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Robert G. Byram
Senior Vice President-Nuclear
610/774-7502
Fax: 610/774-5019

MAY 25 1995

U.S. Nuclear Regulatory Commission
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SUSQUEHANNA STEAM ELECTRIC STATION
GENERIC LETTER 94-03: FINAL INSPECTION
RESULTS FOR UNIT 1 CORE SHROUD
PLA-4320 **FILE R41-2** **Docket No. 50-387**

References: *PLA-4192 from R.G. Byram to Mr. C.L. Miller, "Initial Response to Generic Letter 94-03," dated August 24, 1994.*
PLA-4233 from Mr. R.G. Byram to USNRC, "Interim Response to Generic Letter 94-03," dated December 19, 1994.
PLA-4239 from R.G. Byram to USNRC, "Supplemental Response to Generic Letter 94-03," dated December 22, 1994.
PLA-4310 from Mr. R.G. Byram to USNRC, "Generic Letter 94-03 Interim Inspection Report," dated April 21, 1995.
PLA-4314 from R.G. Byram to USNRC, "Generic Letter 94-03 Additional Inspection Information," dated May 1 1995.
PLA-4316 from R.G. Byram to USNRC, "Unit 1 Core Shroud Independent Review Results," dated May 5, 1995.

This letter provides the final results of the Susquehanna Steam Electric Station (SSES) Unit 1 core shroud inspections per the reporting requirements of NRC Generic Letter 94-03. All Unit 1 core shroud horizontal welds have been ultrasonically inspected in accordance with the guidelines as defined in the BWR Core Shroud Inspection and Flaw Evaluation Guidelines prepared by General Electric Nuclear Energy for the BWROG Vessel Internals Inspection project, GENE-523-113-0894 for Category B plants. Significant cracking (> 10% of weld length) was found in four of the welds (see "Inspection Results" in Attachment 1 to this PLA).

PP&L conducted an analytical evaluation of the cracking found and the effects on core shroud structural integrity. In order to verify the results of this evaluation, PP&L contracted with Structural Integrity Associates to provide an independent review. These evaluations provided the assurance that operation of SSES Unit 1 is justified for at least an additional cycle. A copy of PP&L's final evaluation results, EC-062-1024, Rev. 1, "Unit 1 Shroud Weld Defect Evaluation", less appendices, is included as Attachment 2 to this PLA. The appendices to EC-062-1024, Rev.

A018

1 are available upon NRC request. Please be aware that minor differences in data exist between the final inspection results reported herein and the preliminary inspection results previously forwarded to NRC under cover of the referenced PLA-4310 dated 4/21/95 and PLA-4314 dated 5/1/95. These differences do not, however, change any of the conclusions regarding operation of the Unit 1 shroud for an additional cycle.

If you have any questions, please call our Mr. James B. Wesner at 610-774-4023.

Very truly yours,

R.G. Byram

Attachment: Inspection Results

copy: NRC Region I
Ms. M. Banerjee - NRC Sr. Resident Inspector
Mr. C. Poslusny - NRR Sr. Project Manager

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA)
: SS
COUNTY OF LEHIGH)

I, ROBERT G. BYRAM, being duly sworn according to law, state that I am Senior Vice President - Nuclear of Pennsylvania Power & Light Company and that the facts set forth on the attached Final Inspection Results For Unit 1 Core Shroud regarding Generic Letter 94-03 issued pursuant to 10CFR50.54(f) are true and correct to the best of my knowledge, information and belief.

Robert G. Byram
Senior Vice President - Nuclear

Sworn to and subscribed
before me this 25th day
of May , 1995.

Notary Public

NOTARIAL SEAL
CHERYL L. DIEHL, Notary Public
Allentown, Lehigh County, PA
My Commission Expires February 17, 1996

INSPECTION RESULTS
UNIT 1 CORE SHROUD

PP&L committed to perform the scope of shroud inspections defined by GENE-523-113-0894, "BWR CORE SHROUD INSPECTION AND FLAW EVALUATION GUIDELINES" for Category B plants during the Unit 1 8th Refueling and Inspection Outage (U18RIO) in the references PLA-4233. We also stated our intent to inspect all remaining shroud welds (required for Category C plant inspections) during the U1-8RIO, outage schedule permitting. GENE-523-113-0894, Table 3.2 for Limited Inspection (Category B), requires expansion of inspections to Category C, Comprehensive Inspection, any time significant cracking is identified.

