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ROBERT C. MECREDY
Vice President
Nuclear Operations

December 31, 2001

United States Nuclear Regulatory Commission
Document Control Desk
Attention: Robert L. Clark
Project Directorate I
Washington, DC 20555-0001

Subject: Supplemental Response to NRC Bulletin 2001-01, Subject: *Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles*
R. E. Ginna Nuclear Power Plant
Docket No. 50-244

References: (1) Letter from R.C. Mecredy, RG&E, to R.L. Clark, NRC, Subject: *Response to NRC Bulletin 2001-01*, dated September 4, 2001.
(2) Letter from R.L. Clark, NRC, to R.C. Mecredy, RG&E, Subject: *R.E. Ginna Nuclear Power Plant Telephone Conference Summary, Re: Responses to Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles" (TAC No. MB2632)*, dated October 29, 2001.
(3) Public Meeting with NRC Staff, Rockville, MD, December 12, 2001.

Dear Mr. Clark:

On August 3, 2001, the Nuclear Regulatory Commission issued the referenced Bulletin requesting that all addressees provide to the NRC a written response within 30 days in accordance with the provisions of 10 CFR 50.54(f) with respect to the structural integrity of their reactor pressure vessel head penetration (VHP) nozzles. Specifically, the Bulletin requested information concerning the extent of VHP nozzle leakage and cracking that has been found to date, the inspections and repairs that have been undertaken to satisfy applicable regulatory requirements, and future inspection plans. For those plants considered to have a moderate susceptibility ranking to this phenomenon (such as Ginna Station), the Bulletin stated that the plants should perform an effective visual examination of the reactor vessel head at the next scheduled refueling outage or provide a basis for concluding that plans for future inspections will ensure compliance with applicable regulatory requirements.

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RG&E provided an initial response with respect to Ginna Station in a letter dated September 4, 2001 (Reference 1). Within this letter, RG&E provided a summary of the inspections performed to date, including an inspection during the 1999 refueling outage (RFO) in which all VHP nozzles were inspected using Eddy Current techniques. RG&E also stated that it was pursuing a replacement of the reactor vessel head during the Fall 2003 RFO. Based on the 1999 RFO inspection and the replacement option, RG&E indicated that a decision to perform an effective visual inspection of the reactor head during the March 2002 RFO had not been reached pending further analysis. However, a final decision on inspection would be submitted by December 31, 2001.

Subsequent to the September 4, 2001 RG&E letter, a conference call was held with NRC Staff concerning our response (Reference 2). During this call, the NRC requested that a meeting be held to facilitate their understanding of our technical basis for deferring any inspections during the March 2002 RFO.

The requested meeting was held on December 12, 2001 (Reference 3). During this meeting, RG&E made several presentations, providing technical details related to the 1999 RFO inspection, evaluation of the actual reactor vessel head temperature, crack growth rate analysis, probabilistic safety analysis (PSA) insights, and the status of the reactor vessel head replacement project. These presentations were made specifically with respect to Ginna Station and resulted in substantive discussions and interactions with the Staff.

Accordingly, the purpose of this letter is to summarize the technical basis for RG&E's determination that it need not perform a qualified visual inspection of the reactor head during the March 2002 RFO. The bases for this determination are as follows:

1. RG&E performed an Eddy Current examination of all 38 VHPs (including the CRDMs, instrumentation ports, and head vent) during the 1999 RFO. A complete description of the inspection techniques and results was presented at the public meeting on December 12, 2001 (Reference 3). Important highlights of this inspection include:
    a. The inspection examined the internal nozzle surface within ± 2 inches of the weld area. Within this inspection area, 93% of the surface area was examined (thermal sleeve interferences prohibited a complete inspection). For the 8 penetrations in which 100% inspection could not be achieved, the uninspected areas occurred in regions of lower applied stress intensity factor (i.e., the uphill weld areas - see Enclosure 1). This is discussed further in Item 2 below.
    b. The inspection was performed using personnel and techniques with extensive experience from European plants. Prior to performance of the inspection, the techniques and personnel were evaluated using an EPRI blind performance test to confirm that cracking could be detected. Also, all inspections required online review by an RG&E NDE Level III technician.
    c. No cracking within the inspection area was detected. While one penetration showed shallow craze type indications, subsequent inspection with an ultrasonic probe showed that the indications were below the minimum detection capability of the probe (< 0.8 mm). They also only covered approximately 5% of the surface area of the affected penetration.

d. Subsequent review of the 1999 RFO inspection data following the announcement of the Oconee cracks resulted in no change to the inspection findings. Also, mockups of tubing containing OD initiated cracks showed that the Eddy Current equipment could detect flaws at a 0.042" subsurface.

2. Using the 1999 RFO inspections as a starting point, RG&E contracted Structural Integrity to perform a crack growth analysis for the Ginna Station VHPs. These analyses are provided in Enclosure 2. Specific highlights of these analyses include:

   a. The most severe location from the point of view of applied stress intensity factor is a downhill side flaw on the nozzles with a 43.5 degree angle to the head (i.e., the outermost radius). This is due to the fact that the Ginna Station weld design contains more weld metal in the downhill section than the uphill section. A 100% internal surface examination was achieved on these penetrations during the 1999 RFO.

   b. Two crack growth analyses were performed for these limiting nozzles. The first analysis assumes an initial circumferential throughwall crack of 90 degrees. This bounds most of the cracks observed within the industry to date which may not have been detected in 1999 (i.e., not throughwall). The second analysis assumes an initial circumferential throughwall crack of 180 degrees which bounds the uninspected areas from the 1999 RFO inspections (i.e., 166 degrees - see Enclosure 1). These analyses indicate a throughwall crack growth to the code allowable 300 degrees circumference at 88,500 hours (10.1 EFPY) and 48,000 hours (5.48 EFPY), respectively. These are beyond the projected 4.16 EFPY until the September 2003 RFO.

3. RG&E has reviewed information with respect to the expected temperatures within the Reactor vessel head. Based on installed thermocouples and information presented in WCAP-9404, *Study of Reactor Vessel Upper Head Region Fluid Temperature*, RG&E believes that the temperature of 580°F as used in the susceptibility model is conservatively high by up to 5°F. While the reduction in temperature used in the susceptibility models would not push Ginna Station beyond the 30 EFPY threshold for moderately susceptible plants, it does provide additional margin to the Oconee conditions. RG&E has confirmed with Westinghouse that this WCAP was previously submitted to the NRC as proprietary information.

4. RG&E has contracted with B&W Canada to procure a new reactor vessel head. The purchase order for the forging of the new head has been issued with the head scheduled for replacement during the September 2003 RFO. RG&E plans to use the March 2002 RFO to obtain additional information necessary to support the vessel head replacement in the subsequent outage (e.g., optical templating).

5. Based on the information provided above, RG&E believes there is a technical basis for concluding that a circumferential throughwall crack did not exist as of the 1999 RFO inspection. If a throughwall crack had been initiated following this inspection, it would not grow beyond code allowable length prior to the September 2003 RFO. As an additional measure to effectively manage any potential risk with deferring an inspection, RG&E has reviewed the risk insights with respect to a VHP LOCA using the Ginna Station PSA. Specific details related to this review are presented in Enclosure 3. In support of this information, RG&E is also committing to the following:
   a. During the first training cycle following the startup from the March 2002 RFO, licensed operators will be trained on the highest risk sequences for a postulated VHP LOCA. This will be completed by June 30, 2002.
   b. RG&E will submit the most recent revision of the Ginna Station PSA to the NRC by February 1, 2002.

In summary, based on the analyses described within this submittal, RG&E has concluded that a technical basis exists for not performing an additional inspection of the VHPs at Ginna Station during the March 2002 RFO. RG&E plans to install a new reactor vessel head during the subsequent RFO in September 2003. No further action is being requested by the NRC. However, if additional information is required from RG&E, please contact us as soon as possible. Any deviation from our current proposed course of action after February 1, 2002 will have significant impacts on outage schedule and the ability to obtain equipment and personnel to support an inspection.

Very truly yours,

Robert C. Mecredy

Sworn and subscribed before me
on December 31, 2001

Michalene A. Bunts

Notary Public

MICHALENE A BUNTS
Notary Public, State of New York
Registration No. 01BU6018576
Monroe County
Commission Expires Jan 11, 2003

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Enclosures 1 - 3

xc: Mr. Robert L. Clark (Mail Stop O-8-E9)
Project Directorate I
Division of Licensing Project Management
Office of Nuclear Regulatory Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Regional Administrator, Region I
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475 Allendale Road
King of Prussia, PA 19406

U.S. NRC Ginna Senior Resident Inspector

ENCLOSURE 1

ILLUSTRATION OF UNINSPECTED VHPs DURING 1999 RFO

GINNA - CRDM INSPECTION USING AN EDDY CURRENT BLADE PROBE

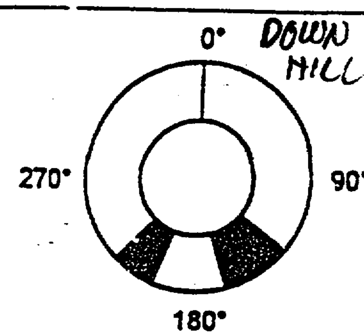
99-0499

DARK AREAS NOT INSPECTED DUE TO ANNULUS RESTRICTION

Adapter 26

128-164° , 0-226 mm
202-224° , 0-226 mm

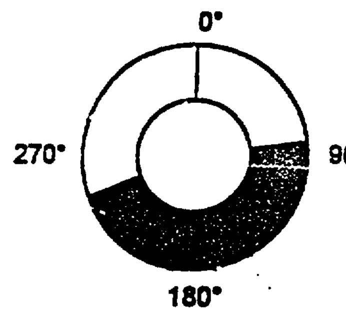
Retest complete



Adapter 27

82-248° , 0-226 mm

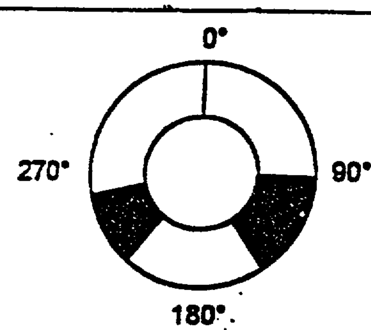
Retest 160-200°



Adapter 28

92-146° , 0-226 mm
220-258° , 0-226 mm

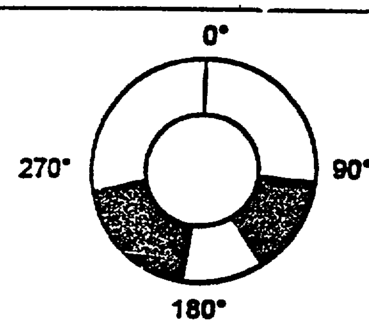
Retest complete



Adapter 29

96-146° , 0-226 mm
188-258° , 0-226 mm

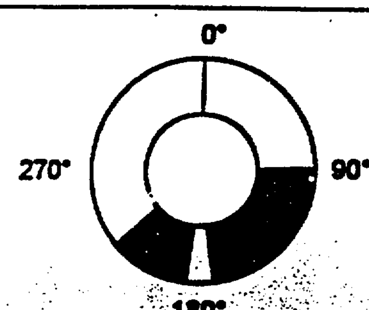
Retest complete



Adapter 30

88-172° , 0-226 mm
186-228° , 0-226 mm

Retest complete



5 . 2004 AIR 99-0499 DISPOSITION ATTACHMENT 3 PG 2 OF 2.

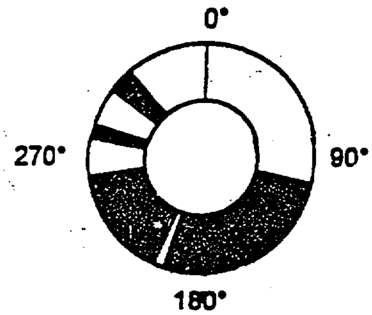
GINNA - CRDM INSPECTION USING AN EDDY CURRENT BLADE PROBE

99-0499

Adapter 31

102-198° , 0-226 mm
204-260° , 0-226 mm
280-286° , 0-226 mm
306-318° , 0-226 mm

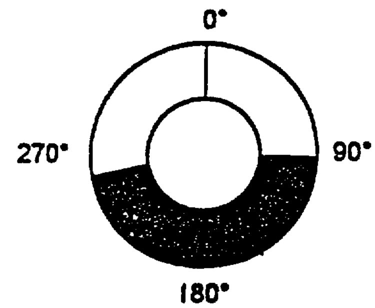
Retest complete



Adapter 32

92-258° , 0-226 mm

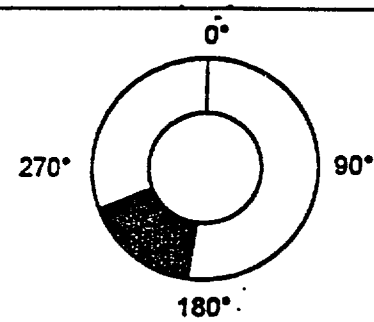
Retest 160-200°



Adapter 33

188-248° , 0-226 mm

Retest complete



PENETRATION 34, 35, 36 + 37 WERE COMPLETELY INSPECTED FOR THE FULL 360°.

NOTE THE WORD ADAPTER = PENETRATION FOR DISCUSSION PURPOSES.

AJB. 4-14-99
RGP 4/14/99

ENCLOSURE 2

STRUCTURAL INTEGRITY (SI) & DOMINION ENGINEERING CALCULATIONS

1. SI, W-RGE-13Q-307, Revision 0, Development of PWSCC Crack Growth Correlation for Ginna Operating Temperature
2. SI, W-RGE-13Q-308, Revision 0, Limiting Crack Growth to Allowable Flaw Size
3. SI, W-RGE-13Q-309, Revision 0, CRDM Allowable and Critical Circumferential Flaw Sizes (GINNA)
4. Dominion Engineering, C-7612-00-1, Revision 0, Ginna CRDM Stress Analysis

STRUCTURAL INTEGRITY Associates, Inc.	# CALCULATION PACKAGE	FILE No.: W-RGE-13Q-307 PROJECT No.: W-RGE-13Q

PROJECT NAME: Top Head Cracking Support

CLIENT: Rochester Gas & Electric/Ginna Nuclear Station

CALCULATION TITLE: Development of a PWSCC Crack Growth Correlation for Ginna Operating Temperature

Document Revision	Affected Pages	Revision Description	Project Mgr. Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1-5	Original Issue VENDOR DESIGN ANALYSIS REVIEW ☐ Approved - No Memorandum Required ☑ Approved - Memorandum Attached ☐ Not Approved - Vendor Notified Approval of this design analysis does not relieve supplier from full compliance with contract or purchase order requirements. Approved By [signature] Date 12/27/01 NS&L Review By NO IBLR (N/A) Date 12/27/01 (Required if impact on COLR Values) ROCHESTER GAS & ELECTRIC CORP. ROCHESTER, NY	H. L. Gustin [signature] 12/19/01	H. L. Gustin 12/19/01 [signature] 12/19/01 P. C. Riccardella 12/19/01 [signature] 12/19/01

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1.0 INTRODUCTION / STATEMENT OF PROBLEM / OBJECTIVE

The purpose of the present calculation is to develop a PWSCC crack growth correlation corresponding to the MRP 95th percentile correlation, but adjusted to a reference temperature of 580° F. The MRP correlation is standardized to 617° F. The developed correlation will be used for crack growth calculations for Ginna Nuclear Power Plant CRDM penetrations. The Ginna head temperature is 580° F, and it is recognized that temperature has a strong effect on crack growth rate.

2.0 TECHNICAL APPROACH OR METHODOLOGY

2.2 MRP Correlations

The referenced presentation [1, page 44] gives the MRP mean crack growth correlation at 325° C (617° F) as:

$$da/dt \text{ (in units of m/s)} = 2.50 \times 10^{-12} (K-9)^{1.11}$$

By comparing the MRP mean and 95% confidence curves on page 44 of [1], at, e.g., K = 40 MPa√(m), it is estimated that
the 95% MRP curve is approximately a multiple of 3.33 times the mean MRP curve. That is,

$$(da/dt)_{95} \cong 3.33 \times (da/dt)_{Mean}$$

or

$$(da/dt)_{95} \cong 8.33 \times 10^{-12} (K-9)^{1.11} \text{ (units of m/s) @ 325°C}$$

Converting these correlations to English units gives:

$$(da/dt)_{Mean\ English} = 3.933 \times 10^{-7} (K-8.188)^{1.11} \text{ (units of inch/hour at 617° F)}$$

Using the same scale factor (3.33) as above for the 95% correlation gives:

$$(da/dt)_{95\ English} = 1.31 \times 10^{-6} (K-8.188)^{1.11} \text{ inch/hour at 617°F}$$

2.2 Temperature Adjustment Factor

To adjust the above correlations to 580° F, the following temperature adjustment factor is used, consistent with MRP methodology:

$$A = e^{(Qg/Rgas)*((1/Ttest)-(1/Tref))}$$

where

Qg= activation energy= 31.05 kcal/mol

Rgas= ideal gas constant= 1.103 x 10-3 kcal/mol-°R

Ttest = the MRP temperature in °Rankine = 617 +459.67 = 1076.67 °R

Tref = the Ginna temperature in °Rankine = 580 + 459.67 = 1039.67 °R

Substituting gives:

$A = 0.395$

This value is used to adjust the 617° F MRP crack growth correlations for 580° F applicability.

The adjusted correlations are

$$(da/dt)_{95\ English}\ @580°F = A*(da/dt)_{95\ English}\ @617°F = 5.17 \times 10^{-07}\ (K-8.188)^{1.11} \text{ in inch/hour}$$

or

$$(da/dt)_{95\ metric}\ @580°F = A*\ (da/dt)_{95\ metric} = 3.287 \times 10^{-12}\ (K-9)^{1.11} \text{ in m/s}$$

This correlation is appropriate for use in flaw growth calculations for Ginna.

3.0 REFERENCES

1. MRP/EPRI, "MRP Alloy 600/82/182 Status Update", presented to the NRC on November 27, 2001.

STRUCTURAL INTEGRITY Associates, Inc.	CALCULATION PACKAGE	FILE No.: W-RGE-13Q-308 PROJECT No.: W-RGE-13Q

PROJECT NAME: Top Head CRDM Cracking Support

CLIENT: Rochester Gas & Electric Corp. for Ginna Nuclear Station

CALCULATION TITLE: Limiting Crack Growth to Allowable Flaw Size

Document Revision	Affected Pages	Revision Description	Project Mgr. Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1-7 appendices A (1-7) B (1-7) C (1-6) D (1-6) Files on Project CDROM	Original Issue VENDOR DESIGN ANALYSIS REVIEW [ ] Approved - No Memorandum Required [X] Approved - Memorandum Attached [ ] Not Approved - Vendor Notified Approval of this design analysis does not relieve supplier from full compliance with contract or purchase order requirements. Approved By: [signature] Date 12/21/01 NS&L Review By: RJG no COLR impact Date 12/27/01 (Required if impact on COLR Values) ROCHESTER GAS & ELECTRIC CORP. ROCHESTER, NY	H. L. Gustin [signature] 12/20/01	H. L. Gustin [signature] 12/20/01 Gary L. Stevens [signature] 12/20/01

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1.0 PURPOSE

Previous calculations have developed a crack growth correlation applicable to the Ginna CRDM penetrations [1], and have documented finite element analyses that developed K vs a results for CRDM nozzles at various locations in the Ginna top head [2,3,4]. Allowable and critical flaw size calculations [5] were performed to demonstrate the flaw tolerance of the limiting nozzles in the presence of very conservative hypothetical throughwall circumferentially oriented flaws.

The purpose of the present calculation is to apply the above results in predicting the time that would be required for the hypothetical flaws to grow to the allowable size, under the limiting conditions. The life prediction resulting from these calculations is compared to the time from the inspections performed on the Ginna penetrations (Spring 1999) to the anticipated head replacement in the fall of 2003.

2.0 METHODOLOGY

In order to conservatively assess the remaining life of Ginna CRDM components in the absence of near term NDE of each penetration, the following fracture mechanics based crack growth calculations were performed. The assumptions used in these calculations were:

1. Although there are no known circumferential flaws in any Ginna penetration, and no ID surface connected indications of any orientation were reported as a result of the 100% eddy current examination performed in the spring of 1999, a hypothetical throughwall circumferentially oriented flaw was assumed as the starting point for crack growth calculations. Two cases were considered. Case one assumed a circumferentially oriented throughwall flaw extending 90 degrees around the circumference of the weld. Case 2 assumed an initial flaw length of 180 degrees. The first case is considered to be conservative, since no ID connected defects were reported in 1999. The second case is believed to bound any flaw reported in the industry as of the date of this calculation. The latter case is therefore very conservative, since the Ginna operating temperature in the head region is very low compared to other plants, and PWSCC appears to be very temperature sensitive.

