Supplement #3

THE FINAL SUPPLEMENT TO THE "ENGINEERING EVALUATION OF THE WNP-2 SACRIFICIAL SHIELD WALL" SUBMITTED TO NRC IN AUGUST 1980

1. INTRODUCTION

The purpose of this report is to provide information that closes all NRC related open items on the WNP-2 Sacrificial Shield Wall (SSW), including those previously identified (Ref. 1) and those occurring since August 1980. Any additional activities associated with the SSW will be handled by normal WNP-2 procedures and documentation associated with those activities will be available for review at WNP-2 files.

The original report on the engineering evaluation of the WNP-2 Sacrificial Shield Wall identified a number of open items (Section I.D) which required additional testing or analysis to close out some aspects of the evaluation. In addition, structural deficiencies were identified during the girth weld modification and during the testing of samples removed from ring beam #6. The significance of these deficiencies with respect to the evaluation of the SSW has been addressed as an additional open item. This supplement closes out the open items and commitments. As will be discussed, the additional testing and analysis supports the conclusions of Ref. 1.

2. OPEN ITEMS

The following open items were previously identified:

2.1 Performance of qualification tests for electroslag welding procedures to confirm the mechanical properties of the weldments.

2.2 Removal of ASTM A588 material from the top ring (ring #6) of the Sacrificial Shield Wall to determine the NDT properties of this steel and to determine the margin between the NDT and the operating temperature.

2.3 Cold forming of ASTM A36 plate to the radius of the SSW for testing to confirm the assumed small shift in NDT produced by cold work.

2.4 Performance of a three-dimensional, finite element, dynamic analysis of the SSW to confirm the stress distribution used in the Ref. 1 evaluation.

[illegible]

2.5 Submittal of final conclusions by the United Kingdom Welding Institute (consultant to the Supply System) considering additional information obtained since their original report on the structural adequacy of the SSW.

Additionally, a number of deficiencies were detected during the performance of the girth weld and during the testing of samples removed from ring beam #6. These deficiencies have received special interest and add to the population of defects evaluated in Ref. 1. Their implications for the structural evaluation of the SSW have been addressed in this report supplement.

3. RESOLUTION OF OPEN ITEMS

3.1 Confirmation of Mechanical Properties of Electroslag Welds

A number of electroslag weld (ESW) qualification test plates were made to confirm the toughness and tensile properties of the ESW weld.

Direction for these tests was provided in Refs. 2 and 3. The scope of testing, due to early results, was modified by Ref. 4.

The results of these tests are presented in Tables 1 and 2.

The NDT values for the ESW weld metal ranged from -10°F to +20°F.

The test data obtained supports the assumption, made in Ref. 1, that the maximum NDT value for the electroslag welds was +20°F. This provides a minimum margin of 80°F between the NDT value of 20°F and the operating temperature of the SSW.

The tensile properties (refer to Table 2) of the electroslag welds exceeded the minimum specified values for ASTM A36 in all cases.

Five of the A588 specimens did not meet the Code specified strength levels. One coupon contained a defect; the other specimens' strength levels were marginally low. In view of the low design stress levels in the SSW (see Section 3.4 of this supplement), substantial design margin exists and the noted low strength values are therefore not a concern for the structural adequacy of the SSW.

3.2 Testing of ASTM A588 Material

The web of ring beam #6 was made from 2-1/4 inch thick ASTM A588 Grade B material. Three heats were used, each supplied by the same steel fabricator.

The outside flange was made from 2-1/2 inch thick ASTM A588 material, one heat of Grade B and one of Grade H. The Grade B material was supplied by the same steel fabricator as the web.

The inside flange was made from the same heat of 2-1/2 inch thick ASTM A588 Grade H material. This heat was not used elsewhere.

The material used for the inside flange was inaccessible because of the presence of the reactor pressure vessel. Therefore, samples were taken from the outside flange Grade H material and two of the four heats of Grade B (1 x 2-1/2" thick and 1 x 2-1/4" thick).

In addition to the base metal, two electroslag welds were sampled. One was used to characterize the weld and the other to characterize the heat affected zone.

Directions for the extraction and testing of these samples were given in Refs. 5, 6, and 7.

Results of the tests are shown in Table 3.

The NDT values for the ASTM A588 base material and heat affected zone confirm the assumptions of Ref. 1 and provide a minimum margin of 70°F between the maximum NDT and the operating temperature of the SSW.

The NDT value for the electroslag weld metal was higher. This increase is attributed to the low manganese level of the particular weld which was tested, possibly combined with pick up of precipitation hardening elements from the ASTM A588. The manganese level in the other weld tested was significantly higher. (Section 3.3 discusses the effect of cold forming on A588 NDT temperature.)

The NDT value of 60°F (see Table 3) provides a margin of at least 40°F between the temperature of the top ring of the SSW and the NDT. The outside surface temperature of the SSW is predicted to be 100°F and the inside about 140°F at the top of the SSW (Ref. 8).

The maximum stress level developed in the top ring is in member 47 (see Section 3.4 of this supplement). This maximum stress is 10.1 ksi or about 25% of the yield strength of the ESW weld zone. At this stress level a margin of 40°F is more than adequate to provide crack arrest conditions (see Ref. 1).

The three locations where the ASTM A588 material was removed for testing have been repaired. The work was performed in accordance with PED 215-CS-A716.

3.3 Effect of Cold Forming on the NDT of ASTM A36 and A588 Material

Some plates used in the construction of the SSW were cold formed to the radius of the wall. This cold forming could have changed the nil-ductility transition temperature of the material.

ASTM A588 material removed from ring beam #6 (see Section 3.2) was in the cold formed condition. Hence, the data discussed in Section 3.2 bounds the effect of cold forming on this material.

To determine the effect of cold forming on ASTM A36 tests were performed. Details of the program are given in Ref. 9. The results are presented in Table 4.

These results demonstrate that the level of cold work used in the SSW does not significantly affect the toughness of ASTM A36 steel. Thus the conclusions in Ref. 1 with respect to the bounding NDT values for ASTM A36 are not affected.

Also, the data obtained on ASTM A588 from the top ring of the SSW can be applied to both as-received material and material rolled to the radius of the SSW.

3.4 Results of Three-dimensional, Finite Element Dynamic Analysis

The conclusions of Ref. 1 were based upon stress levels calculated using a simplified dynamic analysis (see III.B.2 of Ref. 1). The Supply System committed to performing a three-dimensional, finite element, dynamic analysis to confirm the conclusions of the simplified analysis.

The three-dimensional analysis is reported in Ref. 10. The results demonstrate that the controlling members, which are those adjacent to pipe penetrations and close to pipe whip restraints, have a maximum stress level less than 18 ksi. Many of the controlling members have much lower maximum stress levels. This is less than half the minimum Code specified static yield stress for ASTM A36. It should also be noted that in members subject to significant bending, these maximum stress levels only occur at localized areas of the members.

This analysis confirms the conclusions of Ref. 1 with respect to the stress levels in the SSW.

3.5 Deficiencies Detected during Girth Weld Installation and Testing of Samples from Ring Beam #6

3.5.1 Deficiencies Identified during Girth Weld Repair

The following deficiencies were identified during preparation of the girth weld joint:

(i) Linear indications in electroslag welds were discovered adjacent to the girth weld. Details of this deficiency are given in Figures 1 and 2. This deficiency was detected in two of the thirty-two electroslag welds in ring #3 which intersect the girth weld.

