VERMONT YANKEE NUCLEAR POWER CORPORATION

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FVY 86-36

REPLY TO
ENGINEERING OFFICE
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FRAMINGHAM, MASSACHUSETTS 01701
TELEPHONE 617-872-8100

May 5, 1986

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Office of Nuclear Reactor Regulation
Mr. Daniel R. Muller, Director
BWR Project Directorate #2
Division of Licensing

References:
a) License No. DPR-28 (Docket No. 50-271)
b) Letter, USNRC to All BWR Facilities, IE Information Notice 84-41, dated 6/1/84
c) Letter, VYNPC to USNRC, FVY 83-50, dated 6/3/83
d) Letter, VYNPC to USNRC, FVY 84-93, dated 7/30/84

Dear Sir:

Subject: Core Spray Nozzle Weld Overlay

During ultrasonic inspections of the core spray nozzle weld butter performed in accordance with our commitment relative to I&E Notice 84-41, Reference b), weld defects indicative of intergranular stress corrosion cracking (IGSCC) were detected. Vermont Yankee initiated a conference call with the NRC on April 28, 1986 to notify the NRC of these indications and present the NRC with our initial assessment and action plan.

In response to the staff's request made during this conference call, we hereby provide Vermont Yankee's proposed repair/design parameters to address and remedy the inspection findings.

Background

In 1984, IGSCC was detected in the Iconel 182 weld butter on several reactor pressure vessel nozzles at a domestic reactor. This cracking was discovered when the nozzle safe ends were removed as part of a recirculation pipe replacement program. The cracking at that reactor was observed by liquid penetrant examination of the inside surface of the nozzle. Since the cracking was actually in the weld metal, standard ultrasonic techniques were not able to detect the cracking.

The nuclear industry funded a development program by the Electric Power Research Institute (EPRI) to develop special ultrasonic (UT) techniques for inspecting the Iconel 182 nozzle weld butter. Vermont Yankee committed to perform an inspection when the technique became available.

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Q PDR

Rec'd w/check $150.00

The metallurgical geometry of the core spray nozzle safe end at Vermont Yankee is shown in Figure 1. The Iconel 182 nozzle butter is the area showing the indication of IGSCC. A description of the inspection methodology and the inspection results is contained in Appendix A.

Repair Methodology

The repair approach will be to apply a weld overlay similar to those applied at Vermont Yankee in 1983 and 1984 [References c) and d)].

The application of these overlays is slightly different since previous overlays were applied over stainless steel base metal. For the core spray nozzles, the base metals are low alloy steel on the nozzle side of the weld and Iconel 600 on the safe end side of the weld. The presence of the low alloy steel requires that specialized weld processes be developed. The repair approach will be an extension of the pressure vessel repair procedure described in ASME Code Case N-432.

The first step is to apply a weld overlay of 0.125 inches minimum thickness over the low alloy steel nozzle. This will be done with the nozzle drained and preheated to between 300° to 400°F. This will be accomplished in approximately three to four layers in the so-called "butter-temper" process to ensure any embrittlement caused by the first weld layer is tempered by the subsequent layers. The 0.125 inch minimum thickness is selected to ensure sufficient thickness so that the application of the actual overlay does not affect the nozzle base metal. Typical weld parameters are shown in Appendix B (these are for information only; the actual weld parameters will be developed by mockup testing at Vermont Yankee).

Following completion of this process, the actual weld overlay is applied. The overlay is designed for a minimum five-year lifetime. The overlay design is in compliance with the ASME Code, Section XI, Subsection IWB-3640 and draft NUREG 0313, Revision 2. The overlay is a full structural overlay; no credit is taken for the thickness of the butter-temper layers. The details of the design are included in Appendix C.

Following installation, the overlay will be inspected in accordance with the current EPRI/NRC weld overlay inspection criteria, as would apply to Iconel, using personnel qualified at the EPRI NDE Center.

Repair Qualification

All procedures and welders will be qualified in accordance with the appropriate ASME Code requirements. In addition, in order to verify the effectiveness of the low alloy steel butter temper process, micro-hardness readings will be taken on the mockup before welding, following the first layers, and following the complete butter-temper process to demonstrate the tempering of any possible embrittlement. In addition, Charpy V-notch tests will be conducted to demonstrate proper recovery of toughness.

Schedule of Performance

Mockup development is currently underway with actual repair scheduled to begin the week of May 25, 1986. In addition to the special weld procedure, development of a safe end/nozzle/vessel shell plate mockup has been established for personnel training.

In accordance with the provisions of 10 CFR 170.12, an application fee of $150.00 is enclosed.

In order to maintain our 1986 startup schedule, your immediate attention to this matter is requested. We are willing to meet with you and your staff at your earliest convenience, if necessary.