2. Stress and stress intensity factor analyses were performed using finite element methods [2,3,4]. Analyses considered hypothetical defects on the uphill and downhill sides of the penetrations. The effects of the angle between the vertically oriented nozzles and the head were considered. The conclusion of these analyses was that the most severe location from the point of view of applied stress intensity factor was the downhill side flaw on nozzles and the 43.5 degree angle to the head. These nozzles are the outermost on the head. It should be noted that analyses for other plants have shown the uphill side flaws to be most severe. The difference of the Ginna design is that the weld design applies significantly more downhill weld metal, as compared to other previously reviewed designs. Weld residual stress is in large part a function of the quantity of

local weld metal that is cooling and shrinking during the welding process. Therefore, the observation that for the Ginna configuration the limiting location is downhill is consistent.

3. The crack growth correlation developed in [1] was used. This corresponds to the MRP 95% confidence correlation, adjusted for the Ginna head temperature of 580 degrees F.

4. Allowable and critical flaw sizes for the limiting Ginna location were determined in [5]. The allowable flaw size for a circumferential flaw is 300 degrees of circumference.

5. This calculation determines the time required to grow from the assumed flaw size (90 degree or 180 degree) to the allowable flaw size (300 degree). Since the hypothetical flaw is assumed to be through wall, only growth in the circumferential direction is considered. No growth in the throughwall direction is considered.

3.0 GEOMETRY

The penetration tube has an OD of 4 inches, and a wall thickness of 0.625 inches. The circular mean circumference is thus

$$C_{circle} = 2\pi\,(OR + IR)/2 = 10.6 \text{ inch}$$

Where the mean radius is thus 1.6875 inch

So, in this case, a 360 degree flaw would have a length of 10.6 inches.

However, the weld-tube interface makes an angle of 43.5 degrees from the horizontal, so the probable crack path, which would follow the weld, would actually form an ellipse with the minor axis ("b") being the mean radius as included above, and the major axis ("a") being

$$a = b \sec(43.5 \text{ degrees}) = 2.3264 \text{ inches}$$

The perimeter of the ellipse is

$$P = \pi(a+b)K \text{ [6]}$$

where

$$K = (1 + m^2/4 + m^4/64 + m^6/256 + \ldots)$$

and

$$m = (a-b)/(a+b)$$

So, using the dimensions for a,b above

P = 12.69 inch.

For the purpose of the Ginna crack growth, this number is appropriate for use as the circumference of the CRDM 43.5 degree penetration, along the weld-tube interface. Use of the circular circumference (10.6 inch) is very conservative. The crack growth calculations will be performed using cases with both the circular and elliptical circumferences (perimeters), for completeness.

4.0 CRACK GROWTH CALCULATIONS

The SI proprietary fracture mechanics program pc-CRACK [7] was used to perform a series of crack growth calculations. The derived crack growth correlation [1] used was

$$da/dt = 5.1707 \times 10^{-07} (K-8.188)^{1.11} \text{ inch/hour}$$

The K vs a distribution for the limiting case (43.5 degree penetration, downhill side flaw) derived in [2] was taken as

FLAW ANGLE	APPLIED K (KSI-√IN)
90	34.744
180	47.240
220	51.855
260	58.081
300	63.722

Starting throughwall flaw lengths of 90 degrees and 180 degrees, centered on the downhill dead center location were used.

Because the stress intensity factor results were input in the K vs a option, pc-CRACK does not use any of the included geometry stress intensity factor models. However, for the purpose of defining the allowable flaw, the "throughwall circumferential flaw in a cylinder" model was selected.

The allowable flaw length was taken as 300 degrees, as noted in [5].

Angular flaw length was converted to inches of circumference by multiplying the selected circumference value by the ratio of the angle to 360 degrees.

Because the flaw will grow from both ends, the length (inches) of the starting flaw, the allowable flaw, and all intermediate values were divided by two. The crack growth then represents the growth rate of one crack tip, and the total crack growth is twice the growth of one tip.

The crack growth time is taken as 8000 hours per year, to account for non-operating time in plant life. If actual time is greater or less than this amount, the crack growth time to allowable in years may be scaled appropriately.

The pc-CRACK results are summarized in the following Table, and the complete pc-CRACK output in included in Appendices A-D.

STARTING ANGLE (DEGREES)	CIRCLE/ELLIPSE	TIME TO ALLOWABLE (HOURS)	YEARS @ 8000 HOURS/YEAR
90	CIRCLE	84000	10.5
90	ELLIPSE	88500	12.2
180	CIRCLE	42000	5.25
180	ELLIPSE	48000	6

5.0 CONCLUSIONS

The limiting crack growth analysis cases for Ginna show that a 90 degree through wall flaw centered on the downhill side of the limiting 43.5 degree penetration would require about 10.5 years to grow to the allowable flaw length. An initial 180 degree throughwall flaw centered on the 43.5 degree nozzle downhill side would require approximately 6 years to grow to the allowable flaw length. Both of these results are under the conservative set of assumptions described above.

6.0 REFERENCES

1. SI Calculation, "Development of a PWSCC Crack Growth Correlation for Ginna Operating Temperature", Revision 0, SI File No. W-RGE-13Q-307.
2. SI Calculation, "Deterministic Fracture Mechanics Evaluation of Top Head CRDM Nozzle, 43.5° Location, Uphill and Downhill Side Cracking", Revision 0, SI File No. W-RGE-13Q-303.
3. SI Calculation, "Deterministic Fracture Mechanics Evaluation of Top Head CRDM Nozzle, 30° Location, Uphill and Downhill Side Cracking", Revision 0, SI File No. W-RGE-13Q-304.
4. SI Calculation, "Deterministic Fracture Mechanics Evaluation of Top Head CRDM Nozzle, 13.6° Location, Uphill and Downhill Side Cracking", Revision 0, SI File No. W-RGE-13Q-305.
5. SI Calculation, "CRDM Allowable and Critical Flaw Sizes (Ginna)", Revision 0, SI File No. W-RGE-13Q-309.
6. Avallone, E., and T. Baumeister III, Marks' Standard Handbook for Mechanical Engineers, Ninth Edition, McGraw-Hill Book Company, New York, 1986, 1978.
7. Structural Integrity Associates, "pc-CRACK for Windows", Version 3.1-98348, 1998

APPENDIX A

FLAW GROWTH CALCULATIONS, 90 DEGREE INITIAL FLAW, CIRCULAR CIRCUMFERENCE

Linear Elastic Fracture Mechanics

Date: Tue Dec 18 10:22:03 2001
Input Data and Results File: CG90.LFM

Title: Ginna growth calculation for 43.5 downhill penetration (Starting from 90 degrees)

Load Cases:

Case ID: K43down --- K vs a

Depth	K
0.0000	0.0000
1.3250	34.7440
2.6500	47.2400
3.2400	51.8550
3.8300	58.0810
4.4180	63.7220

Case ID	Stress Coefficients C0	C1	C2	C3	Type
K43down	0	0	0	0	K vs a

Crack Model: Through-Wall Circ. Crack in Cylinder Under Tension And Bending

Crack Parameters:
Wall thickness: 0.6250
Half crack length: 4.5000
Poisson ratio: 0.3000
Tension: Co = P/(2*Pi*Rm*t)
Max. bending: C1 = M/(Pi*t*Rm*Rm)
All other stress coefficients are neglected.

--------------------Stress Intensity Factor--------------------

Crack Size	Case K43down
0.0900	2.35997
0.1800	4.71994
0.2700	7.07991
0.3600	9.43988
0.4500	11.7998
0.5400	14.1598
0.6300	16.5198
0.7200	18.8798
0.8100	21.2397
0.9000	23.5997
0.9900	25.9597
1.0800	28.3196
1.1700	30.6796
1.2600	33.0396
1.3500	34.9798
1.4400	35.8286
1.5300	36.6773
1.6200	37.5261
1.7100	38.3749
1.8000	39.2237
1.8900	40.0725
1.9800	40.9213
2.0700	41.7701
2.1600	42.6188
2.2500	43.4676
2.3400	44.3164
2.4300	45.1652
2.5200	46.014
2.6100	46.8628
2.7000	47.6311
2.7900	48.3351
2.8800	49.0391
2.9700	49.743
3.0600	50.447
3.1500	51.151
3.2400	51.855
3.3300	52.8047
3.4200	53.7545
3.5100	54.7042
3.6000	55.6539
3.6900	56.6036
3.7800	57.5534
3.8700	58.4647

3.9600	59.3282
4.0500	60.1916
4.1400	61.055
4.2300	61.9184
4.3200	62.7818
4.4100	63.6452
4.5000	64.5087

Crack Growth Laws:

Law ID: MRP95580
Type: Corrosion
Model: Paris

da/dN = c * (dK)^n
where
dK = Kmax - Kmin
dK > Kthres
Kmax < K1c

Material parameters:
c = 5.1707e-007
n = 1.1100
Kthres = 8.1880

Material Fracture Toughness KIc:

Material ID: Alloy 600

Depth	KIc
0.0000	200.0000
2.0000	200.0000
5.0000	200.0000
12.0000	200.0000

Initial crack size= 1.3300
Max. crack size= 4.5000

Number of blocks= 1
Print increment of block= 1

Revision	0			
Preparer/Date	HLG 12/20/01			
Checker/Date	GLS 12/20/01			

Subblock	Cycles /Time	Calc. incre.	Print incre.	Crk. Grw. Law	Mat.	K1c
Ginna	100000	1000	1000	MRP95580	Alloy 600	

Subblock	Kmax Case ID	Kmax Scale Factor	Kmin Case ID	Kmin Scale Factor
Ginna	K43down	1.0000		

Crack growth results:

Total Cycles /Time	Subblock Cycles /Time	Kmax	Kmin	DeltaK	R	DaDn /DaDt	Da	a	a/thk
Block: 1									
1000	1000	3.45e+001	0.00e+000	3.45e+001	0.00	2.64e-005	2.64e-002	1.356	0.00
2000	2000	3.50e+001	0.00e+000	3.50e+001	0.00	2.68e-005	2.68e-002	1.383	0.00
3000	3000	3.53e+001	0.00e+000	3.53e+001	0.00	2.70e-005	2.70e-002	1.41	0.00
4000	4000	3.55e+001	0.00e+000	3.55e+001	0.00	2.72e-005	2.72e-002	1.437	0.00
5000	5000	3.58e+001	0.00e+000	3.58e+001	0.00	2.74e-005	2.74e-002	1.465	0.00
6000	6000	3.61e+001	0.00e+000	3.61e+001	0.00	2.77e-005	2.77e-002	1.493	0.00
7000	7000	3.63e+001	0.00e+000	3.63e+001	0.00	2.79e-005	2.79e-002	1.52	0.00
8000	8000	3.66e+001	0.00e+000	3.66e+001	0.00	2.81e-005	2.81e-002	1.548	0.00
9000	9000	3.69e+001	0.00e+000	3.69e+001	0.00	2.83e-005	2.83e-002	1.577	0.00
10000	10000	3.71e+001	0.00e+000	3.71e+001	0.00	2.86e-005	2.86e-002	1.605	0.00
11000	11000	3.74e+001	0.00e+000	3.74e+001	0.00	2.88e-005	2.88e-002	1.634	0.00
12000	12000	3.77e+001	0.00e+000	3.77e+001	0.00	2.90e-005	2.90e-002	1.663	0.00
13000	13000	3.79e+001	0.00e+000	3.79e+001	0.00	2.93e-005	2.93e-002	1.692	0.00
14000	14000	3.82e+001	0.00e+000	3.82e+001	0.00	2.95e-005	2.95e-002	1.722	0.00
15000	15000	3.85e+001	0.00e+000	3.85e+001	0.00	2.97e-005	2.97e-002	1.752	0.00
16000	16000	3.88e+001	0.00e+000	3.88e+001	0.00	3.00e-005	3.00e-002	1.782	0.00
17000	17000	3.91e+001	0.00e+000	3.91e+001	0.00	3.02e-005	3.02e-002	1.812	0.00
18000	18000	3.93e+001	0.00e+000	3.93e+001	0.00	3.05e-005	3.05e-002	1.842	0.00
19000	19000	3.96e+001	0.00e+000	3.96e+001	0.00	3.07e-005	3.07e-002	1.873	0.00
20000	20000	3.99e+001	0.00e+000	3.99e+001	0.00	3.10e-005	3.10e-002	1.904	0.00
21000	21000	4.02e+001	0.00e+000	4.02e+001	0.00	3.12e-005	3.12e-002	1.935	0.00
22000	22000	4.05e+001	0.00e+000	4.05e+001	0.00	3.15e-005	3.15e-002	1.967	0.00
23000	23000	4.08e+001	0.00e+000	4.08e+001	0.00	3.17e-005	3.17e-002	1.998	0.00
24000	24000	4.11e+001	0.00e+000	4.11e+001	0.00	3.20e-005	3.20e-002	2.03	0.00
25000	25000	4.14e+001	0.00e+000	4.14e+001	0.00	3.22e-005	3.22e-002	2.063	0.00
26000	26000	4.17e+001	0.00e+000	4.17e+001	0.00	3.25e-005	3.25e-002	2.095	0.00
27000	27000	4.20e+001	0.00e+000	4.20e+001	0.00	3.28e-005	3.28e-002	2.128	0.00
28000	28000	4.23e+001	0.00e+000	4.23e+001	0.00	3.30e-005	3.30e-002	2.161	0.00

29000	29000	4.26e+001	0.00e+000	4.26e+001	0.00	3.33e-005	3.33e-002	2.194	0.00
30000	30000	4.29e+001	0.00e+000	4.29e+001	0.00	3.36e-005	3.36e-002	2.228	0.00
31000	31000	4.33e+001	0.00e+000	4.33e+001	0.00	3.39e-005	3.39e-002	2.262	0.00
32000	32000	4.36e+001	0.00e+000	4.36e+001	0.00	3.41e-005	3.41e-002	2.296	0.00
33000	33000	4.39e+001	0.00e+000	4.39e+001	0.00	3.44e-005	3.44e-002	2.33	0.00
34000	34000	4.42e+001	0.00e+000	4.42e+001	0.00	3.47e-005	3.47e-002	2.365	0.00
35000	35000	4.46e+001	0.00e+000	4.46e+001	0.00	3.50e-005	3.50e-002	2.4	0.00
36000	36000	4.49e+001	0.00e+000	4.49e+001	0.00	3.53e-005	3.53e-002	2.435	0.00
37000	37000	4.52e+001	0.00e+000	4.52e+001	0.00	3.56e-005	3.56e-002	2.471	0.00
38000	38000	4.55e+001	0.00e+000	4.55e+001	0.00	3.58e-005	3.58e-002	2.507	0.00
39000	39000	4.59e+001	0.00e+000	4.59e+001	0.00	3.61e-005	3.61e-002	2.543	0.00
40000	40000	4.62e+001	0.00e+000	4.62e+001	0.00	3.64e-005	3.64e-002	2.579	0.00
41000	41000	4.66e+001	0.00e+000	4.66e+001	0.00	3.67e-005	3.67e-002	2.616	0.00
42000	42000	4.69e+001	0.00e+000	4.69e+001	0.00	3.70e-005	3.70e-002	2.653	0.00
43000	43000	4.72e+001	0.00e+000	4.72e+001	0.00	3.73e-005	3.73e-002	2.69	0.00
44000	44000	4.75e+001	0.00e+000	4.75e+001	0.00	3.76e-005	3.76e-002	2.728	0.00
45000	45000	4.78e+001	0.00e+000	4.78e+001	0.00	3.79e-005	3.79e-002	2.766	0.00
46000	46000	4.81e+001	0.00e+000	4.81e+001	0.00	3.81e-005	3.81e-002	2.804	0.00
47000	47000	4.84e+001	0.00e+000	4.84e+001	0.00	3.84e-005	3.84e-002	2.842	0.00
48000	48000	4.87e+001	0.00e+000	4.87e+001	0.00	3.86e-005	3.86e-002	2.881	0.00
49000	49000	4.90e+001	0.00e+000	4.90e+001	0.00	3.89e-005	3.89e-002	2.92	0.00
50000	50000	4.94e+001	0.00e+000	4.94e+001	0.00	3.92e-005	3.92e-002	2.959	0.00
51000	51000	4.97e+001	0.00e+000	4.97e+001	0.00	3.95e-005	3.95e-002	2.998	0.00
52000	52000	5.00e+001	0.00e+000	5.00e+001	0.00	3.97e-005	3.97e-002	3.038	0.00
53000	53000	5.03e+001	0.00e+000	5.03e+001	0.00	4.00e-005	4.00e-002	3.078	0.00
54000	54000	5.06e+001	0.00e+000	5.06e+001	0.00	4.03e-005	4.03e-002	3.118	0.00
55000	55000	5.09e+001	0.00e+000	5.09e+001	0.00	4.06e-005	4.06e-002	3.159	0.00
56000	56000	5.12e+001	0.00e+000	5.12e+001	0.00	4.08e-005	4.08e-002	3.2	0.00
57000	57000	5.15e+001	0.00e+000	5.15e+001	0.00	4.11e-005	4.11e-002	3.241	0.00
58000	58000	5.19e+001	0.00e+000	5.19e+001	0.00	4.14e-005	4.14e-002	3.282	0.00
59000	59000	5.23e+001	0.00e+000	5.23e+001	0.00	4.18e-005	4.18e-002	3.324	0.00
60000	60000	5.27e+001	0.00e+000	5.27e+001	0.00	4.22e-005	4.22e-002	3.366	0.00
61000	61000	5.32e+001	0.00e+000	5.32e+001	0.00	4.26e-005	4.26e-002	3.409	0.00
62000	62000	5.36e+001	0.00e+000	5.36e+001	0.00	4.30e-005	4.30e-002	3.452	0.00
63000	63000	5.41e+001	0.00e+000	5.41e+001	0.00	4.34e-005	4.34e-002	3.495	0.00
64000	64000	5.45e+001	0.00e+000	5.45e+001	0.00	4.38e-005	4.38e-002	3.539	0.00
65000	65000	5.50e+001	0.00e+000	5.50e+001	0.00	4.42e-005	4.42e-002	3.583	0.00
66000	66000	5.55e+001	0.00e+000	5.55e+001	0.00	4.46e-005	4.46e-002	3.628	0.00
67000	67000	5.59e+001	0.00e+000	5.59e+001	0.00	4.50e-005	4.50e-002	3.673	0.00
68000	68000	5.64e+001	0.00e+000	5.64e+001	0.00	4.55e-005	4.55e-002	3.718	0.00
69000	69000	5.69e+001	0.00e+000	5.69e+001	0.00	4.59e-005	4.59e-002	3.764	0.00
70000	70000	5.74e+001	0.00e+000	5.74e+001	0.00	4.63e-005	4.63e-002	3.811	0.00
71000	71000	5.79e+001	0.00e+000	5.79e+001	0.00	4.68e-005	4.68e-002	3.857	0.00
72000	72000	5.83e+001	0.00e+000	5.83e+001	0.00	4.72e-005	4.72e-002	3.905	0.00
73000	73000	5.88e+001	0.00e+000	5.88e+001	0.00	4.76e-005	4.76e-002	3.952	0.00
74000	74000	5.93e+001	0.00e+000	5.93e+001	0.00	4.80e-005	4.80e-002	4	0.00
75000	75000	5.97e+001	0.00e+000	5.97e+001	0.00	4.84e-005	4.84e-002	4.049	0.00
76000	76000	6.02e+001	0.00e+000	6.02e+001	0.00	4.88e-005	4.88e-002	4.097	0.00
77000	77000	6.06e+001	0.00e+000	6.06e+001	0.00	4.93e-005	4.93e-002	4.147	0.00

78000	78000	6.11e+001	0.00e+000	6.11e+001	0.00	4.97e-005	4.97e-002	4.196	0.00
79000	79000	6.16e+001	0.00e+000	6.16e+001	0.00	5.01e-005	5.01e-002	4.246	0.00
80000	80000	6.21e+001	0.00e+000	6.21e+001	0.00	5.05e-005	5.05e-002	4.297	0.00
81000	81000	6.26e+001	0.00e+000	6.26e+001	0.00	5.10e-005	5.10e-002	4.348	0.00
82000	82000	6.30e+001	0.00e+000	6.30e+001	0.00	5.14e-005	5.14e-002	4.399	0.00
83000	83000	6.35e+001	0.00e+000	6.35e+001	0.00	5.19e-005	5.19e-002	4.451	0.00
84000	84000	6.40e+001	0.00e+000	6.40e+001	0.00	5.23e-005	5.23e-002	4.504	0.00

Crack size exceeded 4.5000 at cycle/time 84000

End of pc-CRACK Output

APPENDIX B

FLAW GROWTH CALCULATIONS, 90 DEGREE INITIAL FLAW, ELLIPTICAL CIRCUMFERENCE

tm
pc-CRACK for Windows
Version 3.1-98348

Structural Integrity Associates, Inc.
3315 Almaden Expressway, Suite 24
San Jose, CA 95118-1557

Linear Elastic Fracture Mechanics

Date: Thu Dec 20 17:10:30 2001
Input Data and Results File: CG90EL2.LFM

Title: Ginna growth calculation for 43.5 downhill penetration (Starting from 90 degree flaw, elliptical circumference)

Load Cases:

Case ID: K43down --- K vs a

Depth	K
0.0000	0.0000
1.3250	34.7440
2.6500	47.2400
3.2400	51.8550
3.8300	58.0810
4.4180	63.7220

Case ID: k43dnell --- K vs a

Depth	K
0.0000	0.0000
1.5900	34.7440
3.1700	47.2400
3.8800	51.8550
4.5800	58.0810
5.2900	63.7220

Case ID	Stress Coefficients C0	C1	C2	C3	Type
K43down	0	0	0	0	K vs a
k43dnell	0	0	0	0	K vs a

Crack Model: Through-Wall Circ. Crack in Cylinder Under Tension And Bending

Crack Parameters:
Wall thickness: 0.6250
Half crack length: 5.2800
Poisson ratio: 0.3000
Tension: Co = P/(2*Pi*Rm*t)
Max. bending: C1 = M/(Pi*t*Rm*Rm)
All other stress coefficients are neglected.