Out of the eight Unit 1 core shroud horizontal welds ultrasonically inspected, six were found to be cracked. Four of these cracked welds exhibited significant cracking (greater than 10% of weld length). No indications were found in the two visually inspected welds. All cracking has been evaluated per the BWRVIP analysis guidelines and submitted to NRC per the referenced PLA-4310, dated 4/21/95. A summary of the inspection results is tabled below.

Weld	Inspection Coverage in %	Number of Cracks	Degree of Cracking	Inches of Cracking	Longest Crack in inches	Deepest Crack in inches
H1	83	3	2.58	4.91	2.42	0.20
H2	83	29	28.6	54.41	9.13	note #1
H3	84	0	NA	NA	NA	NA
H4	83	28	104.73	187.47	50.46	0.7
H5	73	27	105.84	189.45	32.92	0.65
H6A	84	8	6.66	11.92	4.83	0.25
H6B	84	19	38.08	66.05	13.84	0.625
H7	81	0	NA	NA	NA	NA
H8	VT-1	0	NA	NA	NA	NA
H9	VT-1	0	NA	NA	NA	NA

NOTE #1: depth not measured due to weld and transducer package configuration; therefore conservatively assumed to be 2.0 inches for evaluation purposes.

PP&L

NUCLEAR ENGINEERING

ATTACHMENT TO PLA-4320
File # R2-1

CALCULATION / STUDY COVER SHEET
and
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*2. TYPE: CALC >3. NUMBER: EC-062-1024 >4. REVISION: 2

5. TRANSMITTAL#: _____ *>6. UNIT: 1 *>7. QUALITY CLASS: Q *>8. DISCIPLINE: H

>9. DESCRIPTION: Unit 1 Shroud Weld Defect Evaluation

SUPERSEDED BY: EC-

10. Alternate Number: _____ 11. Cycle: _____

12: Computer Code or Model used: DLL Fiche ☐ Disks ☐ Am't _____

13. Application: Shroud, UNIT 1

*>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-523-169-1292, SwRI Project No. 06-8658, SIR-95-048, SIR-94-035

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	Signature John D Vernarr
>22. APPROVED BY / DATE	23. ACCEPTED BY PP&L / DATE
Print Name HERBERT L WEBB	Print Name
Signature H L Webb 5/24/95	Signature

TO BE COMPLETED BY NUCLEAR RECORDS

NR-DCS SIGNATURE/DATE

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Check (x) the appropriate function to *add*, *replace* or *remove* the affected pages.

Revised Pages	Affected Sections	Add	Rpl	Rmv	Description / Purpose of Revision
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1A	CALC		X		NEW REVISION DESCRIPTION SHEET
3	CALC		X		DELETED PARAGRAPH 3 FROM SECTION 2.0

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NUCLEAR ENGINEERING

CALCULATION / STUDY COVER SHEET
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File # R2-1

1. Page 1 of 147

*▷2. TYPE: Calc ▷3. NUMBER: EC-062-1024 ▷4. REVISION: 0

5. TRANSMITTAL#: _____ *▷6. UNIT: 1 *▷7. QUALITY CLASS: Q *▷8. DISCIPLINE: H

▷9. DESCRIPTION: Unit 1 Shroud Weld defect evaluation

SUPERCEDED BY: EC- -

10. Alternate Number: _____ 11. Cycle: _____

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

13. Application: Shroud, ISI, In-vessel Inspection

*▷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-523-169-1292
SwRI Project No. 06-8658 SIR-95-048 SIR-94-035

18. Equipment / Component #: _____

19. DBD Number: _____

▷20. PREPARED BY	▷21. REVIEWED BY
Print Name: Lothar E. Willertz	Print Name: JOHN D. VERNAAR
Signature: Lothar E. Willertz	Signature: John D. Vernaar
▷22. APPROVED BY / DATE	23. ACCEPTED BY PP&L / DATE
Print Name: HERBERT L WOOD	Print Name
Signature: H L Wood 4/28/95	Signature

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▷ REQUIRED FIELDS

TITLE: UNIT 1 SHROUD WELD DEFECT EVALUATION

INDEX

Backup To Calc EC-062-1024

SIA Evaluation of Susquehanna Unit I Examination Results

SIA Software User Manual for the ANSC Computer Program

GENE-523-113-0894, Revision 1, March 1995, BWR CORE SHROUD INSPECTION AND FLAW EVALUATION GUIDELINES

TITLE: UNIT 1 SHROUD WELD DEFECT EVALUATION

1.0 OBJECTIVE

The objective of this calculation is to analyze the indications found by inservice inspection (ISI) of the unit I shroud to determine if they exceed the allowable stresses on the welds during upset and faulted conditions imposed during service.

