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SUBJECT: Forwards revised steam generator weld fracture analyses. Revs incorporate addl info requested during 870327 telcon. Info should be reviewed prior to plant reaching criticality on 870331.

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March 30, 1987

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U. S. Nuclear Regulatory Commission
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Gentlemen:

Docket 50-305
Operating License DPR-43
Kewaunee Nuclear Power Plant
Steam Generator Weld Fracture Analyses (Revision 1)

Reference: 1) Letter from D. C. Hintz (WPSC) to Document Control Desk (NRC) dated March 27, 1987

By letter dated March 27, 1987 (Reference 1) we informed you that additional information requested by NRC staff members to support the issuance of a NRC Safety Evaluation Report, would be submitted on Monday, March 30, 1987. By attachment to this letter we hereby provide Revision 1 to the Steam Generator Weld Fracture Analysis. The revisions to the analysis report were made to incorporate additional information requested by NRC staff members during a telecon on March 27, 1987.

Your immediate attention to review the supplemental information is essential as KNPP is now expected to reach criticality on the evening of Tuesday, March 31, 1987.

Sincerely,

D. C. Hintz
Vice President - Nuclear Power

DSN/jms
Attach.
cc - Mr. Robert Nelson, US NRC
US NRC, Region III

A001
1/1

Attachment to Letter

Dated March 30, 1987

From D. C. Hintz (WPSC) to Document Control Desk (NRC)

Revision 1 to the Evaluation and Analysis of the Indications in the Kewaunee Unit 1 Steam Generator "B" Upper Shell to Cone Weld

EVALUATION AND ANALYSIS OF THE INDICATIONS IN THE KEWAUNEE UNIT 1 STEAM GENERATOR "B" UPPER SHELL TO CONE WELD

1.0 SUMMARY

During the ultrasonic examination of the Kewaunee Unit 1 Steam Generator "B" upper shell to cone weld, nine recordable indications were noted. Two of these were detected with the 45 degree, 2.25 MHz shear wave examinations, and the remaining seven were detected with the 60 degree, 2.25 MHz shear wave examinations. The location of these indications in the weld and past experience with the same weld in other steam generators indicates that all these indications are volumetric in nature, i.e. small slag inclusions and/or voids. An evaluation of these indications (using 50% DAC sizing criteria) to the acceptance standards in Table IWB-3511-1 of the ASME Code Section XI, 1980 Edition results in seven indications which are unacceptable. A similar evaluation using the acceptance standards in Table IWC-3510-1 of the ASME Code Section XI, 1986 Edition results in six unacceptable indications.

Using the rules of IWB-3600 and the guidelines of Appendix A, both from the ASME Code Section XI, 1980 Edition, all the indications are acceptable using 50% DAC sizing levels, and 20% DAC sizing levels without beam spread correction factors. This is shown graphically on Figures 1 and 2.

2.0 ULTRASONIC EVALUATION AND DISCUSSION

Nine recordable indications were noted during the recent examinations of the Kewaunee Unit 1 Steam Generator "B" upper shell to cone weld. A summary of the indications is presented in Table 1. This table provides the measured "2a" value, the measured "S" value, and the measured length with respect to the normal to the inside pressure retaining surface of the component. The 45 degree sizing data was taken using a 2.25 MHz transducer and a 50% DAC sizing criteria. The 60 degree sizing data, with the exception of Indication C, was taken using a 5.0 MHz transducer and the same 50% DAC sizing criteria.