	--------------------Stress Intensity Factor--------------------	
Crack Size	Case K43down	Case k43dnell
0.1056	2.76903	2.30753
0.2112	5.53806	4.61505
0.3168	8.30709	6.92258
0.4224	11.0761	9.2301
0.5280	13.8452	11.5376
0.6336	16.6142	13.8452
0.7392	19.3832	16.1527
0.8448	22.1523	18.4602
0.9504	24.9213	20.7677
1.0560	27.6903	23.0753
1.1616	30.4593	25.3828
1.2672	33.2284	27.6903
1.3728	35.1948	29.9978
1.4784	36.1907	32.3054
1.5840	37.1866	34.6129
1.6896	38.1825	35.5317
1.7952	39.1784	36.3669
1.9008	40.1743	37.2021
2.0064	41.1702	38.0373
2.1120	42.1662	38.8724
2.2176	43.1621	39.7076
2.3232	44.158	40.5428
2.4288	45.1539	41.378
2.5344	46.1498	42.2131
2.6400	47.1457	43.0483
2.7456	47.9878	43.8835
2.8512	48.8138	44.7187
2.9568	49.6398	45.5538
3.0624	50.4658	46.389
3.1680	51.2918	47.2242
3.2736	52.2096	47.9134
3.3792	53.3239	48.5998

3.4848	54.4383	49.2862
3.5904	55.5526	49.9726
3.6960	56.667	50.659
3.8016	57.7813	51.3454
3.9072	58.8216	52.0969
4.0128	59.8347	53.0362
4.1184	60.8478	53.9754
4.2240	61.8609	54.9146
4.3296	62.8739	55.8539
4.4352	63.887	56.7931
4.5408	64.9001	57.7323
4.6464	65.9132	58.6086
4.7520	66.9262	59.4476
4.8576	67.9393	60.2866
4.9632	68.9524	61.1256
5.0688	69.9655	61.9646
5.1744	70.9785	62.8036
5.2800	71.9916	63.6426

Crack Growth Laws:

Law ID: MRP95580
Type: Corrosion
Model: Paris

da/dN = c * (dK)^n
where
dK = Kmax - Kmin
dK > Kthres
Kmax < K1c

Material parameters:
c = 5.1707e-007
n = 1.1100
Kthres = 8.1880

Material Fracture Toughness KIc:

Material ID: Alloy 600

Depth	KIc
0.0000	200.0000
2.0000	200.0000
5.0000	200.0000
12.0000	200.0000

Initial crack size= 1.5900
Max. crack size= 5.2800

Number of blocks= 1
Print increment of block= 1

Subblock	Cycles /Time	Calc. incre.	Print incre.	Crk. Grw. Law	Mat. K1c
Ginna	100000	1000	1000	MRP95580	Alloy 600

Subblock	Kmax Case ID	Kmax Scale Factor	Kmin Case ID	Kmin Scale Factor
Ginna	k43dnell	1.0000		

Crack growth results:

Total Cycles /Time	Subblock Cycles /Time	Kmax	Kmin	DeltaK	R	DaDn /DaDt	Da	a	a/thk
Block: 1									
1000	1000	3.47e+001	0.00e+000	3.47e+001	0.00	2.65e-005	2.65e-002	1.616	0.00
2000	2000	3.49e+001	0.00e+000	3.49e+001	0.00	2.67e-005	2.67e-002	1.643	0.00
3000	3000	3.51e+001	0.00e+000	3.51e+001	0.00	2.69e-005	2.69e-002	1.67	0.00
4000	4000	3.54e+001	0.00e+000	3.54e+001	0.00	2.71e-005	2.71e-002	1.697	0.00
5000	5000	3.56e+001	0.00e+000	3.56e+001	0.00	2.73e-005	2.73e-002	1.724	0.00
6000	6000	3.58e+001	0.00e+000	3.58e+001	0.00	2.74e-005	2.74e-002	1.752	0.00
7000	7000	3.60e+001	0.00e+000	3.60e+001	0.00	2.76e-005	2.76e-002	1.779	0.00
8000	8000	3.62e+001	0.00e+000	3.62e+001	0.00	2.78e-005	2.78e-002	1.807	0.00
9000	9000	3.65e+001	0.00e+000	3.65e+001	0.00	2.80e-005	2.80e-002	1.835	0.00
10000	10000	3.67e+001	0.00e+000	3.67e+001	0.00	2.82e-005	2.82e-002	1.863	0.00
11000	11000	3.69e+001	0.00e+000	3.69e+001	0.00	2.84e-005	2.84e-002	1.892	0.00
12000	12000	3.71e+001	0.00e+000	3.71e+001	0.00	2.86e-005	2.86e-002	1.92	0.00
13000	13000	3.74e+001	0.00e+000	3.74e+001	0.00	2.88e-005	2.88e-002	1.949	0.00
14000	14000	3.76e+001	0.00e+000	3.76e+001	0.00	2.90e-005	2.90e-002	1.978	0.00
15000	15000	3.78e+001	0.00e+000	3.78e+001	0.00	2.92e-005	2.92e-002	2.007	0.00
16000	16000	3.80e+001	0.00e+000	3.80e+001	0.00	2.94e-005	2.94e-002	2.037	0.00
17000	17000	3.83e+001	0.00e+000	3.83e+001	0.00	2.96e-005	2.96e-002	2.066	0.00
18000	18000	3.85e+001	0.00e+000	3.85e+001	0.00	2.98e-005	2.98e-002	2.096	0.00
19000	19000	3.87e+001	0.00e+000	3.87e+001	0.00	3.00e-005	3.00e-002	2.126	0.00
20000	20000	3.90e+001	0.00e+000	3.90e+001	0.00	3.02e-005	3.02e-002	2.156	0.00
21000	21000	3.92e+001	0.00e+000	3.92e+001	0.00	3.04e-005	3.04e-002	2.186	0.00
22000	22000	3.95e+001	0.00e+000	3.95e+001	0.00	3.06e-005	3.06e-002	2.217	0.00

23000	23000	3.97e+001	0.00e+000	3.97e+001	0.00	3.08e-005	3.08e-002	2.248	0.00
24000	24000	3.99e+001	0.00e+000	3.99e+001	0.00	3.10e-005	3.10e-002	2.279	0.00
25000	25000	4.02e+001	0.00e+000	4.02e+001	0.00	3.12e-005	3.12e-002	2.31	0.00
26000	26000	4.04e+001	0.00e+000	4.04e+001	0.00	3.14e-005	3.14e-002	2.341	0.00
27000	27000	4.07e+001	0.00e+000	4.07e+001	0.00	3.16e-005	3.16e-002	2.373	0.00
28000	28000	4.09e+001	0.00e+000	4.09e+001	0.00	3.18e-005	3.18e-002	2.405	0.00
29000	29000	4.12e+001	0.00e+000	4.12e+001	0.00	3.21e-005	3.21e-002	2.437	0.00
30000	30000	4.14e+001	0.00e+000	4.14e+001	0.00	3.23e-005	3.23e-002	2.469	0.00
31000	31000	4.17e+001	0.00e+000	4.17e+001	0.00	3.25e-005	3.25e-002	2.502	0.00
32000	32000	4.20e+001	0.00e+000	4.20e+001	0.00	3.27e-005	3.27e-002	2.534	0.00
33000	33000	4.22e+001	0.00e+000	4.22e+001	0.00	3.29e-005	3.29e-002	2.567	0.00
34000	34000	4.25e+001	0.00e+000	4.25e+001	0.00	3.32e-005	3.32e-002	2.6	0.00
35000	35000	4.27e+001	0.00e+000	4.27e+001	0.00	3.34e-005	3.34e-002	2.634	0.00
36000	36000	4.30e+001	0.00e+000	4.30e+001	0.00	3.36e-005	3.36e-002	2.668	0.00
37000	37000	4.33e+001	0.00e+000	4.33e+001	0.00	3.39e-005	3.39e-002	2.701	0.00
38000	38000	4.35e+001	0.00e+000	4.35e+001	0.00	3.41e-005	3.41e-002	2.735	0.00
39000	39000	4.38e+001	0.00e+000	4.38e+001	0.00	3.43e-005	3.43e-002	2.77	0.00
40000	40000	4.41e+001	0.00e+000	4.41e+001	0.00	3.46e-005	3.46e-002	2.804	0.00
41000	41000	4.43e+001	0.00e+000	4.43e+001	0.00	3.48e-005	3.48e-002	2.839	0.00
42000	42000	4.46e+001	0.00e+000	4.46e+001	0.00	3.50e-005	3.50e-002	2.874	0.00
43000	43000	4.49e+001	0.00e+000	4.49e+001	0.00	3.53e-005	3.53e-002	2.909	0.00
44000	44000	4.52e+001	0.00e+000	4.52e+001	0.00	3.55e-005	3.55e-002	2.945	0.00
45000	45000	4.55e+001	0.00e+000	4.55e+001	0.00	3.58e-005	3.58e-002	2.981	0.00
46000	46000	4.57e+001	0.00e+000	4.57e+001	0.00	3.60e-005	3.60e-002	3.017	0.00
47000	47000	4.60e+001	0.00e+000	4.60e+001	0.00	3.63e-005	3.63e-002	3.053	0.00
48000	48000	4.63e+001	0.00e+000	4.63e+001	0.00	3.65e-005	3.65e-002	3.09	0.00
49000	49000	4.66e+001	0.00e+000	4.66e+001	0.00	3.68e-005	3.68e-002	3.126	0.00
50000	50000	4.69e+001	0.00e+000	4.69e+001	0.00	3.70e-005	3.70e-002	3.163	0.00
51000	51000	4.72e+001	0.00e+000	4.72e+001	0.00	3.73e-005	3.73e-002	3.201	0.00
52000	52000	4.74e+001	0.00e+000	4.74e+001	0.00	3.75e-005	3.75e-002	3.238	0.00
53000	53000	4.77e+001	0.00e+000	4.77e+001	0.00	3.77e-005	3.77e-002	3.276	0.00
54000	54000	4.79e+001	0.00e+000	4.79e+001	0.00	3.79e-005	3.79e-002	3.314	0.00
55000	55000	4.82e+001	0.00e+000	4.82e+001	0.00	3.81e-005	3.81e-002	3.352	0.00
56000	56000	4.84e+001	0.00e+000	4.84e+001	0.00	3.84e-005	3.84e-002	3.39	0.00
57000	57000	4.87e+001	0.00e+000	4.87e+001	0.00	3.86e-005	3.86e-002	3.429	0.00
58000	58000	4.89e+001	0.00e+000	4.89e+001	0.00	3.88e-005	3.88e-002	3.468	0.00
59000	59000	4.92e+001	0.00e+000	4.92e+001	0.00	3.90e-005	3.90e-002	3.507	0.00
60000	60000	4.94e+001	0.00e+000	4.94e+001	0.00	3.93e-005	3.93e-002	3.546	0.00
61000	61000	4.97e+001	0.00e+000	4.97e+001	0.00	3.95e-005	3.95e-002	3.585	0.00
62000	62000	4.99e+001	0.00e+000	4.99e+001	0.00	3.97e-005	3.97e-002	3.625	0.00
63000	63000	5.02e+001	0.00e+000	5.02e+001	0.00	3.99e-005	3.99e-002	3.665	0.00
64000	64000	5.05e+001	0.00e+000	5.05e+001	0.00	4.02e-005	4.02e-002	3.705	0.00
65000	65000	5.07e+001	0.00e+000	5.07e+001	0.00	4.04e-005	4.04e-002	3.746	0.00
66000	66000	5.10e+001	0.00e+000	5.10e+001	0.00	4.06e-005	4.06e-002	3.786	0.00
67000	67000	5.12e+001	0.00e+000	5.12e+001	0.00	4.09e-005	4.09e-002	3.827	0.00
68000	68000	5.15e+001	0.00e+000	5.15e+001	0.00	4.11e-005	4.11e-002	3.868	0.00
69000	69000	5.18e+001	0.00e+000	5.18e+001	0.00	4.14e-005	4.14e-002	3.91	0.00
70000	70000	5.21e+001	0.00e+000	5.21e+001	0.00	4.16e-005	4.16e-002	3.951	0.00
71000	71000	5.25e+001	0.00e+000	5.25e+001	0.00	4.20e-005	4.20e-002	3.993	0.00

72000	72000	5.29e+001	0.00e+000	5.29e+001	0.00	4.23e-005	4.23e-002	4.035	0.00
73000	73000	5.32e+001	0.00e+000	5.32e+001	0.00	4.26e-005	4.26e-002	4.078	0.00
74000	74000	5.36e+001	0.00e+000	5.36e+001	0.00	4.30e-005	4.30e-002	4.121	0.00
75000	75000	5.40e+001	0.00e+000	5.40e+001	0.00	4.33e-005	4.33e-002	4.164	0.00
76000	76000	5.44e+001	0.00e+000	5.44e+001	0.00	4.36e-005	4.36e-002	4.208	0.00
77000	77000	5.48e+001	0.00e+000	5.48e+001	0.00	4.40e-005	4.40e-002	4.252	0.00
78000	78000	5.52e+001	0.00e+000	5.52e+001	0.00	4.43e-005	4.43e-002	4.296	0.00
79000	79000	5.56e+001	0.00e+000	5.56e+001	0.00	4.47e-005	4.47e-002	4.341	0.00
80000	80000	5.60e+001	0.00e+000	5.60e+001	0.00	4.50e-005	4.50e-002	4.386	0.00
81000	81000	5.64e+001	0.00e+000	5.64e+001	0.00	4.54e-005	4.54e-002	4.431	0.00
82000	82000	5.68e+001	0.00e+000	5.68e+001	0.00	4.58e-005	4.58e-002	4.477	0.00
83000	83000	5.72e+001	0.00e+000	5.72e+001	0.00	4.61e-005	4.61e-002	4.523	0.00
84000	84000	5.76e+001	0.00e+000	5.76e+001	0.00	4.65e-005	4.65e-002	4.57	0.00
85000	85000	5.80e+001	0.00e+000	5.80e+001	0.00	4.69e-005	4.69e-002	4.617	0.00
86000	86000	5.84e+001	0.00e+000	5.84e+001	0.00	4.72e-005	4.72e-002	4.664	0.00
87000	87000	5.87e+001	0.00e+000	5.87e+001	0.00	4.75e-005	4.75e-002	4.711	0.00
88000	88000	5.91e+001	0.00e+000	5.91e+001	0.00	4.79e-005	4.79e-002	4.759	0.00
89000	89000	5.95e+001	0.00e+000	5.95e+001	0.00	4.82e-005	4.82e-002	4.808	0.00
90000	90000	5.99e+001	0.00e+000	5.99e+001	0.00	4.86e-005	4.86e-002	4.856	0.00
91000	91000	6.03e+001	0.00e+000	6.03e+001	0.00	4.89e-005	4.89e-002	4.905	0.00
92000	92000	6.07e+001	0.00e+000	6.07e+001	0.00	4.93e-005	4.93e-002	4.954	0.00
93000	93000	6.11e+001	0.00e+000	6.11e+001	0.00	4.96e-005	4.96e-002	5.004	0.00
94000	94000	6.14e+001	0.00e+000	6.14e+001	0.00	5.00e-005	5.00e-002	5.054	0.00
95000	95000	6.18e+001	0.00e+000	6.18e+001	0.00	5.03e-005	5.03e-002	5.104	0.00
96000	96000	6.22e+001	0.00e+000	6.22e+001	0.00	5.07e-005	5.07e-002	5.155	0.00
97000	97000	6.26e+001	0.00e+000	6.26e+001	0.00	5.11e-005	5.11e-002	5.206	0.00
98000	98000	6.31e+001	0.00e+000	6.31e+001	0.00	5.14e-005	5.14e-002	5.257	0.00
99000	99000	6.35e+001	0.00e+000	6.35e+001	0.00	5.18e-005	5.18e-002	5.309	0.00

Crack size exceeded 5.2800 at cycle/time 99000

End of pc-CRACK Output

APPENDIX C

FLAW GROWTH CALCULATIONS, 180 DEGREE INITIAL FLAW, CIRCULAR CIRCUMFERENCE

TM
pc-CRACK for Windows
Version 3.1-98348
(C) Copyright '84 - '98
Structural Integrity Associates, Inc.
3315 Almaden Expressway, Suite 24
San Jose, CA 95118-1557

Linear Elastic Fracture Mechanics

Date: Tue Dec 18 10:25:57 2001
Input Data and Results File: CG180.LFM

Title: Ginna growth calculation for 43.5 downhill penetration (Starting from 180 degrees, circular circumference)

Load Cases:

Case ID: K43down --- K vs a

Depth	K
0.0000	0.0000
1.3250	34.7440
2.6500	47.2400
3.2400	51.8550
3.8300	58.0810
4.4180	63.7220

	Stress Coefficients				
Case ID	C0	C1	C2	C3	Type
K43down	0	0	0	0	K vs a

Crack Model: Through-Wall Circ. Crack in Cylinder Under Tension And Bending

Crack Parameters:
Wall thickness: 0.6250
Half crack length: 4.5000
Poisson ratio: 0.3000
Tension: Co = P/(2*Pi*Rm*t)
Max. bending: C1 = M/(Pi*t*Rm*Rm)
All other stress coefficients are neglected.

