PP&L

NUCLEAR ENGINEERING

CALCULATION / STUDY COVER SHEET
and
NUCLEAR RECORDS TRANSMITTAL SHEET

File # R2-1

1. Page 1 of

*▷2. TYPE: CALC ▷3. NUMBER: EC -062 -1030 ▷4. REVISION: 0

5. TRANSMITTAL#: ______ *▷6. UNIT: 2 *▷7. QUALITY CLASS: Q *▷8. DISCIPLINE: H

▷9. DESCRIPTION: Unit 2 Shroud Defect Evaluation

SUPERSEDED BY: EC- -

10. Alternate Number: ______ 11. Cycle: ______

12. Computer Code or Model used: DLL Fiche [] Discs [] Amount ______

13. Application: ______

*▷14. *AFFECTED SYSTEMS:* 062

** If N/A then line 15 is mandatory.

*▷15. NON-SYSTEM DESIGNATOR: ______

16. Affected Documents: ______

17. References: KF-9412, GENE-523-113-0894 Supplement #1, GENE-523-113-0894-Rev. 1, GENE-523-169-0893, SIR-95-108, SIR-94-035, EC-062-1024

18. Equipment / Component #: ______

19. DBD Number: ______

▷20. PREPARED BY	▷21. REVIEWED BY
Print Name L. E. Willertz	Print Name John D. Vernarr
Signature L E Willertz 10/12/95	Signature John D Vernarr 10/13/95
▷22. APPROVED BY / DATE	**23. ACCEPTED BY PP&L / DATE**
Print Name F G Butler	Print Name
Signature FG Butler 10/13/95	Signature

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FORM NEPM-QA-0221-1, Revision 1

Title: UNIT 2 SHROUD WELD DEFECT EVALUATION

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1.0 OBJECTIVE

The objective of this calculation is to analyze the indications found by inservice inspection (ISI) of the unit 2 shroud welds. The analysis determines if the welds have the minimum allowable safety factors remaining after 3.5 years of additional service, so that continued operation through the next cycle can be assured.

2.0 CONCLUSIONS AND RECOMMENDATIONS

All circumferential welds in the shroud were inspected by UT methods (H1 through H7), or enhanced VT (H8 and H9). H3, H6A, H7, H8, and H9 were free of any indications.

Welds H1, H2, H4, H5, and H6B all were found to have indications which required analysis. All analysis performed with the Distributed Ligament Length (DLL) computer code determined that all welds passed the minimum safety factor requirements of 2.8 for upset stress conditions and 1.4 for faulted stress conditions, after applying 3.5 years of operation and growth to the crack sizes. Safe operation of the shroud can be assured for the next cycle of operation without installing a repair at this time.

The results of these calculations were verified by an independent assessment performed by Structural Integrity Associates, Inc. (Ref. 6.6 and Appendix IX).

3.0 ASSUMPTIONS/INPUTS

3.1 The shroud is a non-pressure boundary surrounding the core of the reactor to provide a barrier which will hold water in the core region should a recirculation line break drain water from the shroud to the vessel wall region. It also provides lateral support for the core to prevent the movement of fuel during a seismic event. Excessive movement of the core would jam control rods and prevent safe shutdown of the reactor.

3.2 Defects were found by ISI in the H1, H2, H4, H5, and H6B welds which require analysis. Welds H3, H6A, and H7 were found to be defect free. The sizes and locations of the defects are summarized in a table in Section 5.0, and details of the calculation can be found in each section of the Appendices related to the analysis of the specific weld.

3.3 The stresses applied to the shroud were analyzed for PP&L by GE and can be found in Reference 6.1. Tables 1, 2, and 3, attachments 1, 2, and 3 to this document, were taken from this report for easy reference when reviewing the calculations.

3.4 The DLL computer program was the same program used by us in CALC EC-062-1024 (Ref. 6.8) to analyze the unit 1 shroud cracks in the spring of 1995. This program was submitted to the NRC for review and approval by the BWRVIP and has been accepted as an approved method of analyzing shroud cracking. (Reference 6.2)

3.5 Assumptions that went into determining the length of the defects after 3.5 years of operation were the following:

3.5.1 Two cycles of operation were used with the knowledge that the 8th cycle will be 1.5 years long, and the 9th cycle will be 2 years long. We assumed the actual availability (hot reactor time) will be 90% of the calendar time.