The use of the higher frequency transducer was justified in part by Paragraph T-451.1 of the ASME Code Section V, Article 4 which states that "other ultrasonic techniques and non-destructive examination methods may be helpful in determining a reflector's true position, size, and orientation". Additionally these indications appear to be quite characteristic of experience with various welds in steam generators and pressurizers at other plants where pre-service ultrasonic examination results based on 2.25 MHz, 50% DAC sizing methods predicted reflectors detected in weld backchip regions had dimensions in excess of those allowable values provided in Section XI of the ASME Code. Attempts were made to confirm the size, location, and orientation of these indications by complementary nondestructive examination methods; i.e., 0 degree longitudinal wave examinations, and both fabrication and field radiography;. No reliable responses could be observed from the shear wave indications using the straight beam examinations. In terms of the radiography, the fabrication radiographs of the areas in question were reviewed with no conclusive results. Additionally, field radiography was performed in selected areas but again no confirmation of the shear wave examination indications could be obtained. These inconclusive results led to physical removal of some of the suspect indications by mechanical means for complete metallurgical characterization. The indications were found to have been caused by small slag inclusions and voids between weld passes in the weld backchip area near the inside surface. Measurements made during the destructive anslysis showed that the ultrasonic sizing using 2.25 MHz, 50% DAC sizing methods exaggerated the true size of the discontinuities in terms of length and/or through-wall dimensions. These results are presented in Table 2.

This experience correlates well with investigations to date which have shown that when sizing volumetric-type reflectors by amplitude drop methods, i.e. 2.25 MHz, 50% DAC , the typical result is that the beam size rather than the reflector size is measured. For example, the lower the test frequency, the larger the beam width resulting in a larger than actual apparent flaw size (References 1-6). Since the indications found in these examinations are similar to those detected at other plants it was appropriate to use higher frequency transducers to obtain more realistic data concerning the through-wall dimensions of the indications. Since the 45 degree indications sized with 2.25 MHz, 50% DAC methods were acceptable to the acceptance standards in Table IWC-3510-1 (ASME Section XI, 1986 Edition) and found acceptable by fracture analysis, no high frequency data was taken.

Using the data in Table 1, two sets of evaluation calculations were performed. The first evaluation compared the characteristics of the indications to the acceptance standards described in Table IWB-3511-1 of the ASME Code Section XI, 1980 Edition. This evaluation resulted in seven indications which were unacceptable (Table 3). The second evaluation used the acceptance standards of Table IWC-3510-1 of the ASME Code Section XI, 1986 Edition as the acceptance criteria. This evaluation resulted in six unacceptable indications (Table 4). The latter ASME Code was used because it contained acceptance standards strictly for Class 2 component welds such as the upper shell to cone weld.

To be more conservative, additional data was taken using a 20% DAC sizing criteria but without the use of beam spread correction factors. The use of this sizing criteria is specified in Nuclear Regulatory Guide 1.150 but with the use of beam spread correction factors. Of course, the size of the indication as delineated in this same regulatory guide is determined, though, by using the greater of the values obtained by the 50% DAC sizing criteria and the 20% DAC sizing criteria with beam spread correction. The 5.0 MHz, 20% DAC sizing data without credit for beam spread correction is summarized on Table 5.

3.0 FRACTURE ANALYSIS

There are two alternative sets of acceptance criteria for continued service without repair in paragraph IWB-3600 of ASME Case Section XI:

1. Acceptance criteria based on flaw size (IWB-3611)
2. Acceptance criteria based on stress intensity factor (IWB-3612)

Both criteria are comparable in accuracy for thick sections, and both have been used for evaluating the nine indications.

To determine the allowable flaw sizes in a weld, finite element analysis methods are used.

All applicable plant transients are analyzed to select the most severe stress profiles through the thickness of the weld. The actual stress profiles are then approximated by third order polynomials and used for calculating the stress intensity factor (K_I) for various crack sizes and aspect ratios.

The resulting K_I's are compared to fracture toughness values (K_{Ia} and K_{Ic}). Critical flaw sizes are then obtained.

The final step involves calculation of crack growth due to fatigue loading. All anticipated plant transients are utilized in determining the resulting flaw size for a specified period of time. This is done for 10, 20, and 30 year intervals.

The nine indications found are all subsurface flaws as defined by IWB-3600. As shown in Figures 1 and 2, all nine indications are acceptable per fracture analysis criteria of IWB-3600. The fracture evaluation methods used for these analyses are essentially the same as those documented to the NRC in Reference 7. There are a few differences between these analyses and those reported in Reference 7. The transients applicable to the Kewaunee steam generators are listed in Table 6. The value of RT_{NDT} was conservatively assumed to be 60°F for the entire region. Best estimates for the RT_{NDT} are 10°F for the weld, and 40°F for the base metal. The stresses used for the analysis were calculated from finite element analyses, and stress distributions through the wall thickness were used in the stress intensity factor calculations. Fatigue crack growth was found to be negligible for the embedded indications, because the stress intensity factors were calculated to be rather low and the cracks are not exposed to the water environment.

