is to provide supplemental stress results of the operating transient analyses for flaw growth assessments on J-groove weld and its adjacent base metal area.

The geometry, materials, and boundary conditions of the SURRY CRDMH and RV Head are described in Reference 3 and 4.

2.0 Background

Due to observed leakage of CRDM Housing nozzle-to-RV Head connections, repairs must be made. The repair process may need to consider the potential flaws remaining within the local region of the J-groove weld and/or the locally adjacent head base material. The presence of remaining flaws must be justified analytically using the local stress fields within the region. Thus, the stress fields resulting from operating transient conditions must be provided as input to the flaw growth assessment.

The FE model described herein represents the repair design (Ref. 5) of the J-groove weld connecting the CRDM Housing nozzle to the RV Closure Head. There are a total of 69 nozzle-to-head connections on the RV Closure Head. Each of the nozzles is aligned vertically. They are located at various radial distances from the vertical centerline of the 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) indicates that the larger the hillside angle is, the more severe the effect is on stress levels in the connecting weld region. Based on this experience, the model herein represents the largest hillside angle (outermost location) of any of the CRDM Housing nozzle locations. This model is considered to produce results that are conservatively bounding all nozzle locations that have a smaller hillside angle.

The model described herein is generated for the purpose of providing detailed stress results for input to flaw growth assessment.

3.0 Analytical Model

To provide the needed stress field refinement, the CRDM Housing nozzle-to-RV Head connection is modeled in three dimensions. This permits detailed accounting for the effects of the hillside orientation. The analysis software program ANSYS (Reference 1) is used for solid modeling, meshing, solution and post-processing of the model. This large 'general purpose' program utilizes the 'finite element' technique as its basis.

The model consists of 'geometry', 'materials' and 'boundary conditions'. The geometry and materials are discussed in Reference 3. The boundary condition is discussed more detail in the following sections.

3.1 Model Boundary Conditions

The analytical model is a three-dimensional model of a 180 degree section of the cylindrical portion of the CRDM Housing nozzle body. Therefore, the model has a mirror plane of symmetry that contains the vertical centerline of the CRDM Housing nozzle and the center of curvature of the RV Head (i.e., this is a vertical plane). The thermal and structural boundary conditions are reflective in this plane.

The outer surfaces of the RV Head thickness are assigned thermal boundary conditions that are insulated (adiabatic). Structurally they are allowed only to deflect in the direction that is radial to the head center of curvature.

For thermal transient type loads (heat transfer coefficient and bulk fluid temperature), the appropriate surfaces are loaded. For the interface between the Primary coolant water temperature and the cladding/J-groove weld (i.e., inside the reactor vessel head), a heat transfer coefficient associated with a 'turbulent' condition is applied. Per Reference 4, a film coefficient of 300 Btu/hr-ft^2-F is used in this analysis. For the inside diameter of the CRDM Housing nozzle, the same heat transfer coefficient for the inside head is applied even though it is expected that there is lack of forced flow due to much limited space. At the RV Head exterior surface, a relatively small film coefficient (representing heat loss through the insulation) is applied in conjunction with the estimated ambient temperature above the head. The small gap between the remaining CRDM Housing nozzle OD and penetration bore are modeled as 'coupled temperatures' to best represent the actual condition.

For pressure, those surfaces in contact with primary coolant water are loaded. These include the RV Head/J-groove weld, CRDM Housing nozzle internal extension and inside diameter. The exterior of the RV Head (and the interface gap between the CRDM Housing nozzle and penetration bore) are not loaded by pressure. The upper end of the CRDM Housing nozzle cylinder has a pressure applied to represent the hydrostatic end load from the CRDM closure.

The model is subjected to the Reactor Coolant outlet thermal and pressure conditions versus time. Per Reference 3, the thermal transients are grouped in 7 cases: Heat-up/Cool-down, Plant loading/unloading, Reactor Trip, Loss of Load, Large Step Decrease, Loss of Flow, and remaining transients.