(ii) Linear indications, slag inclusions and porosity were discovered in guide plate welds (see Figure 3).

(iii) Lack of penetration existed at the weld joint between the bottom flange of ring beam #4 and the exterior web plate. Details of this deficiency are shown in Figure 4. For further discussion and clarification see Part 5.

(iv) Linear indications in the girth weld excavation probably resulted from the repair of deficiency (iii) above.

3.5.2 Samples from Ring Beam #6

One of the samples taken from ring beam #6 contained a field electroslag weld. This weld joined two plates from the front flange plate.

Prior to machining drop weight test plates, the sample was examined by UT and sectioned for macroscopic examination. A subsurface defect was found which extended along the length of the sample. The nature and extent of the defect is shown in Figure 5. It consists of a lack of fusion defect on the sidewall of the weld which originally extended in from the surface of the weld, but was partially excavated and repaired.

In addition, two similar, but shallower defects were observed on the other side of the weld (Figure 5).

3.5.3 Significance of the Deficiencies

These deficiencies are discussed in detail in Ref. 11. It is concluded that the nature and severity of the deficiencies observed during the girth weld repair are bounded by the assumptions of Ref. 1 and that their discovery does not influence the conclusions of Ref. 1 with respect to the integrity of the SSW under design loading conditions.

3.6 Welding Institute Evaluation

The United Kingdom Welding Institute was retained as a consultant for the original evaluation. The additional data and information provided in this supplement have been transmitted to the Welding Institute for their review and comment. They have concurred that the tests and analyses support the original SSW evaluation conclusions and that the recently identified deficiencies are bounded by previous assumptions. (See Attachments 1 and 2.)

4.0 COMPLETED WORK AND CURRENT ACTIVITIES

4.1 Completion of Void Fill Program

As identified in Concern No. 2 of Ref. 1, concrete voids had been located in the SSW. There was a concern that other voids may exist in the SSW and thereby degrade the SSW shielding properties. To resolve this concern, a program was developed to examine the wall to locate and repair such voids. This program was outlined in Ref. 1 and has since been implemented.

Eighty-nine (89) voids were identified in the SSW and filled with BISCO NS-1 high density material. The PED's issued to locate and fill the voids are listed in Table 5. The adequacy of the NS-1 filler material was previously discussed with the NRC and formally addressed in Supplement No. 1 of the Engineering Evaluation of the WNP-2 Sacrificial Shield Wall.

The original void fill program included plugging the drilled fill holes. However, based on the SSW design the holes in the A36 plates have no structural impact and the related radiation streaming and/or contamination are not a concern; therefore, the decision was made to not plug the holes (see References 12 and 13).

4.2 External Weld Defect Repair

Work has been completed in bringing 236 welds into compliance with AWS D1.1 as required by the NRC (see Ref. 14). These welds were identified in previous correspondence as being accessible for repair. Repair of these welds was initiated by PED 215-W-A368 and work was performed in accordance with Bechtel Weld Procedure P1-A-LH (Structural). All work has been inspected to AWS D1.1 and approved by QC.

The total number of welds originally identified for repair was 239; however, three were deleted for the following reasons:

- o Weld No. 211 of weld map W131 was declared inaccessible for repair in NCR 215-08100.

- o Two welds were recorded twice. Welds 147 and 152 of weld map WF 23 were inadvertently recorded as welds 155 and 158 of weld map W23. Welds 155 and 158 are inaccessible as skin plate No. 39V covered these welds.

  Table III C.7 (attached) is a corrected version of the same table in the original report reflecting the preceding changes. This revised table should be used in place of the table in the original report.

4.3 Completion of Defect Removal at Azimuth 187°-30' and 541' Elevation

Supplement No. 2 of the Engineering Evaluation of the WNP-2 Sacrificial Shield Wall, Part II.B identified areas where linear indications appeared during preparation of the SSW girth weld joint. Major work was required to complete the defect removal at 187°-30'. This repair required the removal of a ring 4 skin plate and concrete above the area. This work was initiated by PED 215-CS-A347. Repair was completed in accordance with PED 215-W-A652 and PED 215-W-A750. After completion of the repair, the skin plate was replaced and NS-1 material was placed in the affected compartment in place of the concrete. This work was completed under the direction of PED 215-M-B049 and PED 215-M-B125. All related work has been completed with inspection and acceptance by QC.

During this repair work, additional concerns arose. While welding the skin plate back on at azimuth 187°-30' at 541' elevation, the controlling thermocouple for preheat sensing the temperature on the wall became dislodged. A temperature excursion between 450°F and 475°F occurred in this area of repair. This exceeded the specified preheat of 350°F and was documented on NCR 250-0945.

There was concern that these temperatures could have adversely affected the welds within the area of the 165° to 210° AZ. To disposition the NCR, direction was given by PED 215-W-C287 to magnetic particle inspect all welds from 541'5" elevation to 555' elevation, 165° AZ to 210°AZ. There were no cracks or reportable indications found.

To prevent repeated problems with temperature excursions, temperature recorder charts were added to provide additional temperature monitoring capabilities. A full-time craftsman was assigned to monitor preheat controls, and the welding engineer generated a log to identify when and where preheat was being accomplished.

NCR 250-09544 reported NS-1 had extruded from the wall in the area where temperatures exceeded the 350°F preheat. Concern for a decrease of shielding in this area of the wall existed. To resolve this concern the area has been identified and added to the list of areas to be monitored during the startup radiation scan program.

4.4 Linear Indication on the Sacrificial Shield Wall at 544'6"

A crack was discovered on the Sacrificial Shield Wall at 544'6" elevation and 80° azimuth. The crack was adjacent to weld No. 262 on weld map W61, a diaphragm plate to skin plate weld. This was reported on NCR 215-09021.

There was concern whether the crack was the result of the girth weld at elevation 541'. To ensure such a defect did not exist in other suspect locations, seventeen other locations on the wall of similar configuration were examined. No other cracks or linear indications were found. During excavation it was determined that the crack originated in the root of the weld. The possibility exists that the girth weld either caused the crack to propagate or open. See Reference 15 for details.

The repair work was performed in accordance with AWS D1.1 per PED 215-W-B030 and Bechtel Weld Procedure P1-A-LH. All work was inspected and approved by Q.C.

It should be noted that this specific defect, and others which could be reasonably postulated, are enveloped by the fracture assessment in Section III.D of the original evaluation report.

5.0 Discussion of the 1/4" Incomplete Penetration Identified in Supplement No. 2 of the Engineering Evaluation of the WNP-2 Sacrificial Shield Wall.

5.1 The Engineering Evaluation of the WNP-2 Sacrificial Shield Wall Supplement No. 2, Part II.C identified three locations where incomplete penetration (I.P.) was discovered in the partial penetration flange-to-web plate weld on ring 4. (See Figure 4 of this supplement). The incomplete penetration identified was 1/4" deep; however, the original report addressed 5/32" as the worst I.P. case in Table III D.5.

The purpose of the following discussion is to address the 1/4" I.P. relative to the previous SSW structural assessment.

As discussed in the initial evaluation report (Ref. 1) incomplete penetration promotes failure by plastic collapse rather than by brittle fracture. Table III.D.2 of the initial report lists the critical flaw depth to thickness ratios for plastic collapse to occur. This table lists a/t ratios for static loading and dynamic loading taking into account bending and tension. These ratios were developed by using the actual design stresses of the wall. Burns and Roe Technical Memorandum 1218 reported the results of the three-dimensional finite element dynamic analysis, confirming that the stresses in the SSW for the most critical members and load combinations are less than half of the yield stress of the material. The stresses that were reported in this analysis were less than those used in developing Table III.D.2. These lower stresses allow the a/t ratio to be larger than reported which in turn would allow a larger flaw to exist.