	Revision	0			
	Preparer/Date	HLG 12/20/01			
	Checker/Date	GLS 12/20/01			

--------------------Stress Intensity Factor--------------------

Crack Size	Case K43down
0.0900	2.35997
0.1800	4.71994
0.2700	7.07991
0.3600	9.43988
0.4500	11.7998
0.5400	14.1598
0.6300	16.5198
0.7200	18.8798
0.8100	21.2397
0.9000	23.5997
0.9900	25.9597
1.0800	28.3196
1.1700	30.6796
1.2600	33.0396
1.3500	34.9798
1.4400	35.8286
1.5300	36.6773
1.6200	37.5261
1.7100	38.3749
1.8000	39.2237
1.8900	40.0725
1.9800	40.9213
2.0700	41.7701
2.1600	42.6188
2.2500	43.4676
2.3400	44.3164
2.4300	45.1652
2.5200	46.014
2.6100	46.8628
2.7000	47.6311
2.7900	48.3351
2.8800	49.0391
2.9700	49.743
3.0600	50.447
3.1500	51.151
3.2400	51.855
3.3300	52.8047
3.4200	53.7545
3.5100	54.7042
3.6000	55.6539
3.6900	56.6036
3.7800	57.5534
3.8700	58.4647

3.9600	59.3282
4.0500	60.1916
4.1400	61.055
4.2300	61.9184
4.3200	62.7818
4.4100	63.6452
4.5000	64.5087

Crack Growth Laws:

Law ID: MRP95580
Type: Corrosion
Model: Paris

da/dN = c * (dK)^n
where
dK = Kmax - Kmin
dK > Kthres
Kmax < K1c

Material parameters:
c = 5.1707e-007
n = 1.1100
Kthres = 8.1880

Material Fracture Toughness KIc:

Material ID: Alloy 600

Depth	KIc
0.0000	200.0000
2.0000	200.0000
5.0000	200.0000
12.0000	200.0000

Initial crack size= 2.6500
Max. crack size= 4.5000

Number of blocks= 1
Print increment of block= 1

Subblock	Cycles /Time	Calc. incre.	Print incre.	Crk. Grw. Law	Mat. K1c
Ginna	100000	1000	1000	MRP95580	Alloy 600

Subblock	Kmax Case ID	Kmax Scale Factor	Kmin Case ID	Kmin Scale Factor
Ginna	K43down	1.0000		

Crack growth results:

Total Cycles /Time	Subblock Cycles /Time	Kmax	Kmin	DeltaK	R	DaDn /DaDt	Da	a	a/thk
Block: 1									
1000	1000	4.72e+001	0.00e+000	4.72e+001	0.00	3.73e-005	3.73e-002	2.687	0.00
2000	2000	4.75e+001	0.00e+000	4.75e+001	0.00	3.76e-005	3.76e-002	2.725	0.00
3000	3000	4.78e+001	0.00e+000	4.78e+001	0.00	3.78e-005	3.78e-002	2.763	0.00
4000	4000	4.81e+001	0.00e+000	4.81e+001	0.00	3.81e-005	3.81e-002	2.801	0.00
5000	5000	4.84e+001	0.00e+000	4.84e+001	0.00	3.84e-005	3.84e-002	2.839	0.00
6000	6000	4.87e+001	0.00e+000	4.87e+001	0.00	3.86e-005	3.86e-002	2.878	0.00
7000	7000	4.90e+001	0.00e+000	4.90e+001	0.00	3.89e-005	3.89e-002	2.917	0.00
8000	8000	4.93e+001	0.00e+000	4.93e+001	0.00	3.92e-005	3.92e-002	2.956	0.00
9000	9000	4.96e+001	0.00e+000	4.96e+001	0.00	3.94e-005	3.94e-002	2.995	0.00
10000	10000	4.99e+001	0.00e+000	4.99e+001	0.00	3.97e-005	3.97e-002	3.035	0.00
11000	11000	5.03e+001	0.00e+000	5.03e+001	0.00	4.00e-005	4.00e-002	3.075	0.00
12000	12000	5.06e+001	0.00e+000	5.06e+001	0.00	4.03e-005	4.03e-002	3.115	0.00
13000	13000	5.09e+001	0.00e+000	5.09e+001	0.00	4.05e-005	4.05e-002	3.156	0.00
14000	14000	5.12e+001	0.00e+000	5.12e+001	0.00	4.08e-005	4.08e-002	3.197	0.00
15000	15000	5.15e+001	0.00e+000	5.15e+001	0.00	4.11e-005	4.11e-002	3.238	0.00
16000	16000	5.18e+001	0.00e+000	5.18e+001	0.00	4.14e-005	4.14e-002	3.279	0.00
17000	17000	5.23e+001	0.00e+000	5.23e+001	0.00	4.18e-005	4.18e-002	3.321	0.00
18000	18000	5.27e+001	0.00e+000	5.27e+001	0.00	4.22e-005	4.22e-002	3.363	0.00
19000	19000	5.32e+001	0.00e+000	5.32e+001	0.00	4.25e-005	4.25e-002	3.406	0.00
20000	20000	5.36e+001	0.00e+000	5.36e+001	0.00	4.29e-005	4.29e-002	3.448	0.00
21000	21000	5.41e+001	0.00e+000	5.41e+001	0.00	4.34e-005	4.34e-002	3.492	0.00
22000	22000	5.45e+001	0.00e+000	5.45e+001	0.00	4.38e-005	4.38e-002	3.536	0.00
23000	23000	5.50e+001	0.00e+000	5.50e+001	0.00	4.42e-005	4.42e-002	3.58	0.00
24000	24000	5.54e+001	0.00e+000	5.54e+001	0.00	4.46e-005	4.46e-002	3.624	0.00
25000	25000	5.59e+001	0.00e+000	5.59e+001	0.00	4.50e-005	4.50e-002	3.669	0.00
26000	26000	5.64e+001	0.00e+000	5.64e+001	0.00	4.54e-005	4.54e-002	3.715	0.00
27000	27000	5.69e+001	0.00e+000	5.69e+001	0.00	4.59e-005	4.59e-002	3.761	0.00
28000	28000	5.73e+001	0.00e+000	5.73e+001	0.00	4.63e-005	4.63e-002	3.807	0.00
29000	29000	5.78e+001	0.00e+000	5.78e+001	0.00	4.67e-005	4.67e-002	3.854	0.00
30000	30000	5.83e+001	0.00e+000	5.83e+001	0.00	4.71e-005	4.71e-002	3.901	0.00
31000	31000	5.88e+001	0.00e+000	5.88e+001	0.00	4.76e-005	4.76e-002	3.948	0.00
32000	32000	5.92e+001	0.00e+000	5.92e+001	0.00	4.80e-005	4.80e-002	3.996	0.00
33000	33000	5.97e+001	0.00e+000	5.97e+001	0.00	4.84e-005	4.84e-002	4.045	0.00

34000	34000	6.01e+001	0.00e+000	6.01e+001	0.00	4.88e-005	4.88e-002	4.093	0.00
35000	35000	6.06e+001	0.00e+000	6.06e+001	0.00	4.92e-005	4.92e-002	4.143	0.00
36000	36000	6.11e+001	0.00e+000	6.11e+001	0.00	4.96e-005	4.96e-002	4.192	0.00
37000	37000	6.16e+001	0.00e+000	6.16e+001	0.00	5.01e-005	5.01e-002	4.242	0.00
38000	38000	6.20e+001	0.00e+000	6.20e+001	0.00	5.05e-005	5.05e-002	4.293	0.00
39000	39000	6.25e+001	0.00e+000	6.25e+001	0.00	5.10e-005	5.10e-002	4.344	0.00
40000	40000	6.30e+001	0.00e+000	6.30e+001	0.00	5.14e-005	5.14e-002	4.395	0.00
41000	41000	6.35e+001	0.00e+000	6.35e+001	0.00	5.18e-005	5.18e-002	4.447	0.00
42000	42000	6.40e+001	0.00e+000	6.40e+001	0.00	5.23e-005	5.23e-002	4.499	0.00
43000	43000	6.45e+001	0.00e+000	6.45e+001	0.00	5.27e-005	5.27e-002	4.552	0.00

Crack size exceeded 4.5000 at cycle/time 43000

End of pc-CRACK Output

APPENDIX D

FLAW GROWTH CALCULATIONS, 90 DEGREE INITIAL FLAW, ELLIPTICAL CIRCUMFERENCE

tm
pc-CRACK for Windows
Version 3.1-98348

Structural Integrity Associates, Inc.
3315 Almaden Expressway, Suite 24
San Jose, CA 95118-1557

Linear Elastic Fracture Mechanics

Date: Tue Dec 18 14:32:46 2001
Input Data and Results File: CG180ELL.LFM

Title: Ginna growth calculation for 43.5 downhill penetration (Starting from 180 degree flaw, elliptical circumference)

Load Cases:

Case ID: K43down --- K vs a

Depth	K
0.0000	0.0000
1.3250	34.7440
2.6500	47.2400
3.2400	51.8550
3.8300	58.0810
4.4180	63.7220

Case ID: k43dnell --- K vs a

Depth	K
0.0000	0.0000
1.5900	34.7440
3.1700	47.2400
3.8800	51.8550
4.5800	58.0810
5.2900	63.7220

Case ID	Stress Coefficients C0	C1	C2	C3	Type
K43down	0	0	0	0	K vs a
k43dnell	0	0	0	0	K vs a

Crack Model: Through-Wall Circ. Crack in Cylinder Under Tension And Bending

Crack Parameters:
Wall thickness: 0.6250
Half crack length: 5.2800
Poisson ratio: 0.3000
Tension: Co = P/(2*Pi*Rm*t)
Max. bending: C1 = M/(Pi*t*Rm*Rm)
All other stress coefficients are neglected.

--------------------Stress Intensity Factor--------------------

Crack Size	Case K43down	Case k43dnell
0.1056	2.76903	2.30753
0.2112	5.53806	4.61505
0.3168	8.30709	6.92258
0.4224	11.0761	9.2301
0.5280	13.8452	11.5376
0.6336	16.6142	13.8452
0.7392	19.3832	16.1527
0.8448	22.1523	18.4602
0.9504	24.9213	20.7677
1.0560	27.6903	23.0753
1.1616	30.4593	25.3828
1.2672	33.2284	27.6903
1.3728	35.1948	29.9978
1.4784	36.1907	32.3054
1.5840	37.1866	34.6129
1.6896	38.1825	35.5317
1.7952	39.1784	36.3669
1.9008	40.1743	37.2021
2.0064	41.1702	38.0373
2.1120	42.1662	38.8724
2.2176	43.1621	39.7076
2.3232	44.158	40.5428
2.4288	45.1539	41.378
2.5344	46.1498	42.2131
2.6400	47.1457	43.0483
2.7456	47.9878	43.8835

2.7456	47.9878	43.8835
2.8512	48.8138	44.7187
2.9568	49.6398	45.5538
3.0624	50.4658	46.389
3.1680	51.2918	47.2242
3.2736	52.2096	47.9134
3.3792	53.3239	48.5998
3.4848	54.4383	49.2862
3.5904	55.5526	49.9726
3.6960	56.667	50.659
3.8016	57.7813	51.3454
3.9072	58.8216	52.0969
4.0128	59.8347	53.0362
4.1184	60.8478	53.9754
4.2240	61.8609	54.9146
4.3296	62.8739	55.8539
4.4352	63.887	56.7931
4.5408	64.9001	57.7323
4.6464	65.9132	58.6086
4.7520	66.9262	59.4476
4.8576	67.9393	60.2866
4.9632	68.9524	61.1256
5.0688	69.9655	61.9646
5.1744	70.9785	62.8036
5.2800	71.9916	63.6426

Crack Growth Laws:

Law ID: MRP95580
Type: Corrosion
Model: Paris

da/dN = c * (dK)^n
where
dK = Kmax - Kmin
dK > Kthres
Kmax < K1c

Material parameters:
c = 5.1707e-007
n = 1.1100
Kthres = 8.1880

Material Fracture Toughness KIc:

Material ID: Alloy 600

Depth	KIc
0.0000	200.0000
2.0000	200.0000
5.0000	200.0000
12.0000	200.0000

Initial crack size= 3.1700
Max. crack size= 5.2800

Number of blocks= 1
Print increment of block= 1

Subblock	Cycles /Time	Calc. incre.	Print incre.	Crk. Grw. Law	Mat. KIc
Ginna	100000	1000	1000	MRP95580	Alloy 600

Subblock	Kmax Case ID	Kmax Scale Factor	Kmin Case ID	Kmin Scale Factor
Ginna	k43dnell	1.0000		

Crack growth results:

Total Cycles /Time	Subblock Cycles /Time	Kmax	Kmin	DeltaK	R	DaDn /DaDt	Da	a	a/thk
Block: 1									
1000	1000	4.72e+001	0.00e+000	4.72e+001	0.00	3.73e-005	3.73e-002	3.207	0.00
2000	2000	4.75e+001	0.00e+000	4.75e+001	0.00	3.75e-005	3.75e-002	3.245	0.00
3000	3000	4.77e+001	0.00e+000	4.77e+001	0.00	3.78e-005	3.78e-002	3.283	0.00
4000	4000	4.80e+001	0.00e+000	4.80e+001	0.00	3.80e-005	3.80e-002	3.321	0.00
5000	5000	4.82e+001	0.00e+000	4.82e+001	0.00	3.82e-005	3.82e-002	3.359	0.00
6000	6000	4.85e+001	0.00e+000	4.85e+001	0.00	3.84e-005	3.84e-002	3.397	0.00
7000	7000	4.87e+001	0.00e+000	4.87e+001	0.00	3.86e-005	3.86e-002	3.436	0.00
8000	8000	4.90e+001	0.00e+000	4.90e+001	0.00	3.88e-005	3.88e-002	3.475	0.00
9000	9000	4.92e+001	0.00e+000	4.92e+001	0.00	3.91e-005	3.91e-002	3.514	0.00
10000	10000	4.95e+001	0.00e+000	4.95e+001	0.00	3.93e-005	3.93e-002	3.553	0.00
11000	11000	4.97e+001	0.00e+000	4.97e+001	0.00	3.95e-005	3.95e-002	3.593	0.00
12000	12000	5.00e+001	0.00e+000	5.00e+001	0.00	3.97e-005	3.97e-002	3.632	0.00
13000	13000	5.02e+001	0.00e+000	5.02e+001	0.00	4.00e-005	4.00e-002	3.672	0.00
14000	14000	5.05e+001	0.00e+000	5.05e+001	0.00	4.02e-005	4.02e-002	3.712	0.00
15000	15000	5.08e+001	0.00e+000	5.08e+001	0.00	4.04e-005	4.04e-002	3.753	0.00

16000	16000	5.10e+001	0.00e+000	5.10e+001	0.00	4.07e-005	4.07e-002	3.794	0.00
17000	17000	5.13e+001	0.00e+000	5.13e+001	0.00	4.09e-005	4.09e-002	3.834	0.00
18000	18000	5.16e+001	0.00e+000	5.16e+001	0.00	4.12e-005	4.12e-002	3.876	0.00
19000	19000	5.19e+001	0.00e+000	5.19e+001	0.00	4.14e-005	4.14e-002	3.917	0.00
20000	20000	5.22e+001	0.00e+000	5.22e+001	0.00	4.17e-005	4.17e-002	3.959	0.00
21000	21000	5.26e+001	0.00e+000	5.26e+001	0.00	4.20e-005	4.20e-002	4.001	0.00
22000	22000	5.29e+001	0.00e+000	5.29e+001	0.00	4.23e-005	4.23e-002	4.043	0.00
23000	23000	5.33e+001	0.00e+000	5.33e+001	0.00	4.27e-005	4.27e-002	4.086	0.00
24000	24000	5.37e+001	0.00e+000	5.37e+001	0.00	4.30e-005	4.30e-002	4.129	0.00
25000	25000	5.41e+001	0.00e+000	5.41e+001	0.00	4.34e-005	4.34e-002	4.172	0.00
26000	26000	5.45e+001	0.00e+000	5.45e+001	0.00	4.37e-005	4.37e-002	4.216	0.00
27000	27000	5.48e+001	0.00e+000	5.48e+001	0.00	4.41e-005	4.41e-002	4.26	0.00
28000	28000	5.52e+001	0.00e+000	5.52e+001	0.00	4.44e-005	4.44e-002	4.304	0.00
29000	29000	5.56e+001	0.00e+000	5.56e+001	0.00	4.48e-005	4.48e-002	4.349	0.00
30000	30000	5.60e+001	0.00e+000	5.60e+001	0.00	4.51e-005	4.51e-002	4.394	0.00
31000	31000	5.64e+001	0.00e+000	5.64e+001	0.00	4.55e-005	4.55e-002	4.44	0.00
32000	32000	5.68e+001	0.00e+000	5.68e+001	0.00	4.58e-005	4.58e-002	4.485	0.00
33000	33000	5.72e+001	0.00e+000	5.72e+001	0.00	4.62e-005	4.62e-002	4.532	0.00
34000	34000	5.77e+001	0.00e+000	5.77e+001	0.00	4.66e-005	4.66e-002	4.578	0.00
35000	35000	5.80e+001	0.00e+000	5.80e+001	0.00	4.69e-005	4.69e-002	4.625	0.00
36000	36000	5.84e+001	0.00e+000	5.84e+001	0.00	4.73e-005	4.73e-002	4.672	0.00
37000	37000	5.88e+001	0.00e+000	5.88e+001	0.00	4.76e-005	4.76e-002	4.72	0.00
38000	38000	5.92e+001	0.00e+000	5.92e+001	0.00	4.79e-005	4.79e-002	4.768	0.00
39000	39000	5.96e+001	0.00e+000	5.96e+001	0.00	4.83e-005	4.83e-002	4.816	0.00
40000	40000	6.00e+001	0.00e+000	6.00e+001	0.00	4.86e-005	4.86e-002	4.865	0.00
41000	41000	6.03e+001	0.00e+000	6.03e+001	0.00	4.90e-005	4.90e-002	4.914	0.00
42000	42000	6.07e+001	0.00e+000	6.07e+001	0.00	4.93e-005	4.93e-002	4.963	0.00
43000	43000	6.11e+001	0.00e+000	6.11e+001	0.00	4.97e-005	4.97e-002	5.013	0.00
44000	44000	6.15e+001	0.00e+000	6.15e+001	0.00	5.00e-005	5.00e-002	5.063	0.00
45000	45000	6.19e+001	0.00e+000	6.19e+001	0.00	5.04e-005	5.04e-002	5.113	0.00
46000	46000	6.23e+001	0.00e+000	6.23e+001	0.00	5.08e-005	5.08e-002	5.164	0.00
47000	47000	6.27e+001	0.00e+000	6.27e+001	0.00	5.11e-005	5.11e-002	5.215	0.00
48000	48000	6.31e+001	0.00e+000	6.31e+001	0.00	5.15e-005	5.15e-002	5.267	0.00
49000	49000	6.35e+001	0.00e+000	6.35e+001	0.00	5.19e-005	5.19e-002	5.319	0.00

Crack size exceeded 5.2800 at cycle/time 49000

End of pc-CRACK Output

STRUCTURAL INTEGRITY Associates, Inc.	CALCULATION PACKAGE	FILE No.: W-RGE-13Q-309 PROJECT No.: W-RGE-13Q

PROJECT NAME: Top Head CRDM Cracking Support for Ginna

CLIENT: ROCHESTER GAS & ELECTRIC

CALCULATION TITLE: CRDM Allowable and Critical Circumferential Flaw Sizes (GINNA)

PROBLEM STATEMENT OR OBJECTIVE OF THE CALCULATION:

Determine the allowable and critical circumferential flaw sizes for the CRDM penetrations at GINNA.

Document Revision	Affected Pages	Revision Description	Project Mgr. Approval Signature & Date	Preparer(s) & Checker(s) Signatures & Date
0	1-4	Original Issue	[signature] 12/6/01	[signature] 12/3/01 Gary L. Stevens [signature] 12/6/01 Gary L. Stevens

VENDOR DESIGN ANALYSIS REVIEW

☐ Approved - No Memorandum Required

☑ Approved - Memorandum Attached

☐ Not Approved - Vendor Notified

Approval of this design analysis does not relieve supplier from full compliance with contract or purchase order requirements.

Approved By [signature] Date 12/27/01

NS&L Review By [signature] NO COLR IMPACT Date 12/27/01

(Required if impact on COLR Values)

ROCHESTER GAS & ELECTRIC CORP.
ROCHESTER, NY

References: 1. PWR Materials Reliability Project, "Interim Alloy 600 Safety Assessments for US PWR Plants (MRP-44), Part 2: Reactor Vessel Top Head Penetrations," EPRI Report No. TP-1001491, Part 2, May 2001, SI File Number MRP-01-209.

2. Structural Integrity Associates, "Finite Element Gap Analysis of CRDM Penetrations (Ginna)," Calculation Number W-RGE-13Q-301, Revision 0.

3. ASME Boiler and Pressure Vessel Code, Sections III and XI, 1989 Edition.

Purpose: The purpose of this calculation is to determine the allowable and critical circumferential flaw sizes for the CRDM penetrations at Ginna.

Analysis: Equation 5.1 from Reference 1 and appropriate safety factors can be used to calculate the allowable and critical circumferential flaw sizes in the CRDM penetrations at Ginna:

<u>Allowable Flaw Size</u>

$$P = \frac{\sigma_{flow}}{FS}\left[\frac{A_{wall}\left(1-\frac{\theta}{360}\right)}{A_{bore}+A_{wall}\left(\frac{\theta}{360}\right)}\right]$$

where: P = maximum normal operating pressure acting on the nozzle bore and crack face

σ_{flow} = flow stress = 3.0 S_m

S_m = ASME Code, Section III design stress intensity at temperature

A_{bore} = cross-sectional area of the nozzle bore

A_{wall} = cross-sectional area of the nozzle

θ = circumferential angle of the allowable through-wall flaw

FS = factor-of-safety

	Revision	0			
	Preparer/Date	HLG 11/8/01			
	Checker/Date	GLS 12/6/01			

The nozzle has an outside diameter of 4.00", and a thickness of 0.625"[2]. The material is Alloy 600 [2]. The maximum normal operating pressure is 2,235 psig, with a corresponding maximum operating temperature of 580 °F [2]. From the Appendices of Section III of the ASME Code [3], the allowable stress intensity, S_m, is 23.3 ksi, up to a temperature of 800°F. From Appendix C of Section XI of the ASME Code [3], a factor-of-safety of 3.0 will be used since stress is only due to pressure, for normal/upset loading.