2.0 CONCLUSIONS AND RECOMMENDATIONS

All of the welds, H1, H2, H3, H4, H5, H6A, H6B, and H7 pass the test for limit load calculations based on the Distributed Ligament Length (DLL) Computer Code. The shroud is capable of withstanding all faulted and upset stresses imposed on it for at least one fuel cycle (18 months) to September 1996.

Third party calculations performed by Structural Integrity Associates, Inc. confirmed the above conclusions.

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 around the core should a recirculation line break and drain water from the shroud to 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 the safe shutdown of the reactor.

3.2 Defects have been found in the H1, H2, H4, H5, H6A and H6B welds which have reduced the strength of the shroud; these are the welds that are analyzed in this report. Attached is a copy of the shroud rollout for unit 1 showing the shroud welds inspected and the amount of coverage (percent of the total length of weld that could actually be examined by the UT examination device). The coverage ranged from 72.72% to 84.16% depending on the interferences present on or near the OD of the shroud.

3.3 General Electric has provided PP&L with the loads and stresses under upset and faulted conditions for each weld location in reference 6.1. These are used in the calculations to prove the remaining load carrying capacity of the shroud. Tables 1, 2, and 3, from reference 6.1, are attached for use in the DLL calculations found in Appendix 1 for each weld containing defects.

3.4 The Distributed Ligament Length (DLL) computer program was used by us to verify the adequacy of the welds with the defects present and this program was

distributed to the BWR owners by the BWRVIP. This program is described in reference 6.2. Rev 1 of this program was distributed to the BWR owners on February 17, 1995.

3.5 Verification of the DLL program output was performed by Structural Integrity Associates via their ANSC (Arbitrary Net Section Collapse) program. This verification documentation is included as backup to this report.

3.6 Output solutions are provided with the DLL program. They were run as part of this work to verify the correct operation of the program before and after the calculations on the specific welds were performed.

3.7 The DLL program can be used to verify the remaining load carrying capacity of the welds assuming either the defects are growing circumferentially or radially (through-wall). The following assumptions apply for these two conditions.

3.7.1 Calculation assumptions for defects growing in the circumferential direction:

A. All the defects are all assumed to be through-wall.

B. Remaining sound metal: A very conservative approach was used to determine the amount of sound metal remaining between the defects for the DLL calculation. The ASME Code Section XI Subarticle IWA-3300 requirement is that if the tips of the defects are less than 2t (in our shroud this value is 2*2.0=4.0 inches), then the two defects are considered as one defect and no sound metal is available to support load. In our calculations we added 2t+CG to each end of the defects before we applied this criteria. CG was the crack growth calculated for 2 fuel cycles of operation (3 years) with a 90% availability applied. Crack growth rate was assumed constant at 5E-5 in/hr as recommended in reference 6.3. All cracks remaining after these criteria were applied had length 'lmax';

$$lmax = lisi + 4t + 2CG$$

lisi = the length found by the ISI inspection
2t = 4 inches
CG = (5E-5)*24*365.25*3*0.9 = 1.183 in/3yr

C. All un-inspectable weld metal was conservatively assumed to be completely defective, i.e., no good metal remained in that section.

D. In the H4 weld, some of the metal was exposed to fluences above 3E20. This metal was conservatively assumed to be defective through-wall for the purposes of the DLL limit load calculations.

3.7.2 Calculation assumptions for radially growing defects:

A. A single 360 degree defect with a constant depth was assumed.

B. The maximum depth found in any defect of that particular weld was assumed to exist 360 degrees around the circumference.

C. The defect was assumed to be 0.3 inches deeper than the depth reported in the ISI report and one cycle of crack growth was added to that depth for the purposes of the DLL calculations.

4.0 METHOD

4.1 The calculations for crack lengths after 3 years operation were all performed on EXCEL 5.0 spreadsheets, which are presented in Appendix I, along with the ISI information that provided input to these sheets. The data is arranged for each weld so as to be easily reproduced by anyone knowledgeable in setting up a spreadsheet. First the ISI data is presented; then the spreadsheet is shown; then the DLL program was run to verify the adequacy of the remaining material. PASS or FAIL of the weld in the program output depended on if the calculated safety factor was greater or less than 2.77 for UPSET conditions, or 1.38 for FAULTED conditions.

4.2 Limit load analysis was performed using the DLL program. A small amount of the shroud orientation was calculated to be above the limit of 3E20 n/cm^2, so they were excluded from the limit load analysis as if these locations were through-wall. Appendix II contains the calculations that show the fluence values on the ID and OD of the shroud at the weld locations H4 and H5. None of H5 exceeded 3E20 n/cm^2, but a small amount of the H4 weld did exceed this value.