In comparing the a/t ratio of 0.33 for the 1/4" I.P. in 3/4" thick material to Table III.D.2, there are no a/t ratios in either the static loading or the dynamic loading columns for any of the materials equal to 0.33. Therefore, plastic collapse will not occur. An a/t ratio greater than 0.5 would have to occur before plastic collapse could occur.

In addition, the potential for plastic collapse is reduced by the design of the SSW. For plastic collapse to occur, large strains and displacements are required. The SSW is a redundant structure in that loads are transmitted through many members in parallel. The displacement which can be applied to a weld joint is limited by parallel joints. The design and the evaluation for plastic collapse leads to the conclusion that the 1/4" I.P. will not cause plastic collapse and is enveloped by the original assessment of the wall.

Table III.D.5, attached, is revised, reflecting the 1/4" incomplete penetration, and a corrected typographical error for undercut.

6.0 SUMMARY

The open items identified in Ref. 1 have been closed out by testing or additional analysis. The implications of additional deficiencies identified during the installation of the girth weld, during testing of samples from ring beam #6, and the crack at 544'6" have been evaluated.

It has been determined that the conclusions of Ref. 1 have been reinforced and remain valid with respect to the as-built structural adequacy of the SSW.

REFERENCES

1. "Engineering Evaluation of the WNP-2 Sacrificial Shield Wall"

2. IOM from D. Burns/C. M. King to D. C. Timmins, "Qualification of Leckenby Electroslag Welding Procedures", F-80-1491, dated April 8, 1980

3. IOM from D. Burns to D. C. Timmins, "NDT Testing, SSW Evaluation", EMN-DB-80-11, dated April 25, 1980

4. Letter from G. I. Wells (SS) to P. J. Garcia (WBG), "Sacrificial Shield Wall (SSW) Boecon Welding Procedure Testing", WNP2WBG-215-F-81-034, dated January 7, 1981

5. PED215-W-4926, "Sacrificial Wall Test Samples", dated July 15, 1981

6. Site Support Work Order FJB-1171 (BECWBG-215-81-0432), dated July 31, 1981

7. IOM from D. Burns to D. C. Timmins, "Additional Direction to Anamet", EM-DB-81-74, dated September 15, 1981

8. Burns and Roe Memorandum, V. F. Rubano to R. E. Snaith, "Minimum Temperature of Sacrificial Shield Wall", dated March 24, 1980

9. IOM from D. Burns to D. C. Timmins, "Effect of Cold Work on the NDT Temperature of ASTM A36 Steel Plate Used in the SSW of WNP-2", EMN-DB-80-41, dated October 16, 1980

10. Burns and Roe Technical Memorandum 1218, "Stress Evaluation of the WNP-2 Sacrificial Shield Wall - Using 3-Dimensional Model for Dynamic Analysis", dated January 8, 1981

11. IOM from D. Burns to D. C. Timmins, "Evaluation of Deficiencies Found During the Girth Weld Repair and During Testing of Material from Ring Beam #6, SSW, WNP-2", EM-DB-81-76, dated September 18, 1981

12. IOM from J. O. Parry to D. E. Larson, "Visual Inspection of WNP-2 Sacrificial Shield Wall", dated February 23, 1982

13. Letter from B. A. Holmberg (SS) to A. Cygelman (B&R) WPBR-F-82-029 dated February 18, 1982

14. Letter from the NRC to R. L. Ferguson, "Review of Defects in the WNP-2 Sacrificial Shield Wall", dated February 25, 1981

15. IOM from P. J. Inserra to W. G. Keltner, "Sacrificial Shield Wall Crack at 544'6" - 80^{o}AZ: Synopsis of Events", F-82-1148 (SS2-PE-82-68)

TABLE 1

RESULTS OF NDT TESTING ON ELECTROSLAG WELD TEST PLATES

Plate No.	Thickness	Base Metals	Weld Metals	NDT Values Weld	NDT Values Base Metal	NDT Values HAZ*
A5	2"	A36 - A36	EM 12K/Linde 124 Flux	-10°F	-10°F (1)	+20°F
A7	2"	A36 - A36		+20°F (2)	--	--
A8	1-1/2"	A36 - A36		--	--	+10°F
B5	3"	A36 - A36		+10°F	-20°F	--
B6	3"	A36 - A36		-10°F	-40°F	--
B7	3"	A36 - A36		+20°F (3)	--	--
E1	2-1/2"	A588 GRB-A588 GRH		+20°F	--	--
E2	2-1/2"	A588 GRB-A588 GRH		+10°F	--	--
E3	2-1/2"	A588 GRH-A588 GRH		0°F	--	--
F2	2-1/2"	A36 - A588		+10°F (4)	+30°F (A36) -20°F (A588)	+10°F (A36) +10°F (A588)

(1) Only one no break obtained
(2) One no break obtained at +10; one break at +20°F
(3) One no break obtained at +10 and +20°F; one break at +20°F
(4) One no break at -10°F; one no break at 0°F; one break at +10

* Heat Affected Zone (HAZ)

TABLE 2

RESULTS OF TENSILE TESTS ON ELECTROSLAG TEST PLATES

	Transverse Tension Tests			All Weld Metal Tension Tests			
Plate No.	Yield Strength psi	Ultimate Strength psi	Elongation %	Yield Strength psi	Ultimate Strength psi	Elongation %	% RA**
B5	45290 49940 49570 46980	68000 67120 66110 66090	45 45.5 43.5 46.0	47030	69310	27	64.8
B7	44240 42780 49080 46990	62770 62030 64420 64370	40 39.5 40 44	46270	64430	26	59.4
E2	56640 *44150 56160 59360	74890 44150 73010 74050	33 4 37.5 36.5	52740	75370	26	54.7
E3	47880 51850 51740 52020	70760 71290 69240 69680	33 38 36.5 39.5	49000	71390	27	64.2
F2	50280 55210 53770 53390	69940 70610 70070 70220	39 39.5 41.5 40.5	52250	73500	27.5	61.3

* Flaw in weld
** Reduction of Area (RA)

TABLE 3

RESULTS OF TESTING OF MATERIAL FROM RING #6
OF SACRIFICIAL SHIELD WALL

Sample	Heat No./ Weld No.	Specification and Grade	NDT Temp.	Yield Strength (Transverse)	Ultimate Strength (Transverse)	Analysis %C	Analysis %Mn
T-2-A	801S29340	A588 Grade B	+30°F			0.14	1.07
0-7-A	801S26800	A588 Grade B	+20°F			0.15	1.04
0-8-A	52690	A588 Grade H	+20°F			0.11	0.77
0-8/7-G	WF109-6	ESW Weld	+60°F	41500 psi 40,000psi	61700 psi 58300 psi	0.11	0.67
0-7/8-J-HZ	WF109-24	ESW HAZ in Heat No. 52690	+30°F (Note 1)			0.12 (Note 2)	0.83

Note (1) Break obtained at +30°F after no break at +20°F and +30°F
(2) Obtained on weld metal

TABLE 4

EFFECT OF COLD FORMING ON THE NDT OF ASTM A36

Heat No.	Thickness	Inside Diameter Radius	NDT Temperature As Received	NDT Temperature Cold Formed (Note 1)
155602	1-1/2"	86"	+10°F	0°F
155768	1-1/2"	86"	-10°F	-10°
205957	1-1/2"	79.5"	-10°F	0°F

Note (1) The plates were cold rolled to the radii noted above. The minimum radius for the SSW is 156". The radii used for cold forming were calculated to bound the strain level in 3" thick plates formed to a radius of 156".