The above equation will be solved for a term "x", which is defined as θ/360:

$$A_{wall} = \pi\,(2^2 - 1.375^2) = 6.63 \text{ in}^2$$

$$A_{bore} = \pi\,(1.375^2) = 5.94 \text{ in}^2$$

$$P = 2{,}235 \text{ psig}$$

$$\sigma_{flow} = 3.0\ S_m = (3)(23{,}300) = 69{,}900 \text{ psi}$$

$$FS = 3.0$$

Therefore:

$$(2{,}235) = \frac{(69{,}900)}{3.0}\left[\frac{6.63(1-x)}{5.94+6.63x}\right]$$

$$\frac{(2{,}235)(5.94)}{(23{,}300)} + \frac{(2{,}235)(6.63x)}{(23{,}300)} = 6.63\text{-}6.63x$$

$$7.266x = 6.060$$

$$x = 0.834$$

$$\theta = 360x = 300.25°$$

Therefore, the allowable circumferential flaw length for any through-wall flaw in the Ginna CRDM penetrations is 300°.

Critical Flaw Size

The critical flaw size is determined from the above equation but using a factor-of-safety of 1.0.

Using the same calculational method above, the corresponding critical flaw size is 338.8°.

DOMINION ENGINEERING, INC.
6862 ELM STREET McLEAN, VIRGINIA 22101

Title: Ginna CRDM Stress Analysis
Task No.: 76-12 Calculation No.: C-7612-00-1 Revision No.: 0

Ginna CRDM Stress Analysis

Record of Revisions				
Rev.	**Description**	**Prepared by Date**	**Checked by Date**	**Reviewed by Date**
0	Original Issue	D. Arguelles 10/31/01	J.E. Broussard 10/31/01	J.E. Broussard 10/31/01

The last revision number to reflect any changes for each section of the calculation is shown in the Table of Contents. The last revision numbers to reflect any changes for tables and figures are shown in the List of Tables and the List of Figures. Changes made in the latest revision, except for Rev. 0 and revisions which change the calculation in its entirety, are indicated by a double line in the right hand margin as shown here.

VENDOR DESIGN ANALYSIS REVIEW
☐ Approved - No Memorandum Required
☑ Approved - Memorandum Attached
☐ Not Approved - Vendor Notified
Approval of this design analysis does not relieve supplier from full compliance with contract or purchase order requirements.
Approved By: [signature] 12/27/01
NS&L Review By: [signature] 12/27/01
(Required if impact on ...)
ROCHESTER GAS & ELECTRIC
ROCHESTER ...

Table of Contents

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1.0 Purpose

The purpose of this calculation is to document the results of finite element stress analyses of the Ginna CRDM penetrations. In this analysis, a number of nozzle geometries spanning the range of penetration angles in the Ginna head are investigated.

2.0 Summary of Results

Four cases were run, bounding the CRDM penetration angles at Ginna. These cases support the following conclusions:

1. The maximum CRDM ID hoop stresses are in the vicinity of the J-groove weld, and are in excess of the corresponding axial stresses, suggesting that PWSCC cracking should be axially oriented.

2. Using a constant CRDM yield strength, maximum hoop and axial stresses tend to increase with increasing angle.

3.0 Input Requirements

The following values are used in this calculation:

1. The local configuration of the J-groove weld attaching the CRDM to the RPV head. The details used for each model are taken from Babcock and Wilcox drawings (References 2a through 2c).

2. Detailed dimensions of the RPV head and CRDM nozzles. These values are taken from the Babcock and Wilcox drawings and are as follows:
   - Nozzle OD = 4.000 inches – Ref. (2a and 2c)
   - Nozzle ID = 2.750 inches – Ref. (2c)
   - Cladding thickness = 0.156 inches – Ref. (2a)
   - RPV Head Inner Radius (to cladding) = 66 5/32 inches – Ref. (2a)
   - RPV Head Thickness (excluding cladding) = 5.75 inches – Ref. (3)

3. CRDM nozzle yield strength. A bounding nozzle yield strength of 58.0 ksi is assumed for all cases.

4. Operating pressure and temperature. These have been assumed to be 2,235 psi and 600 °F.

4.0 Assumptions

The following modeling assumptions were used for the CRDM nozzle modeling described in this calculation:

1. Operating conditions were assumed to be 2,235 psig and 600 °F.

2. A 0.005 inch counterbore (measured radially) was modeled in the shell penetration, extending to the bottom of the uphill weld butter layer.
3. The CRDM nozzle was assumed to be flush with the penetration. No clearance or interference fit was assumed. Previous analyses have shown that assuming no interference fit produces conservative nozzle stresses as compared to stresses calculated with interference fits typically specified for CRDM nozzles.
4. A single bounding nozzle yield strength of 58.0 ksi was assumed for all cases.
5. Two passes of welding were performed: an inner pass and an outer pass. The model geometry was designed such that each weld pass is approximately the same volume.
6. The following room-temperature yield strengths were used in association with the elastic-perfectly plastic hardening laws described in Section 5.1:
   - Inco 182 Welds: 75.0 ksi
   - Low-Alloy Steel Shell: 70.0 ksi
   - Stainless Steel Cladding: 40.0 ksi

5.0 Analysis

5.1 Finite Element Analyses

Finite element analyses of the Ginna CRDM nozzles were performed for a total of four cases, selected to bracket the range of penetration angles in the RPV head. Four cases were analyzed: 0°, 13.6°, 30.0°, and 43.5°. Figure 5-1 shows the element geometry and node numbering scheme for the 43.5 degree nozzle model. The numbering scheme used is identical for all cases considered in this calculation.

ANSYS finite element analyses were performed using a model developed for commercial customers and described in a 1994 EPRI report on the subject of PWSCC of Alloy 600 components in PWR primary system service (Ref. 1). The analyses were performed on an HP B2000 workstation, under the HP-UX 10.20 operating system and ANSYS Revision 5.7, which is maintained in accordance with the provisions for control of software described in Dominion Engineering, Inc.'s QA Manual for Safety-Related Nuclear Work, DEI-002. The finite element model has been improved and refined since it was described in Reference (1). All work described in this calculation was performed using the file cirse.base, version 1.1.2, which features the following improvements over the model described in Reference (1):

1. While the material properties used for the nozzle material continue to make use of multi-linear isotropic hardening, the material properties for the weld and weld buttering, head shell, and stainless steel cladding are now modeled using elastic-perfectly plastic hardening laws. This assumption gives

more realistic stresses in the portions of the model where a high degree of plastic strain occurs at elevated temperatures, such as within the J-groove welds.

2. The ability to refine the mesh in the various regions of the model. The model geometry used in this calculation makes use of approximately twice the mesh refinement in the J-groove weld areas as is shown in reference 1, and uses greater mesh refinement in other areas of the model, such as the nozzle.

3. The ability to perform four-pass welding, as an alternative to two passes. This feature produces more satisfactory results with J-groove welds that are deep compared to the wall thickness of the adjacent nozzle, such as for head vent and thermocouple RPV head penetrations.

5.2 Analytical Results Summary

Summaries of the analytical results for each of the models analyzed are contained in Attachment 1 to this calculation. These summaries show the maximum hoop and axial stresses at the ID of the nozzle, at the "uphill" (closest to the top of the head) and "downhill" circumferential planes, as well as "above" the weld (axial portion of the nozzle including the weld region and extending through the head shell) and "below" the weld (axial portion of the nozzle extending into the RPV). The analytical results of the modeling performed are summarized in Table 5-1. Plots of the hoop stresses in each of the four model cases are shown in Figures 5-2 through 5-5.

Table 5-1. Analysis Cases and Selected Results for Ginna CRDM Nozzles

Nozzle Angle	Yield Strength (ksi)	Max Uphill ID Hoop Stress (ksi)	Max Downhill ID Hoop Stress (ksi)	Max Uphill ID Axial Stress (ksi)	Max Downhill ID Axial Stress (ksi)
0°	58.0	58.9	58.9	40.1	40.1
13.6°	58.0	62.5	61.7	53.0	44.0
30.0°	58.0	66.5	62.8	58.2	50.5
43.5°	58.0	71.7	67.8	58.6	52.7

Figures 5-2 through 5-5 and Attachment 1 show that the maximum hoop stresses are in the vicinity of the J-groove weld, and are in excess of the corresponding axial stresses, suggesting that PWSCC cracking should be axially oriented. The results also show that operating plus residual stresses are influenced by penetration angle, with higher angles generally leading to higher maximum hoop and axial stresses (see Figure 5-6). Although nozzle yield strength is known to strongly influence nozzle operating stresses, this

effect is not apparent because all cases are run at the same strength. Examining the above cases, hoop and axial stresses at both the uphill and downhill sides of the nozzle tend to increase with increasing angle. Additionally, the maximum ID hoop stress tends to occur at the uphill side of the nozzle, in the axial portion of the nozzle that extends through the head penetration (referred to as "above the weld"). The maximum ID axial stress also tends to occur at the uphill side of the nozzle, but in the axial position that extends into the reactor pressure vessel (referred to as "below the weld").

5.3 Additional Files Stored Electronically

In addition to the condensed post-processing included in this calculation, more voluminous output results have been saved electronically in the following directories and filenames:

/data/t7612/Gin-0A/Gin-0A.nodelocs.txt
/data/t7612/Gin-0A/Gin-0A.results.txt

/data/t7612/Gin-13A/Gin-13A.nodelocs.txt
/data/t7612/Gin-13A/Gin-13A.results.txt

/data/t7612/Gin-30A/Gin-30A.nodelocs.txt
/data/t7612/Gin-30A/Gin-30A.results.txt

/data/t7612/Gin-43A/Gin-43A.nodelocs.txt
/data/t7612/Gin-43A/Gin-43A.results.txt

These files have been transmitted to Structural Integrity via e-mail and on CD-ROM on disk D-7612-00-1, Revision 0.

6.0 <u>References</u>

1. PWSCC of Alloy 600 Materials in PWR Primary System Penetrations, EPRI TR-103696, July 1994.

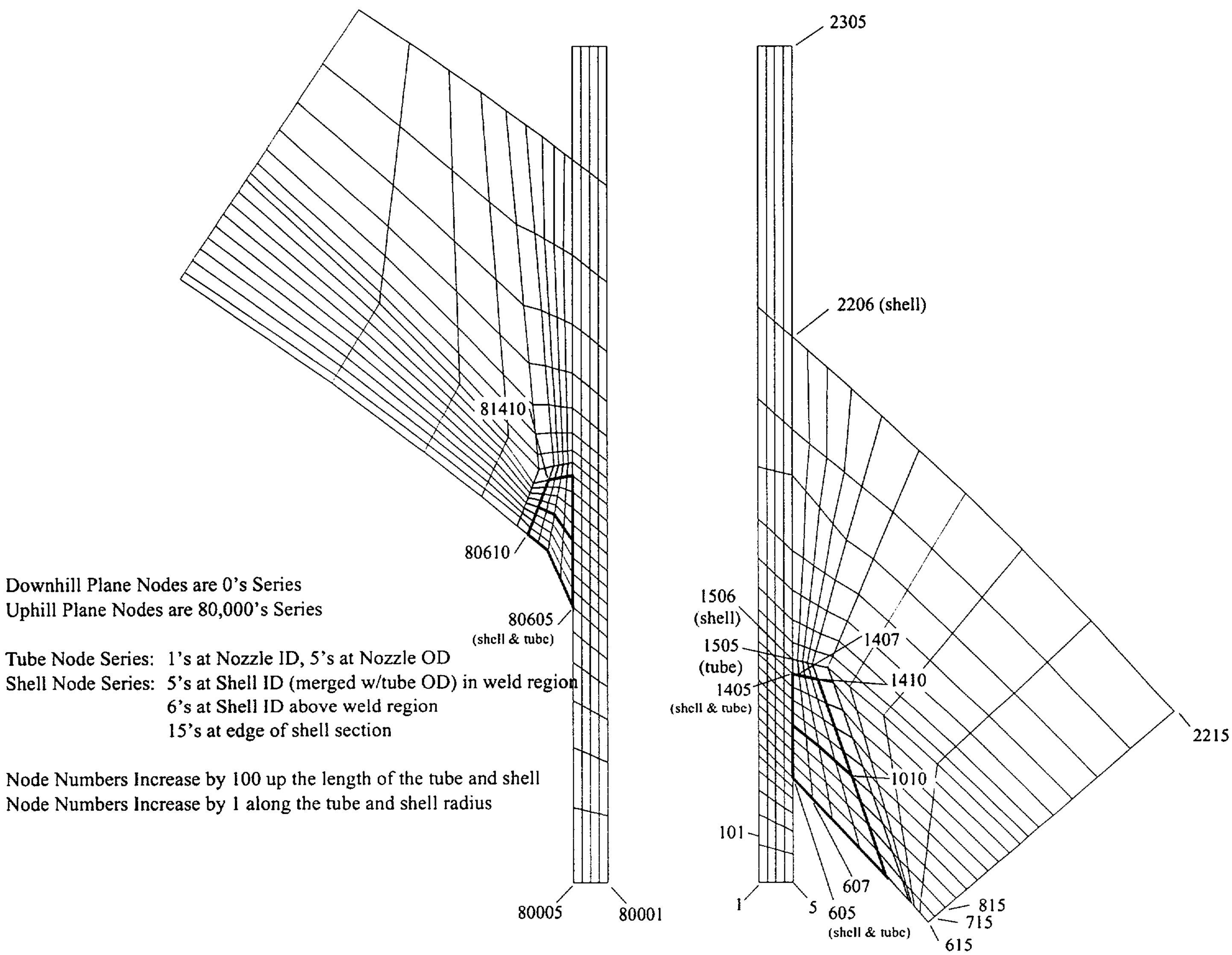
2. Babcock and Wilcox Drawings for Contract No. 610-0110-52:

   a. B&W Drawing No. 117813-E, Revision 8, Closure Head Sub-Assembly

   b. B&W Drawing No. 117807-E, Revision 6, Closure Head Assembly

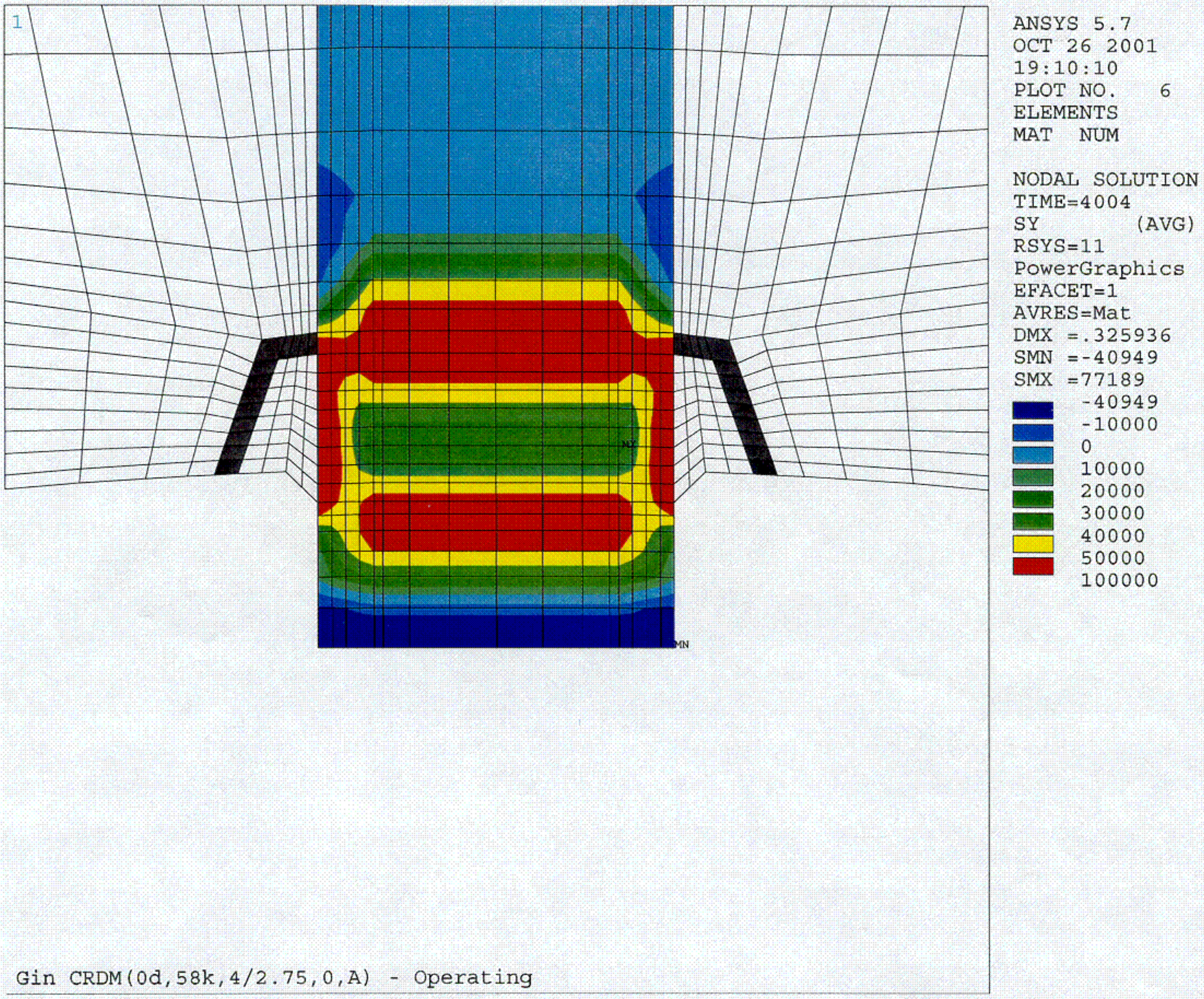
   c. B&W Drawing No. 117810-E, Revision 4, Detail & Sub-Assembly Control Rod Mechanism Housing