Table 3.1 Transients

Case	Transients
HUCD	HeatUp and CoolDown
PLUL	Plant Loading/Unloading
RTRP	Reactor Trip
LL	Loss of Load
LD	large Step Decrease
LF	Loss of Flow
Remaining Transients (RA)	10% Step Increase (2000 cycles) 10% Step Decrease (2000 cycles) Loss-of-AC Power (40 cycles)

The temperature and pressure values for the above transients are shown in the following pages.

Table 3.2 HUCD Transient		
Time (hrs)	Temperature (°F)	Pressure (psi)
0	70	385
4.77	547	2235
11	547	2235
15.77	70	385
19	70	385

Table 3.3 PLUL Transient		
Time (hrs)	Temperature (°F)	Pressure (psi)
0	547	2285
0.3333	600	2285
3	600	2285
3.3333	547	2285
6	547	2285

Table 3.4 Reactor Trip		
Time (hrs)	Temperature (°F)	Pressure (psi)
0	600	2235
0.0036	560	2035
0.011	522	1855
1	522	1855

Table 3.5 Loss of Load		
Time (hrs)	Temperature (°F)	Pressure (psi)
0	600	2235
0.0069	634	2485
3	634	2485

3.0208	547	1585
6	547	1585

Table 3.6 Large Step Decrease		
Time (hrs)	Temperature (°F)	Pressure (psi)
0	600	2235
0.017	613	2335
0.133	528	1960
3	528	1960

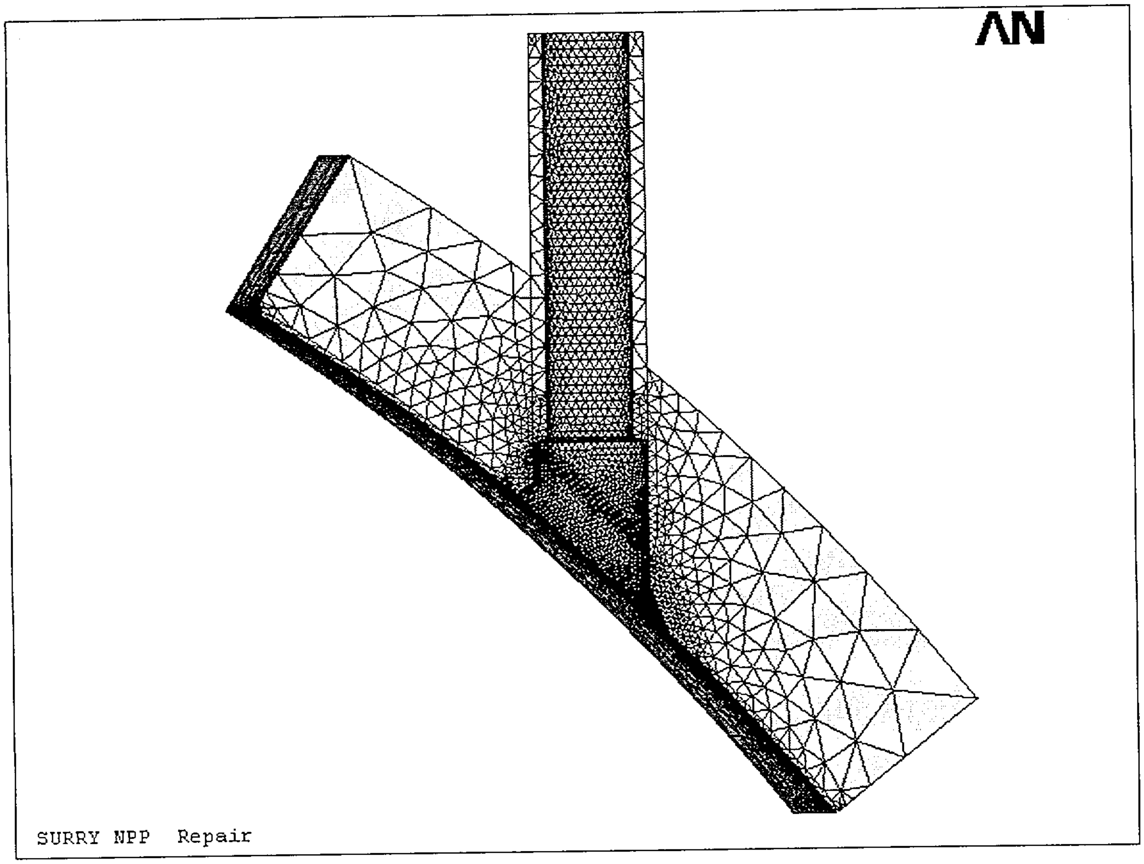
Table 3.7 Loss of Flow		
Time (hrs)	Temperature (°F)	Pressure (psi)
0	600	2235
0.0028	616	2200
3	616	2200
3.025	547	1860
6	547	1860