Table 5

ADDITIONAL PEDs - CONCRETE VOID PROGRAM

A347 - Remove plate #14
B049 - Partial Fill Compt 14 (B125)
A168 - Drill holes
A370 - Angle change
A165 - Void Fill
3452 - NDE Method
A155 - Make tapered plugs
A505 - NDE - SAC Wall
A548 - Word change to A505
A619 - Word change to A505
A628 - 3/4" hole - plate 187
A637 - 5/8" hole - 187
A649 - Drill holes
A655 - Drill holes
A660 - Drill holes
A714 - Drill holes
A724 - Drill holes
A725 - Drill holes
A852 - Drill holes
A877 - Drill holes
A901 - Drill holes
A919 - Drill holes
A926 - Void Fill
A968 - Drill holes
A977 - Drill holes
A979 - Drill holes
A980 - Drill holes
A981 - Drill holes
A990 - Fill Voids
B024 - Fill Voids
B015 - Drill holes
B016 - Drill holes
B017 - Drill holes
B018 - Drill holes
B039 - Drill holes

B040 - Fill Voids
B042 - Delete sheets in PED's
B047 - Drill holes
B053 - Fill Voids
A982 - Drill holes
B069 - Drill holes
B070 - Drill holes
B079 - Fill Voids
B071 - Drill holes
B106 - Drill holes
B116 - Drill holes
B090 - Drill holes
B136 - Drill holes
B091 - Drill holes
B144 - Fill Voids
B092 - Allow Fills
B093 - Clarification for "B"
B137 - Drill holes
B158 - Drill holes
B159 - Drill holes
B177 - Fill Voids
B200 - Drill holes
B187 - Fill Voids
B160 - Locate holes
B209 - Drill NS-1
B214 - Word change
B215 - Refills
B222 - Drill hole
B224 - Triple Amt. plugs
B223 - Fill Voids
B235 - Drill holes
B253 - Refills
B080 - Documentation changes
B165 - Drill hole closure

TABLE III.C.7

BURNS AND ROE VISUAL INSPECTION DATA

Total Welds Evaluated	1698	
Total Acceptable Welds	1408	
Total Inaccessible Welds	54	
No. Exceptions by Weld	236	(1)
No. Fillet Welds with Exceptions	193	
No. Groove Welds with Exceptions	43	

Defect Breakdown

Defect Type	No. Recorded (c)	
Cracks	None	
Undercut	32	
Porosity	14	
Crater Fill, Cavity	74	
Underfill	4	
Overlap	9	(1)
Convex Fillet	5	
Excess Reinforcement	38	
LOF (a)	6	
Arc Strikes, Slag, Temporary Attachments	17	
Undersize Fillet (b), Unequal Leg, Weld Profile	101	
Linear indications, file, knife marks	3	

(a) These incomplete fusion defects are less than 1 inch in length and may in actuality be acute fillet re-entrant angles or indications other than lack of fusion between the base metal and weld.

(b) Percentage of fillet weld length affected varies.

(c) Multiple defects exist in certain welds.

Table III.D.5

SUMMARY OF WORST CASE DEFECTS IN WELDMENTS

Region	Defect Type	Largest Reported Length x Width x Depth (a) Inches	Potential Failure Mode
Parent Plate	Arc Strike	3/8 x 3/8 x 1/32	F
	Lamellar Tears	None	P, (F)
Heat Affected Zone	H-cracking	None	F, (P)
	Liquation Cracks	None	F
Fusion Boundary	Lack of Fusion	8 x 0 x 0 (b) 39 x 0 x 0 (ESW)(e)	P, F
Weld Metal	Crack	13 x 0 x 1/8 (c)	P, F
	Undercut	8 x 0 x 1/8 24 x 0 x 0 (ESW)	P, (F) (1)
	Undersized Fillet	26 x 0 x 1/4 (d)	P
	Overlap	3 x 0 x 1/8	F
	Underfill	4 x 0 x 1/8 24 x 0 x 0 (ESW)	P
	Excess Reinforcement	72 x 0 x 1/4	--
	Porosity	8 x 0 (boundary area) 19 x 1 (boundary area, ESW)	(P)
	Crater Fill	1 x 1/2 x 3/8	(P)
	Incomplete Penetration	Varies x 0 x 1/4 (f)	P, F
	Slag Inclusions	1-1/2 x 0 x 0	F

F - Fracture, P = Plastic collapse, ( ) - signified lower probability

(a) Depth in the thru-thickness direction.
(b) 0 - signifies dimension unknown.
(c) One 2-1/2 inch long crack extended through the 1-3/4 inch thick electroslag weld. No other such occurrences have been identified in the documentation.
(d) Worst case based upon percentage reduction in are from original weld size
(e) Available information from industry sources indicates a maximum depth for this type of corner lack of fusion of 1/2".
(f) Identified at various locations analysis takes into account full length.