3. Reactor Vessel Closure Head Documentation Package, B&W Nuclear Technologies, B&W Contract No. 610-0110-52



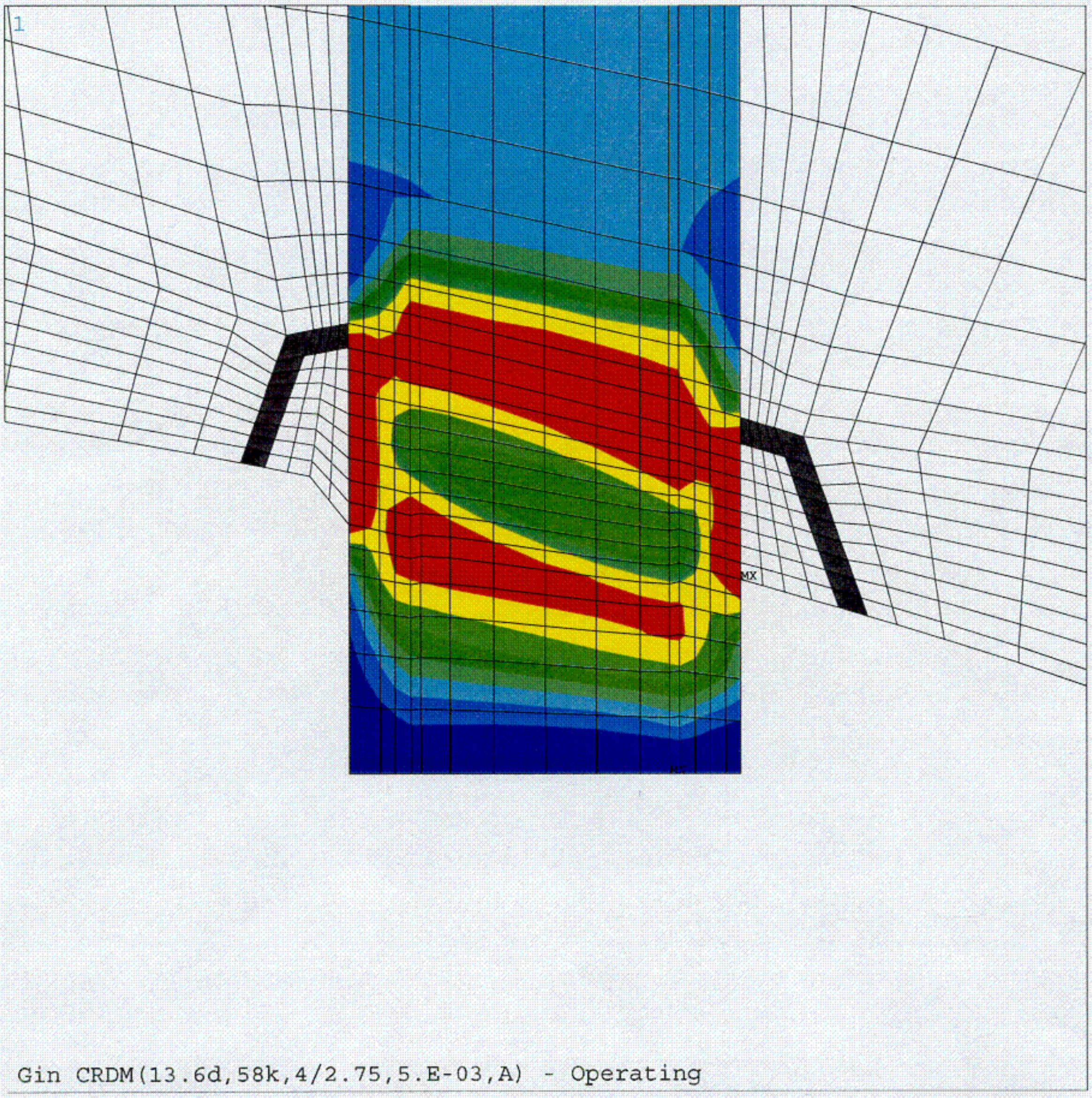
CRDM Nozzle Node Numbering Scheme

Figure 5-1



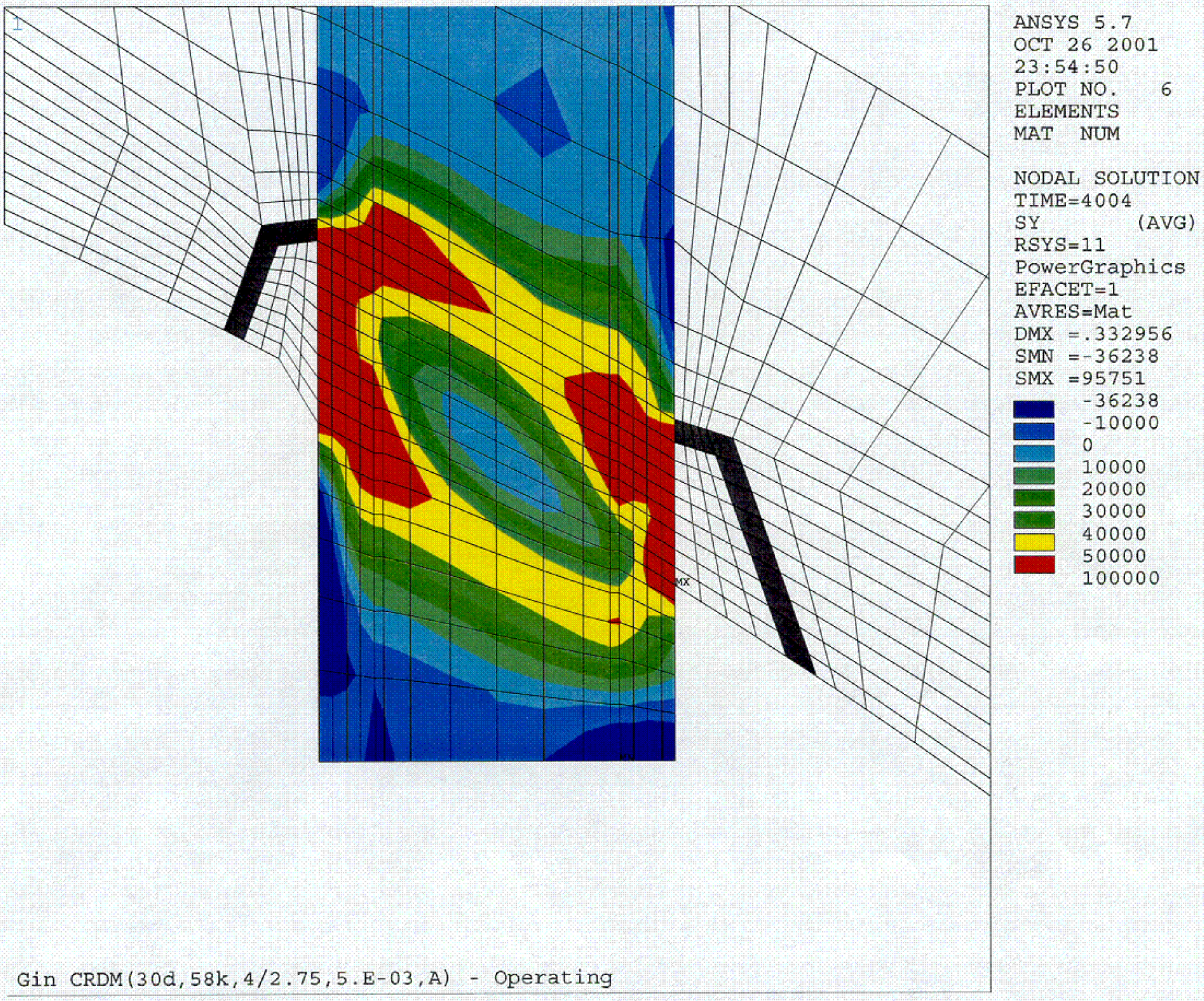
Operating Plus Residual Hoop Stresses - 0 CRDM Nozzle

