Commonwealth Edison
Dresden Nuclear Power Station
6500 North Dresden Road
Morris, Illinois 60450
Telephone 815/942-2920

June 30, 1994

Mr. William T. Russell, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Document Control Desk

Subject: Dresden Nuclear Power Station Units 2 and 3
Quad Cities Nuclear Power Station Units 1 and 2
Clarification of Information Related to Commonwealth Edison's (ComEd) Finite Element Analysis Model Related to the Core Shroud Cracking Issue at Dresden and Quad Cities Stations
NRC Docket Nos. 50-237/249 and 50-254/265

References: (a) Teleconference between ComEd (J. Williams, P. Piet, et. al.) and NRC staff (J. Stang, K. Wichman, et. al.), dated June 29, 1994.

(b) Meeting between ComEd (J. Williams, P.Piet, et. al.) and NRC staff (Strosnider, Capra, Wichman, Hermann), dated June 27, 1994.

Dear Mr. Russell:

During the Reference (a) teleconference, ComEd and the NRC staff discussed issues related to the core shroud cracking at Dresden Unit 3 and Quad Cities Unit 1. The purpose of the teleconference was to further clarify issues discussed during the Reference (b) meeting.

The purpose of this letter is to clarify our position with respect to limit load analysis of the H5 weld, to clarify our description of the finite element model (FEM) used to evaluate the validity of limit load analysis for determining the minimum allowable the H5 weld ligament for the core shrouds at Dresden Unit 3 and Quad Cities Unit 1, and to provide free body diagrams illustrating the forces imposed on the shroud. This information is provided (see attachments) to support the assessment of the structural integrity of the H5 weld.

ADO1 1/1

Please direct any questions you may have concerning this response to this office.

Sincerely,

Peter L. Piet
Nuclear Licensing Administrator

Attachments:

1) H. Mehta to T. Spry, "Instability and Weld Metal Toughness Considerations in the Structural Evaluation of H5 Weld at the Quad Cities and Dresden Plants," June 28, 1994.

2) G. Stevens to J. Williams, "Description of Finite Element Model Used for H5 Weld Ligament Limit Load Validity Evaluation," June 28, 1994.

3) J. Dawn, et al, to J. Stang, et al, ligament calculation procedure, free body diagrams, and limit load evaluation, June 30, 1994.

cc: J.B. Martin, Regional Administrator - RIII
J. Stang, Project Manager - NRR
C. Patel, Project Manager - NRR
C. Miller, Senior Resident Inspector - Quad Cities
M. Leach, Senior Resident Inspector - Dresden
Office of Nuclear Facility Safety - IDNS

GE Nuclear Energy
Engineering & Licensing Consulting Services Projects

June 28, 1994

To: Tom Spry
Com Ed

cc: S. Ranganath
G.L. Stevens

From: Har Mehta

Subject: Instability and Weld Metal Toughness Considerations in the Structural Evaluation of H5 Weld at the Quad Cities and Dresden Plants

The following information on the subject topic is provided to help you in the assessment of structural integrity of the H5 weld. The details and the verification of this evaluation are documented in DRF # 137-0010-7, Item # GENE-523-A101-0694.

Instability

The question regarding potential for instability at or prior to reaching the limit load may come up from someone recalling the load versus displacement plot of one of the widely reported surface-cracked pipe tests (Figure 1) by Battelle (Reference 1). However, there are differences between that test and the cracking considered at the H5 weld in the shroud:

- The flaw configuration (length and depth) used in the Battelle test was predicted to experience unstable crack growth based on the assessment diagram shown in Figure 2. The region marked by 'leak' is where a surface crack would grow in a stable manner resulting in a leak situation. Instability is predicted in the region marked by 'fracture'. The Battelle test pipe had a crack depth to thickness ratio of 0.5 and the crack extended over 50% of the circumference. Thus, the Battelle pipe configuration would plot in the 'fracture' region in Figure 2. In contrast, a fully circumferential flaw with more than 90% through wall depth (considered in the required remaining ligament calculations based on limit load) would plot in the 'leak' region and thus be stable.

Based on the preceding discussion, it is concluded that the flaw geometry being evaluated in the analysis of H5 weld is expected to be stable under applied loadings.

Weld Toughness

In determining the required minimum ligament at the H5 weld, the limit load approach was used with a flow stress of $3S_m$. This approach is reasonable since the observed cracking at the H5 weld is in the base metal. This section addresses the following issue: how much is the required ligament calculation affected if the indication is assumed to grow in the weld region? For the purpose of this evaluation, the H5 weld was assumed to be made by the submerged arc welding (SAW) process. The SAW welds have somewhat lower toughness compared to the base metal.

Estimation scheme methods of elastic-plastic fracture mechanics were used in this evaluation. A fully circumferential crack geometry subjected to remote tension loading was assumed in the evaluation. The SAW J-T curve (Figure 3) used in the development of IWB-3640 procedures was used in this evaluation. The J-integral values were determined by using the GE/EPRI estimation scheme (Reference 2). The results indicated that the load predicted by using the SAW fracture toughness properties was approximately 20% lower than that predicted by the limit load approach. It should be noted that the SAW J-T curve used in the IWB-3640 calculations is very conservative (i.e., its use results in under predicting the loads).

References

[1] EPRI Report NP-2347, "Instability Predictions for Circumferentially Cracked Type-304 Stainless Steel Pipes Under Dynamic Loading," April 1982.

[2] "An Engineering Approach for Elastic-Plastic Fracture Analysis," EPRI Report No. NP-1931, July 1981.