It should be mentioned that some elevation of the hydrotest (1350 psi) and leak test (1085 psi) temperatures over the specified temperature will be required to ensure the margins of IWB-3600 are maintained, and these temperatures will be provided along with the complete technical details of the analysis in the final report.

In addition to satisfying the fracture criteria, it is required that the primary stress limits of Section III paragraph NB-3000 be satisfied. A local area reduction of pressure retaining membrane must be used, equal to the area of indication; and the stresses increased to reflect the smaller cross section. This criteria also was evaluated and found acceptable.

4.0 REFERENCES

1. Gruber, G. J., Hendrix, G. J. and Schick, W. R., "Characterization of Flaws in Piping Welds Using Satellite Pulses", MATERIALS EVALUATION, April 1984.

2. Cook, R. V., Latimer, P. J. and McClung, R. W., "Flaw Measurement Using Ultrasonics in Thick Pressure Vessel Steel, "final report on Contract No. W-7405-eng-26, prepared by Oak Ridge National Laboratory for the U.S. Nuclear Regulatory Commission, Aug. 1982, Oak Ridge, TN.

3. Doctor, S. R., Becker, F. L., Hessler, P. G. and Selby, G. P., "Effectiveness of U.S. Inservice Inspection Techniques - A Round Robin Test," Proceedings of Specialist Meeting on Defect Detection and Sizing, Ispra, Italy, May 3-6, 1983. Joint Research Center, Ispra (Va), Italy.

4. Jessop, T. J., Mudge, P. J. and Harrison, J. D., "Ultrasonic Measurement of Weld Flaw Size," National Cooperative Highway Research Program Report 242, prepared for the Transportation Research Board by The Welding Institute, Dec. 1981. The Welding Institute, Cambridge, England.

5. Mudge, P. J. and Jessop, T. J., " Size Measurement and Characterization of Weld Defects by Ultrasonic Testing: Findings of a Collaborative Programme," Proceedings of NDE in Relation to Structural Integrity, Paris, France, Aug. 24-25, 1981. Applied Science Publishers, Ltd., London, England.

6. Rishel, R.D., "Summary Report: Volumetric Flaw Depth Sizing," MT-SMART-807, September 12, 1985 (submitted to Seabrook Power Station).

7. Lee, Y.S. and Bamford, W.H. "Background and Technical Basis for the Handbook on Flaw Evaluation for Byron Units 1 and 2 Steam Generators and Pressurizers," Westinghouse Electric Report WCAP 11063.

TABLE 1 :
SUMMARY OF ULTRASONIC TEST INDICATIONS FOUND IN THE
KEWAUNEE UNIT 1 STEAM GENERATOR "B" WELD 2-5
(50% DAC SIZING)

DATA	INDICATION	MEASURED "2a"	"S" (inside surface)	LENGTH
45 degree	A	0.61"	0.37"	0.60"
45 degree	B	0.43"	0.45"	0.10"
60 degree *	A	0.37"	1.02"	0.75"
60 degree *	B	0.35"	0.75"	0.50"
60 degree **	C	0.65"	0.63"	0.90"
60 degree *	D	0.28"	0.69"	1.10"
60 degree *	E	0.65"	0.75"	0.63"
60 degree *	F	0.26"	1.93"	1.00"
60 degree *	G	0.35"	1.79"	2.75"

* Revised evaluation of data based on the use of 5.0 MHz tranducers.

** Using the 5.0 MHz transducer this indication only had a ultrasonic signal response of 50% DAC. According to the examination procedure no further sizing data needed to be taken. As a result the 2.25 Mhz transducer data is given.