Table 3.8 Remaining Transients		
Time (hrs)	Temperature (°F)	Pressure (psi)
0	575	2235
0.044	620	2485
3	620	2485
3.025	595	2235
6	595	2235

3.2 Overall 3D Finite Element Model

Using the above items as parameters, the CRDMH Connection 3D FE model is developed. The resulting overall model is depicted in Figure 3.1, 3.2, and 3.3. The model is comprised of approximately 92,000 nodes and 62,000 elements. The element type chosen is the ANSYS SOLID87 (3D 10-Node Tetrahedral Thermal Solid) for the thermal analysis. This element is converted to element type SOLID92 (3D 10-Node Tetrahedral Structural Solid) for the structural solutions. These elements have the capability of having surface loads applied (such as heat transfer or pressure) and having structural boundary conditions applied (such as guided displacements, constraints, etc.).

FIGURE 3.1
Overall 3D Finite Element Model



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(for legibility concerns)

FIGURE 3.2
Overall 3D Finite Element Model

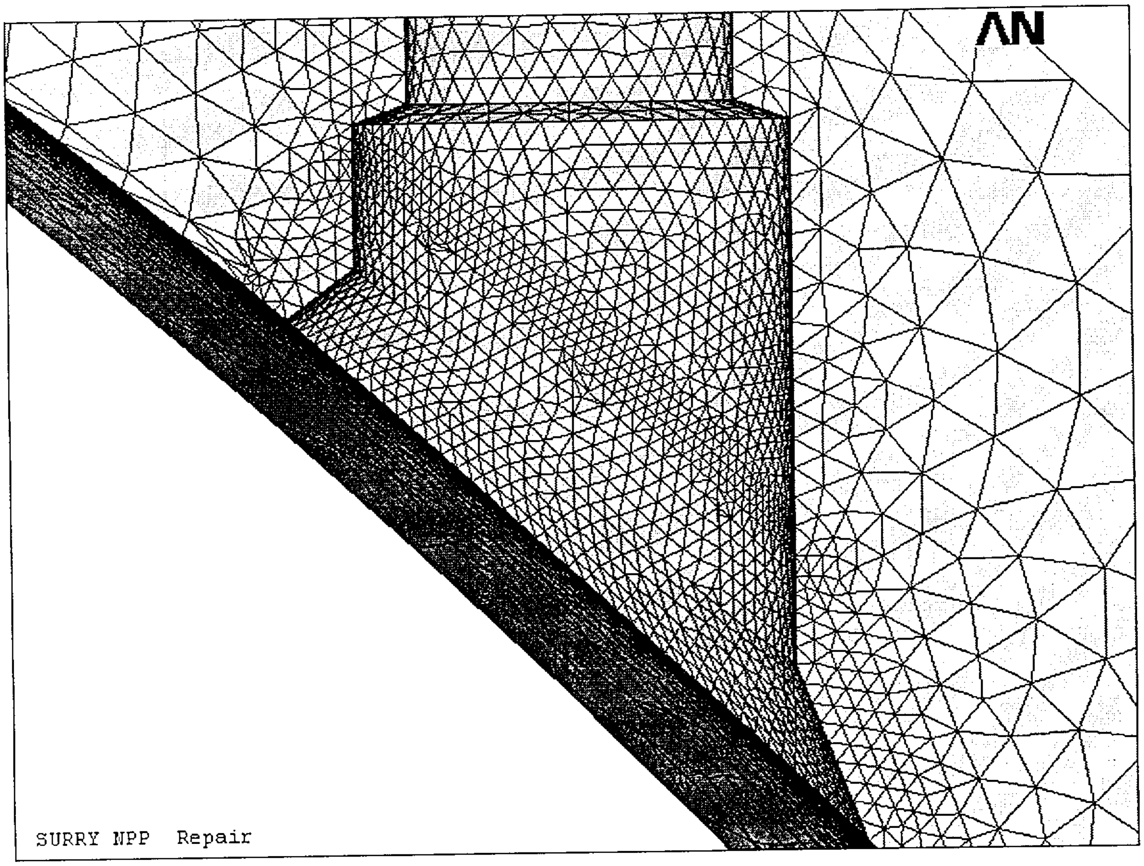

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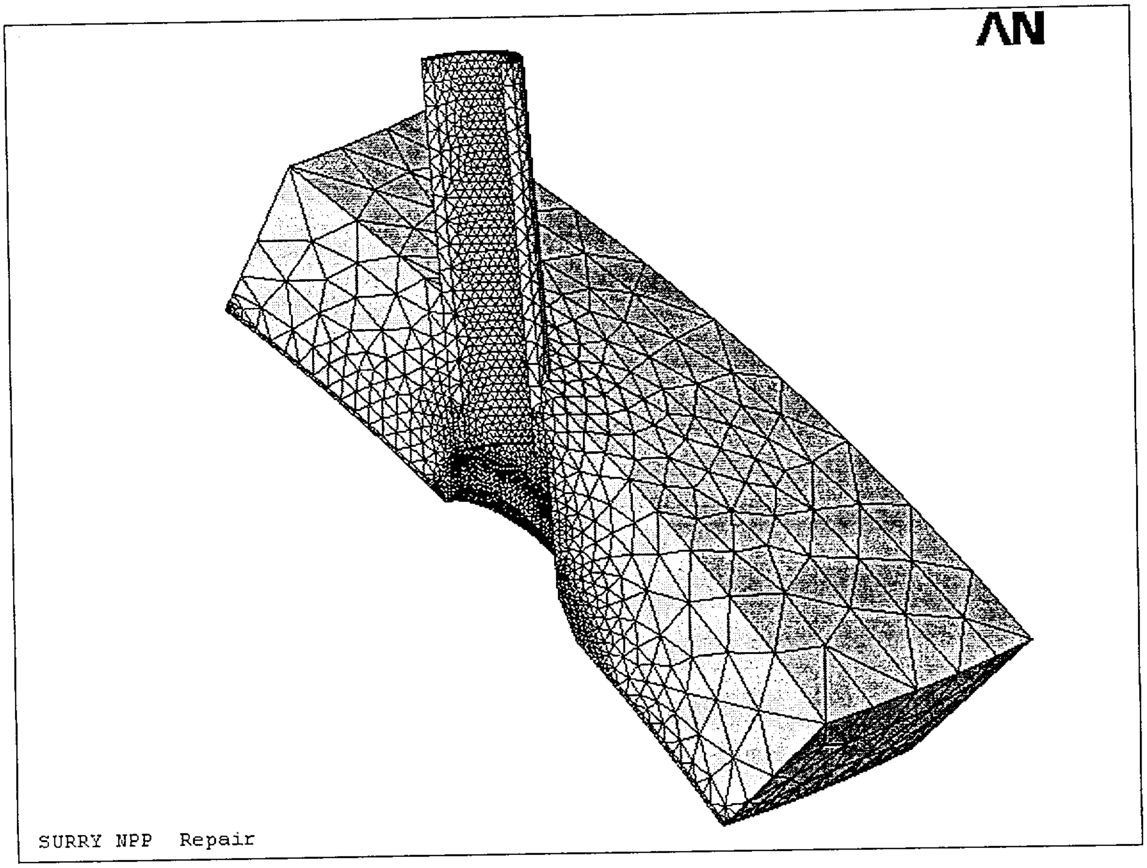
FIGURE 3.3
Overall 3D Finite Element Model