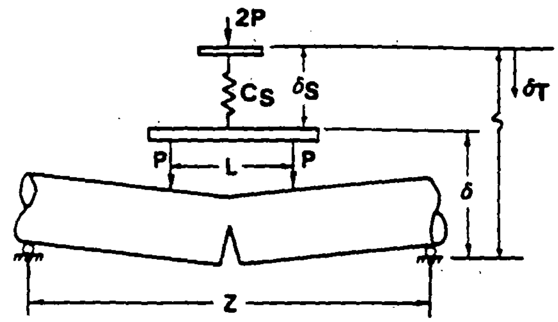


Figure 1a A Four-Point-Bend Loading System

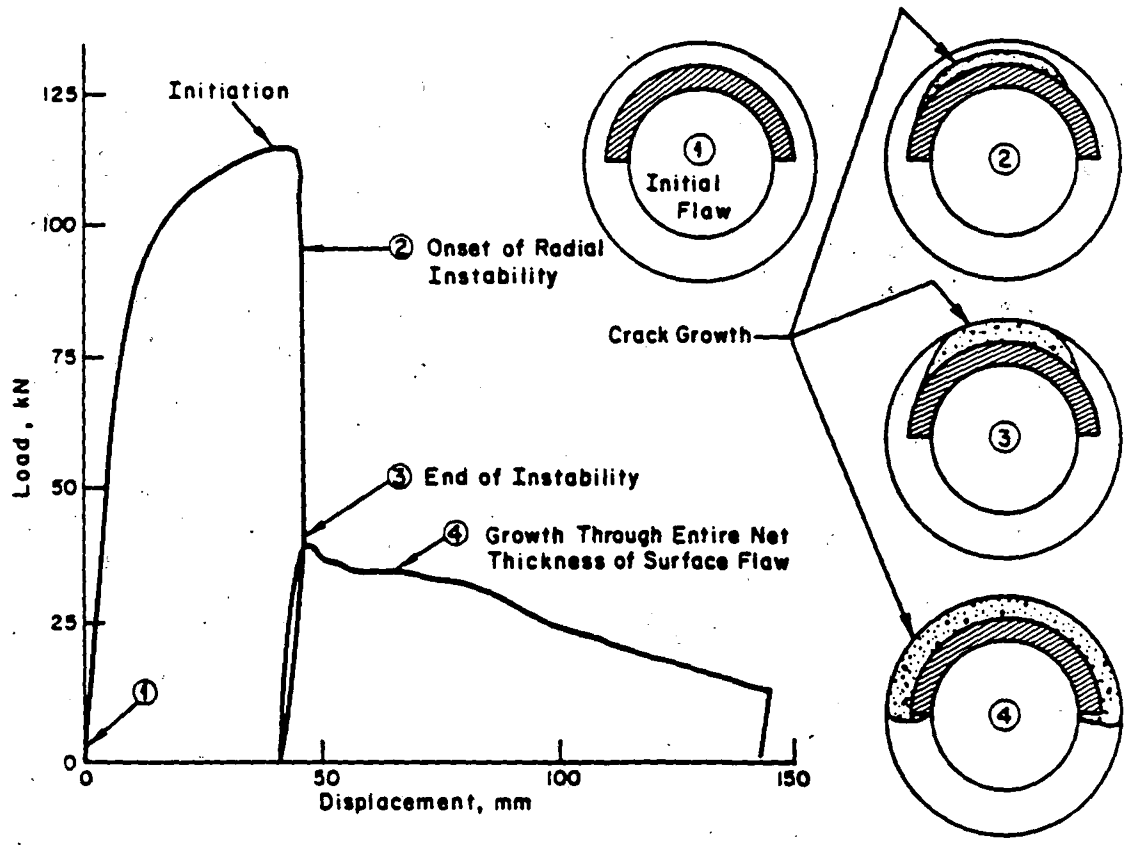


Figure 1b Load Displacement Record of Surface Cracked Pipe Experiment 10S

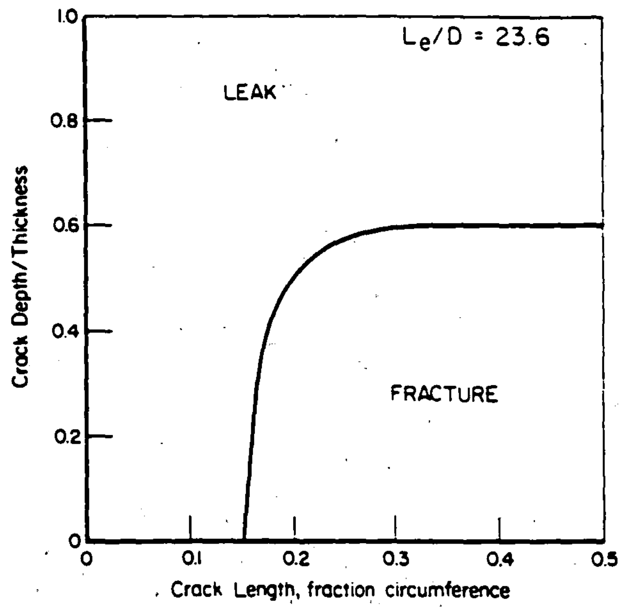


Figure 2 Safety Assessment Diagram for a 4-inch Pipe

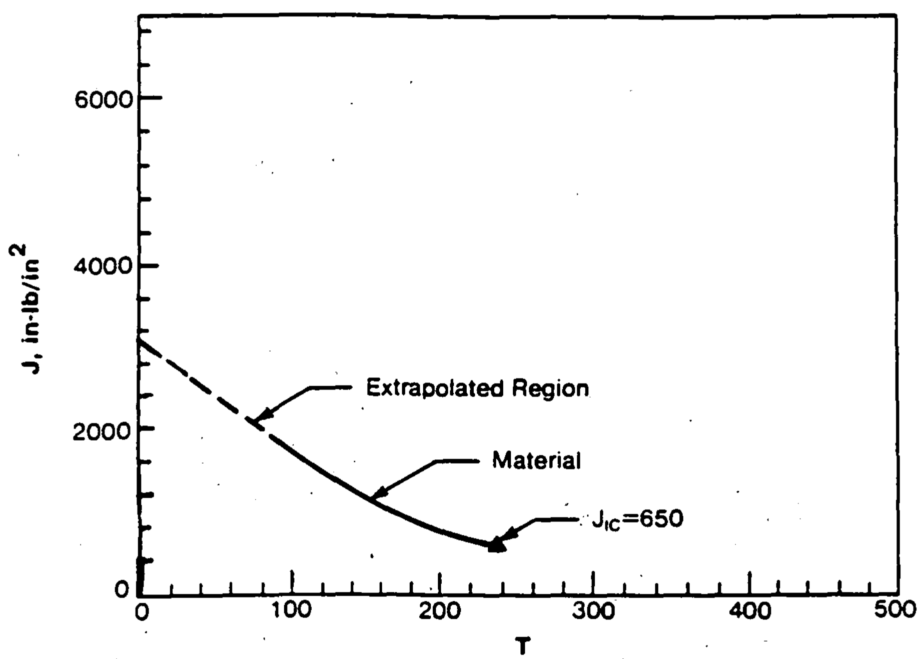
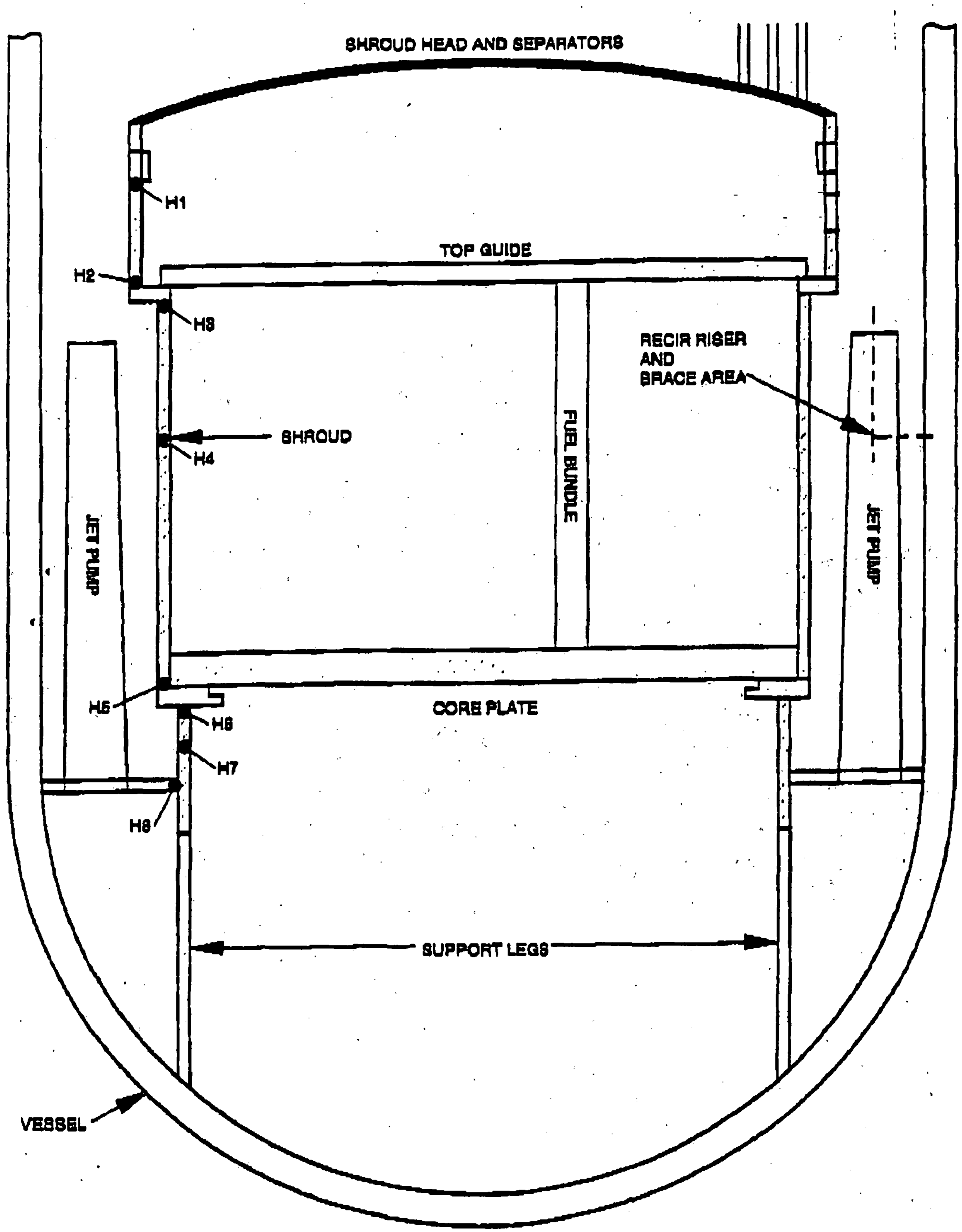


Figure 3 Material J-T Curve used for SAW Analysis

Dresden and Quad Cities Core Shroud Structural Configuration



GE Nuclear Energy

Structural Mechanics Projects
175 Curtner Avenue M/C 747
San Jose, CA 95125
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FAX: (408) 925-1150

GLS 94-13
June 28, 1994

cc: S. Ranganath
H. Mehta
DRF 137-0010-7
(GE-NE-523-A69-0594)

TO: Joe Williams, ComEd
FAX: (815) 942-2920, X-2265

FROM: Gary L. Stevens -- GE San Jose

SUBJECT: Description of Finite Element Model Used for H5 Weld Ligament Limit Load Validity Evaluation

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Per your request, this letter provides a detailed description of the finite element model (FEM) used in the shroud weld H5 ligament limit load validity evaluation for the Commonwealth Edison plants. Please note that this is a parametric study only, and was not used to determine minimum ligament sizes for the H5 weld.

PURPOSE

The purpose of this finite element evaluation was to parametrically study the effect of loading in the H5 weld region with a deep flaw (i.e., small ligament) present. Of particular interest was the appropriateness of the use of limit load methodology for the determination of the minimum ligament size. Based on this, a FEM was constructed that properly represented the H5 weld geometry so that stresses from applied loading could be assessed across the remaining ligament, and compared to those stresses obtained from simplified strength of materials calculations typically used in limit load evaluations. The main intent was to ensure that no amplification effects were present in this region due to the offset geometry or the presence of a deep flaw, thereby providing evidence that strength of materials calculations are adequate.

Plot #1 (attached) shows an overall view of the FEM. The model was constructed using the ANSYS computer code [1], and is comprised of two-dimensional (2-D), axisymmetric, isoparametric solid elements. The H5 weld region was modeled in detail, including the fillet weld, the core plate support ring, and enough of the upper and lower shroud cylindrical portions so that end effects were not significant in the region of interest.

A load was applied to the top end of the model, as noted in Plot #1. A detailed plot showing the load application is shown in Plot #2. An equivalent uniform pressure tensile load of 1,372 psi was applied to the end of the model. This stress was derived from the screening criteria [2] primary loads specific to this location for the faulted event (consisting of main steam line break + safe shutdown earthquake loads), including the appropriate ASME Code safety factor of 1.4, and represents the maximum combined primary membrane plus bending stresses at a section 50" above the H5 weld. Only sustained stresses induced by primary loads are required for limit load evaluation, so secondary stresses (e.g., thermal, welding residual, local bending) were not considered.

For the purposes of demonstrating the appropriateness of limit load methodology, the magnitude of the applied load is inconsequential since the intent was to parametrically assess the effect of a deep flaw on the stress distribution in the remaining ligament; however, an approximate order-of-magnitude load was desired, so the screening criteria loads formed the basis for determining this load. Since the model is elastic and linear, the results can be scaled for any other desired load. It should also be pointed out that, since the model is an axisymmetric 2-D model, the applied load is equivalent to pure axial tensile loading on a 3-D cylinder; however, the results closely approximate those in a 3-D cylinder under an applied moment loading at the location where primary bending stresses are maximum.

The boundary conditions were applied to the bottom end of the model, as noted in Plot #1. Plot #3 shows a detailed view of this end of the model with the boundary conditions applied. The bottom end of the model was fixed in the vertical (shroud axial) direction. Restraint in the shroud radial and circumferential directions come from the axisymmetric assumption.

The ANSYS input file listing for this model is also attached for your information. The detailed results obtained from this model were previously described in the Reference 3 letter. If you require further information on this subject, please don't hesitate to contact me.