TABLE 2 :
NONDESTRUCTIVE VERSUS DESTRUCTIVE TESTING RESULTS
USING 2.25 MHZ, 50% DAC SIZING

PHYSICAL SAMPLE	DISTANCE FROM ID SURFACE		THROUGH-WALL DEPTH		LENGTH	
	UT	ACTUAL	UT	ACTUAL	UT	ACTUAL
CORE #1 (Plant 1)	**	**	.37" to 1.03	0.09"	1.18" to 3.18"	1.15"
CORE #2 (Plant 1)	**	**	.16" to .58"	0.02"	.63" to .75"	0.45"
CORE #1 (Plant 2)	0.00"	0.08" to 0.33" *	0.24"	0.01" to 0.33"	0.88"	0.25" to 0.28"
CORE #2 (Plant 2)	0.16"	0.82"	0.53"	0.18"	0.88"	0.27"
GRINDING (Plant 2)	0.05"	**	0.37"	**	1.00"	**
GRINDING (Plant 2)	0.00"	0.375"	0.45"	0.094"	3.5"	**
GRINDING (Plant 2)	0.00"	0.125"	0.51"	0.156"	3.25"	**
GRINDING (Plant 2)	0.02"	0.156"	0.43"	0.219"	0.75"	0.375"
GRINDING (Plant 2)	0.00"	**	0.24"	**	0.75"	**
GRINDING (Plant 2)	0.00"	0.219"	0.33"	0.343"	1.0"	0.438"

* One UT indication was found to be four indications upon metallurgical evaluation. The values show the range of sizes for these four defects.

** Dimensions not reported.

TABLE 3 :
RESULTS OF THE ASME SECTION XI, 1980 EDITION CALCULATIONS USING THE ACCEPTANCE STANDARDS OF TABLE IWB-3511-1

DATA	IND.	MEASURED "2a"	TYPE OF IND.	"a"	"S"	"l"	a/t ALLOW.	a/t * ACT.
45 deg.	A	0.61"	subsurf.	0.31"	0.37"	0.60"	7.2%	8.4%
45 deg.	B	0.43"	subsurf.	0.22"	0.45"	0.10"	7.2%	5.9%
60 deg.	A	0.37"	subsurf.	0.19"	1.02"	0.75"	4.1%	5.1%
60 deg.	B	0.35"	subsurf.	0.18"	0.75"	0.50"	5.3%	4.9%
60 deg.	C	0.65"	subsurf.	0.33"	0.63"	0.90"	5.4%	8.9%
60 deg.	D	0.28"	subsurf.	0.14"	0.69"	1.10"	3.1%	3.8%
60 deg.	E	0.65"	subsurf.	0.33"	0.75"	0.63"	7.2%	8.9%
60 deg.	F	0.26"	subsurf.	0.13"	1.93"	1.00"	3.1%	3.5%
60 deg.	G	0.35"	subsurf.	0.18"	1.79"	2.75"	2.8%	4.9%

* The measured base metal thickness of 3.7" was used rather than the measured weld thickness of 3.9" due to the irregular nature of the weld crown.

TABLE 4 :
RESULTS OF THE ASME SECTION XI, 1986 EDITION CALCULATIONS USING THE ACCEPTANCE STANDARDS OF TABLE IWC-3510-1

DATA	IND.	MEASURED "2a"	TYPE OF IND.	"a"	"S"	"l"	a/t ALLOW.	a/t * ACT.
45 deg.	A	0.61"	subsurf.	0.31"	0.37"	0.60"	8.9%	8.4%
45 deg.	B	0.43"	subsurf.	0.22"	0.45"	0.10"	8.9%	5.9%
60 deg.	A	0.37"	subsurf.	0.19"	1.02"	0.75"	4.4%	5.1%
60 deg.	B	0.35"	subsurf.	0.18"	0.75"	0.50"	6.0%	4.9%
60 deg.	C	0.65"	subsurf.	0.33"	0.63"	0.90"	6.2%	8.9%
60 deg.	D	0.28"	subsurf.	0.14"	0.69"	1.10"	3.1%	3.8%
60 deg.	E	0.65"	subsurf.	0.33"	0.75"	0.63"	8.9%	8.9%
60 deg.	F	0.26"	subsurf.	0.13"	1.93"	1.00"	3.1%	3.5%
60 deg.	G	0.35"	subsurf.	0.18"	1.79"	2.75"	2.6%	4.9%

* The measured base metal thickness of 3.7" was used rather than the measured weld thickness of 3.9" due to the irregular nature of the weld crown.