Figure 5-2



Operating Plus Residual Hoop Stresses - 13.6 CRDM Nozzle

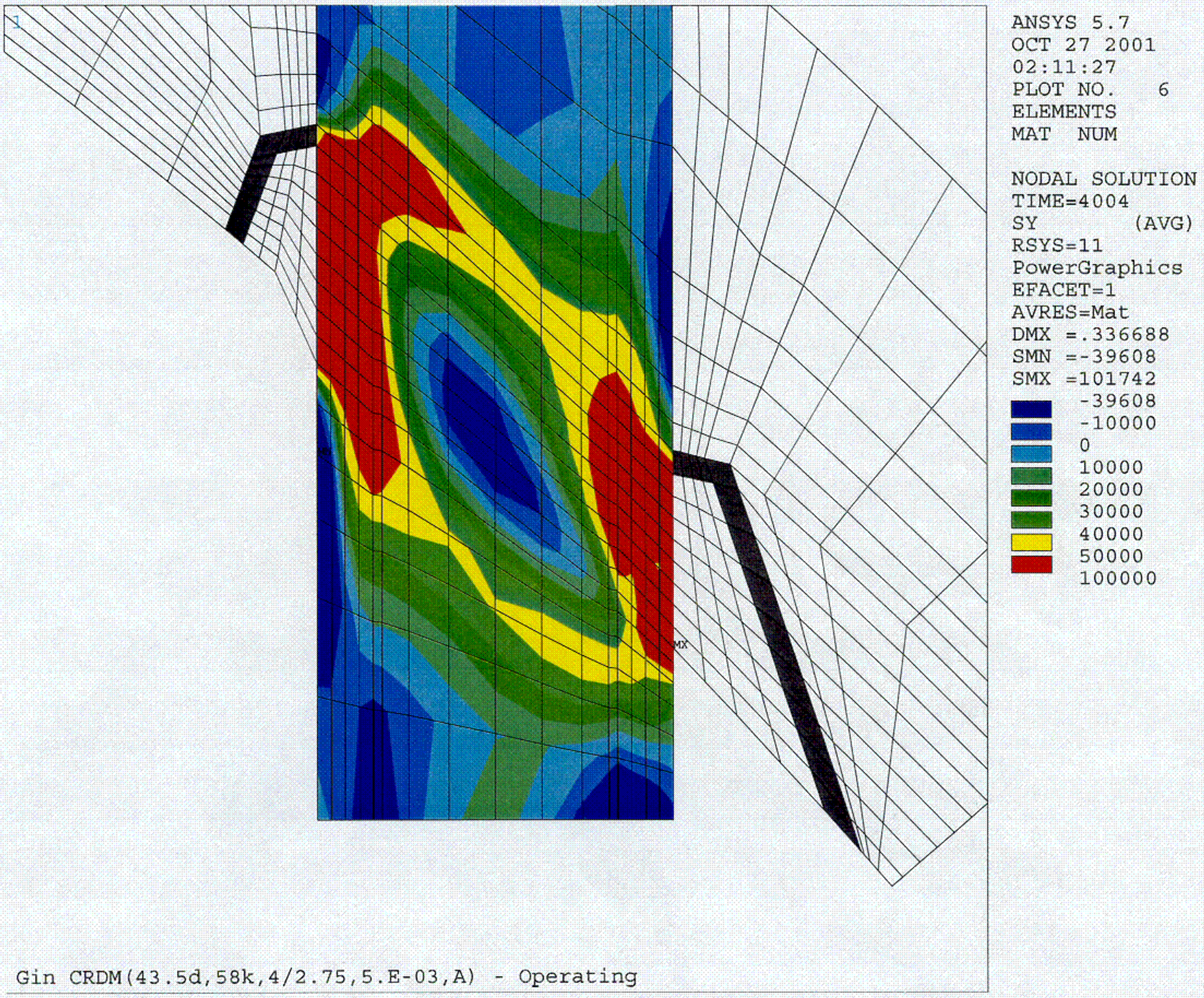
Figure 5-3



Operating Plus Residual Hoop Stresses - 30.0 CRDM Nozzle

Figure 5-4

C03

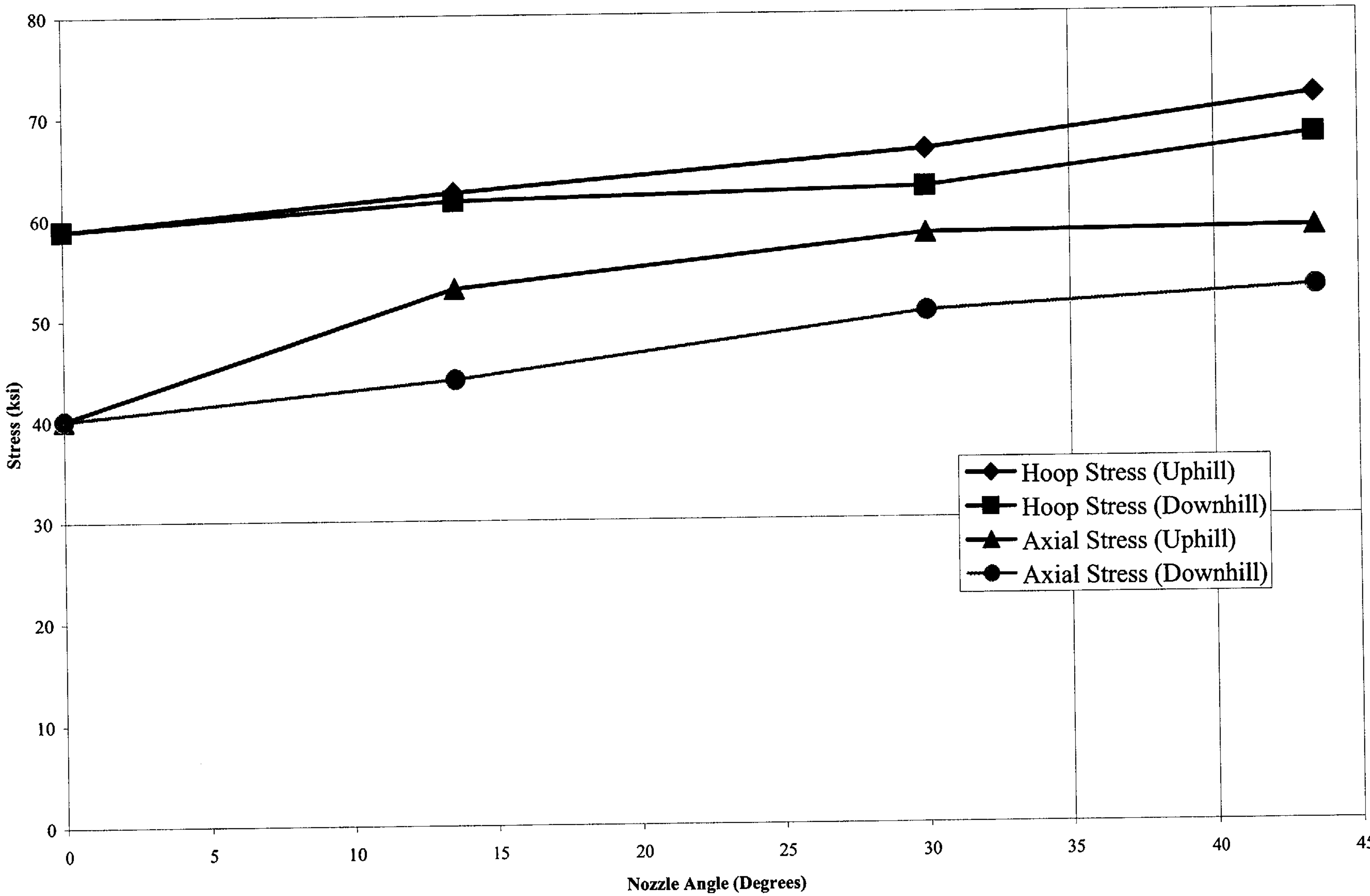


43.5 ajB. (TYP) 12-27-01 per telecon w/ DOM. ENG. STEVE HUNT

Operating Plus Residual Hoop Stresses - ~~48.5~~ CRDM Nozzle

Figure 5-5

Figure 5-6. CRDM Stresses as a Function of Nozzle Angle



```
DESCRIPTION:  FEA of Ginna CRDM NOZZLES (0 DEG)
              REVISION A: 58.0 ksi TUBE STRENGTH

ANALYSIS DATE (YYMMDD): 20011026.     ANSYS VERSION:  5.7
cirse.base MODEL VERSION: 1.1.2
TITLE:  Gin CRDM(  0.0d, 58.0k, 4.00/2.75, 0.000,A)

                          Max. Hoop Stress (psi)     Max. Axial Stress (psi)
                            Uphill    Downhill         Uphill     Downhill
I.S. Above Weld             58916.     58916.          35260.      35260.
I.S. Below Weld             58811.     58811.          40070.      40070.
Midwall Above Weld          54665.     54665.
Midwall Below Weld          46175.     46175.
 ---------------
Max. Lateral Deflection:  0.0000"          Max. Ovality:  0.0000"

 ************ INSIDE SURFACE STRESSES (psi) *************

 ** Downhill side, below weld **
Max Hoop  @ Node    501.  Hoop :  58811.  Axial:  14097.   Ratio:  4.17
Max Axial @ Node    301.  Axial:  40070.  Hoop :  50289.   Ratio:  1.26
 ** Downhill side, above weld **
Max Hoop  @ Node   1401.  Hoop :  58916.  Axial:  14164.   Ratio:  4.16
Max Axial @ Node   1601.  Axial:  35260.  Hoop :  54091.   Ratio:  1.53
 ** Uphill side, below weld **
Max Hoop  @ Node  80501.  Hoop :  58811.  Axial:  14097.   Ratio:  4.17
Max Axial @ Node  80301.  Axial:  40070.  Hoop :  50289.   Ratio:  1.26
 ** Uphill side, above weld **
Max Hoop  @ Node  81401.  Hoop :  58916.  Axial:  14164.   Ratio:  4.16
Max Axial @ Node  81601.  Axial:  35260.  Hoop :  54091.   Ratio:  1.53

 ************ INPUT PARAMETERS ********************

SYD=58000.     HDALLOY=302.     HPRESS=3110.     OPRESS=2235.
CTHK=0.1560    STHK=5.9060      SA=69.1090       THETA= 0.00     TOR=2.0000
TIR=1.3750     HCBORE=0.000     HCBOTZ= 0.000    LTIP=2.0000
HGRATE= 75.    TRIMFLAG=0.      OTEMP=600.       BUTTFIX=0.
BOTZAUTO=0.    HCBOTINC= 0.000 PARATRIM=0.       TRIMANG=  0.00
FOURPASS=0.    PRESSFLG=0.

DD1= 1.2910      DD2= 1.5362      DD3= 1.2478      DD4= 1.4764      DD5= 0.4371
DD6= 0.6200      DD7= 0.8913      DD8= 1.1574      DD9= 1.1006     DD10= 0.3536
DD11= 0.0000     DDRF= 0.3536

UU1= 1.2910      UU2= 1.5362      UU3= 1.2478      UU4= 1.4764      UU5= 0.4371
UU6= 0.6200      UU7= 0.8913      UU8= 1.1574      UU9= 1.1006     UU10= 0.3536
UU11= 0.0000     UURF= 0.3536

NRTUBE= 4.     NRWELD= 4.     NRBUTT= 1.     NRBASE= 4.
NATTIP= 6.     NACLAD= 1.     NAWELD= 8.     NAHOLE= 7.
NAEXTN= 1.     GRAD1= 6.0     GRAD2= 4.0     GRAD3= 4.0
GRAD4= 5.0     GRAD5= 5.5     GRAD6= 7.9

Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 0. 0.

HGTARG=3250.0    PASS1MXT=3191.7    PASS2MXT=3309.2
```

```
DESCRIPTION:  FEA of Ginna CRDM NOZZLES (13.6 DEG)
              REVISION A: 58.0 ksi TUBE STRENGTH

ANALYSIS DATE (YYMMDD): 20011028.     ANSYS VERSION:  5.7
cirse.base MODEL VERSION: 1.1.2
TITLE:  Gin CRDM( 13.6d, 58.0k, 4.00/2.75, 0.005,A)

                         Max. Hoop Stress (psi)      Max. Axial Stress (psi)
                           Uphill    Downhill         Uphill     Downhill
I.S. Above Weld            62515.     61724.          33802.      43999.
I.S. Below Weld            62515.     52643.          52953.      37377.
Midwall Above Weld         54354.     55336.
Midwall Below Weld         47601.     50088.
 ---------------
Max. Lateral Deflection:  0.0090"           Max. Ovality:  0.0084"

 ************ INSIDE SURFACE STRESSES (psi) *************

 ** Downhill side, below weld **
Max Hoop  @ Node    301.  Hoop :  52643.  Axial:  28777.   Ratio:  1.83
Max Axial @ Node    201.  Axial:  37377.  Hoop :  37991.   Ratio:  1.02
 ** Downhill side, above weld **
Max Hoop  @ Node   1301.  Hoop :  61724.  Axial:  19829.   Ratio:  3.11
Max Axial @ Node   1601.  Axial:  43999.  Hoop :  50587.   Ratio:  1.15
 ** Uphill side, below weld **
Max Hoop  @ Node  80601.  Hoop :  62515.  Axial:  28274.   Ratio:  2.21
Max Axial @ Node  80401.  Axial:  52953.  Hoop :  48675.   Ratio:  0.92
 ** Uphill side, above weld **
Max Hoop  @ Node  80601.  Hoop :  62515.  Axial:  28274.   Ratio:  2.21
Max Axial @ Node  81601.  Axial:  33802.  Hoop :  53788.   Ratio:  1.59

 ************ INPUT PARAMETERS ********************

SYD=58000.     HDALLOY=302.     HPRESS=3110.    OPRESS=2235.
CTHK=0.1560    STHK=5.9060      SA=69.1090      THETA=13.60      TOR=2.0000
TIR=1.3750     HCBORE=0.005     HCBOTZ=66.133   LTIP=2.4839
HGRATE= 74.    TRIMFLAG=0.      OTEMP=600.      BUTTFIX=0.
BOTZAUTO=1.    HCBOTINC= 0.000  PARATRIM=0.     TRIMANG=  0.00
FOURPASS=0.    PRESSFLG=0.

DD1= 1.3298     DD2= 1.5871     DD3= 1.3170     DD4= 1.5690     DD5= 0.4542
DD6= 0.6424     DD7= 0.9950     DD8= 1.2867     DD9= 1.2227     DD10= 0.4484
DD11= 0.0000    DDRF= 0.0000

UU1= 1.3524     UU2= 1.5954     UU3= 1.1812     UU4= 1.3532     UU5= 0.4476
UU6= 0.6329     UU7= 0.8542     UU8= 1.0987     UU9= 1.0450     UU10= 0.3929
UU11= 0.0000    UURF= 0.3929

NRTUBE= 4.     NRWELD= 4.     NRBUTT= 1.     NRBASE= 4.
NATTIP= 6.     NACLAD= 1.     NAWELD= 8.     NAHOLE= 7.
NAEXTN= 1.     GRAD1= 6.0     GRAD2= 4.0     GRAD3= 4.0
GRAD4= 5.0     GRAD5= 5.5     GRAD6= 7.9

Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 1. 1. 1. 0.

HGTARG=3250.0     PASS1MXT=3202.2     PASS2MXT=3310.8
```

```
DESCRIPTION:  FEA of Ginna CRDM NOZZLES (30.0 DEG)
              REVISION A: 58.0 ksi TUBE STRENGTH

ANALYSIS DATE (YYMMDD): 20011028.     ANSYS VERSION:  5.7
cirse.base MODEL VERSION: 1.1.2
TITLE:  Gin CRDM( 30.0d, 58.0k, 4.00/2.75, 0.005,A)

                            Max. Hoop Stress (psi)     Max. Axial Stress (psi)
                              Uphill    Downhill         Uphill     Downhill
I.S. Above Weld               66469.     62789.          52058.       50495.
I.S. Below Weld               62489.     51417.          58183.       33995.
Midwall Above Weld            58290.     62677.
Midwall Below Weld            51269.     55406.
 ---------------
Max. Lateral Deflection:  0.0220"             Max. Ovality:  0.0323"

 ************ INSIDE SURFACE STRESSES (psi) ************

 ** Downhill side, below weld **
Max Hoop  @ Node    301.  Hoop :  51417.  Axial:  13101.   Ratio:  3.92
Max Axial @ Node    201.  Axial:  33995.  Hoop :  33280.   Ratio:  0.98
 ** Downhill side, above weld **
Max Hoop  @ Node   1101.  Hoop :  62789.  Axial:  15145.   Ratio:  4.15
Max Axial @ Node   1601.  Axial:  50495.  Hoop :  47817.   Ratio:  0.95
 ** Uphill side, below weld **
Max Hoop  @ Node  80601.  Hoop :  62489.  Axial:  52058.   Ratio:  1.20
Max Axial @ Node  80501.  Axial:  58183.  Hoop :  54227.   Ratio:  0.93
 ** Uphill side, above weld **
Max Hoop  @ Node  80701.  Hoop :  66469.  Axial:  38905.   Ratio:  1.71
Max Axial @ Node  80601.  Axial:  52058.  Hoop :  62489.   Ratio:  1.20

 ************ INPUT PARAMETERS ********************

SYD=58000.     HDALLOY=302.     HPRESS=3110.     OPRESS=2235.
CTHK=0.1560    STHK=5.9060      SA=69.1090       THETA=30.00       TOR=2.0000
TIR=1.3750     HCBORE=0.005     HCBOTZ=59.939    LTIP=3.1547
HGRATE= 73.    TRIMFLAG=0.      OTEMP=600.       BUTTFIX=0.
BOTZAUTO=1.    HCBOTINC= 0.000 PARATRIM=0.       TRIMANG=  0.00
FOURPASS=0.    PRESSFLG=0.

DD1= 1.3576     DD2= 1.5785     DD3= 1.4698     DD4= 1.7384     DD5= 0.4555
DD6= 0.6494     DD7= 1.2376     DD8= 1.5744     DD9= 1.4914     DD10= 0.5814
DD11= 0.0000    DDRF= 0.0000

UU1= 1.3606     UU2= 1.5854     UU3= 1.1116     UU4= 1.2332     UU5= 0.4396
UU6= 0.6173     UU7= 0.8257     UU8= 1.0456     UU9= 0.9914     UU10= 0.4308
UU11= 0.0000    UURF= 0.4308

NRTUBE= 4.     NRWELD= 4.     NRBUTT= 1.     NRBASE= 4.
NATTIP= 6.     NACLAD= 1.     NAWELD= 8.     NAHOLE= 7.
NAEXTN= 1.     GRAD1= 6.0     GRAD2= 4.0     GRAD3= 4.0
GRAD4= 5.0     GRAD5= 5.5     GRAD6= 7.9

Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 1. 1. 0.

HGTARG=3250.0     PASS1MXT=3210.5     PASS2MXT=3307.4
```

```
DESCRIPTION:  FEA of Ginna CRDM NOZZLES (43.5 DEG)
              REVISION A: 58.0 ksi TUBE STRENGTH

ANALYSIS DATE (YYMMDD): 20011028.     ANSYS VERSION:  5.7
cirse.base MODEL VERSION: 1.1.2
TITLE:  Gin CRDM( 43.5d, 58.0k, 4.00/2.75, 0.005,A)

                          Max. Hoop Stress (psi)     Max. Axial Stress (psi)
                            Uphill   Downhill          Uphill     Downhill
I.S. Above Weld             71690.    67763.           56373.      52656.
I.S. Below Weld             60869.    45894.           58578.      25240.
Midwall Above Weld          69635.    69601.
Midwall Below Weld          54414.    62053.
 ---------------
Max. Lateral Deflection:  0.0358"          Max. Ovality:  0.0565"

 ************ INSIDE SURFACE STRESSES (psi) *************

 ** Downhill side, below weld **
Max Hoop  @ Node     301.  Hoop :  45894.  Axial:  -5892.   Ratio: -7.79
Max Axial @ Node     201.  Axial:  25240.  Hoop :  24780.   Ratio:  0.98
 ** Downhill side, above weld **
Max Hoop  @ Node     901.  Hoop :  67763.  Axial:  24315.   Ratio:  2.79
Max Axial @ Node    1501.  Axial:  52656.  Hoop :  53979.   Ratio:  1.03
 ** Uphill side, below weld **
Max Hoop  @ Node   80601.  Hoop :  60869.  Axial:  56373.   Ratio:  1.08
Max Axial @ Node   80501.  Axial:  58578.  Hoop :  57126.   Ratio:  0.98
 ** Uphill side, above weld **
Max Hoop  @ Node   80901.  Hoop :  71690.  Axial:  32837.   Ratio:  2.18
Max Axial @ Node   80601.  Axial:  56373.  Hoop :  60869.   Ratio:  1.08

 ************ INPUT PARAMETERS *********************

SYD=58000.     HDALLOY=302.    HPRESS=3110.    OPRESS=2235.
CTHK=0.1560    STHK=5.9060     SA=69.1090      THETA=43.50     TOR=2.0000
TIR=1.3750     HCBORE=0.005    HCBOTZ=51.609   LTIP=3.8979
HGRATE= 73.    TRIMFLAG=0.     OTEMP=600.      BUTTFIX=0.
BOTZAUTO=1.    HCBOTINC= 0.000 PARATRIM=0.     TRIMANG=  0.00
FOURPASS=0.    PRESSFLG=0.

DD1= 1.3640     DD2= 1.5563     DD3= 1.6108     DD4= 1.8943     DD5= 0.4492
DD6= 0.6383     DD7= 1.6839     DD8= 2.0903     DD9= 1.9707    DD10= 0.7130
DD11= 0.0000    DDRF= 0.0000

UU1= 1.3650     UU2= 1.5480     UU3= 1.0140     UU4= 1.0515     UU5= 0.4436
UU6= 0.6273     UU7= 0.8218     UU8= 1.0195     UU9= 0.9613    UU10= 0.4619
UU11= 0.0000    UURF= 0.4619

NRTUBE= 4.     NRWELD= 4.     NRBUTT= 1.     NRBASE= 4.
NATTIP= 6.     NACLAD= 1.     NAWELD= 8.     NAHOLE= 7.
NAEXTN= 1.     GRAD1= 6.0     GRAD2= 4.0     GRAD3= 4.0
GRAD4= 5.0     GRAD5= 5.5     GRAD6= 7.9

Counterbore Unselect Flags (0-8 in order): 0. 0. 0. 0. 0. 0. 0. 1. 0.

HGTARG=3250.0     PASS1MXT=3231.0     PASS2MXT=3296.9
```

ENCLOSURE 3

PSA INSIGHTS

The current Ginna Station PSA models were solved for medium break LOCAs which encompasses breaks between 1.5 inch and 5.5 inch diameter. The VHPs at Ginna Station are 4 inch diameter and fall within this range. The model quantification included the following considerations:

1. The frequency of initiator LIMBLOCA was set to 1.0 and a truncation limit of 1E-10 was used.
2. The failure rate for the operators transferring to recirculation (event RRHFDRECRC-M) was changed from 5.3E-03 to 1.20E-03 which is the value used for small LOCAs (1 - 1.5 inch). This change was made for the following reasons:
    a. The dominating factor for this human action is the time available to accomplish the transfer to sump recirculation. The time used for RRHFDRECRC-M is for a 5.5 inch LOCA where only 13 minutes would potentially be available to complete sump transfer once operator cues are reached. This is primarily due to the fact that the Containment Spray (CS) pumps would actuate and rapidly drain the RWST. Based on simulator runs, a 4 inch LOCA would not be expected to cause an automatic CS actuation. Also, if the RHR and SI pumps were stopped at an RWST level of 28% as called out in the Emergency Operating Procedures (EOPs), operators would have up to 55 minutes to accomplish the task. The small LOCA analysis assumes at least 48 minutes is available.
    b. A failure of a nozzle would at worst cause a 4 inch LOCA. However, the more likely LOCA size is based on the ID of the nozzle, or 2.75 inches. This is because a 4 inch LOCA could only be created by the ejection of the entire nozzle. A 2.75 inch LOCA provides even more time to accomplish the task (up to 77 minutes).

The quantification results are shown in Table 3-1 (attached). Table 3-2 (attached) provides a listing of the top 10 sequences. As can be seen from both tables, the operators failing to transfer to recirculation is the largest risk contributor.

RG&E had previously submitted the Ginna Station PSA to the NRC (References 1 and 2). The table below shows the differences in values calculated between Reference 2 and in this enclosure.

Version	MBLOCA CCDP	Top Sequences
1997	1.03E-02	a. Operator fails transfer to recirc b. CCF of RHR pumps c. CCF of RHR suction and injection valves & CCW d. CCF of SI pumps e. RWST suction failures f. Operator fails to close AOV 371 g. RHR test and maintenance

Version	MBLOCA CCDP	Top Sequences
2001	2.23E-03(1)	a. Operator fails to transfer to recirc b. RWST suction failures c. Test and Maintenance of RHR, SI, and CCW d. CCFs of SI pumps e. CCFs within RHR and CCW f. Throttling position of CCW manual valves

(1) CCDP = 6.33E-03 if use higher value for operator failure to achieve sump recirculation

As can be seen, both versions of the PSA have the same set of equipment and human actions, although their relative ranking may have changed. The only significant difference is the treatment of AOV 371 which the current model shows to only result in an insignificant loss of RHR fluid. Major changes to the PSA models since the 1997 submittal include:

1. Update of all data. This includes:
    a. Equipment failure rates and unavailabilities are now primarily based on a composite of historical data from 1980 - 1988 and 1994 - 2000. They were previously based solely on data prior to 1990.
    b. Common cause failure (CCF) data is now based on NUREG/CR-5497 (Reference 3).
    c. Initiator frequencies are now based on NUREG/CR-5750 (Reference 4).

2. Additional modeling details. The current PSA encompasses almost 5000 separate components and closely matches the flowpaths of the EOPs.

References

1. Letter from R.C. Mecredy, RG&E, to A.R. Johnson, NRC, Subject: *Generic Letter 88-20*, dated March 15, 1994.

2. Letter from R.C. Mecredy, RG&E, to G.S. Vissing, NRC, Subject: *Generic Letter 88-20, Level 1 Probabilistic Safety Assessment (PSA)*, dated January 15, 1997.

3. NUREG/CR-5497, *Common-Cause Failure Parameter Estimation*, October 1998.

4. NUREG/CR-5750, *Rates of Initiating Events at U.S. Nuclear Power Plants, 1987 - 1995*, February 1999.

TABLE 3-1

Cutsets with Descriptions Report
MLOCAS = 2.23E-03
D:\CAFTA-W\QUANT\LEVEL1\MLOCAS.CUT   12/27/2001 2:30 PM

#	Inputs	Description	Rate	Exposure	Event Prob	Probability
1	LIMBLOCA	Medium LOCA (1.5-5.5)		4.00E-05	1.00E+00	1.20E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE			1.00	1.00E+00
	RRHFDRECRC-M	OPERATOR FAILS TO CORRECTLY SHIFT THE RHR SYSTEM TO RECIRCULATION			5.30E-03	1.20E-03
2	LIMBLOCA	Medium LOCA (1.5-5.5)		4.00E-05	1.00E+00	1.65E-04
	MLO	TAG - MEDIUM LOCA SEQUENCE			1.00	1.00E+00
	RHXVK00856	MANUAL VALVE 856 TRANSFERS CLOSED		1.49E-07	1107.00	1.65E-04
3	LIMBLOCA	Medium LOCA (1.5-5.5)		4.00E-05	1.00E+00	1.06E-04
	MLO	TAG - MEDIUM LOCA SEQUENCE			1.00	1.00E+00
	SICCMPSI1X	PSI01A, PSI01B & PSI01C FAIL TO START FOR INJECTION DUE TO COMMON CAUSE			1.06E-04	1.06E-04
4	LIMBLOCA	Medium LOCA (1.5-5.5)		4.00E-05	1.00E+00	6.22E-05
	MLO	TAG - MEDIUM LOCA SEQUENCE			1.00	1.00E+00
	RHCVN00854	CHECK VALVE 854 FAILS TO OPEN [INJECTION]		6.22E-05	1.00	6.22E-05
5	LIMBLOCA	Medium LOCA (1.5-5.5)		4.00E-05	1.00E+00	5.42E-05
	MLO	TAG - MEDIUM LOCA SEQUENCE			1.00	1.00E+00
	RHCCPUMPAB	COMMON CAUSE FAILURE OF RHR PUMPS A AND B TO START			5.42E-05	5.42E-05
6	LIMBLOCA	Medium LOCA (1.5-5.5)		4.00E-05	1.00E+00	5.08E-05
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00	
	RWMM00RWST	INSUFFICIENT FLOW AVAILABLE FROM TSI01 (RWST)			5.08E-05	5.08E-05
7	LIMBLOCA	Medium LOCA (1.5-5.5)		4.00E-05	1.00E+00	3.57E-05
	CCCC738A/B	COMMON CAUSE FAILURE OF MOV'S 738A AND 738B TO OPEN			3.57E-05	3.57E-05
	MLO	TAG - MEDIUM LOCA SEQUENCE			1.00	1.00E+00
8	LIMBLOCA	Medium LOCA (1.5-5.5)		4.00E-05	1.00E+00	3.46E-05
	CCMM00738A	MOV 738A FAILS TO OPEN		4.00E-03	4.00E-03	
	MLO	TAG - MEDIUM LOCA SEQUENCE			1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE			8.65E-03	8.65E-03
9	LIMBLOCA	Medium LOCA (1.5-5.5)		4.00E-05	1.00E+00	2.80E-05
	CCMM00738B	MOV 738B FAILS TO OPEN		4.00E-03	4.00E-03	
	MLO	TAG - MEDIUM LOCA SEQUENCE			1.00	1.00E+00
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE			7.00E-03	7.00E-03
10	LIMBLOCA	Medium LOCA (1.5-5.5)		4.00E-05	1.00E+00	2.60E-05
	CCHFL0780A	CCW THROTTLING VALVE 780A MISPOSITIONED			3.00E-03	3.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE			1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE			8.65E-03	8.65E-03

11	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.60E-05
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHHFL0000A	LATENT HUMAN FAILURE OF RHR TRAIN A		3.00E-03	3.00E-03
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03
12	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.20E-05
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RRSMP00A/B	CONTAINMENT SUMP SCREENS PLUGGED [RECIRC]	2.20E-05	1.00	2.20E-05
13	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.10E-05
	CCHFL0780B	CCW THROTTLING VALVE 780B MISPOSITIONED		3.00E-03	3.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE		7.00E-03	7.00E-03
14	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.10E-05
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHHFL0000B	LATENT HUMAN FAILURE OF RHR TRAIN B		3.00E-03	3.00E-03
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE		7.00E-03	7.00E-03
15	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.60E-05
	CCMM00738A	MOV 738A FAILS TO OPEN	4.00E-03	4.00E-03	
	CCMM00738B	MOV 738B FAILS TO OPEN	4.00E-03	4.00E-03	
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
16	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.20E-05
	CCHFL0780A	CCW THROTTLING VALVE 780A MISPOSITIONED		3.00E-03	3.00E-03
	CCMM00738B	MOV 738B FAILS TO OPEN		4.00E-03	4.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
17	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.20E-05
	CCHFL0780B	CCW THROTTLING VALVE 780B MISPOSITIONED		3.00E-03	3.00E-03
	CCMM00738A	MOV 738A FAILS TO OPEN		4.00E-03	4.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
18	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.06E-05
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SIMMINJECB	VALVE FAILURES IN SI PUMP B INJECTION LINE TO LOOP A COLD LEG		3.10E-03	3.10E-03
	SITMTRAINA	SI TRAIN A DISCHARGE VALVES UNAVAILABLE DUE TO TEST OR MAINT		3.43E-03	3.43E-03
19	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	9.43E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RWMM896A/B	MOV 896A OR 896B TRANSFERS CLOSED (FAILS CS AND SI FROM RWST)		9.43E-06	9.43E-06
20	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	9.00E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHHFL0000A	LATENT HUMAN FAILURE OF RHR TRAIN A		3.00E-03	3.00E-03
	RHHFL0000B	LATENT HUMAN FAILURE OF RHR TRAIN B		3.00E-03	3.00E-03
21	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	8.78E-06
	CCPPJ_COMM	PIPE RUPTURE IN THE COMMON CCW PIPING	3.66E-07	24.00	8.78E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00

22	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	8.24E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMVR0857B	MOV 857B TRANSFERS OPEN - LOSS OF FLOW	2.29E-07	36.00	8.24E-06
23	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	8.19E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SIMMINJECA	VALVE FAILURES IN SI PUMP A INJECTION LINE TO LOOP B COLD LEG		2.24E-03	2.24E-03
	SITMTRAINB	SI TRAIN B DISCHARGE VALVES UNAVAILABLE DUE TO TEST OR MAINT		3.65E-03	3.65E-03
24	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	7.42E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMMAC01AA	RHR PUMP A (PAC01A) FAILS TO START		8.58E-04	8.58E-04
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03
25	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	7.09E-06
	CCCCPUMP/R	COMMON CAUSE FAILURE OF CCW PUMPS TO RUN		7.09E-06	7.09E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
26	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	7.04E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SIPPJMBL0B	CONDITIONAL PROBABILITY OF MBLOCA IN THE B SI LINE		1.93E-03	1.93E-03
	SITMTRAINB	SI TRAIN B DISCHARGE VALVES UNAVAILABLE DUE TO TEST OR MAINT		3.65E-03	3.65E-03
27	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	6.96E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SIMMINJECA	VALVE FAILURES IN SI PUMP A INJECTION LINE TO LOOP B COLD LEG		2.24E-03	2.24E-03
	SIMMINJECB	VALVE FAILURES IN SI PUMP B INJECTION LINE TO LOOP A COLD LEG		3.10E-03	3.10E-03
28	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	6.52E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SICCMPSI1Y	PSI01A, PSI01B & PSI01C FAIL TO RUN DURING INJECTION DUE TO CCF		6.52E-06	6.52E-06
29	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	6.35E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHPPJINJLN	PIPING - COMMON INJECTION LINE RUPTURE [INJECTION]	5.29E-07	12.00	6.35E-06
30	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	6.01E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMMAC01BA	RHR PUMP B (PAC01B) FAILS TO START		8.58E-04	8.58E-04
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE		7.00E-03	7.00E-03
31	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	5.99E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SIMMINJECB	VALVE FAILURES IN SI PUMP B INJECTION LINE TO LOOP A COLD LEG		3.10E-03	3.10E-03
	SIPPJMBL0B	CONDITIONAL PROBABILITY OF MBLOCA IN THE B SI LINE		1.93E-03	1.93E-03
32	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	5.93E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RWCCM0896X	COMMON CAUSE FAILURE OF MOVS 896A AND 896B TO CLOSE (RECIRC)		5.93E-06	5.93E-06