4.3 Appendix III contains the output verification of the DLL program comparing the output files that came with the program to those generated before and after the calculations for our shroud conditions.

4.4 Structural Integrity Associated, Inc.'s report showing independent calculations performed with their ANSC program used as backup for this report.

4.5 The ANSC Users Manual which was produced and verified within SI's Quality Assurance Program and used as backup for this report.

4.6 Rev. 1 of the GENE-523-113-0894 "BWR CORE SHROUD INSPECTION AND FLAW EVALUATION GUIDELINES" used as backup for this report.

4.7 To verify the accuracy of the spreadsheets and the output of the DLL program, John Vemarr performed a line-by-line review and ran the DDL program on his computer.

5.0 RESULTS

WELD ID	% Inspected	% Cracked	Deepest Defect	Longest Defect	Safety Factor Upset	Safety Factor Faulted	(note #)
H1	83.18%	0.86%	0.2"	1.27 deg	40.61	20.57	
H2	83.18%	9.55%	N/E	N/E	12.91	6.97	
H3	84.07%	0%	N/A	N/A	N/A	N/A	
H4	82.72%	35.17%	0.7"	28.19 deg	4.31	2.41	
H4	"	"	"	"	6.95	4.21	(1)
H5	72.72%	40.43%	0.65"	18.39 deg	2.92	1.87	
H5	"	"	"	"	4.77	3.08	(2)
H6A	83.87%	2.22%	0.25"	2.7 deg	10.42	6.74	
H6B	84.16%	12.57%	0.625"	7.98 deg	5.38	3.56	
H7	80.77%	0%	N/A	N/A	N/A	N/A	
Notes:	(1). Calculation for a circumferential defect 1.592" deep.						
	(2). Calculation for a circumferential defect 1.542" deep.						
Rev 1, 5/4/95							

5.1 The above table shows a summary of the results we obtained from inspecting for defects of the shroud welds and the calculations performed using the DLL program. The DLL program output shows that these welds all passed the criteria of having a larger safety factor than 2.77 for the Faulted stress conditions, and 1.39 for the Upset stress conditions. The conclusion is that the shroud is able to continue operation for at least 1.5 years or one fuel cycle.

5.2 Attached to this report in the backup section, is a report from Structural Integrity Associates (Ref. 6.6) which verifies the conclusions shown above. They used a similar fracture mechanics program developed by their own engineers which relies on the same fracture mechanics concepts as that developed in the DLL program. These two programs have been shown to give the same results using the same inputs. SIA however refined their assumptions and performed calculations on all of the defects in a particular weld assuming they started 0.3" deeper than that found by ISI and then grew them at 5E-5"/hr for 3 years. Their safety factors are, in all cases, slightly larger than ours because this method leaves a little more good metal present than when one assumes all defects to be through-wall like we did. Thus, our calculations were slightly more conservative than theirs.

5.3 The one case where SIA results showed significantly larger values than ours was on the H4 weld where we assumed all metal exposed to >3E+20 n/sm^2 was cracked through-wall. SIA carried their calculations one step further and assumed all the metal was above this value, and they then performed the Linear Elastic Fracture Mechanics (LEFM) calculations. The results of their LEFM calculations show that the remaining metal is still sufficient to continue in service for 1.5 years or one cycle of operation.

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 GENE-523-113-0894, Rev 1, "BWR Core Shroud Inspection and Flaw Evaluation Guidelines", March 1995.

6.4. GENE-523-169-1292, Rev. 1, October 1993.

6.5. "Susquehanna Unit 1 Dosimeter Testing", Final report, SwRI Project No. 06-8658, September 1986.

6.6. Letter SIR-95-048, Rev. 0 dated April 26, 1995.

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

ATTACHMENTS

Stress and examination information for all shroud welds.