TABLE 5 :
SUMMARY OF ULTRASONIC TEST INDICATIONS FOUND IN THE KEWAUNEE UNIT 1 STEAM GENERATOR "B" WELD 2-5
(20% DAC SIZING)

DATA	IND. I.D.	MEASURED "2a"	"S" (inside surface)	LENGTH
45 deg.	A	*	*	*
45 deg.	B	*	*	*
60 deg.	A	0.52"	0.96"	1.05"
60 deg.	B	0.47"	0.79"	1.05"
60 deg.	C	0.57"	0.65"	0.90"
60 deg.	D	0.73"	0.51"	1.50"
60 deg.	E	0.65"	0.83"	0.95"
60 deg.	F	0.39"	1.89" **	1.20"
60 deg.	G	0.35"	1.67"	3.13"

* Data not taken.

** The reflector is nearer to the outside surface than the inside surface. "S" to the outside surface is 1.77".

TABLE 6

TRANSIENT GROUPING FOR FATIGUE CRACK GROWTH ANALYSIS
KEWAUNESS UPPER SHELL TO CONE WELD

Transient Group	Description	Cycles	Total Cycles In Group
1	Heatup and Cooldown*	200	210
	Turbine Roll Test	10	
2	Plant Loading 15% to 100% and Plant Unloading 100% to 150%	18300	18300
3	Large Step Load Decrease*	200	4200
	Small Step Load Increase	2000	
	Small Step Load Decrease	2000	
4	Hot Standby Operation*	18300	18300
5	Loss of Load	80	80
6	Loss of Power	40	40
7	Loss of Flow	80	80
8	Reactor Trip	400	400
9	Secondary Side Pipe Break	1	1
10	Secondary Hydro Test	5	5
11	OBE	50	50