3.5.2 Defect length evaluation for determining the amount of 'sound metal' for the DLL program inputs proceeded as follows:

A. Reference 6.3 was utilized as the guidelines for the determination of the defect length for analysis purposes.

B. The length of the defect for evaluation purposes was a combination of:

1. The ISI length determined by the GE Tracker UT device.

2. The growth of the crack for 3.5 years assuming a growth rate of 5E-5 inches/hour and 90% availability. (5E-5 * 24 * 365.25 * 3.5 * 0.9 = 1.38 inches)

3. The error in determining the position of the end of the defect if the examination tool had to be moved over a holddown bolt lug. The error amounted to adding 0.5 degrees of error (one inch) to each end of some of the longer defects which spanned lugs on the shroud.

4. A value of 0.4 inches on either end of the defect to account for error in determining the actual length of the defect by the UT device since all defects were on the same side of the weld as the UT sensor.

C. Supplemental analysis was performed using the GE Tracker data of reference 6.5. To determine if the answers we got using the reference 6.3 uncertainty factors for the crack length would be much different if we used the newest uncertainty data published in reference 6.5, we developed spreadsheets and calculations using these modified numbers. In particular, the length evaluation factor in Attachment 4 was different for each type of transducer used. Thus instead of a 0.4 inch addition to the end of each defect, we used either 0.336, 0.364 or 0.190 inches. The difference did not produce any appreciable change in the resulting safety factor. The change was less than one part in 100 in all cases. These spreadsheets and DLL output files follow the data generated using the November 21, 1995 uncertainty factor calculations in the Appendices for each weld.

3.6 Assumptions that determined the depth of the defects after 3.5 years. The depth was the sum of:

1. the UT determined depth,

2. plus the UT examination error of 0.15 inches.

3. plus the 3.5 years growth (1.38")

NOTE: Supplemental calculations were performed using the updated depth evaluation factors for depth shown in Attachment 4 from reference 6.5 for weld H6B only. The factors of 0.112" and 0.108" instead of the NRC approved value of 0.15" made only a small change in the safety factor for this weld in the DLL program output as shown in appendix VII.

3.7 Determination of the amount of sound metal for the DLL calculation.

A. For all welds which were cracked, we determined the amount of sound metal for the DLL calculation as follows.

1. We first determined the length of the crack using the criteria in section 3.5.

2. Then we assumed that all cracks were through wall.

3. Then we added all unexamined sections of welds as if they were through wall cracks.

4. Then we determined which defects were within 4 inches of each other. All defects closer than 4" (2t) were considered to be one defect.

5. The remaining segments between defects and unexamined areas were considered to be uncracked and able to be input into the DLL program for evaluation of the safety factors.

B. An exception to the above evaluation was made for the weld H6B which would not pass the DLL criteria without additional metal being present. We determined from the depth measurements that some cracks would not propagate through wall via the evaluation criteria in section 3.6. We added three of these locations to the evaluation using the remaining wall thickness after 3.5 years in these locations. This data input in the DLL program was enough to get H6B to pass the safety factor requirements of the DLL program.

C. Another variation was added to the evaluation of the H4 weld. In this case, the peak neutron fluence was determined to be approximately 5E20 n/cm^2 by the end of the next two cycles of operation in March 1998 (Ref. 6.4). The evaluation could not then be based on a limit load analysis, but was evaluated using the Linear Elastic Fracture Mechanics (LEFM) evaluation of the DLL program. The peak fluence at the H5 weld was below the threshold of 3E20 at 2.7E20 n/cm^2 so limit load analysis still holds for this weld.

4.0 METHOD

4.1 The DLL program was run prior to and after the evaluation of the welds using sample program data from Reference 6.2 to show that the program was operating properly on the same computer the weld data was run. In addition, two separate engineers ran the same data on two separate computers to verify and check the spreadsheets and the DLL output.

4.2 All ISI data and evaluation of the defect sizes after 3.5 years was performed on an EXCEL spreadsheet using appropriate procedures. The spreadsheets and the formulas used in them are displayed in Appendices I through VIII for each of the welds.

4.3 All ISI data relevant to the evaluation of each weld is displayed in the appropriate section of Appendices I through VIII.

4.4 All outputs of the DLL program for both UPSET and FAULTED conditions are displayed in the appropriate section of Appendices I through VIII.