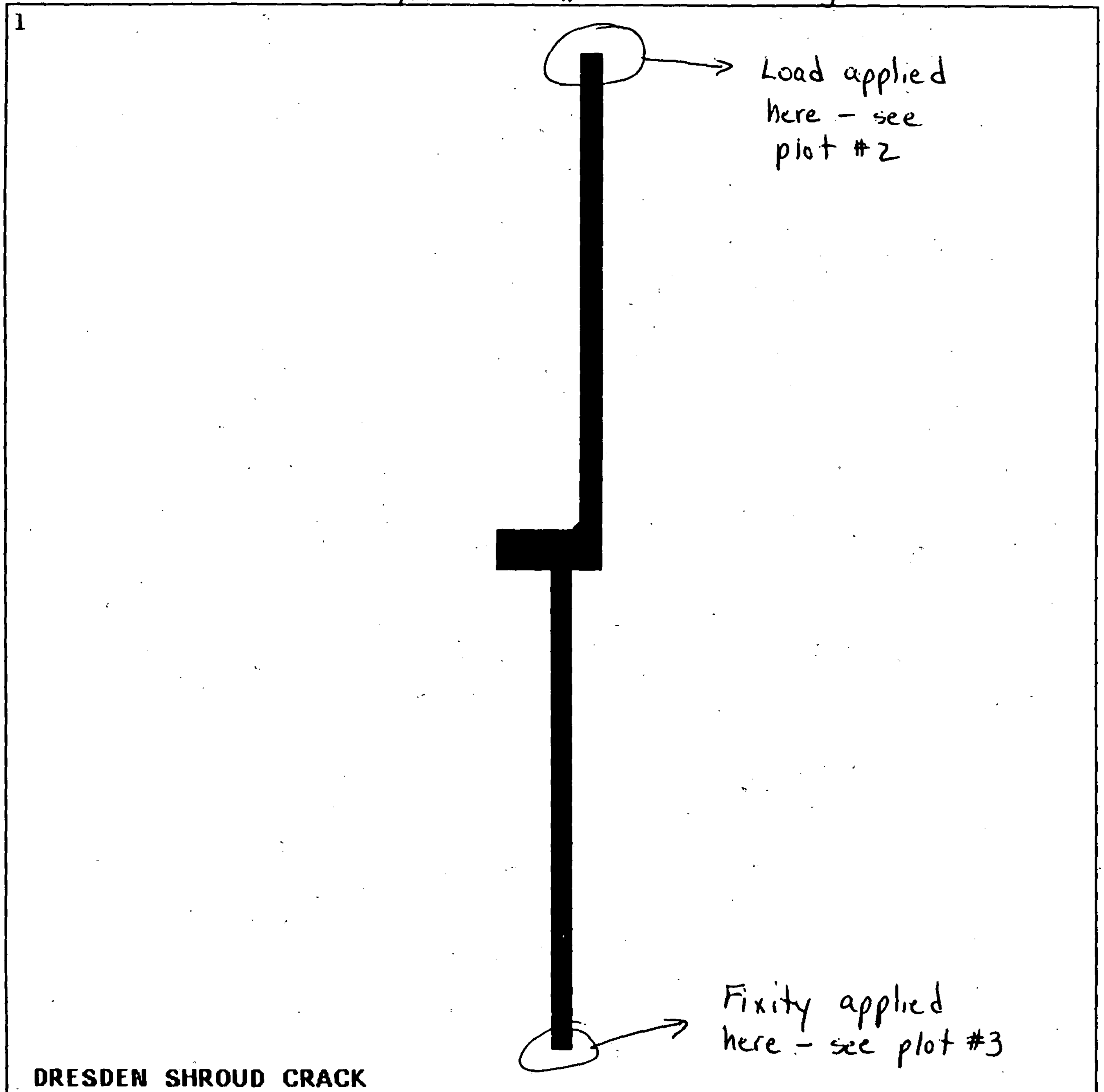
REFERENCES

[1] G. J. DeSalvo and R. W. Gorman, ANSYS Engineering Analysis System User's Manual, Swanson Analysis Systems, Inc., Houston, PA, Revision 4.4a, May 1, 1989.

[2] GE Report GENE-523-05-0194, Revision 0, " Evaluation and Screening Criteria for the Dresden 2 and 3 Shrouds," W.F. Weitze, GE Nuclear Energy, March 1994.

[3] Letter GLS 94-11 from Gary L. Stevens (GE) to Tom Spry (CECo), " Response to Commonwealth Edison Technical Audit Questions," June 8, 1994.

PLOT #1: 2-D axisymmetric model of H5 region



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JUN 27 1994
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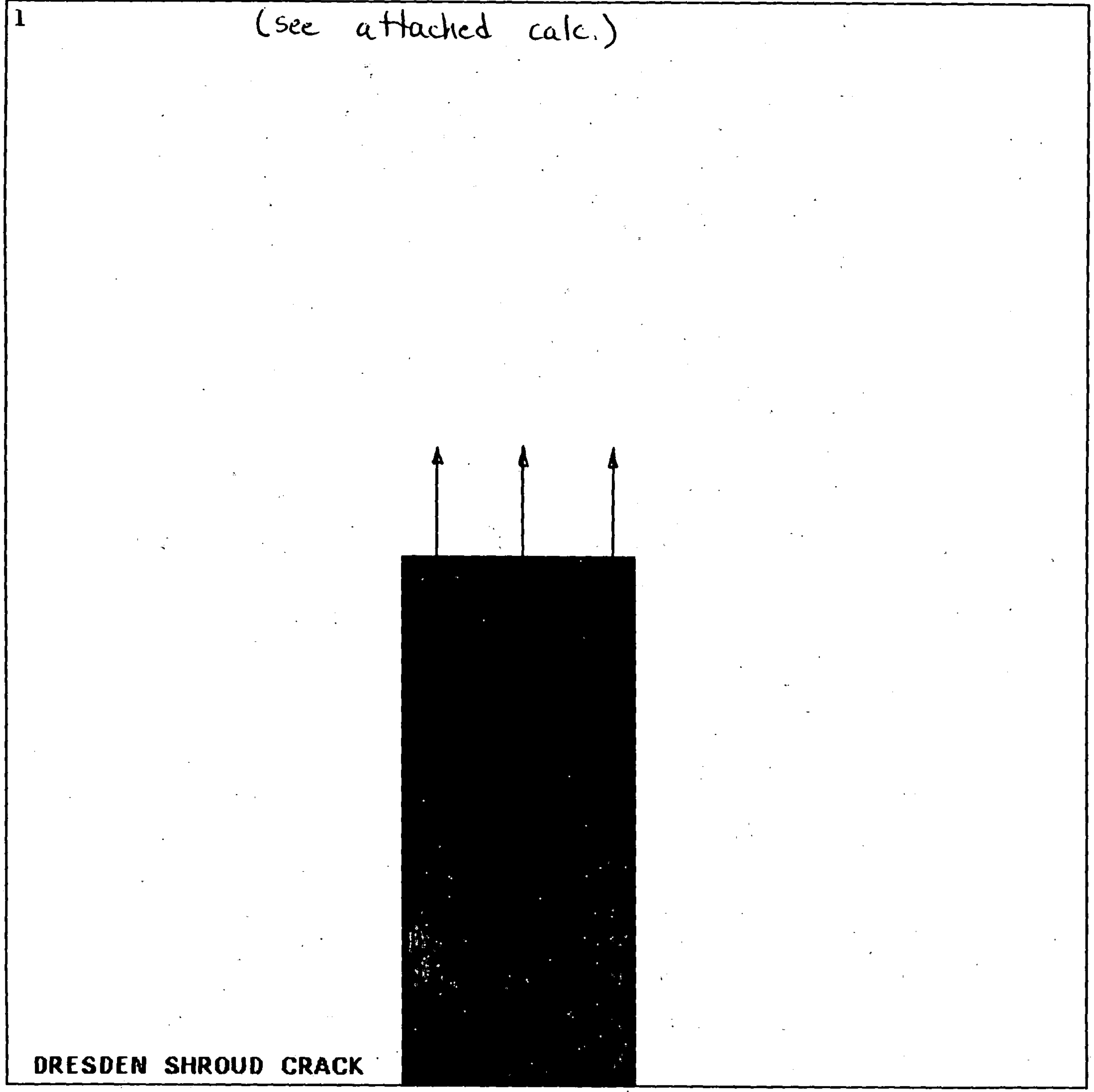
PLOT #1

PLOT #2: Load applied to end of model (top)

(see attached calc.)



ANSYS 4.4A1
JUN 27 1994
16:13:36
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PRES

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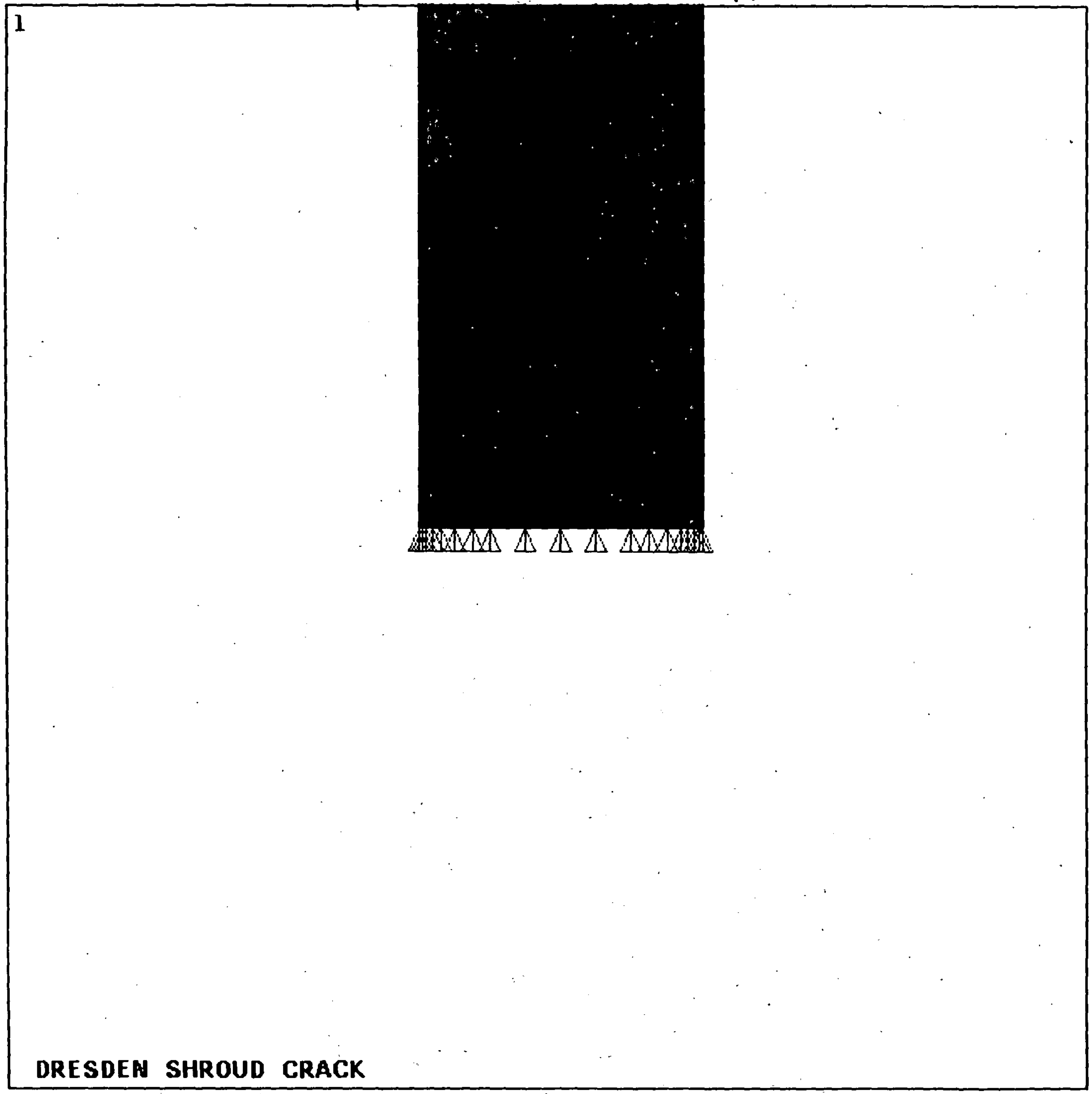
PLOT #2