*Umbrella Transient

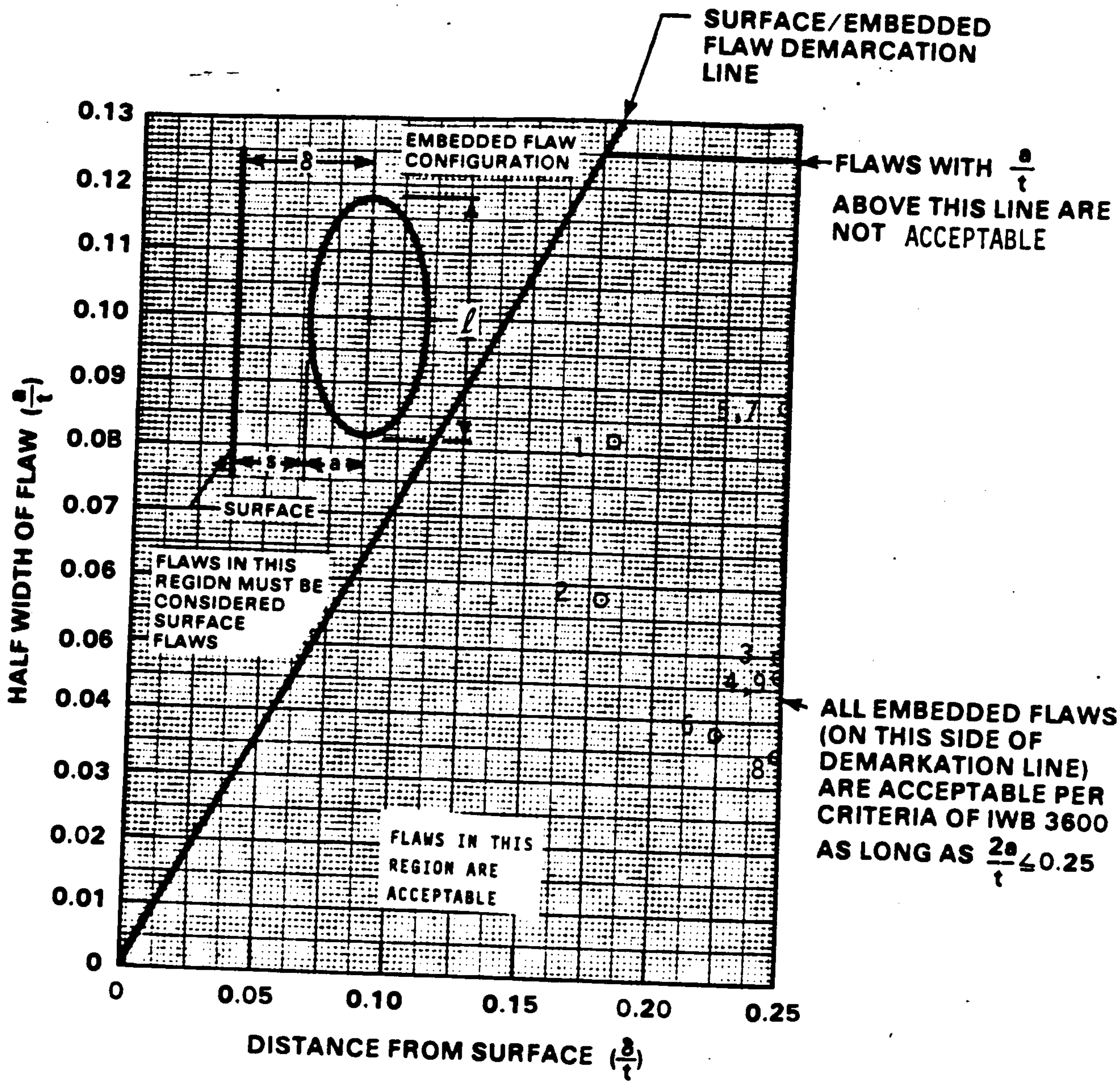

Figure 1 FRACTURE ANALYSIS RESULTS FOR INDICATIONS FOUND IN THE KEWAUNEE UNIT 1 STEAM GENERATOR "B" WELD 2-5

	DATA	IND.	MEASURED "2a"	TYPE OF IND.	"S"	"l"	a/t * ACT.	δ/t	Accept-able?
1.	45 deg.	A	0.61"	subsurf.	0.37"	0.60"	8.4%	0.182	Yes
2.	45 deg.	B	0.43"	subsurf.	0.45"	0.10"	5.9%	0.180	Yes
3.	60 deg.	A	0.37"	subsurf.	1.02"	0.75"	5.1%	0.326	Yes
4.	60 deg.	B	0.35"	subsurf.	0.75"	0.50"	4.9%	0.250	Yes
5.	60 deg.	C	0.65"	subsurf.	0.63"	0.90"	8.9%	0.258	Yes
6.	60 deg.	D	0.28"	subsurf.	0.69"	1.10"	3.8%	0.224	Yes
7.	60 deg.	E	0.65"	subsurf.	0.75"	0.63"	8.9%	0.291	Yes
8.	60 deg.	F	0.26"	subsurf.	1.93"	1.00"	3.5%	0.557	Yes
9.	60 deg.	G	0.35"	subsurf.	1.79"	2.75"	4.9%	0.531	Yes

* The measured base metal thickness of 3.7" was used rather than the measured weld thickness of 3.9" due to the irregular nature of the weld crown.