4.5 A third independent analysis was performed by Structural Integrity Associates, Inc. on the H4 and H6B welds to verify the outcome of our analysis because of the amount of cracking experienced in these two welds. Appendix IX contains SIA's report.

5.0 RESULTS

5.1 The table at the end of this section summarizes the results of the ISI examination and the DLL program outputs. Also included are comparable results from the unit 1 shroud inspected in March 1995.

5.2 In all cases, each weld passed the screening criteria with the appropriate factors of safety for the UPSET and FAULTED conditions.

5.3 A diagram is included after the table which shows the distribution of cracks and their locations. Some of the defects were found on the OD of welds H4 and H5. All other cracks originated on the ID (core side) of the shroud.

UNIT 2 SHROUD EVALUATION SUMMARY

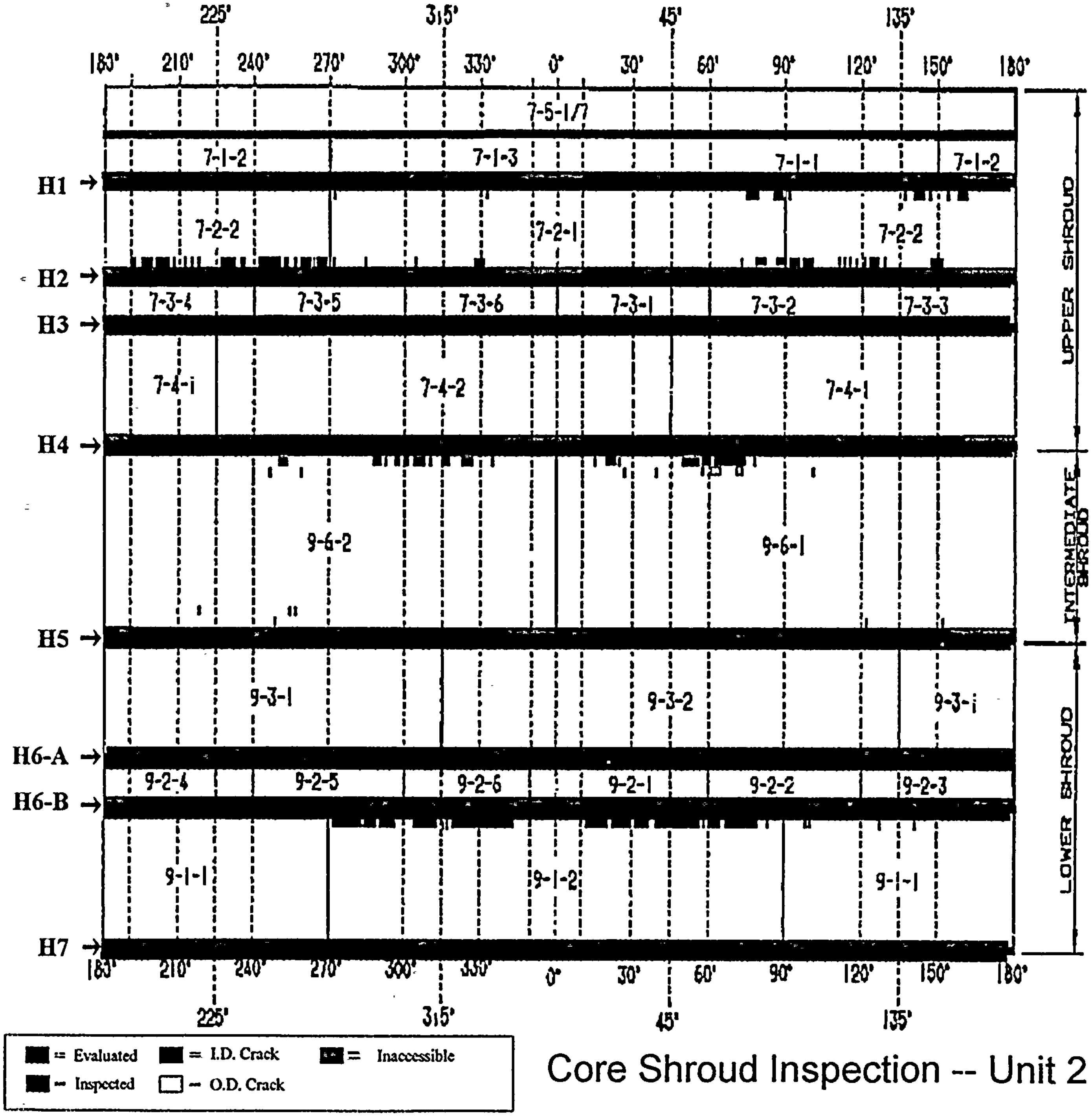
Parameter	H1	H2	H3	H4	H5	H6A	H6B	H7
% of weld length inspected	83.95%	83.97%	83.9%	83.48%	82.18%	82.19%	84.34%	84.33%
Total Flaw lengths found	41.32" (4.91)	180.68" (54.41)	0" (0)	123.4" (187.47)	8.48" (189.45)	0" (11.92)	211.06" (66.05)	0" (0)
% flawed in inspected length	7.12% (0.86)	31.13% (9.6)	0% (0)	22.72% (35.17)	1.59% (40.43)	0% (2.22%)	39.68% (12.57)	0% (0)
Largest Flaw length	8.39" (2.42)	16.22" (9.13)	0" (0)	15.71" (50.46)	2.51" (32.92)	0" (4.83)	42.99 (13.84)	0 (0)
Deepest Flaw	0.6" (0.2)	0.65" (NA)	0" (0)	0.7" (0.7)	0.4" (0.65)	0" (0.25)	0.75" (0.625)	0" (0)
Upset condition safety factor from DLL program	41.32 (40.61)	14.10 (12.91)	NA	13.24 (4.31) LEFM=141.3* ksi*in^0.5	13.74 (2.92)	NA (10.42)	2.84 (5.38)	NA
Faulted condition safety factor from the DLL program	20.88 (20.57)	7.48 (6.97)	NA	7.77 (2.41) LEFM=120.3* ksi*in^0.5	8.71 (1.87)	NA (6.74)	1.85 (3.57)	NA