Contents:

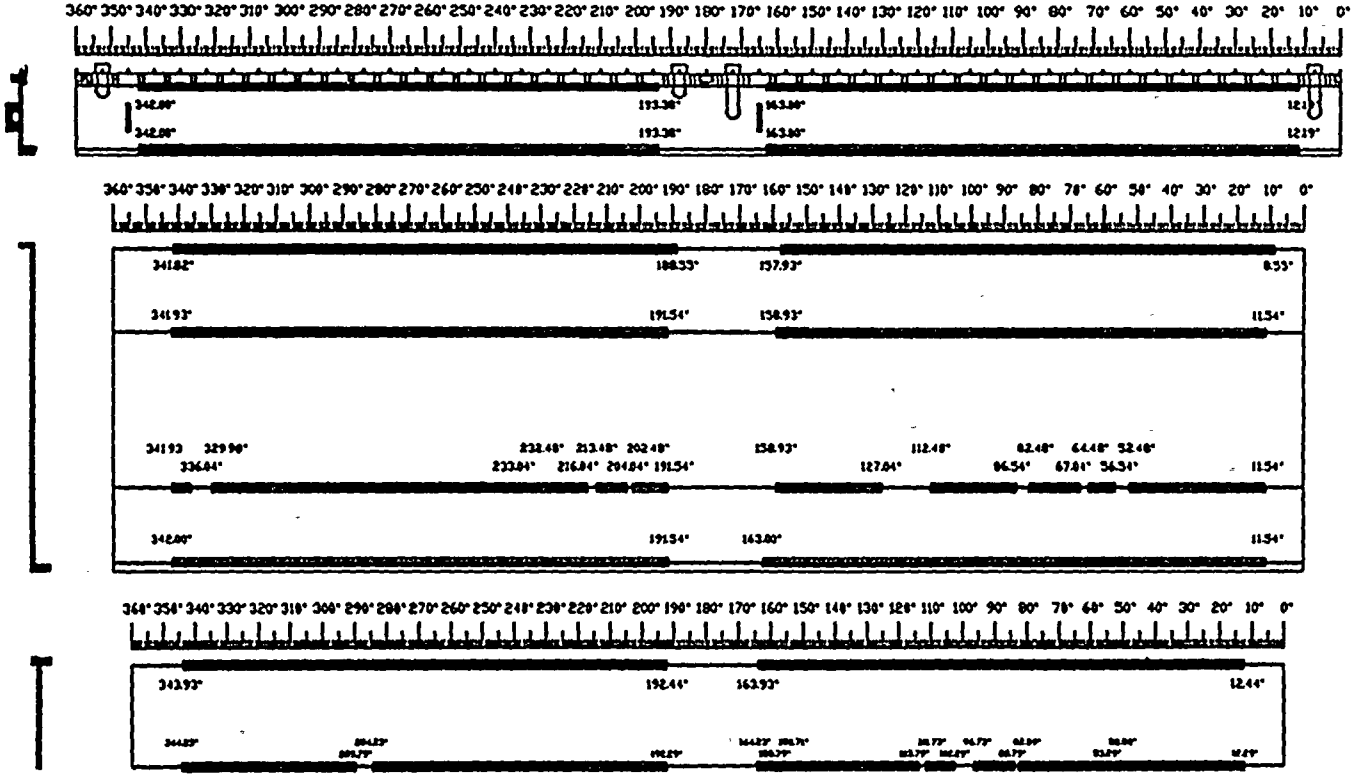
1. Susquehanna 1 - Shroud Rollout; Actual UT Exam Coverage.

2. Table 1, Limiting Seismic Loads for Susquehanna Units 1 and 2,.and Table 2, Pressure Drop Values for Susquehanna Units 1 and 2; from Ref. 6.1.

3. Table 3, Shroud Stresses for Susquehanna Units 1 and 2; from Ref. 1

SUSQUEHANNA 1 - SHROUD ROLLOUT

ACTUAL UT EXAM COVERAGE



COVERAGE
83.18%
83.18%
84.07%
82.72%
72.72%
83.87%
84.16%
80.77%

SKETCH RELEASE RECORD

REV	DATE	PREPARED	REVIEWED	INIT.	APPROVED	INIT.	PURPOSE
0	02/28/95	JIM COLLINS	XXXXX		XXXXX		SHROUD ROLLOUT
1	04/19/95	JIM COLLINS	XXXXX		XXXXX		SHROUD ROLLOUT
2	04/21/95	JIM COLLINS	XXXXX		XXXXX		SHROUD ROLLOUT

NOTE: THIS SKETCH IS FOR ISI PROGRAM USE ONLY AND SHALL NOT BE USED FOR FABRICATION/INSTALLATION.

GE DRF NO.

PROJECT: SSEC-1

TITLE: SHROUD UT INSPECTION

SKETCH NO.: SSEC-01-ROLL

CALC EC-062-1024
Page 9

ATTACHMENT 10

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

Ko f. 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

Ref. 6.1

APPENDICES

APPENDIX I: Information and calculations for all defective shroud welds

APPENDIX II: Fluence calculations for the H4 and H5 weld locations

APPENDIX III: QA validation of the DLL program for computer programs