PLOT #3: Boundary conditions (fixed) applied to model (bottom)



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PLOT #3

ANSYS FEM Input File Listing

(7 pages)

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MAT,3
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EDELET,1844,1845,1
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EDELET,1892,1893,1
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EDELET,1940,1941,1
EDELET,1964,1965,1
EDELET,1988,1989,1
EDELET,2012,2013,1
EDELET,2036,2037,1
EDELET,2060,2061,1
EDELET,2084,2085,1
EDELET,2108,2109,1
EDELET,2132,2133,1
EDELET,2156,2157,1
EDELET,2180,2181,1
EDELET,2204,2205,1
EDELET,2228,2229,1
EDELET,2252,2253,1
C***
C***
P,2973,2974,-1372,,2990,1
D,1,UY,0,,19,1
C***
C*** THERMAL TRANSIENT
C***
ITER,1,1,1
TIME,0
LWRITE
AFWRITE
FINISH
/EXEC
/INPUT,27
FINISH
```

To: John Stang 301-504-3861
Keith Wichman 301-504-0260
Joe Williams 815-942-2920 x2265
Bob Walsh 309-654-2241 x2265

From: John Dawn 408-925-6416 (Phone)
Tom Behringer 408-951-9749 (Pager)

Attached per your request are the following attached documents.

1. Procedure to calculate the minimum required ligament at H5 (2 pages)

2. Dresden and Quad Cities Core Shroud structural configuration (3 pages)

3. Free body diagram of forces on core shroud for limit load calculations - Quad Cities (1 page)

4. Free body diagram for limit load calculations at H5 - Quad Cities (1 page)

5. Quad Cities Unit 1 Shroud Weld H5 Limit Load Evaluation For MS LOCA (1 page)

6. Quad Cities Unit 1 Shroud Weld H5 Limit Load Evaluation For RR LOCA (1 page)

Note: The description of the FEM is being sent by fax from the Dresden Station.

RECEIVED
JUL 30

To: John Stang 301-504-3861
Keith Wichman 301-504-2260
Joe Williams 815-942-2920 x2265
Bob Walsh 309-654-2241 x2265

From: John Dawn 408-925-6416 (Phone)
Tom Behringer 408-951-9749 (Pager)

Attached per your request are the following documents.

1. Free body diagram of forces on core shroud for limit load calculations - Quad Cities (revised)(1 page)

2. Free body diagram for limit load calculations at H5 - Quad Cities (revised)(1 page)

3. Free body diagram of forces on core shroud for limit load calculations - Dresden (New)(1 page)

4. Free body diagram for limit load calculations at H5 - Dresden (New) (1 page)

5. Quad Cities Shroud Summary of Loads and Stresses at each Horizontal Weld Location COMED Design Review (Rev 1) (5 pages)

6. Dresden Core Shroud Summary of Loads and Stresses at each Horizontal Weld Location COMED Design Review (Rev 1) (5 pages)

7. RR LOCA Allowable Force Calculation (Generic for Dresden and Quad Cities) (New) (1 page)

8. Dresden and Quad Cities Core Shroud Structural Configuration (revised)(1 page)

Note: (1) Items 1&2 were originally faxed on June 29 but are revised as of June 30. Items 5&6 were part of the submittal on June 25 but are revised as of June 30. This revision was made to improve the accuracy by eliminating some of the simplifing assumptions that were originally used. The revision does not affect/impact any design analysis and is only for numerical consistency in summary the documents.

(2) Item 7 is a new document being submitted for your information.

Procedure To Calculate The Minimum Ligament Required At H5

1. Calculate the primary forces acting on the shroud, i.e., weight (DL), buoyancy (B), seismic vertical, seismic horizontal, upward pressure on the shroud head during normal operation, upward pressure on the shroud head during main steam LOCA, upward pressure on the shroud head during RR LOCA (same value as for normal), lateral asymmetric loads on the shroud during a RR LOCA blowdown, lateral asymmetric loads on the shroud during a RR LOCA acoustic.

2. Calculate the gross section properties of the shroud at H5 using the original 2" wall thickness (excluding the fillet weld). Calculate the centerline section modulus, shroud head area, shroud wall area and moment of inertia.

3. Determine the primary tensile stresses at H5 (Pm = membrane stresses due to axial loads, Pb = bending stresses due to seismic and asymmetric loads).

4. Sum the primary stresses in the shroud wall at H5 for each load combination to determine the maximum tensile stress (i.e. Pm + Pb). Note that steps 1 through 4 are defined in the COMED summary charts (files CSSTRES1.XLS and CSSTRES2.XLS) which were used to verify the GE analysis results.

5. Utilizing the maximum primary tensile stresses Pm and Pb, perform a limit load analysis to determine the minimum ligament size required. The methodology as defined in the 1983 Ranganath and Mehta paper was utilized in conjunction with the ASME Section 11, Appendix C, C-3320 factors of safety.

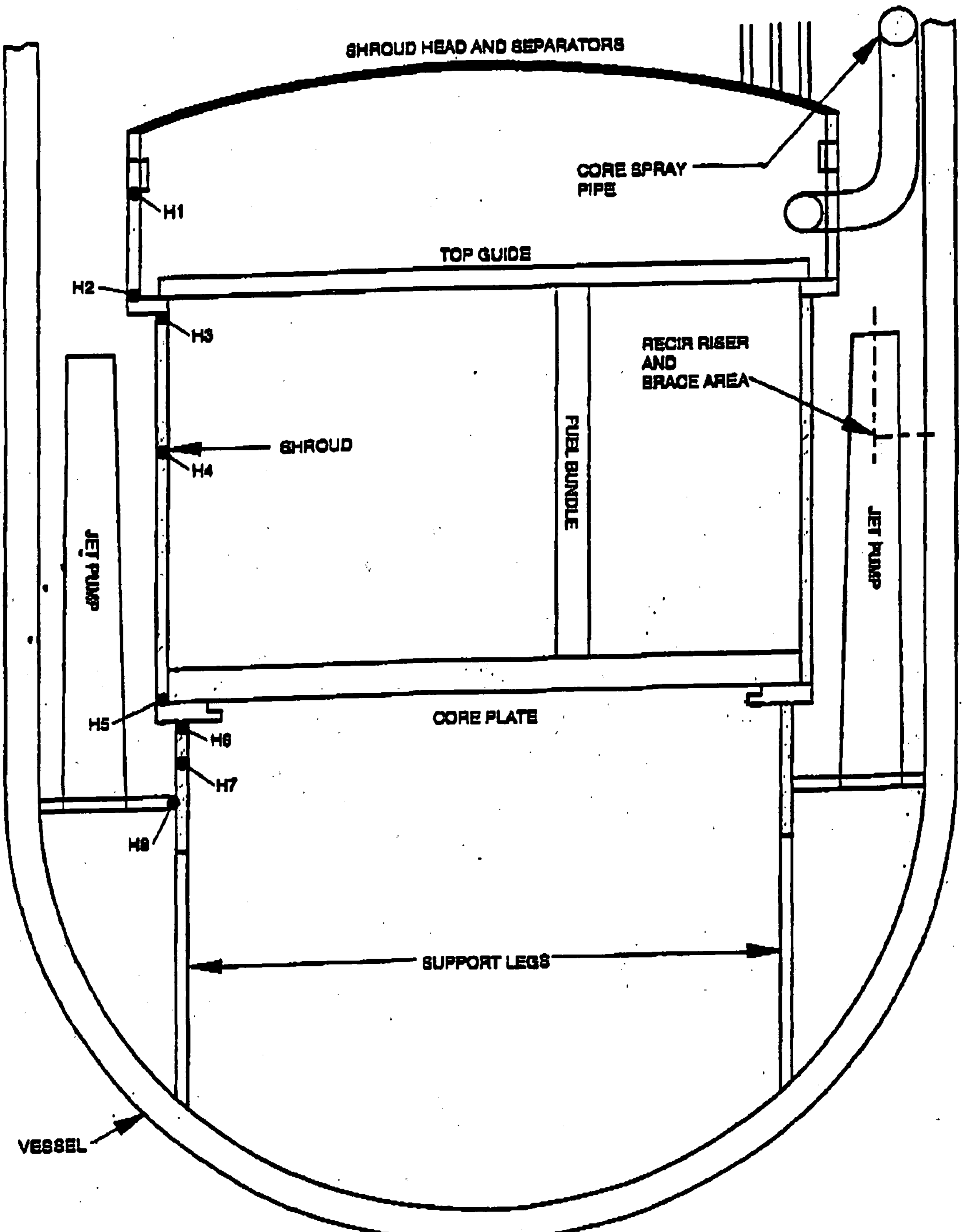
6. For Quad Cities the governing load combination is DL+B+MSLOCA+DBEvert+DBEhorz. See the attached sheets for the limit load evaluations for both the RRLOCA and MSLOCA combinations with the DBE.

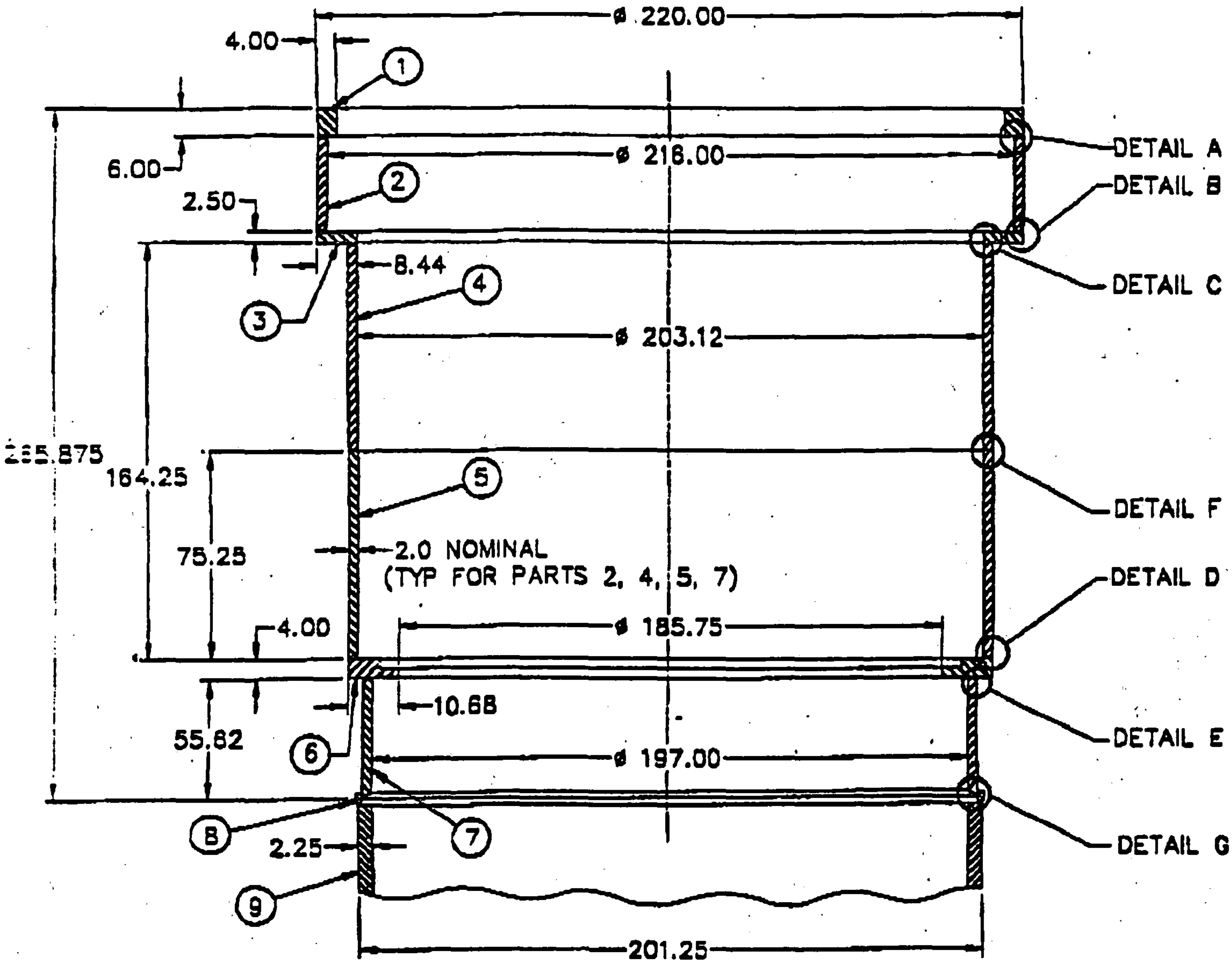
7. From the attached limit load calculations the minimum required ligament for Quad Cities is 0.12" (MSLOCA) and 0.11" (RRLOCA).

8. Verify that the minimum ligament size calculated will remain in the elastic range for the magnitude of the applied loads and that stress intensification factors do <u>not</u> need to be applied due to the offset geometry. Perform this verification using a finite element model of the applicable portion of the shroud and by applying a uniform tensile load equivalent to the maximum stress applied across the entire area of the shroud wall (note that the equivalent stress is of the same magnitude as the stresses on the section but is