AZ. 135°-150°

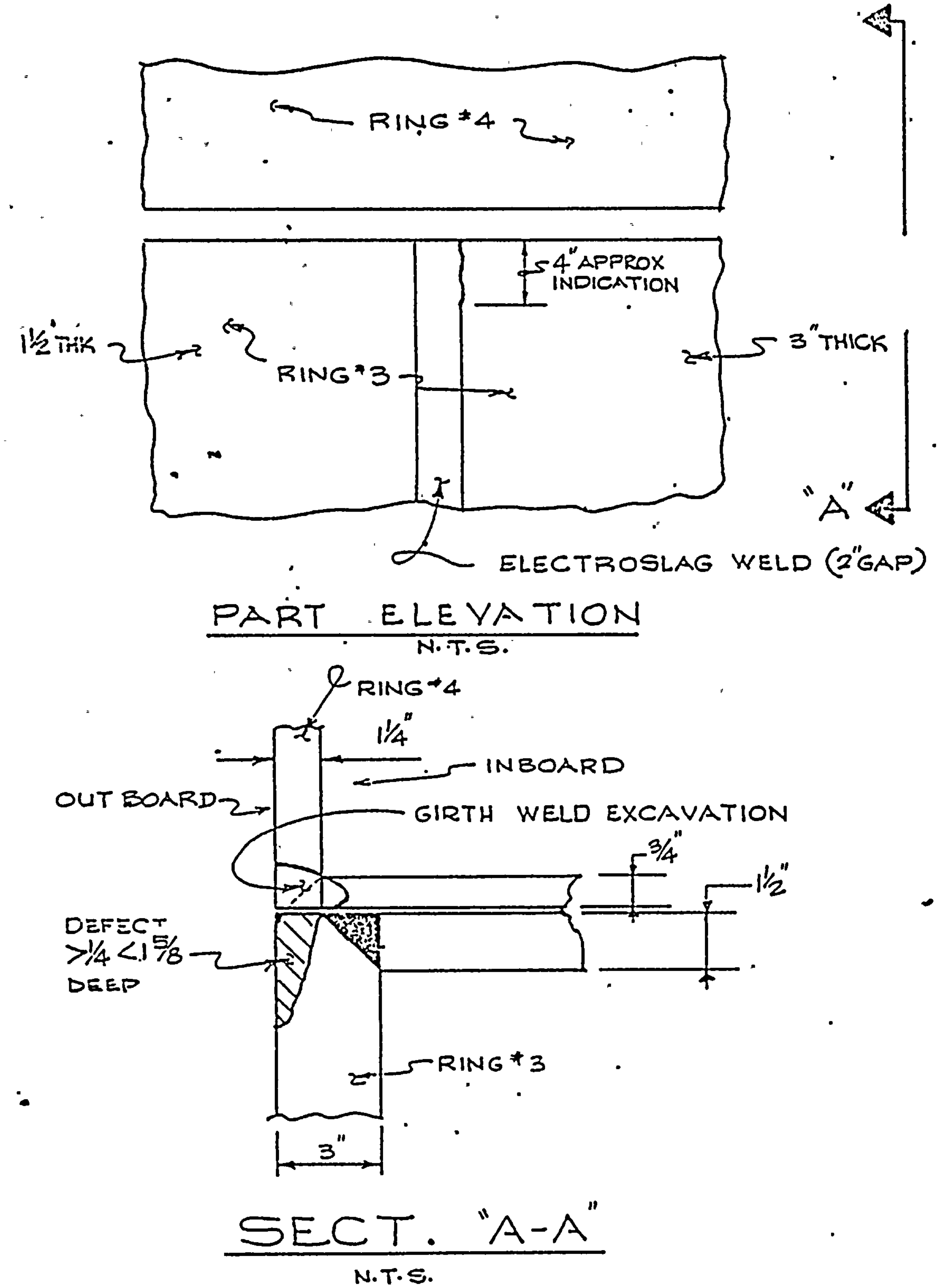


FIG 1. LINEAR INDICATION IN RING 3 AT 135°-150° AZ

(AZ 90°-105°)

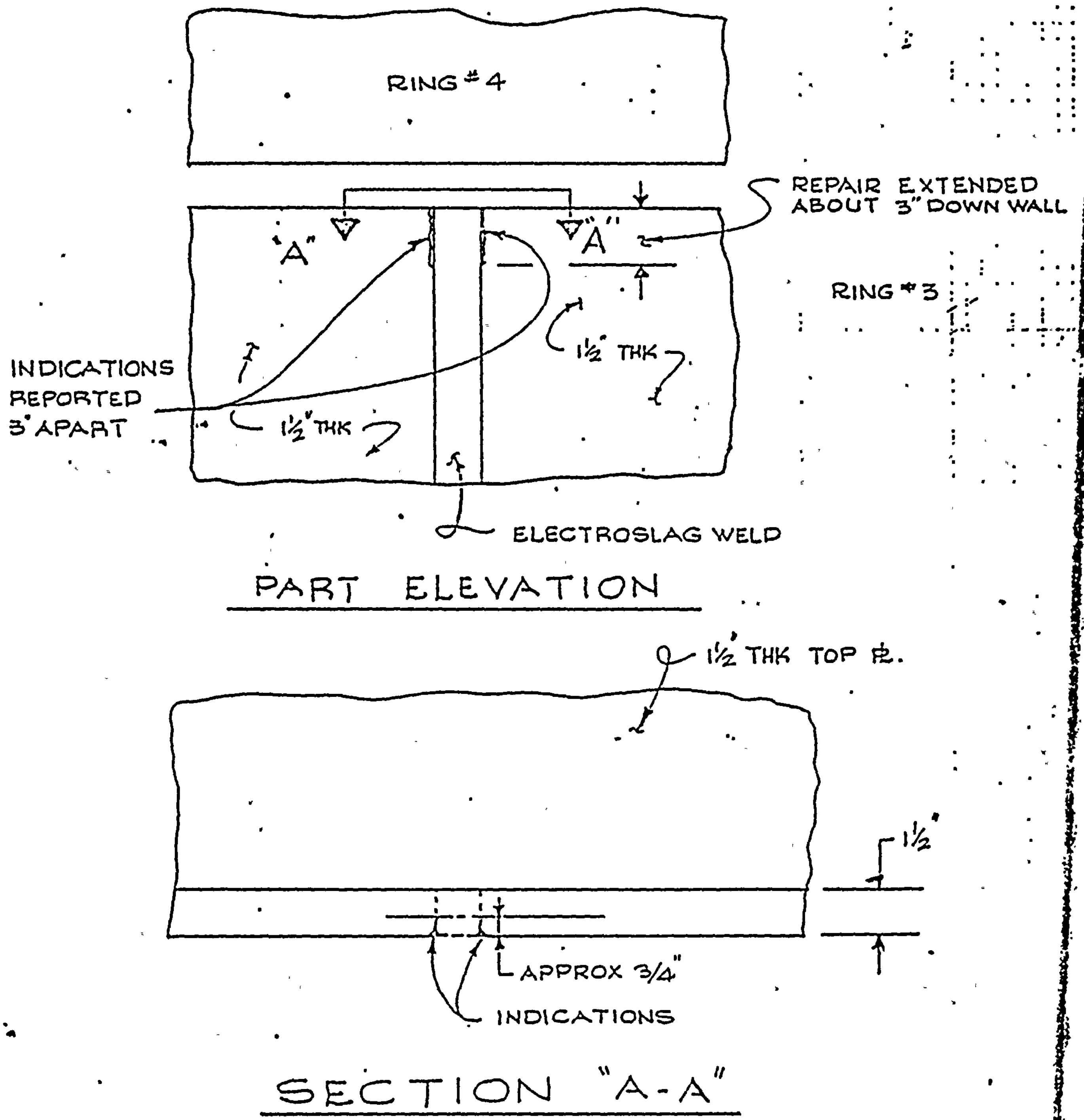


FIG. 2. LINEAR INDICATIONS IN RING 3 AT 90-105° AZ.