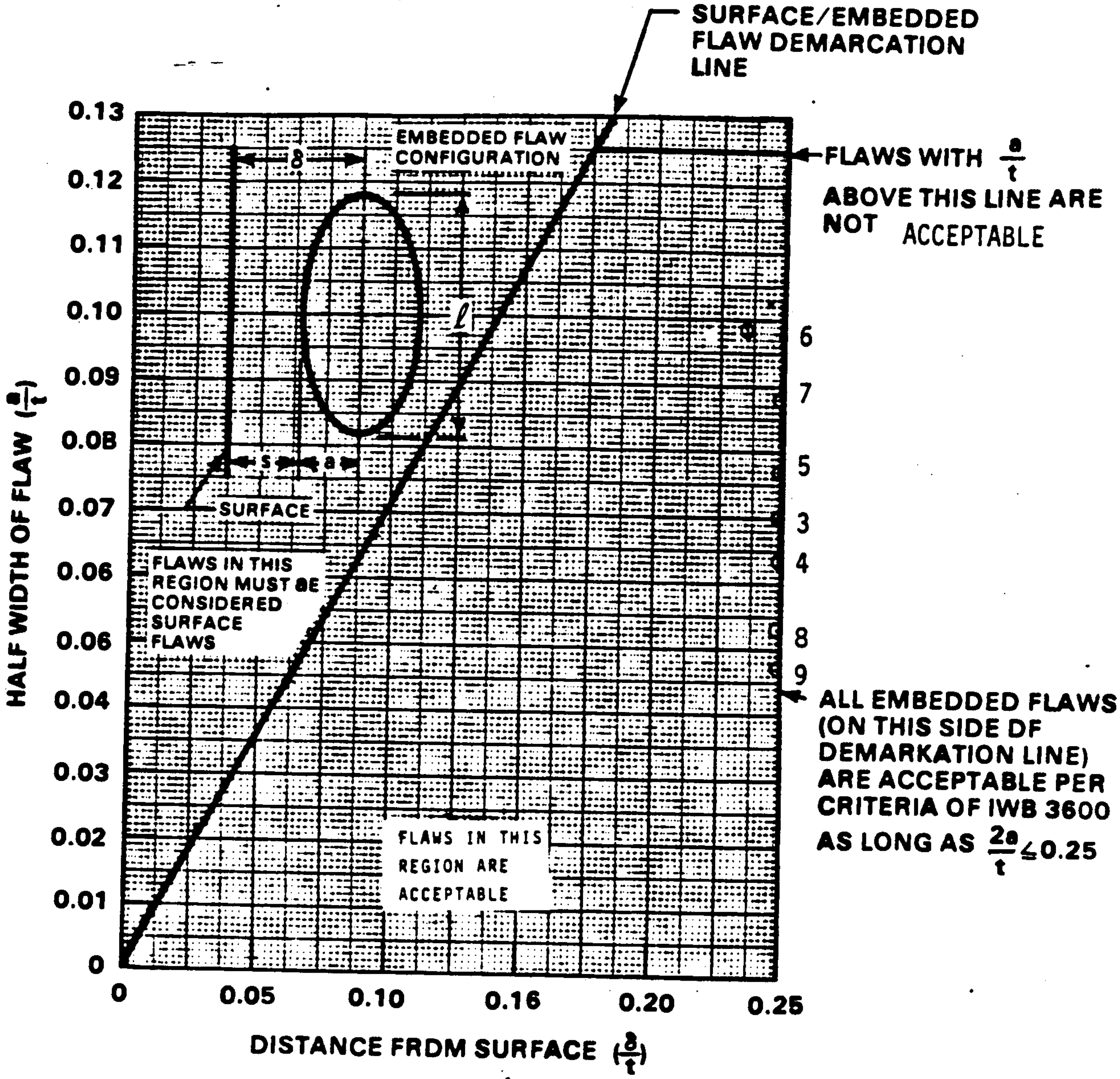

Figure 2

SUMMARY OF ULTRASONIC TEST INDICATIONS FOUND IN THE KEWAUNEE UNIT 1 STEAM GENERATOR "B" WELD 2-5 (20% DAC SIZING)

	DATA	IND. I.D.	MEASURED "2a"	a/t	"S" (inside surface)	δ/t	LENGTH
1.	45 deg.	A	*		*		*
2.	45 deg.	B	*		*		*
3.	60 deg.	A	0.52"	0.0703	0.96"	0.330	1.05"
4.	60 deg.	B	0.47"	0.0635	0.79"	0.278	1.05"
5.	60 deg.	C	0.57"	0.0770	0.65"	0.253	0.90"
6.	60 deg.	D	0.73"	0.0986	0.51"	0.236	1.50"
7.	60 deg.	E	0.65"	0.0878	0.83"	0.312	0.95"
8.	60 deg.	F	0.39"	0.0530	1.89" **	0.560	1.20"
9.	60 deg.	G	0.35"	0.0470	1.67"	0.498	3.13"

* Data not taken.
** The reflector is nearer to the outside surface than the inside surface. "S" to the outside surface is 1.77".