not the same numerical value). Utilize a 0.25 inch remaining ligament (note actual QC minimum ligament is 0.12") to calculate the stress distribution due to the offset geometry and verify that even with a flaw depth of 92% of the material thickness (i.e. deep flaw) that the average stresses (10 ksi) are equivalent to what would be calculated by statics.

Dresden and Quad Cities Core Shroud Structural Configurati

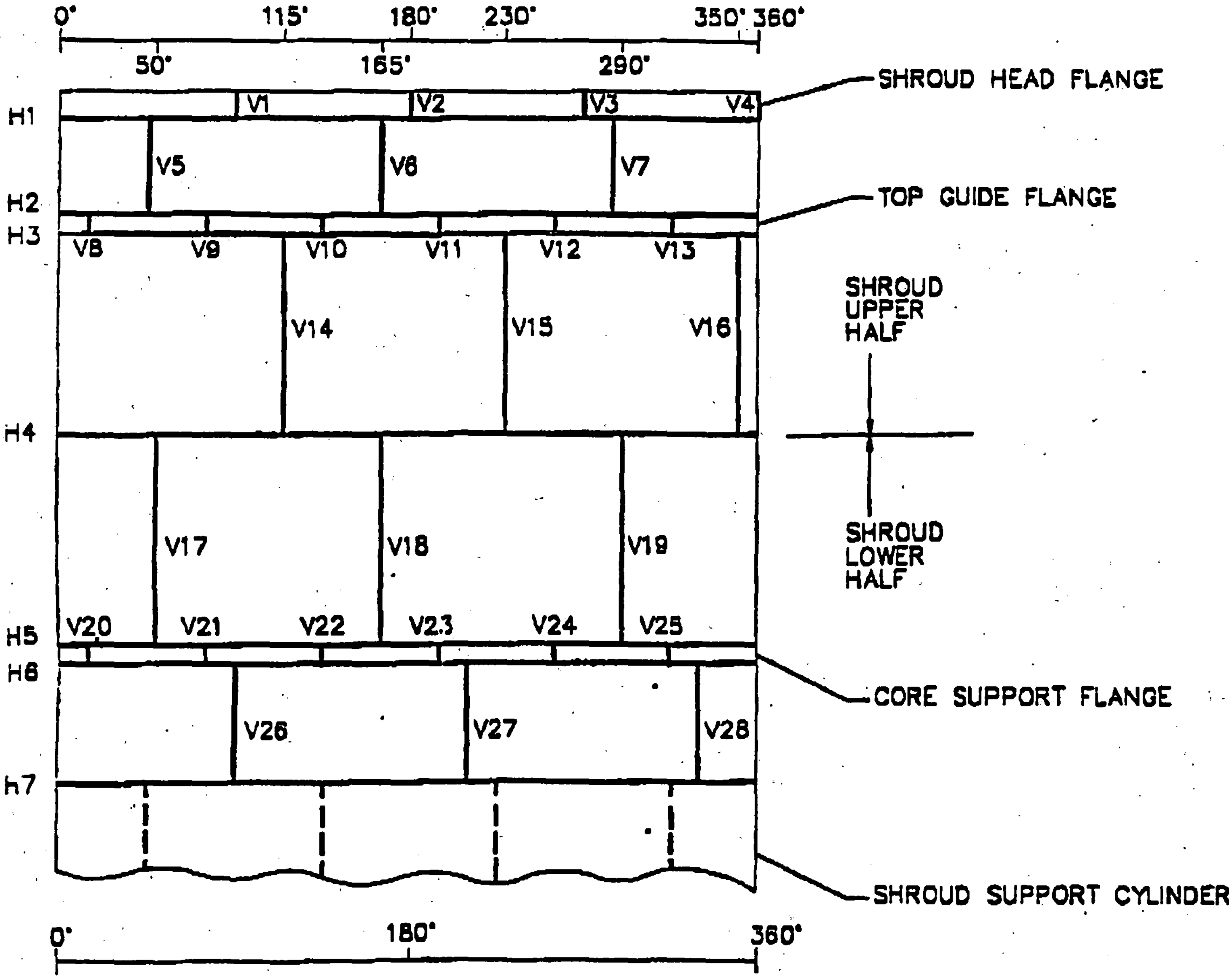




SHROUD SECTION VIEW

NOTES:

1. CORE SPRAY SPARGER ASSEMBLY, INTERNAL AND EXTERNAL BRACKETS/PADS ARE NOT SHOWN FOR CLARITY.
2. ALL DIMENSIONS ARE REFERENCE.
3. PART NO. 8 (BACKUP RING) IS NOT A PART OF THE VENDOR FABRICATED SHROUD. THE BACKUP RING IS PART OF THE FIELD WELD H7.
4. PART NO. 9 (SHROUD SUPPORT CYLINDER) IS A PART OF THE VESSEL. THE SHROUD SUPPORT CYLINDER IS PART OF THE FIELD WELD H7.



SHROUD SURFACE DEVELOPMENT

NOTES:

1. AZIMUTHAL LOCATIONS OF LONGITUDINAL (VERTICAL) WELDS FOR V14 (AT 115°), V15 (AT 230°), V16 (AT 350°), V17 (AT 50°), V18 (AT 165°) AND V19 (AT 290°) WERE IDENTIFIED FROM THE DRESDEN 3 VESSEL INSPECTION REPORTS DONE BY COMMONWEALTH EDISON COMPANY (CECo.).
2. AZIMUTHAL LOCATIONS OF LONGITUDINAL (VERTICAL) WELDS NOT ADDRESSED IN NOTE 1 ARE NOT DEFINED ON THE EXISTING DOCUMENTATION.
3. AZIMUTHAL LOCATIONS OF LONGITUDINAL (VERTICAL) WELDS FOR THE SHROUD SUPPORT CYLINDER ARE NOT DEFINED.

Free Body Diagram Of Forces On Core Shroud For Limit Load Calculations - Quad Cities

(1) DL (Kips)	DL (Kips)	(5) DBEvert. (Kips)	Buoyancy (Kips)	(2) MSLOCA (Kips)	(3) RRLOCA (Kips)		Shear RRLOCA Blowdown (Kips)	Moment RRLOCA Blowdown (In-Kips)	Shear RRLOCA Acoustic (Kips)	Moment RRLOCA Acoustic (In-Kips)	Shear DBEhorz. (Kips)	Moment DBEhorz. (In-Kips)
219.87	219.87	-35.18	-27.29	-732.87	-293.15	H1	N/A	N/A	N/A	N/A	86.00	1.038E+04
28.87	248.74	-39.80	-30.88	Note 4	Note 4	H2	N/A	N/A	N/A	N/A	676.00	2.320E+04
1.40	250.14	-40.02	-31.05	Note 4	Note 4	H3	N/A	N/A	N/A	N/A	676.00	2.480E+0[illegible]
70.27	320.41	-51.27	-39.78	Note 4	Note 4	H4	N/A	N/A	175.00	5.621E+03	830.00	8.620E+04
93.29	413.70	-66.19	-51.36	Note 4	Note 4	H5	17.20	1.061E+03	175.00	1.879E+04	1208.00	1.544E+05
1.91	415.61	-66.50	-51.59	N/A	N/A	H6	17.20	1.130E+03	175.00	1.949E+04	1208.00	1.592E+05
18.97	434.58	-69.53	-53.95	N/A	N/A	H7	17.20	2.087E+03	175.00	2.923E+04	1184.00	2.260E+05
						H8						

Fixed Base

Notes:

1. DL includes the weight of the shroud head, separators and top guide applied at H1
2. Dp for QC=20 psi, Dp for Dresden=12 psi, values shown are QC
3. Dp for QC=8 psi, Dp for Dresden=7 psi,values shown are QC
4. Force is applied at the head and is constant from H1 through H5
5. SSE Vertical= Weight x 0.16g (QC), Weight x 0.133g (Dresden)

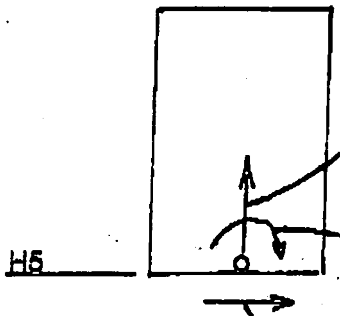
Sign Convention:
(+) is down (compression on H5)
(-) is upward (tension on H5)

Prepared By: T. J. Behringer Date: 6/30/94

Reviewed By: J. A. Dawn Date: 6/30/94

Approved By: J. D. Williams Date: 6/30/94

A. For DBE + Main Steam LOCA



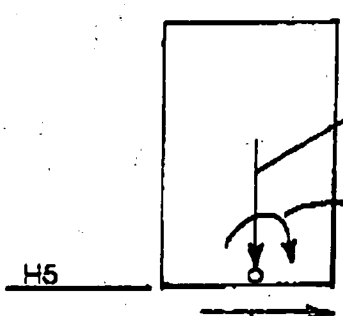
F = DL+B+DBE+MSloca
F= 413.70 - 51.36 - 66.19 - 732.87
F= -436.72 Kips
Pm= F/Area= -338.86 psi

Moment DBE= 1.544E+05 In.-Kip
Pb=Mc/I= -2335.99 psi

Shear DBE = 1208.00 Kips

Maximum Tension Stress = -338.86 - 2335.99 = -2674.840 psi

B. For DBE + Reactor Recirculation LOCA (Blowdown)



F = DL+B+DBE+RRloca
F= 413.70 - 51.36 - 66.19 - 293.15
F= 3.00 Kips
Pm= F/Area= 2.328 psi

Moment = Moment DBE + Moment RRblowdown
Moment=1.544E+05 + 1.061E+03=1.555E+05 In.-Kip
Pb=Mc/I= -2352.046 psi

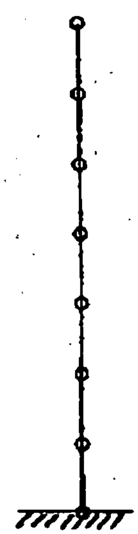
Shear = Shear DBE + Shear RRblowdown
Shear = 1208.00 + 17.20 = 1225.20 Kips

Maximum Tension Stress = 2.328 - 2352.046 = -2354.374 psi

Prepared By:	T. J. Behringer	Date:	6/30/94
Reviewed By:	J. A. Dawn	Date:	6/30/94
Approved By:	J. D. Williams	Date:	6/30/94

Free Body Diagram Of Forces On Core Shroud For Limit Load Calculations - Dresden

(1) DL (Kips)	DL (Kips)	(5) DBEvert. (Kips)	Buoyancy (Kips)	(2) MSLOCA (Kips)	(3) RRLOCA (Kips)		Shear RRLOCA Blowdown (Kips)	Moment RRLOCA Blowdown (In-Kips)	Shear RRLOCA Acoustic (Kips)	Moment RRLOCA Acoustic (In-Kips)	Shear DBEhorz. (Kips)	Moment DBEhorz. (In-Kips)
219.87	219.87	-29.31	-27.29	-439.72	-256.50	H1	N/A	N/A	N/A	N/A	50.00	6.480E+03
28.87	248.74	-33.16	-30.86	Note 4	Note 4	H2	N/A	N/A	N/A	N/A	372.00	1.356E+04
1.40	250.14	-33.34	-31.05	Note 4	Note 4	H3	N/A	N/A	N/A	N/A	372.00	1.444E+0[illegible]
70.27	320.41	-42.71	-39.78	Note 4	Note 4	H4	N/A	N/A	175.00	5.621E+03	386.00	4.680E+04
93.29	413.70	-55.15	-51.36	Note 4	Note 4	H5	17.20	1.061E+03	175.00	1.879E+04	654.00	8.020E+04
1.91	415.61	-55.40	-51.59	N/A	N/A	H6	17.20	1.130E+03	175.00	1.949E+04	654.00	8.280E+04
18.97	434.58	-57.93	-53.95	N/A	N/A	H7	17.20	2.087E+03	175.00	2.923E+04	732.00	1.206E+05



Fixed Base

Notes:

1. DL includes the weight of the shroud head, separators and top guide applied at H1
2. Dp for Dresden=12 psi, Dp for QC=20 psi, values shown are Dresden
3. Dp for Dresden=7 psi, Dp for QC=8 psi,values shown are Dresden
4. Force is applied at the head and is constant from H1 through H5
5. SSE Vertical= Weight x 0.16g (QC), Weight x 0.133g (Dresden)

Sign Convention:

(+) is down (compression on H5)

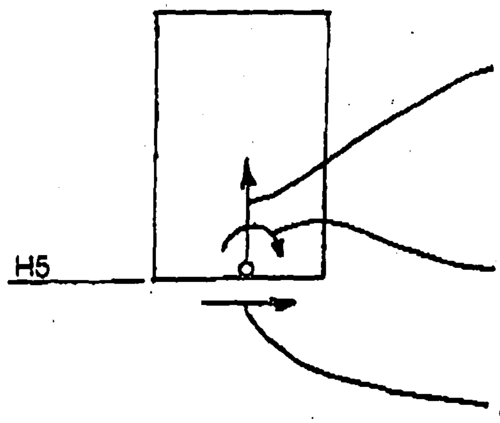
(-) is upward (tension on H5)

Prepared By: T. J. Behringer Date: 6/30/94

Reviewed By: J. A. Dawn Date: 6/30/94

Approved By: J. D. Williams Date: 6/30/94

A. For DBE + Main Steam LOCA



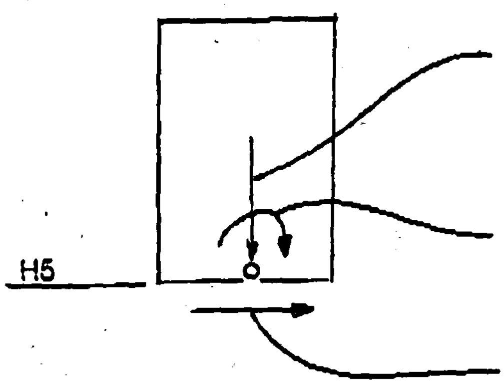
F = DL+B+DBE+MSloca
F= 413.70 - 51.36 - 55.15 - 439.72
F= -132.53 Kips
Pm= F/Area= -102.832 psi