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4.0 Thermal Results

Based on the delta-T values between cladding and base metal, stress calculations are done at the following time points in the transients:

Load cases for Static Runs

4.1 HUCD Transient

Load case	Time (hr)	Temp. (°F)	Press. (psi)	Description
1	0.001	70	385	Initial condition
2	4.77	547	2235	End of Heatup
3	11.0	547	2235	End of Steady State
4	12.94	353	1483	Max. Delta T
5	15.77	70	385	End of Cooldown
6	19.0	70	385	End of Run

4.2 Plant Loading/Unloading Transients

Load case	TIME(Hr)	Temp. (°F)	Press. (psi)	Description
1	0.001	547	2235	Initial condition
2	0.333	600	2235	End of Plant Loading
3	3.000	600	2235	End of Steady State
4	3.333	547	2235	End of Plant Unloading

4.3 Reactor Trip

Load case	TIME(Hr)	Temp. (°F)	Press. (psi)	Description
1	0.001	600	2235	Initial condition
2	0.110	522	1855	Local Minimum
3	0.14296	522	1855	Local Minimum
4	1.00	522	1855	End of Run

4.4 Loss of Load

Load case	TIME(Hr)	Temp. (°F)	Press. (psi)	Description
1	0.001	600	2235	Initial condition
2	0.10768	634	2485	Local Maximum
3	3.00	634	2485	End of Steady State
4	3.0208	547	1585	Local Minimum
5	3.4719	547	1585	Local Minimum

4.5 Large Step Decrease

Load case	TIME(Hr)	Temp. (°F)	Press. (psi)	Description
1	0.001	600	2235	Initial condition
2	0.017667	613	2335	Local Maximum
3	0.13433	528	1960	End of LD
4	0.22575	528	1960	Local Minimum

4.6 Loss of Flow

Load case	TIME(Hr)	Temp. (°F)	Press. (psi)	Description
1	0.001	600	2235	Initial condition
2	0.13694	616	2200	Local Maximum
3	3.0250	547	1860	Local Minimum

4.7 Remaining Transients

Load case	TIME(Hr)	Temp. (°F)	Press. (psi)	Description
1	0.001	575	2235	Initial condition
2	0.0454	620	2485	End of Heatup
3	0.14393	620	2485	Local Maximum
3	3.00	620	2485	End of Steady State
4	3.1517	595	2235	Local Minimum
5	3.1833	595	2235	Local Minimum

* Transient time scale is as defined in Reference 3.

5.0 Stress Results

Stress analysis is performed at each of the previously listed time points. The model is loaded by nodal temperatures (thermal gradients) and internal pressure (see Table 4.1 - 4.7 for applicable values). The results of the stress analyses are contained in the output file ***st.out

The area selected for this study is original J-groove weld. The original J-groove locations include paths through the remnant portion of the original J-groove welds and adjacent RV head base metal on uphill and downhill (See Fig. 5-1). The stresses tabulated herein are to be used as input to flaw growth assessments.