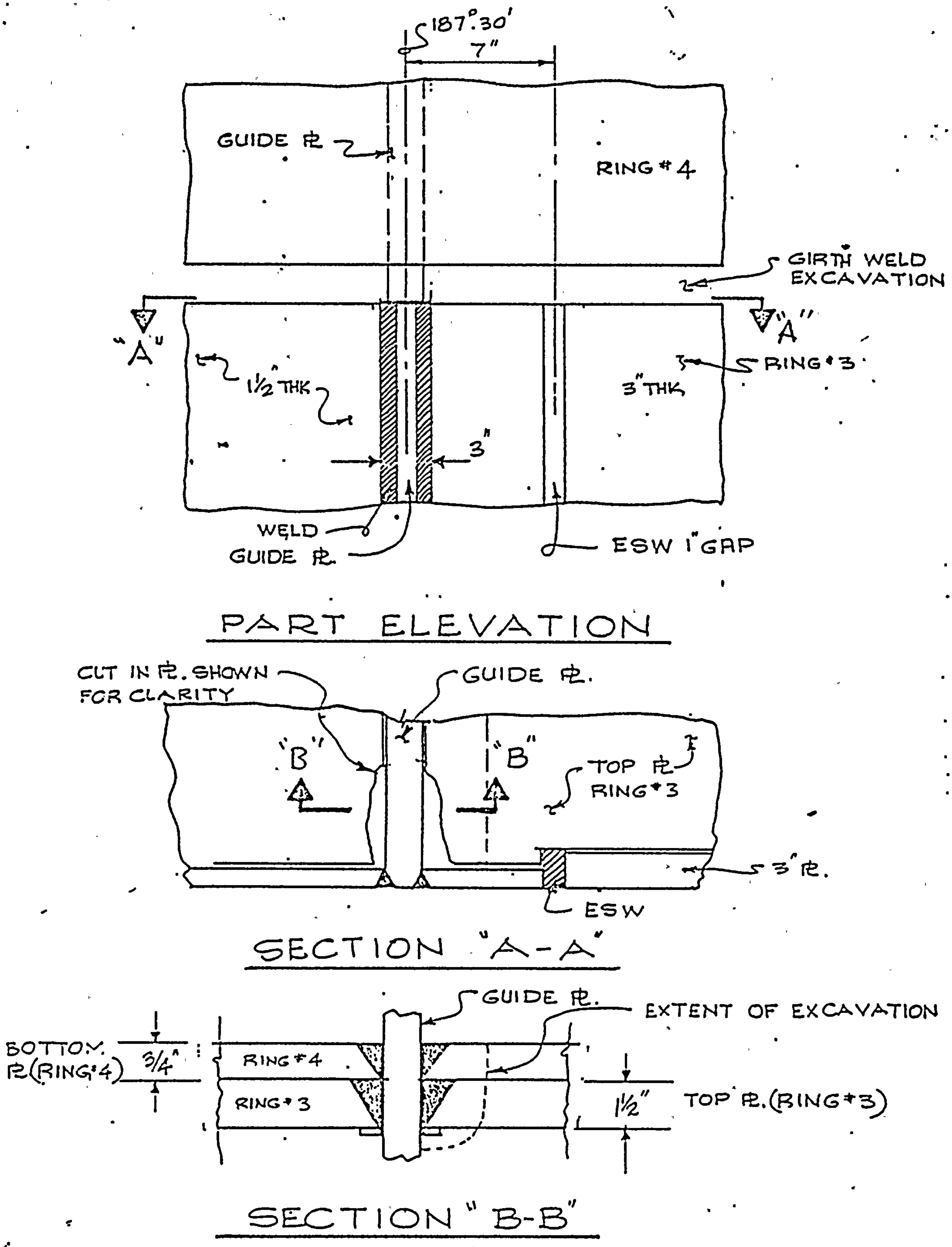
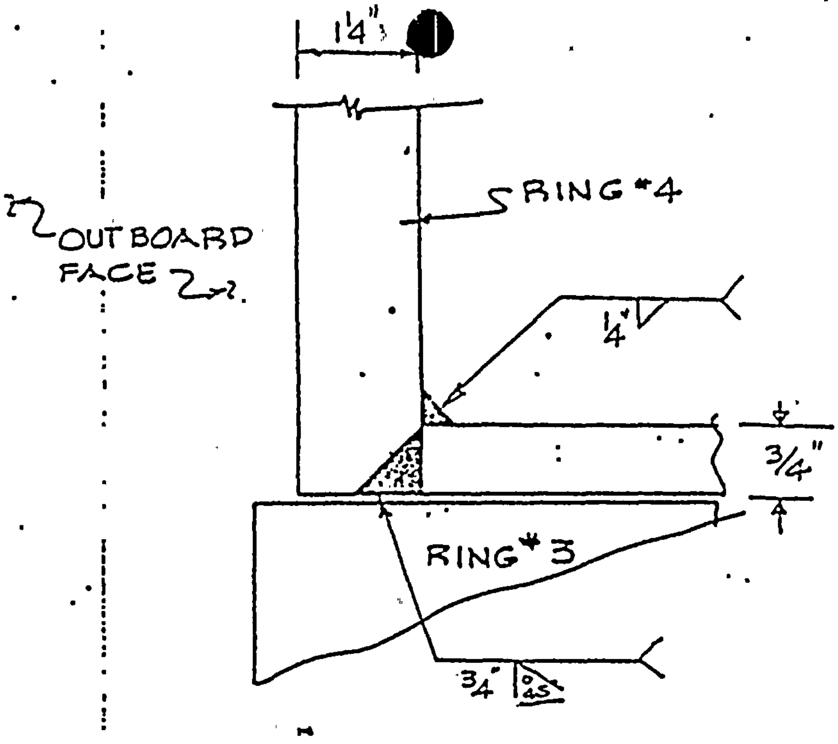
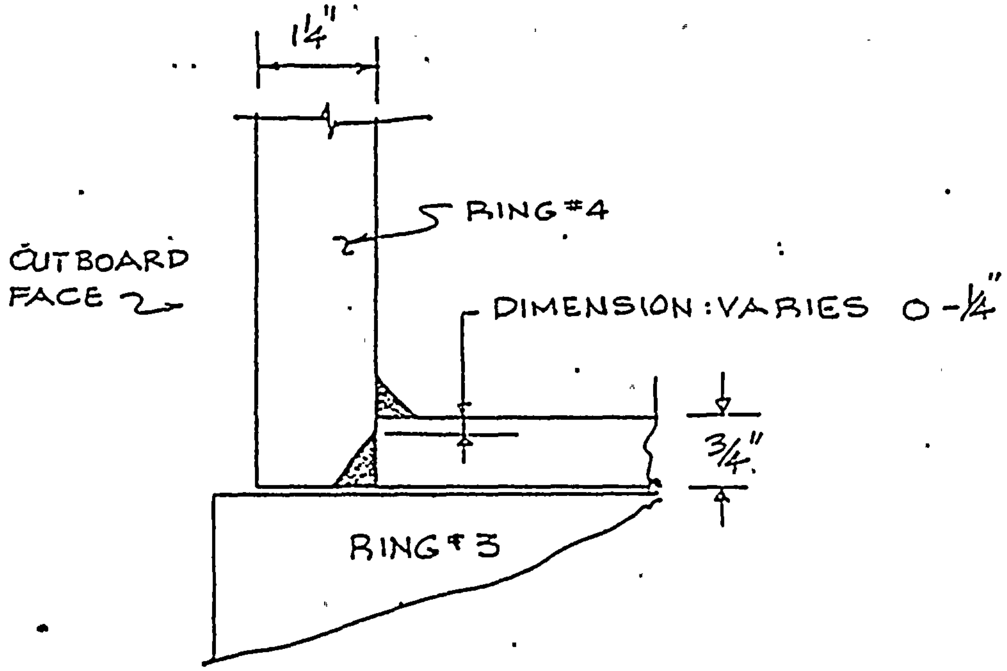