Moment DBE= 8.020E+04 in.-Kip
Pb=Mc/I= -1213.38 psi

Shear DBE = 654.00 Kips

Maximum Tension Stress = -102.832 - 1213.38 = -1316.212 psi

B. For DBE + Reactor Recirculation LOCA (Blowdown)



F = DL+B+DBE+RRloca
F= 413.70 - 51.36 - 55.15 - 256.50
F= -50.69 Kips
Pm= F/Area= -39.331 psi

Moment = Moment DBE + Moment RRblowdown
Moment=8.020E+04 + 1.061E+03=8.126E+04 in.-Kip
Pb=Mc/I= -1229.350 psi

Shear = Shear DBE + Shear RRblowdown
Shear = 654.00 + 17.20 = 671.20 Kips

Maximum Tension Stress = -39.331 - 1229.350 = -1268.681 psi

Prepared By:	T. J. Behringer	Date:	6/30/94
Reviewed By:	J. A. Dawn	Date:	6/30/94
Approved By:	J. D. Williams	Date:	6/30/94

Quad Cities Unit 1 Shroud Weld H5 Limit Load Evaluation for MSLOCA

NOTE: Inputs are highlighted in the output below.

Case #2: The neutral axis is located such that $\alpha + \beta > \pi$ (this is checked below)

$$\beta = \frac{(1 - d/t - P_m{*}SF/\sigma_f)\pi}{2 - d/t}$$

(Reference: "Engineering Methods for the Assessment of Ductile Fracture Margin in Nuclear Power Plant Piping," S. Ranganath and H.S. Mehta, 1983.)

$$P_b' = (2{*}\sigma_f/\pi) * (2 - d/t) \sin\beta$$

Given:

P_m =	278	psi	
P_b =	2,337	psi	
Safety Factor, SF =	1.4	(for Faulted conditions = limiting per Screening Criteria)	
P_m*SF =	389	psi	
P_b*SF =	3,272	psi	
S_m =	16,900	psi (at 550°F for 304 SS)	
$3S_m$ =	50,700	psi = σ_f	
α =	180	° =	3.141592654 radians

Thus:

β = (3.117476128 - 3.141592654 d/t) / (2 - d/t) [1]

P_b' = 32276.62246 * (2 - d/t) sinβ [2]

Solving by trial and error:

d/t	β from [1] (radians)	P_b' from [2] (psi)	Difference = P_b' - P_b*SF	β (°)	α + β > π ?
0.1000	1.4754	61,047	57,775	84.5	YES
0.2000	1.3829	57,075	53,803	79.2	YES
0.3000	1.2784	52,557	49,285	73.3	YES
0.4000	1.1630	47,408	44,136	66.6	YES
0.5000	1.0311	41,534	38,262	59.1	YES
0.6000	0.8804	34,838	31,566	50.4	YES
0.7000	0.7064	27,237	23,965	40.5	YES
0.8000	0.5035	18,688	15,416	28.8	YES
0.9000	0.2637	9,253	5,982	15.1	YES
0.9100	0.2373	8,269	4,998	13.6	YES
0.9200	0.2104	7,280	4,008	12.1	YES
0.9300	0.1830	6,284	3,013	10.5	YES
0.9400	0.1551	5,284	2,013	8.9	YES
0.9500	0.1266	4,280	1,008	7.3	YES
0.9600	0.0976	3,272	1	5.6	YES
0.9601	0.0973	3,262	-9	5.6	YES
0.9602	0.0971	3,252	-20	5.6	YES

Minimum Required Ligament = 0.12 inches

Quad Cities Unit 1 Shroud Weld H5 Limit Load Evaluation for RRLOCA

NOTE: Inputs are highlighted in the output below.

Case #2: The neutral axis is located such that $\alpha + \beta > \pi$ (this is checked below)

$$\beta = \frac{(1 - d/t - P_m{*}SF/\sigma_f)\pi}{2 - d/t}$$

(Reference: "Engineering Methods for the Assessment of Ductile Fracture Margin in Nuclear Power Plant Piping," S. Ranganath and H.S. Mehta, 1983.)

$$P_b' = (2{*}\sigma_f/\pi) * (2 - d/t) \sin\beta$$

Given:

P_m =	0	psi	
P_b =	2,620	psi	2620
Safety Factor, SF =	1.4	(for Faulted conditions = limiting per Screening Criteria)	
P_m*SF =	0	psi	
P_b*SF =	3,668	psi	
S_m =	16,900	psi (at 550°F for 304 SS)	
$3S_m$ =	50,700	psi = σ_f	
α =	180	° =	3.141592654 radians

Thus:

β = (3.141592654 - 3.141592654 d/t) / (2 - d/t) [1]

P_b' = 32276.62246 * (2 - d/t) sinβ [2]

Solving by trial and error:

d/t	β from [1] (radians)	P_b' from [2] (psi)	Difference = $P_b' - P_b$*SF	β (°)	$\alpha + \beta > \pi$?
0.1000	1.4881	61,116	57,448	85.3	YES
0.2000	1.3963	57,215	53,547	80.0	YES
0.3000	1.2936	52,776	49,108	74.1	YES
0.4000	1.1781	47,712	44,044	67.5	YES
0.5000	1.0472	41,929	38,261	60.0	YES
0.6000	0.8976	35,329	31,661	51.4	YES
0.7000	0.7250	27,824	24,156	41.5	YES
0.8000	0.5236	19,366	15,698	30.0	YES
0.9000	0.2856	10,003	6,335	16.4	YES
0.9100	0.2594	9,024	5,356	14.9	YES
0.9200	0.2327	8,039	4,371	13.3	YES
0.9300	0.2055	7,048	3,380	11.8	YES
0.9400	0.1778	6,052	2,384	10.2	YES
0.9500	0.1496	5,051	1,383	8.6	YES
0.9600	0.1208	4,046	378	6.9	YES
0.9637	0.1100	3,673	5	6.3	YES
0.963[illegible]	0.1098	3,663	-5	6.3	YES

Minimum Required Ligament = 0.11 inches

Quad Cities Core Shroud Summary of Loads and Stresses At Each Horizontal Weld Location COMED Design Review Revision 1

Shroud Weld Designation	Combined Stresses DL+B+U+OBE (Psi) Compression	Combined Stresses DL+B+U+OBE (Psi) Tension	Combined Stresses DL+B+F MS LOCA (Psi)	Combined Stresses DL+B+SSE (Psi) Compression	Combined Stresses DL+B+SSE (Psi) Tension	Combined Stresses DL+B+F+SSE MS LOCA (Psi) Compression	Combined Stresses DL+B+F+SSE MS LOCA (Psi) Tension
H1	-16.748	-155.785	-394.452	253.947	-24.126	-281.099	-559.172
H2	85.886	-224.870	-375.992	440.754	-180.757	-94.292	-715.803
H3	114.614	-260.596	-398.650	514.149	-236.271	-54.494	-804.914
H4	622.481	-681.677	-350.895	1482.128	-1126.187	913.485	-1694.830
H5	1196.003	-1139.982	-287.496	2565.773	-2106.198	1997.130	-2674.840
H6	1309.596	-1249.421	N/A	2796.965	-2321.069	N/A	N/A
H7	1858.550	-1774.226	N/A	3881.584	-3383.966	N/A	N/A
H8	1737.728	-1662.773	N/A	3621.664	-3179.337	N/A	N/A

References: GE-NE-523-02-0194 QC-1 Evaluation and Screening Criteria for H5 Weld
GE-NE-523-A79-0594 QC-1 Evaluation of the Indications for H5 Weld

Symbols: DL= Dead Loads
B= Buoyancy Forces
U= Upset Loads Due To A 8 psi Dp
F= Faulted Loads Due To A 20 psi Dp (MS LOCA)
RR LOCA= Lateral Loads And Induced Bending Due To A RR Line Break

Inputs: Vertical OBE = 0.08g
Vertical DBE = 0.16g
Density Water= 0.036
Density Shroud= 0.290

Shroud Head Area = 36643.54 In.^2

Prepared By: T. J. Behringer *T J Behringer* Date: 6/30/94

Reviewed By: J. A. Dawn *J. Dawn* Date: 6/30/94

Approved By: J. D. Williams *J D Williams* Date: 6/30/94

Quad Cities Core Shroud Summary of Loads and Stresses At Each Horizontal Weld Location COMED Design Review Revision 1