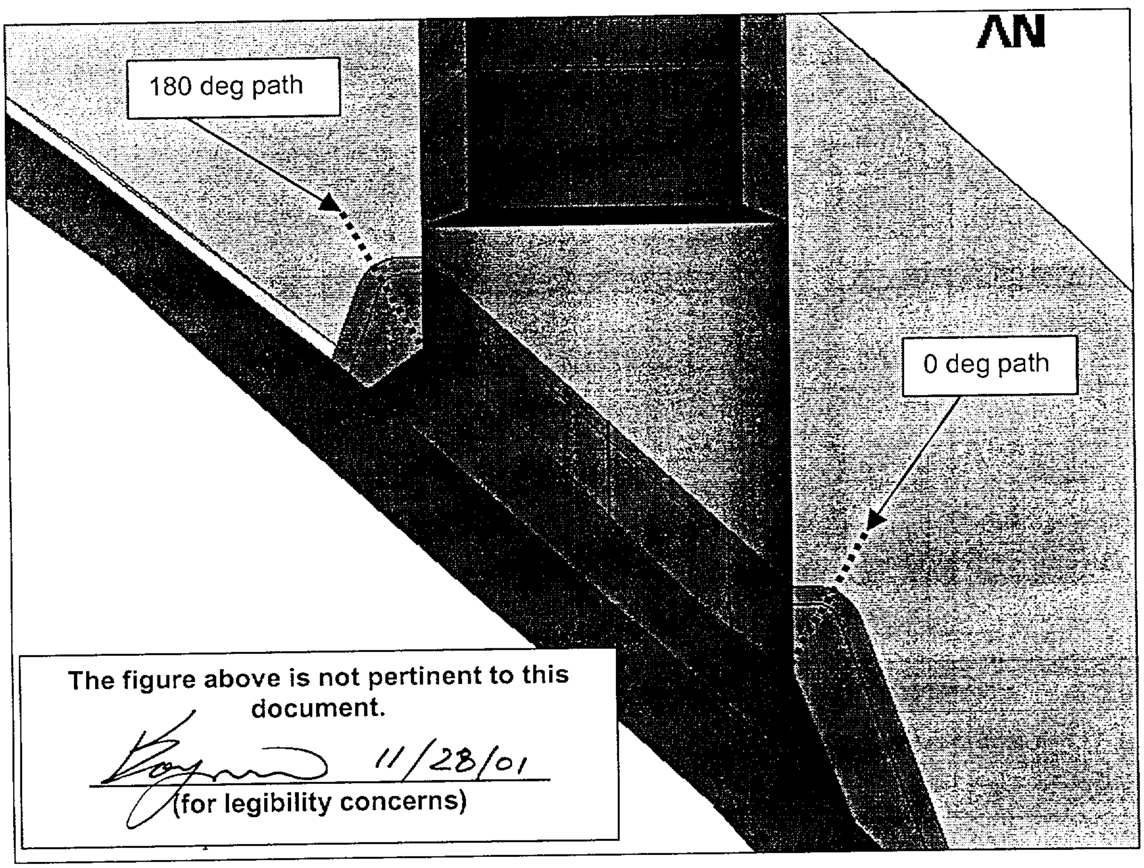

Fig. 5-1 Close-up of Paths Through Original Welds/Head

For J-groove weld, there are two line segments in a path: 1) from corner of chamfer to buttering and 2) from buttering to base metal. And, each segment has five checking points.

The stress results are in cylindrical coordinate system.
SX = radial to CRDMH Nozzle; SY = hoop; SZ = axial

THE COMPUTER OUTPUT CONTAINING DETAILED STRESSES HAS BEEN REMOVED FOR PROPRIETARY REASONS.

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6.0 References

1) "ANSYS" Finite Element Computer Code, Version 5.7, Swanson Analysis Systems, Inc., Houston, Pa.

2) FRA-ANP Document 32-1213353-00, "ANSYS-386 Version 4.4A Validation Report", dated 4/92

NOTE: Although this document is for version 4.4A, the same problems apply to other versions of ANSYS. Therefore, if the verification problem is run on a later version of ANSYS (version 5.6 for this analysis) and the results match the closed form results of the validation report, the other version of ANSYS is concluded to be acceptable

3) FRA-ANP Document 51-5015050-02, " SURRY CRDM Nozzle ID Temper Bead Weld Repair Requirements"

4) FRA-ANP Document 51-5015197-00,01, "SURRY 1&2 Reconciliation with Turkey Point 3 RV HD & CRM Noz."