33	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	5.50E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMVR0850A	MOV 850A TRANSFERS OPEN [INJECTION]	2.29E-07	24.00	5.50E-06
34	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	5.50E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMVR0850B	MOV 850B TRANSFERS OPEN [INJECTION]	2.29E-07	24.00	5.50E-06
35	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	5.23E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SWCCPUMPSR	Common Cause Failure Of Service Water Pumps To Run		5.23E-06	5.23E-06
36	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	4.97E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SIPPJMBL0A	CONDITIONAL PROBABILITY OF MBLOCA IN THE A SI LINE		1.45E-03	1.45E-03
	SITMTRAINA	SI TRAIN A DISCHARGE VALVES UNAVAILABLE DUE TO TEST OR MAINT		3.43E-03	3.43E-03
37	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	4.51E-06
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGDGF0001A	DIESEL GENERATOR KDG01A FAILS TO RUN	1.86E-03	24.00	4.46E-02
	DGDGF0001B	DIESEL GENERATOR KDG01B FAILS TO RUN	1.86E-03	24.00	4.46E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
38	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	4.24E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03
	RHXVK00717	MANUAL VALVE 717 TRANSFERS CLOSED [INJECTION]	1.49E-07	3291.00	4.90E-04
39	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	4.05E-06
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGCC000RUN	DIESEL GENERATORS FAIL TO RUN (COMMON CAUSE)		1.79E-03	1.79E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
40	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.73E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHCC697A/B	CHECK VALVES 697A, 697B FAIL TO OPEN <COMMON CAUSE EVENT>		3.73E-06	3.73E-06

41	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.73E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHCC710A/B	CHECK VALVES 710A, 710B FAIL TO OPEN <COMMON CAUSE EVENT>		3.73E-06	3.73E-06
42	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.73E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHCC853A/B	CHECK VALVES 853A, 853B FAIL TO OPEN <COMMON CAUSE EVENT>		3.73E-06	3.73E-06
43	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.73E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RRCC697A/B	CHECK VALVES 697A/B FAIL TO OPEN <COMMON CAUSE EVENT>		3.73E-06	3.73E-06
44	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.73E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RRCC710A/B	CHECK VALVES 710A/B FAIL TO OPEN <COMMON CAUSE EVENT>		3.73E-06	3.73E-06
45	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.69E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RWHFL0896A	MOTOR OPERATED VALVE 896A IS LEFT UNAVAILABLE AFTER TESTING OR MAINT		3.00E-03	3.00E-03
	RWMVC0896B	MOV 896B FAILS TO CLOSE ON DEMAND (RECIRCULATION)	1.23E-03	1.00	1.23E-03
46	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.69E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RWHFL0896B	MOTOR OPERATED VALVE 896B IS LEFT UNAVAILABLE AFTER TESTING OR MAINT		3.00E-03	3.00E-03
	RWMVC0896A	MOV 896A FAILS TO CLOSE ON DEMAND (RECIRCULATION)	1.23E-03	1.00	1.23E-03
47	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.43E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE		7.00E-03	7.00E-03
	RHXVK00715	MANUAL VALVE 715 TRANSFERS CLOSED [INJECTION]	1.49E-07	3291.00	4.90E-04
48	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.43E-06
	CCMM00738A	MOV 738A FAILS TO OPEN		4.00E-03	4.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMMAC01BA	RHR PUMP B (PAC01B) FAILS TO START		8.58E-04	8.58E-04
49	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.43E-06
	CCMM00738B	MOV 738B FAILS TO OPEN		4.00E-03	4.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMMAC01AA	RHR PUMP A (PAC01A) FAILS TO START		8.58E-04	8.58E-04
50	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.36E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SICCM0867X	COMMON CAUSE FAILURE TO OPEN OF CHECK VALVES 867A & 867B		3.36E-06	3.36E-06
51	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.36E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SICCM0878X	CHECK VALVES 878G AND 878J FAIL TO OPEN DUE TO COMMON CAUSE		3.36E-06	3.36E-06
52	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.36E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SICCM0889X	CHECK VALVES 870A, 870B, 889A AND 889B FAIL TO OPEN DUE TO CCF		3.36E-06	3.36E-06

53	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	3.25E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SIMMINJECA	VALVE FAILURES IN SI PUMP A INJECTION LINE TO LOOP B COLD LEG		2.24E-03	2.24E-03
	SIPPJMBL0A	CONDITIONAL PROBABILITY OF MBLOCA IN THE A SI LINE		1.45E-03	1.45E-03
54	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.79E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHCC852A/B	MOVS 852A, 852B FAIL TO OPEN <COMMON CAUSE EVENT>		2.79E-06	2.79E-06
55	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.79E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHCCPUMPBA	COMMON CAUSE FAILURE OF RHR PUMPS A AND B TO RUN		2.79E-06	2.79E-06
56	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.79E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RRCC850A/B	MOVS 850A/B FAIL TO OPEN <COMMON CAUSE EVENT>		2.79E-06	2.79E-06
57	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.57E-06
	CCHFL0780A	CCW THROTTLING VALVE 780A MISPOSITIONED		3.00E-03	3.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMMAC01BA	RHR PUMP B (PAC01B) FAILS TO START		8.58E-04	8.58E-04
58	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.57E-06
	CCHFL0780B	CCW THROTTLING VALVE 780B MISPOSITIONED		3.00E-03	3.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMMAC01AA	RHR PUMP A (PAC01A) FAILS TO START		8.58E-04	8.58E-04
59	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.57E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHHFL0000A	LATENT HUMAN FAILURE OF RHR TRAIN A		3.00E-03	3.00E-03
	RHMMAC01BA	RHR PUMP B (PAC01B) FAILS TO START		8.58E-04	8.58E-04
60	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	2.57E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHHFL0000B	LATENT HUMAN FAILURE OF RHR TRAIN B		3.00E-03	3.00E-03
	RHMMAC01AA	RHR PUMP A (PAC01A) FAILS TO START		8.58E-04	8.58E-04
61	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.96E-06
	CCMM00738A	MOV 738A FAILS TO OPEN	4.00E-03	4.00E-03	
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHXVK00715	MANUAL VALVE 715 TRANSFERS CLOSED [INJECTION]	1.49E-07	3291.00	4.90E-04
62	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.96E-06
	CCMM00738B	MOV 738B FAILS TO OPEN		4.00E-03	4.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHXVK00717	MANUAL VALVE 717 TRANSFERS CLOSED [INJECTION]	1.49E-07	3291.00	4.90E-04
63	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.92E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE	1.00	1.00E+00	
	SICCF897/8	COMMON CAUSE FAILURE OF 897 AND 898 TO CLOSE		1.92E-06	1.92E-06

64	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.76E-06
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGDGF0001A	DIESEL GENERATOR KDG01A FAILS TO RUN	1.86E-03	24.00	4.46E-02
	DGTM00001B	DIESEL GENERATOR KDG01B UNAVAILABLE DUE TO TESTING OR MAINT		0.02	1.74E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
65	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.62E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMVN0852B	MOV 852B FAILS TO OPEN 3.12E-04		1.00	3.12E-04
	RRPPJMBL0A	CONDITIONAL PROBABILITY OF MBLOCA IN A RHR LINE		5.20E-03	5.20E-03
66	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.62E-06
	CCXVK00728	MANUAL VALVE 728 TRANSFERS CLOSED	6.73E-08	24.00	1.62E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
67	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.57E-06
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGDGF0001B	DIESEL GENERATOR KDG01B FAILS TO RUN	1.86E-03	24.00	4.46E-02
	DGTM00001A	DIESEL GENERATOR KDG01A UNAVAILABLE DUE TO TESTING OR MAINT		0.02	1.55E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
68	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.51E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RWMVC0896A	MOV 896A FAILS TO CLOSE ON DEMAND (RECIRCULATION)	1.23E-03	1.00	1.23E-03
	RWMVC0896B	MOV 896B FAILS TO CLOSE ON DEMAND (RECIRCULATION)	1.23E-03	1.00	1.23E-03
69	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.47E-06
	CCHFL0780A	CCW THROTTLING VALVE 780A MISPOSITIONED		3.00E-03	3.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHXVK00715	MANUAL VALVE 715 TRANSFERS CLOSED [INJECTION]	1.49E-07	3291.00	4.90E-04
70	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.47E-06
	CCHFL0780B	CCW THROTTLING VALVE 780B MISPOSITIONED		3.00E-03	3.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHXVK00717	MANUAL VALVE 717 TRANSFERS CLOSED [INJECTION]	1.49E-07	3291.00	4.90E-04
71	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.47E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00

	RHHFL0000A	LATENT HUMAN FAILURE OF RHR TRAIN A		3.00E-03	3.00E-03
	RHXVK00715	MANUAL VALVE 715 TRANSFERS CLOSED [INJECTION]	1.49E-07	3291.00	4.90E-04
72	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.47E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHHFL0000B	LATENT HUMAN FAILURE OF RHR TRAIN B		3.00E-03	3.00E-03
	RHXVK00717	MANUAL VALVE 717 TRANSFERS CLOSED [INJECTION]	1.49E-07	3291.00	4.90E-04
73	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.43E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03
	RHXVK00714	MANUAL VALVE 714 TRANSFERS CLOSED [INJECTION]	1.49E-07	1107.00	1.65E-04
74	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.43E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03
	RHXVK0709A	MANUAL VALVE 709A TRANSFERS CLOSED [INJECTION]	1.49E-07	1107.00	1.65E-04
75	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.22E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMVN0852A	MOV 852A FAILS TO OPEN 3.12E-04		1.00	3.12E-04
	RRPPJMBL0B	CONDITIONAL PROBABILITY OF MBLOCA IN B RHR LINE		3.90E-03	3.90E-03
76	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.21E-06
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	DG1ARUN	FLAG - DG A IS RUNNING AND TIED TO BUSES 14 AND 18		3.15E-03	3.15E-03
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGDGF0001A	DIESEL GENERATOR KDG01A FAILS TO RUN	1.86E-03	24.00	4.46E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03
77	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.15E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE		7.00E-03	7.00E-03
	RHXVK00716	MANUAL VALVE 716 TRANSFERS CLOSED [INJECTION]	1.49E-07	1107.00	1.65E-04
78	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.15E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE		7.00E-03	7.00E-03
	RHXVK0709B	MANUAL VALVE 709B TRANSFERS CLOSED [INJECTION]	1.49E-07	1107.00	1.65E-04

79	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.03E-06
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGDGF0001A	DIESEL GENERATOR KDG01A FAILS TO RUN	1.86E-03	24.00	4.46E-02
	DGMMBSTART	FAILURES OF D/G B TO START		0.01	1.02E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
80	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.03E-06
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGDGF0001B	DIESEL GENERATOR KDG01B FAILS TO RUN	1.86E-03	24.00	4.46E-02
	DGMMASTART	FAILURES OF D/G A TO START		0.01	1.02E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
81	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.00E-06
	DCMMAB01AD	Failure of Circuit E63 (To Bus 14 - Normal)		1.16E-04	1.16E-04
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03
82	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	1.00E-06
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	SWCXXSUCTN	TOTAL FAILURE OF COMMON SW/FIRE WATER SUCTION (NON-INITIATOR)		1.00E-06	1.00E-06
83	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	9.81E-07
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BRUN	FLAG - DG B IS RUNNING AND TIED ONTO BUSES 16 AND 17		3.15E-03	3.15E-03
	DGDGF0001B	DIESEL GENERATOR KDG01B FAILS TO RUN	1.86E-03	24.00	4.46E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE		7.00E-03	7.00E-03

84	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	8.86E-07
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRT767	Loss of Offsite Circuit 767 Following Reactor Trip		2.79E-03	2.79E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DGDGF0001A	DIESEL GENERATOR KDG01A FAILS TO RUN	1.86E-03	24.00	4.46E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03
85	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	8.77E-07
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DGDGF0001A	DIESEL GENERATOR KDG01A FAILS TO RUN	1.86E-03	24.00	4.46E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03
86	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	8.11E-07
	DCMMAB01BD	Failure of Circuit E168 (To Bus 16 - Normal)		1.16E-04	1.16E-04
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE		7.00E-03	7.00E-03
87	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	8.08E-07
	CCXVK00769	MANUAL VALVE 769 TRANSFERS CLOSED	6.73E-08	12.00	8.08E-07
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
88	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	7.87E-07
	ACAA100_0X	FLAG - OFFSITE POWER MODE 100/0 (CKT 767 SUPPLIES BUSES 12A AND 12B)		0.14	1.44E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGDGF0001A	DIESEL GENERATOR KDG01A FAILS TO RUN	1.86E-03	24.00	4.46E-02
	DGDGF0001B	DIESEL GENERATOR KDG01B FAILS TO RUN	1.86E-03	24.00	4.46E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
89	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	7.36E-07
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHMMAC01AA	RHR PUMP A (PAC01A) FAILS TO START		8.58E-04	8.58E-04
	RHMMAC01BA	RHR PUMP B (PAC01B) FAILS TO START		8.58E-04	8.58E-04

90	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	7.29E-07
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BRUN	FLAG - DG B IS RUNNING AND TIED ONTO BUSES 16 AND 17		3.15E-03	3.15E-03
	DGDGF0001B	DIESEL GENERATOR KDG01B FAILS TO RUN	1.86E-03	24.00	4.46E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RRPPJMBL0A	CONDITIONAL PROBABILITY OF MBLOCA IN A RHR LINE		5.20E-03	5.20E-03
91	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	7.17E-07
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRT751	Loss of Offsite Circuit 751 Following Reactor Trip		2.79E-03	2.79E-03
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGDGF0001B	DIESEL GENERATOR KDG01B FAILS TO RUN	1.86E-03	24.00	4.46E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE		7.00E-03	7.00E-03
92	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	7.13E-07
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGCC0START	DIESEL GENERATORS FAIL TO START (COMMON CAUSE)		3.15E-04	3.15E-04
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
93	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	7.09E-07
	ACAA50_50A	FLAG - OFFSITE POWER MODE 50/50 ALT (CKT 751 TO BUS 12B, CKT 767 TO BUS 12A)		0.83	8.25E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGDGF0001B	DIESEL GENERATOR KDG01B FAILS TO RUN	1.86E-03	24.00	4.46E-02
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000A	RHR TRAIN A OOS FOR MAINTENANCE		7.00E-03	7.00E-03
94	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	7.07E-07
	ACAA100_0X	FLAG - OFFSITE POWER MODE 100/0 (CKT 767 SUPPLIES BUSES 12A AND 12B)		0.14	1.44E-01
	ACLOPRTALL	Loss of All Off-Site Power Following Reactor Trip		2.76E-03	2.76E-03
	ACTRAINA	TAG - Failure of AC Train A		1.00	1.00E+00
	ACTRAINB	TAG - Failure of AC Train B		1.00	1.00E+00
	DG1ANOTRUN	FLAG - DG 1A IS NOT RUNNING AND TIED TO BUSES 14 AND 18		1.00	9.97E-01
	DG1BNOTRUN	FLAG - DG B IS NOT RUNNING AND TIED ONTO BUSES 16 AND 17		1.00	9.97E-01
	DGCC000RUN	DIESEL GENERATORS FAIL TO RUN (COMMON CAUSE)		1.79E-03	1.79E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00

95	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	6.62E-07
	ESRTDRHR1A	TIMING RELAY (AGASTAT) 2/RHRP1A FAILS TO OPERATE	7.65E-05	1.00	7.65E-05
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03
96	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	6.60E-07
	CCMM00738A	MOV 738A FAILS TO OPEN	4.00E-03	4.00E-03	
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHXVK00716	MANUAL VALVE 716 TRANSFERS CLOSED [INJECTION]	1.49E-07	1107.00	1.65E-04
97	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	6.60E-07
	CCMM00738A	MOV 738A FAILS TO OPEN		4.00E-03	4.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHXVK0709B	MANUAL VALVE 709B TRANSFERS CLOSED [INJECTION]	1.49E-07	1107.00	1.65E-04
98	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	6.60E-07
	CCMM00738B	MOV 738B FAILS TO OPEN		4.00E-03	4.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHXVK00714	MANUAL VALVE 714 TRANSFERS CLOSED [INJECTION]	1.49E-07	1107.00	1.65E-04
99	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	6.60E-07
	CCMM00738B	MOV 738B FAILS TO OPEN		4.00E-03	4.00E-03
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHXVK0709A	MANUAL VALVE 709A TRANSFERS CLOSED [INJECTION]	1.49E-07	1107.00	1.65E-04
100	LIMBLOCA	Medium LOCA (1.5-5.5)	4.00E-05	1.00E+00	6.36E-07
	CCXVK0741A	MANUAL VALVE 741A TRANSFERS CLOSED	6.73E-08	1092.00	7.35E-05
	MLO	TAG - MEDIUM LOCA SEQUENCE		1.00	1.00E+00
	RHTM00000B	RHR TRAIN B OOS FOR MAINTENANCE		8.65E-03	8.65E-03

Report Summary:

Filename: D:\CAFTA-W\QUANT\LEVEL1\MLOCAS.CUT
Print date: 12/27/2001 2:30 PM
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TABLE 3-2

Total Top Event Probability = 2.23E-03

1. 1 sequences, contributing 1.20E-03 53.74%		
MLOCAS	1.20E-03	
LIMBLOCA	1.00E+00	Medium LOCA (1.5-5.5)
MLO	1.00E+00	TAG - MEDIUM LOCA SEQUENCE
RRHFDRECRC-M	1.20E-03	OPERATOR FAILS TO CORRECTLY SHIFT THE RHR SYSTEM TO RECIRCULATION AND ISOL CS
2. 1 sequences, contributing 1.65E-04 7.39%		
MLOCAS	1.65E-04	
LIMBLOCA	1.00E+00	Medium LOCA (1.5-5.5)
MLO	1.00E+00	TAG - MEDIUM LOCA SEQUENCE
RHXVK00856	1.65E-04	MANUAL VALVE 856 TRANSFERS CLOSED
3. 1 sequences, contributing 1.06E-04 4.73%		
MLOCAS	1.06E-04	
LIMBLOCA	1.00E+00	Medium LOCA (1.5-5.5)
MLO	1.00E+00	TAG - MEDIUM LOCA SEQUENCE
SICCMPSI1X	1.06E-04	PSI01A, PSI01B & PSI01C FAIL TO START FOR INJECTION DUE TO COMMON CAUSE
4. 1 sequences, contributing 6.22E-05 2.79%		
MLOCAS	6.22E-05	
LIMBLOCA	1.00E+00	Medium LOCA (1.5-5.5)
MLO	1.00E+00	TAG - MEDIUM LOCA SEQUENCE
RHCVN00854	6.22E-05	CHECK VALVE 854 FAILS TO OPEN [INJECTION]
5. 1 sequences, contributing 5.42E-05 2.43%		
MLOCAS	5.42E-05	
LIMBLOCA	1.00E+00	Medium LOCA (1.5-5.5)
MLO	1.00E+00	TAG - MEDIUM LOCA SEQUENCE
RHCCPUMPAB	5.42E-05	COMMON CAUSE FAILURE OF RHR PUMPS A AND B TO START
6. 1 sequences, contributing 5.08E-05 2.27%		
MLOCAS	5.08E-05	
LIMBLOCA	1.00E+00	Medium LOCA (1.5-5.5)
MLO	1.00E+00	TAG - MEDIUM LOCA SEQUENCE
RWMM00RWST	5.08E-05	INSUFFICIENT FLOW AVAILABLE FROM TSI01 (RWST)

7. 1 sequences, contributing 3.57E-05 1.60%

MLOCAS	3.57E-05	
LIMBLOCA	1.00E+00	Medium LOCA (1.5-5.5)
CCCC738A/B	3.57E-05	COMMON CAUSE FAILURE OF MOV'S 738A AND 738B TO OPEN
MLO	1.00E+00	TAG - MEDIUM LOCA SEQUENCE

8. 1 sequences, contributing 3.46E-05 1.55%

MLOCAS	3.46E-05	
LIMBLOCA	1.00E+00	Medium LOCA (1.5-5.5)
CCMM00738A	4.00E-03	MOV 738A FAILS TO OPEN
MLO	1.00E+00	TAG - MEDIUM LOCA SEQUENCE
RHTM00000B	8.65E-03	RHR TRAIN B OOS FOR MAINTENANCE

9. 1 sequences, contributing 2.80E-05 1.25%

MLOCAS	2.80E-05	
LIMBLOCA	1.00E+00	Medium LOCA (1.5-5.5)
CCMM00738B	4.00E-03	MOV 738B FAILS TO OPEN
MLO	1.00E+00	TAG - MEDIUM LOCA SEQUENCE
RHTM00000A	7.00E-03	RHR TRAIN A OOS FOR MAINTENANCE

10. 1 sequences, contributing 2.60E-05 1.16%

MLOCAS	2.60E-05	
LIMBLOCA	1.00E+00	Medium LOCA (1.5-5.5)
MLO	1.00E+00	TAG - MEDIUM LOCA SEQUENCE
RHHFL0000A	3.00E-03	LATENT HUMAN FAILURE OF RHR TRAIN A
RHTM00000B	8.65E-03	RHR TRAIN B OOS FOR MAINTENANCE