Shroud Weld Designation	Combined Stresses DL+B+F+SSE RR LOCA Blowdown (Psi) Compression	Combined Stresses DL+B+F+SSE RR LOCA Blowdown (Psi) Tension	Combined Stresses DL+B+F+SSE RR LOCA Accoustic (Psi) Compression	Combined Stresses DL+B+F+SSE RR LOCA Accoustic (Psi) Tension
H1	39.928	-238.144	39.928	-238.144
H2	226.736	-394.775	226.736	-394.775
H3	286.692	-463.728	286.692	-463.728
H4	1254.671	-1353.644	1254.671	-1353.644
H5	2354.372	-2349.711	2622.608	-2617.946
H6	N/A	N/A	N/A	N/A
H7	N/A	N/A	N/A	N/A
H8	N/A	N/A	N/A	N/A

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Quad Cities Core Shroud Summary of Loads and Stresses At Each Horizontal Weld Location COMED Design Review

Revision 1

Shroud Weld Designation	Weld Elevation (inches)	Shroud Outside Radius (in.)	Shroud Inside Radius (in.)	Shroud Thickness (in.)	Shroud Area (in.^2)	Shroud Centerline Section Modulus (in.^3)
H1	391.375	110.000	108.000	2.000	1369.734	7.466E+04
H2	357.875	110.000	108.000	2.000	1369.734	7.466E+04
H3	356.375	103.560	101.560	2.000	1288.807	6.610E+04
H4	266.375	103.560	101.560	2.000	1288.807	6.610E+04
H5	191.125	103.560	101.560	2.000	1288.807	6.610E+04
H6	187.125	100.500	98.500	2.000	1250.354	6.221E+04
H7	131.500	100.500	98.500	2.000	1250.354	6.221E+04
H8	120.531	100.625	98.375	2.250	1406.648	6.999E+04

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Quad Cities Core Shroud Summary of Loads and Stresses At Each Horizontal Weld Location COMED Design Review Revision 1

Shroud Weld Designation	OBE Moment (In-Kips)	DBE Moment (In-Kips)	RR LOCA Moment Blowdown (In-Kips)	RR LOCA Moment Accoustic (In-Kips)	Shear OBE (Kips)	Shroud Weight (Kips)	Buoyant Force (Kips)	Vertical OBE Uplift (Kips)	Vertical DBE Uplift (Kips)	Effective Weight OBE (Kips)	Effective Weight DBE (Kips)
H1	5.190E+03	1.038E+04	N/A	N/A	43.00	219.87	-27.29	-17.59	-35.18	174.99	157.40
H2	1.160E+04	2.320E+04	N/A	N/A	338.00	248.74	-30.88	-19.90	-39.80	197.96	178.06
H3	1.240E+04	2.480E+04	N/A	N/A	338.00	250.14	-31.05	-20.01	-40.02	199.08	179.07
H4	4.310E+04	8.620E+04	N/A	N/A	415.00	320.41	-39.78	-25.63	-51.27	255.00	229.37
H5	7.720E+04	1.544E+05	1.061E+03	1.879E+04	604.00	413.70	-51.36	-33.10	-66.19	329.25	296.15
H6	7.960E+04	1.592E+05	1.130E+03	1.949E+04	604.00	415.61	-51.59	-33.25	-66.50	330.77	297.52
H7	1.130E+05	2.260E+05	2.087E+03	2.923E+04	592.00	434.58	-53.95	-34.77	-69.53	345.87	311.10
H8	1.190E+05	2.380E+05	2.275E+03	3.114E+04	592.00	434.58	-53.95	-34.77	-69.53	345.87	311.10

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Quad Cities Core Shroud Summary of Loads and Stresses At Each Horizontal Weld Location COMED Design Review Revision 1

Shroud Weld Designation	Horizontal Bending OBE Pbs (Psi)	Horizontal Bending DBE Pbs (Psi)	Dead Load Stresses Pmd (Psi)	Buoyancy Stresses Pmb (Psi)	Vertical OBE Stresses (Psi)	Vertical DBE Stresses (Psi)	Upset & Normal(8Psi) Pressure Stresses Pm (Psi)	MS LOCA Faulted(20Psi) Pressure Stresses Pm (Psi)	RRLOCA Bending Stresses Blowdown Pbrl1 (Psi)	RRLOCA Bending Stresses Accoustic Pbrl2 (Psi)	Combined Stresses DL+B+N (Psi)
H1	69.52	139.04	160.520	-19.927	-12.842	-25.683	-214.018	-535.046	N/A	N/A	-73.425
H2	155.38	310.76	181.597	-22.543	-14.528	-29.056	-214.018	-535.046	N/A	N/A	-54.964
H3	187.61	375.21	194.086	-24.093	-15.527	-31.054	-227.457	-568.643	N/A	N/A	-57.464
H4	652.08	1304.16	248.610	-30.862	-19.889	-39.778	-227.457	-568.643	N/A	N/A	-9.709
H5	1167.99	2335.99	320.995	-39.848	-25.680	-51.359	-227.457	-568.643	16.056	284.292	53.690
H6	1279.51	2559.02	332.394	-41.263	-26.592	-53.183	-234.452	N/A	18.165	313.297	56.679
H7	1816.39	3632.78	347.566	-43.146	-27.805	-55.610	-234.452	N/A	33.544	469.769	69.967
H8	1700.25	3400.50	308.947	-38.352	-24.716	-49.432	-208.402	N/A	32.511	444.988	62.193

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Dresden Core Shroud Summary of Loads and Stresses At Each Horizontal Weld Location COMED Design Review Revision 1

Shroud Weld Designation	Combined Stresses DL+B+N (Psi)	Combined Stresses DL+B+U+OBE (Psi) Compression	Combined Stresses DL+B+U+OBE (Psi) Tension	Combined Stresses DL+B+F MS LOCA (Psi)	Combined Stresses DL+B+SSE (Psi) Compression	Combined Stresses DL+B+SSE (Psi) Tension	Combined Stresses DL+B+F+SSE MS LOCA (Psi) Compression	Combined Stresses DL+B+F+SSE MS LOCA (Psi) Tension
H1	-46.673	-13.981	-100.778	-180.434	205.993	32.399	-115.034	-288.629
H2	-28.212	50.491	-131.140	-161.973	316.478	-46.784	-4.549	-367.811
H3	-29.032	67.257	-151.212	-171.193	362.590	-74.348	21.405	-415.533
H4	18.723	356.170	-351.888	-123.438	892.666	-523.450	551.480	-864.635
H5	82.122	667.402	-545.979	-60.039	1451.739	-975.023	1110.554	-1316.208
H6	85.985	729.288	-601.658	N/A	1577.769	-1084.123	N/A	N/A
H7	99.274	1045.367	-893.185	N/A	2196.641	-1680.463	N/A	N/A
H8	88.243	986.343	-851.070	N/A	2066.826	-1608.001	N/A	N/A

References: GE-NE-523-05-0194 Dre.-3 Evaluation and Screening Criteria for H5 Weld
GE-NE-523-A69-0594 Dre.-3 Evaluation of the Indications for the H5 Weld

Symbols: DL= Dead Loads
B= Buoyancy Forces
U= Upset Loads Due To A 7 psi Dp
F= Faulted Loads Due To A 12 psi Dp (MS LOCA)
RR LOCA= Lateral Loads And Induced Bending Due To A RR Line Break

Inputs: Vertical OBE = 0.0667g
Vertical DBE = 0.1333g
Density Water= 0.036
Density Shroud= 0.290

Shroud Head Area = 36643.54 In.^2

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Dresden Core Shroud Summary of Loads and Stresses At Each Horizontal Weld Location COMED Design Review Revision 1

Shroud Weld Designation	Combined Stresses DL+B+F+SSE RR LOCA Blowdown (Psi) Compression	Combined Stresses DL+B+F+SSE RR LOCA Blowdown (Psi) Tension	Combined Stresses DL+B+F+SSE RR LOCA Accoustic (Psi) Compression	Combined Stresses DL+B+F+SSE RR LOCA Accoustic (Psi) Tension