NOTES: Passing criteria:
Upset condition >= 2.8
Faulted condition >= 1.4
Upset/faulted LEFM >= 150 ksi*in^0.5
* The DLL LEFM results include the factors of safety 2.8 and 1.4, respectively.
Therefore actual K(upset) = 139.9/2.8 = 50.0 and K(faulted) = 119/1.4 = 85.

( ) data is from Unit 1 shroud examined spring 1995 for comparison purposes.

Welds H8 and H9 were found to be defect free by enhanced VT examinations.

October 10,1995
10:23 am



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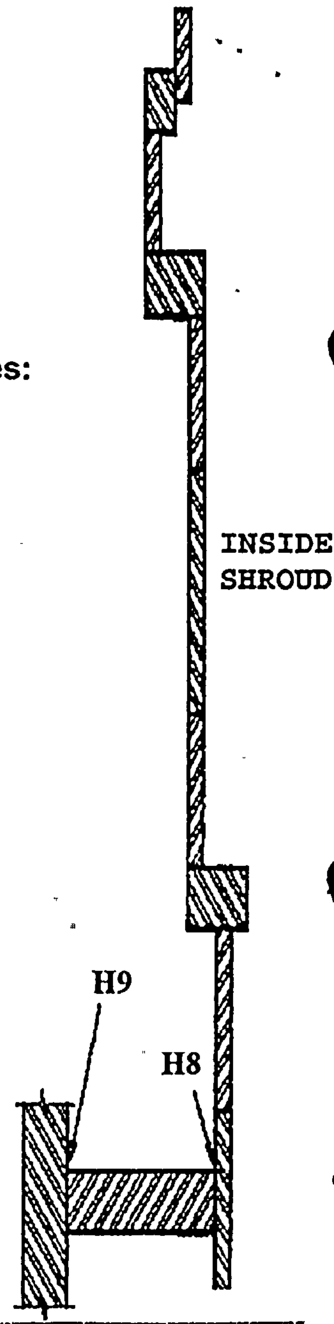
Notes:



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6.0 REFERENCES

6.1 Letter Report from the General Electric Company, KF-9412, dated December 22, 1994.

6.2 GENE-523-113-0894, Supplement 1, "BWR Core Shroud Distributed Ligament Length Computer Program", September 1994.

6.3 BWR-VIP Core Shroud NDE Uncertainty & Procedure Standard, November 21, 1994, EPRI NDE Center, Charlotte, NC.

6.4 GENE-523-169-0893, Rev. 1, March 17, 1994.

6.5 "Reactor Pressure Vessel and Internals Examination Guidelines", BWRVIP Inspection Committee, September 15, 1995. Draft report reviewed and accepted by PP&L.