FIG 3. GUIDE PLATE WELDS AT AZ 187°30' (SIMILAR AT 67° AND 300-31

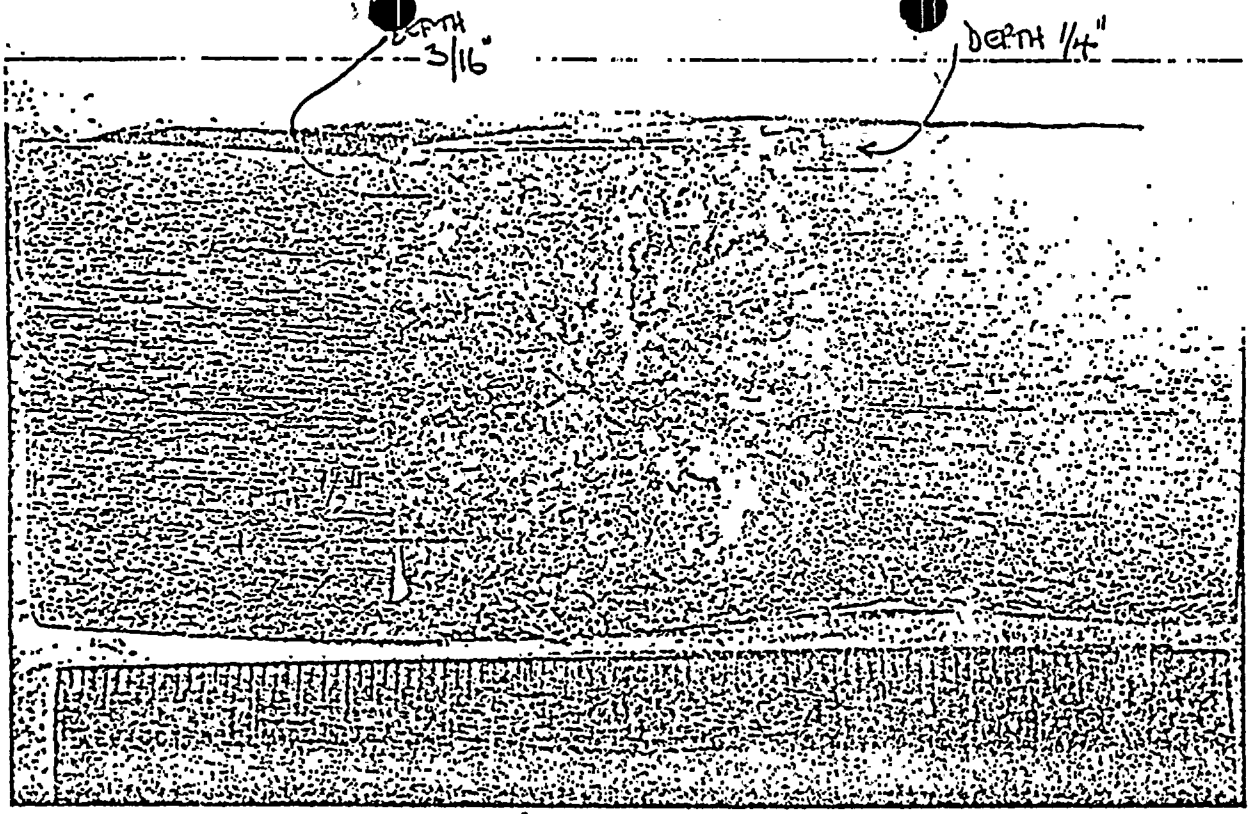


A: JOINT REQ'D BY LECKENBY DRAWING #66

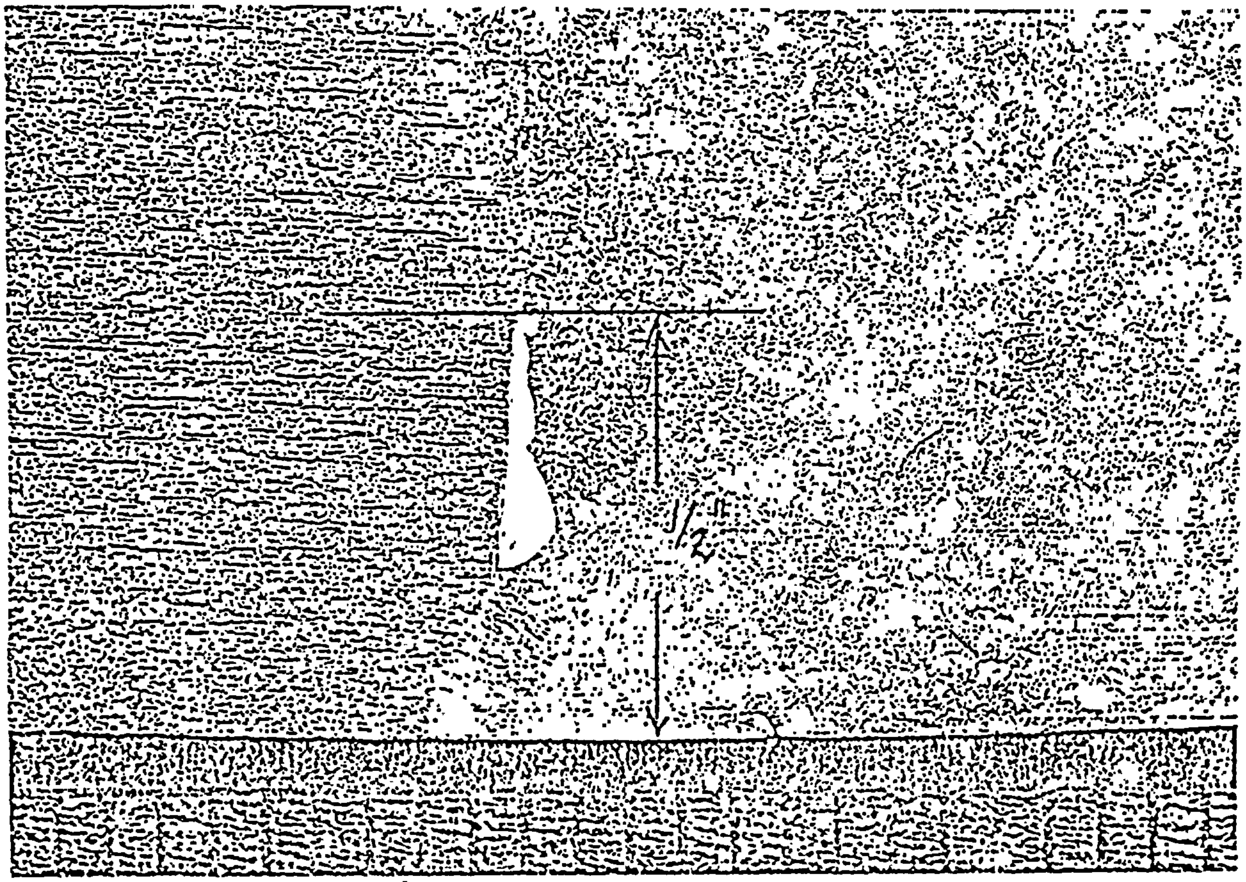


B: AS-BUILT CONDITION AT AZ. 90°-105°, 0°-15°, AND 180°-195°.

Fig. 4. Lack of penetration at Az. 90-105, 0-15, and 180-195°.



A. COMPLETE SECTION SHOWING THREE LACK OF FUSION DEFECTS



B. VIEW OF LOWER LEFT. DEFECT. NOTE PARTIAL REPAIR (1 DIV = 1/16")

FIG. 5 TRANSVERSE MACROSECTION THROUGH ELECTROSLAG WELD
[illegible] SEAM #6

Attachment 1

THE WELDING INSTITUTE

PLEASE REPLY TO RESEARCH LABORATORY ABINGTON HALL ABINGTON CAMBRIDGE CB1 6AL
Telephone CAMBRIDGE 0223 891162 Telegrams WELDASERCH CAMBRIDGE Telex 81183

LONDON OFFICE 54 PRINCES GATE EXHIBITION ROAD LONDON SW7 2PG
Telephone 01-584 8556 Telegrams WELDINST LONDON S.W.7

AAW/VAN/119 10 February 1982

Mr R A Moen
Washington Public Power Supply System
PO Box 968
3000 George Washington Way
Richland
Wa. 99352
USA.