H1	18.727	-154.867	18.727	-154.867
H2	129.212	-234.050	129.212	-234.050
H3	163.565	-273.373	163.565	-273.373
H4	693.641	-722.475	693.641	-722.475
H5	1268.770	-1190.104	1537.006	-1458.339
H6	N/A	N/A	N/A	N/A
H7	N/A	N/A	N/A	N/A
H8	N/A	N/A	N/A	N/A

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Dresden Core Shroud Summary of Loads and Stresses At Each Horizontal Weld Location COMED Design Review
Revision 1

Shroud Weld Designation	Weld Elevation (Inches)	Shroud Outside Radius (In.)	Shroud Inside Radius (In.)	Shroud Thickness (In.)	Shroud Area (In.^2)	Shroud Centerline Section Modulus (In.^3)
H1	391.375	110.000	108.000	2.000	1369.734	7.466E+04
H2	357.875	110.000	108.000	2.000	1369.734	7.466E+04
H3	355.375	103.560	101.560	2.000	1288.807	6.610E+04
H4	266.375	103.560	101.560	2.000	1288.807	6.610E+04
H5	191.125	103.560	101.560	2.000	1288.807	6.610E+04
H6	187.125	100.500	98.500	2.000	1250.354	6.221E+04
H7	131.500	100.500	98.500	2.000	1250.354	6.221E+04
H8	120.531	100.625	98.375	2.250	1406.648	6.999E+04

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Dresden Core Shroud Summary of Loads and Stresses At Each Horizontal Weld Location COMED Design Review Revision 1

Shroud Weld Designation	OBE Moment (In-Kips)	DBE Moment (In-Kips)	RR LOCA Moment Blowdown (In-Kips)	RR LOCA Moment Accoustic (In-Kips)	Shear OBE (Kips)	Shroud Weight (Kips)	Buoyant Force (Kips)	Vertical OBE Uplift (Kips)	Vertical DBE Uplift (Kips)	Effective Weight OBE (Kips)	Effective Weight DBE (Kips)
H1	3.240E+03	6.480E+03	N/A	N/A	25.00	219.87	-27.29	-14.67	-29.31	177.91	163.27
H2	6.780E+03	1.356E+04	N/A	N/A	186.00	248.74	-30.88	-16.59	-33.16	201.27	184.70
H3	7.220E+03	1.444E+04	N/A	N/A	186.00	250.14	-31.05	-16.68	-33.34	202.40	185.74
H4	2.340E+04	4.680E+04	N/A	N/A	193.00	320.41	-39.78	-21.37	-42.71	259.26	237.92
H5	4.010E+04	8.020E+04	1.061E+03	1.879E+04	327.00	413.70	-51.36	-27.59	-55.15	334.75	307.20
H6	4.140E+04	8.280E+04	1.130E+03	1.949E+04	327.00	415.61	-51.59	-27.72	-55.40	336.30	308.62
H7	6.030E+04	1.206E+05	2.087E+03	2.923E+04	366.00	434.58	-53.95	-28.99	-57.93	351.65	322.70
H8	6.430E+04	1.286E+05	2.275E+03	3.114E+04	366.00	434.58	-53.95	-28.99	-57.93	351.65	322.70

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Shroud Weld Designation	Horizontal Bending OBE Pbs (Psi)	Horizontal Bending DBE Pbs (Psi)	Dead Load Stresses Pmd (Psi)	Buoyancy Stresses Pmb (Psi)	Vertical OBE Stresses (Psi)	Vertical DBE Stresses (Psi)	Upset & Normal(7Psi) Pressure Stresses Pm (Psi)	MS LOCA Faulted(12Psi) Pressure Stresses Pm (Psi)	RRLOCA Bending Stresses Blowdown Pbrrl1 (Psi)	RRLOCA Bending Stresses Accoustic Pbrrl2 (Psi)
H1	43.40	86.80	160.520	-19.927	-10.707	-21.397	-187.266	-321.028	N/A	N/A
H2	90.82	181.63	181.597	-22.543	-12.113	-24.207	-187.266	-321.028	N/A	N/A
H3	109.23	218.47	194.086	-24.093	-12.946	-25.872	-199.025	-341.186	N/A	N/A
H4	354.03	708.06	248.610	-30.862	-16.582	-33.140	-199.025	-341.186	N/A	N/A
H5	606.69	1213.38	320.995	-39.848	-21.410	-42.789	-199.025	-341.186	16.056	284.292
H6	665.47	1330.95	332.394	-41.263	-22.171	-44.308	-205.146	N/A	18.165	313.297
H7	969.28	1938.55	347.566	-43.146	-23.183	-46.330	-205.146	N/A	33.544	469.769
H8	918.71	1837.41	308.947	-38.352	-20.607	-41.183	-182.352	N/A	32.511	444.988

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RR LOCA Allowable Force Calculation

PURPOSE: This calculation determines the allowable reactor recirculation LOCA blowdown force. This force is determined based on the maximum stress that the given ligament can tolerate.

Initial Flaw Depth =	1.24	inches
Crack Growth Rate =	5.00E-05	inch/hour
Δa =	0.1	inch/ 3 months
Section Thickness =	3.00	inches
Section Modulus =	6.610E+04	inches3
Lever Arm =	61.7	inches

Operating Period (months)	Crack Growth (inches)	Crack Depth, a (inches)	Remaining Ligament (inches)	a/t	$P_{b(allow)}$ (psi)	Allowable Force (kips)	Factor Of Safety Compared To The Calculated Force=17.2 Kips
0	0.0	1.24	1.76	0.4133	33,562	35,955	2090
3	0.1	1.34	1.66	0.4467	32,219	34,518	2007
6	0.2	1.44	1.56	0.4800	30,820	33,018	1920
9	0.3	1.54	1.46	0.5133	29,357	31,450	1829
12	0.4	1.64	1.36	0.5467	27,824	29,808	1733
15	0.5	1.74	1.26	0.5800	26,228	28,098	1634
18	0.6	1.84	1.16	0.6133	24,561	26,312	1530
21	0.7	1.94	1.06	0.6467	22,815	24,442	1421
24	0.8	2.04	0.96	0.6800	21,001	22,498	1308
27	0.9	2.14	0.86	0.7133	19,111	20,474	1190
30	1.0	2.24	0.76	0.7467	17,138	18,360	1067
33	1.1	2.34	0.66	0.7800	15,095	16,171	940
36	1.2	2.44	0.56	0.8133	12,978	13,903	808
39	1.3	2.54	0.46	0.8467	10,783	11,552	672
42	1.4	2.64	0.36	0.8800	8,528	9,136	531
45	1.5	2.74	0.26	0.9133	6,214	6,657	387
48	1.6	2.84	0.16	0.9467	3,844	4,118	239

NOTE: Crack Growth is based on the crack growth rate identified above and assumes 8,000 hours per year.
Crack Depth is the sum of the initial crack depth and the crack growth.
Remaining Ligament is the section thickness identified above less the crack depth.
a/t is the crack depth divided by the section thickness.
$P_{b(allow)}$ is the maximum allowable bending stress computed by limit load techniques for the given remaining ligament size.

NOTE: P_m at this location is compressive as a result of deadweight, bouyancy and pressure loads; therefore, a value of 0 psi was conservatively used.

Allowable Force is $P_{b(allow)}$*Section Modulus/Lever Arm.
Section Modulus is computed for the H5 weld location and does not include the fillet weld.
Lever Arm is the distance between the H5 weld and the point of load application for the RR LOCA force.

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