6.6 Letter SIR-95-108, Rev. 0, Dated October 9, 1995.

6.7 Software User Manual; ANSC for Determining Net Section Collapse of Arbitrarily Thinned Cylinder, Report No. SIR-94-035.

6.8 CALC EC-062-1024, Unit 1 Shroud Weld Defect Evaluation.

Attachment 1
Tables 1 and 2
from Reference 6.1

Table 1
Limiting Seismic Loads for Susquehanna Units 1 and 2
(References 1 to 4)

Weld	Elevation Above Vessel Zero (in)	Upset		Faulted	
		Shear (kips)	Moment (in-kips)	Shear (kips)	Moment (in-kips)
H1	398.000	489	41943	830	70590
H2	362.375	647	59495	958	95662
H3	359.875	654	61105	967	97898
H4	314.875	767	91570	1099	139681
H5	231.875	934	160336	1435	237110
H6-A	191.250	977	198870	1620	292513
H6-B	186.875	979	203131	1615	298495
H7	131.500	981	257347	1585	374479
H8	121.500	981	267131	1585	388165

Table 2
Pressure Drop Values for Susquehanna Units 1 and 2
(Reference 5)

	Upset	Faulted
Shroud Head ΔP (psi)	10.4	27.4
Core Plate ΔP (psi)	21.3	23.0

Attachment 2
Table 3
from Reference 6.1

Table 3
Shroud Stresses for Susquehanna Units 1 and 2[1]

Weld	Upset P_m (ksi)	Upset P_b (ksi)	Faulted P_m (ksi)	Faulted P_b (ksi)
H1	0.282	0.562	0.740	0.946
H2	0.282	0.797	0.740	1.281
H3	0.265	0.924	0.696	1.481
H4	0.265	1.385	0.696	2.113
H5	0.265	2.426	0.696	3.587
H6-A	0.265	3.009	0.696	4.425
H6-B	0.479	3.273	0.911	4.810
H7	0.479	4.147	0.911	6.035
H8	0.479	4.305	0.911	6.255

[1] See Appendix A for details

Dynamic Loads and Stresses:

Table 2 below shows the loads applied to each weld for Dynamic Upset and Faulted conditions. The section modulus Z = pi/4(Ro^4-Ri^4)/Rm was calculated at each weld location. The bending stresses were calculated for Dynamic Upset and Faulted conditions using standard strength of materials equations (stress = M/Z).

TABLE 2: SEISMIC LOADS AND STRESSES FOR EACH WELD LOCATION

Weld	Outside Radius (in)	Inside Radius (in)	Thick. (in)	Section Modulus (in^3)	Upset Moment (in-kip)	Faulted Moment (in-kip)	Upset Pb (ksi)	Faulted Pb (ksi)	Upset Pm (ksi)	Faulted Pm (ksi)
H1	110.00	108.00	2.000	7.47E+04	4.19E+04	7.06E+04	0.562	0.946	0.282	0.740
H2	110.00	108.00	2.000	7.47E+04	5.95E+04	9.57E+04	0.797	1.281	0.282	0.740
H3	103.56	101.56	2.000	6.61E+04	6.11E+04	9.79E+04	0.924	1.481	0.265	0.696
H4	103.56	101.56	2.000	6.61E+04	9.16E+04	1.40E+05	1.385	2.113	0.265	0.696
H5	103.56	101.56	2.000	6.61E+04	1.60E+05	2.37E+05	2.426	3.587	0.265	0.696
H6-A	103.56	101.56	2.000	6.61E+04	1.99E+05	2.93E+05	3.009	4.425	0.265	0.696
H6-B	100.38	98.38	2.000	6.21E+04	2.03E+05	2.98E+05	3.273	4.810	0.479	0.911
H7	100.38	98.38	2.000	6.21E+04	2.57E+05	3.74E+05	4.147	6.035	0.479	0.911
H8	100.38	98.38	2.000	6.21E+04	2.67E+05	3.88E+05	4.305	6.255	0.479	0.911

Inside radius and thickness - Reference 761E764 for H1 to H7, Reference 919D988AE for H8

Upset and Faulted moments are determined on Sheet 1.

Attachment 3
Table 2 Spreadsheet
from Appendix A in
Reference 6.1

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