5) FRA-ANP Drawing 02-5015149E-02, "CRDM Nozzle ID Temperbead Weld Repair"

7.0 Computer Files and Program Verification

Computer Files

The following is a listing of computer files used to document CRDMH's J-groove weld stresses. These files reside on the Framatome ANP COLD Storage system. These files are "FRA-ANP Proprietary".

Run Name	Run Date	Description
SURRY_HUCD_th.out SURRY_HUCD_st.out	11/4/01 11/5/01	HUCD Transient Case
SURRY_PLUL_th.out SURRY_PLUL_st.out	11/1/01 11/2/01	Plant Loading/Unloading Transient Case
SURRY_RTRP_th.out SURRY_RTRP_st.out	11/9/01 11/12/01	Reactor Trip Transient Case
SURRY_LL_th.out SURRY_LL_st.out	11/9/01 11/12/01	Loss of Load
SURRY_LD_th.out SURRY_LD_st.out	11/13/01 11/13/01	Large Step Decrease
SURRY_LF_th.out SURRY_LF_st.out	11/10/01 11/13/01	Loss of Flow
SURRY_RA_th.out SURRY_RA_st.out	11/14/01 11/14/01	Remaining Transient Case
path_w1_HUCD.out path_w2_HUCD.out path_w1_PLUL.out path_w2_PLUL.out path_w1_RTRP.out path_w2_RTRP.out path_w1_LL.out path_w2_LL.out path_w1_LD.out path_w2_LD.out path_w1_LF.out path_w2_LF.out path_w1_RA.out path_w2_RA.out	11/6/01 11/6/01 11/2/01 11/2/01 11/12/01 11/14/01 11/12/01 11/14/01 11/14/01 11/14/01 11/13/01 11/13/01 11/14/01 11/14/01	Post-process to define path and obtain linearized stresses
VM187.out	11/8/01	Verification problem solution (structural/stress calculation)
VM96.out	11/8/01	Verification problem solution (temperature distribution)

Verification of ANSYS Program:

The finite element analyses done in this calculation were made using the ANSYS computer program. Test cases verifying the suitability and accuracy of this program for this analysis were analyzed and the results of the test cases are included in files VM96.OUT and VM187.OUT (listed in the above table). The results of these solutions confirm that the ANSYS program is executing correctly.

Attachment 5

Framatome ANP Affidavit
for Withholding Proprietary Information

Surry Power Station Units 1 and 2
Virginia Electric and Power Company
(Dominion)

AFFIDAVIT

STATE OF WASHINGTON)
) ss.
COUNTY OF BENTON)

1. My name is Jerald S. Holm. I am Manager, Product Licensing, for Framatome ANP ("FRA-ANP"), and as such I am authorized to execute this Affidavit.

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

3. I am familiar with FRA-ANP documents (51-5012728-03, 02-5015149E-02, 32-5015651-00, 32-5015650-00, 32-5015624-00, 32-5014640-00, 32-5015219-00, 51-5015197-01) transmitted with the letter to Document Control Desk from Dominion, Serial No. 01-637B, which are referred to herein as "Document." Information contained in this Document has been classified by FRA-ANP as proprietary in accordance with the policies established by FRA-ANP 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 FRA-ANP 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 the Document be withheld from public disclosure.

6. The following criteria are customarily applied by FRA-ANP to determine whether information should be classified as proprietary:

(a) The information reveals details of FRA-ANP'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 FRA-ANP.

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

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

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

8. FRA-ANP 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 26th day of November, 2001.

Susan K. McCoy
NOTARY PUBLIC, STATE OF WASHINGTON
MY COMMISSION EXPIRES: 1/10/04

SUSAN K. McCOY
COMMISSION EXPIRES
NOTARY
PUBLIC
1-10-04
STATE OF WASHINGTON