Dear Mr Moen,

Draft Supplement No 3, WNP-2 SSW Evaluation - LD 22757

Further to my telex of 1 February 1982, I should like to clarify my comments on your draft supplement. My main concern was with the electroslag welds used to attach the pipe whip restraints. It is apparent from the high incidence of rejects reported in Section III.C.8 of the Engineering Evaluation that either the weld procedure was incorrect or it was not being followed. The defect described as "shrink" is most probably what we would call a solidification crack, aligned vertically on the weld centre-line. The most likely cause is welding too rapidly, so that a very deep weld pool is formed. The high wire feed speed would require a high voltage or current to raise the heat input sufficiently, as you reported. These solidification cracks can be fairly sharp, and are most probably surrounded by regions of poor toughness, owing to the segregation of non-metallic inclusions to the weld centre-line during cooling. If this conjecture is correct, then the result is a large, potentially crack-like defect with its tip in a region of low toughness. The values taken for the NDT temperatures of electroslag welds in A36 and A588 steels may not represent upper bounds for these particular welds, so that there is a potential risk of fast fracture.

Possible courses of action would be to repair all the defective electroslag welds in the pipe whip restraints, or to measure the NDT temperatures at the weld centre-line on some of these particular welds.

/continued .....

Mr R A Moen
Washington Public Power Supply System 10 February 1982

There were a number of other more minor points which I feel should be made clear, but which do not reduce the level of confidence in the structural integrity of the SSW.

1. In Section III.C.2 of the Engineering Evaluation, it is stated that the entrapment of slag at the outside corners of electroslag welds results in defects which are not equivalent to planar lack of fusion. In our experience, these defects usually arise from inadequate heat input and/or poor weld procedure, which in turn cause lack of fusion at the corners. The slag which becomes trapped in the defect is a symptom of its presence rather than a cause of the defect per se. The defect is essentially lack of fusion and can be planar and crack-like, with a sharp tip. However, the presence of these defects does not reduce the level of safety of the SSW, because the NDT temperatures of these electroslag welds should be low enough to ensure crack arrest.

2. The tests on the electroslag welds are indicative of NDT temperatures below +20°F, but do not prove the case. This is because:-

i) The dilution in electroslag welds is high, typically 40-50%. Therefore the properties of the weld metal will vary significantly with base metal composition. Since the relevant base metal specifications are rather loose (particularly for A36 steel), there is no guarantee that the same weld procedure will produce the same weld properties in welds fabricated from different heats of base metal. I am assuming, from the information you sent me, that base materials for the test plates were procured at random from a steel stockist, and not cut from the SSW.

ii) The cooling rates in the test plates were probably lower than in the SSW, because in the fabrication of the former relatively narrow plates were used (5-12in. in width). To simulate the cooling rates more closely, we would recommend that either the same width of plate be used as in the structure, or where the structure contains very large plates, the test plate width be at least 36in. either side of the weld.

However, your tests do provide support for the estimate of the upper bound NDT temperature of +20°F used in our report LD 22526. Using the lower stresses which you have calculated the crack arrest temperature is less than the minimum service temperature by a substantial margin.

3. The draft version of LD 22526 assumed a dynamic elevation of the flow stress of 65%, but examination of further work suggested

Mr R A Moen
Washington Public Power Supply System 10 February 1982

that this could be an overestimate. Therefore a lower bound to the dynamic elevation was taken to be 30% in the final version of LD 22526. However, in Table III.D.2 you have used the earlier assumption of 65%. The difference is relatively insignificant, because with a maximum dynamic stress of 18 ksi, this 30% elevation still gives allowable defect sizes which exceed those likely to be present in the SSW.

4. A very minor point is that in your Draft Supplement No 3, Sections 3.5.1 and 3.5.2, you refer to figures 1 to 5, which were not attached. I assume that these are the same figures as occur in your reference 11 and the attachment thereto.

In conclusion, I am happy that, with the exception of the electroslag welds in the pipe whip restraints, your subsequent work has increased the level of confidence in the structural integrity of the SSW above that which obtained at the time of issue of our report LD 22526.

Yours sincerely,

pp. A A Willoughby

Attachment 2

INTERNAL DISTRIBUTION

PW Harness/lb
DC Timmins/lb
PJI/lb
TRAM/lb
DW Porter
C. Control
Corr. File
WNP-2 Files

THIS LETTER SATISFIES COMMITMENT NO. ______

THIS LETTER (DOES) (DOES NOT) ESTABLISH A NEW COMMITMENT.

WPPSS CORRESPONDENCE NO. ______

April 2, 1982
G02-82-361

Dr. A. A. Willoughby
The Welding Institute
Abington, Cambridge CB1-6AL
United Kingdom

FILE COPY

Subject: SUPPLY SYSTEM NUCLEAR PROJECT NO. 2
WNP-2 SSW EVALUATION-LD 22757, SUPPLEMENT 3

In reference to your letter AAW/VAN/119 of February 10, 1982, you have expressed some concerns over data and conclusions in our Draft Supplement 3, WNP-2 SSW Evaluation-LD 22757. This letter hopes to clarify any outstanding concerns.

1. Concerns over electroslag welds used to attach pipe-whip restraints need not be addressed for the following reasons:

   a. Pipe-whip restraints fabricated employing the ESW process have been completely refabricated using SAW, FCAW, and/or SMAW. This refabrication was made necessary primarily due to the low mechanical (impact) properties expected in these welds. It should be clarified that ESW was employed only in joining the pipe-whip restraint web plates to their associated base plates. These base plates are, in turn, bolted to pipe-whip supports.

   b. Pipe-whip supports have been attached to the SSW employing FCAW and SMAW processes and were not welded with the ESW process.

   c. Some electroslag welds were employed in attaching structural steel to the SSW. They were radiographed and repaired as necessary.

2. The concern over entrapment of slag at the outside corners of the electroslag welds resulting in planar and crack-like lack of fusion is not significant due to the following reasons:

   a. The SSW fabricator (Leckenby Co.) had established a repair program to address this type of defect. Subsequent UT examination has verified that such defects were being repaired by Leckenby.

   b. Illustrations provided with original fabrication defect descriptions indicate the re-entrant angles at the interface of the lack-of-fusion regions and sound fusion regions were not sharp and thus not crack-like.

AUTHOR:	PJ Inserra *(signature)*		FOR SIGNATURE OF:	RA Moen	
SECTION					
FOR APPROVAL OF	PW Harness	DC Timmins			
APPROVED	*(signature)*	*(signature)*			
DATE	4/1/82	4/1/82			

3. Item 3 of your letter discusses the different dynamic elevations of flow stress used to formulate the critical flaw depth to thickness ratio. As you stated, the final version of LD 22526 used a dynamic elevation of 30 percent (Table 5), as opposed to 65 percent used in Table III.D.2 of the supplement. It is understood that 30 percent dynamic elevation is more conservative than 65 percent. However, Table III.D.2 has used a design stress of roughly 0.5 yield stress which is the actual case for the designed structure, as opposed to the full yield stress of a given material as employed in Table 5 for calculation of the a/t ratio.

   We concur that the differences between the a/t ratios of Table 5 and Table III.D.2 are insignificant when the actual design stress is used with a dynamic elevation of 30 percent.

In conclusion, we appreciate your clarification of comments on Draft Supplement No. 3. I hope this letter puts to rest any remaining concerns over the draft supplement.

Richard A. Moen

R. A. Moen - 430
Lead, Welding & Materials

PJI/taj