Very truly yours,

VERMONT YANKEE NUCLEAR POWER CORPORATION

Warren P. Murphy

Warren P. Murphy
Vice President and
Manager of Operations

CORE SPRAY SAFE END

PICTORAL VIEW

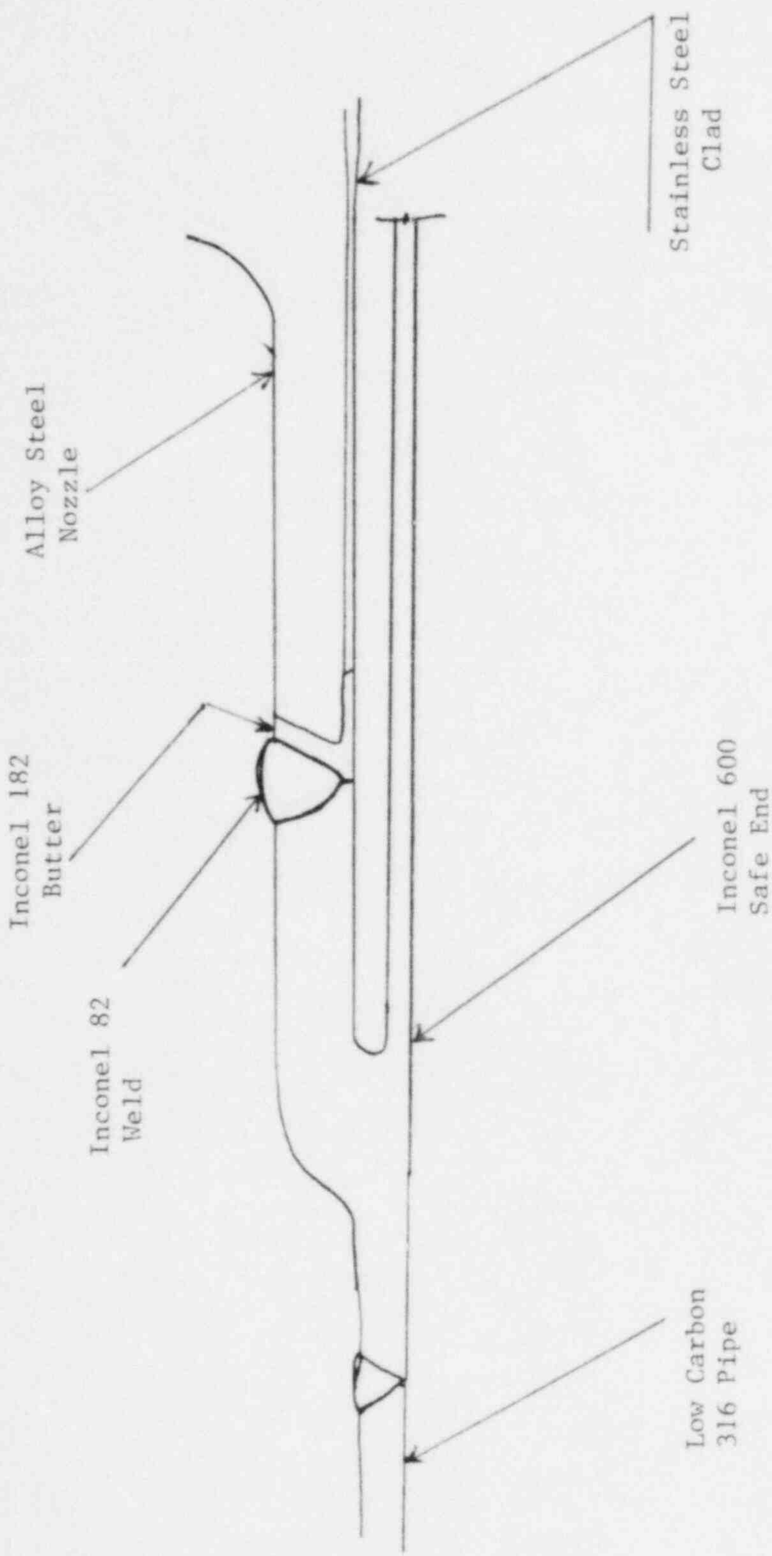

Figure 1

APPENDIX A

APPENDIX A

The Vermont Yankee N5 nozzle reducer to safe-end welds (stainless to Inconel), the Inconel safe-end threaded regions, and the Inconel safe-end to nozzle welds were examined during the 1985-1986 refueling outage. Examinations included liquid penetrant and ultrasonics; both manual and P-scan. The reducer to safe-end welds and the safe-end threaded region showed no indications interpreted to be defects.

The safe-end to nozzle weld including the nozzle buttering showed linear indications during the O.D. surface liquid penetrant examination. The N5B weld contained 37 individual linear indications located approximately .060 inches out-board of the nozzle in the Inconel butter spread circumferentially around the nozzle O.D. Of the indications noted, two individual indications were rejectable to Section XI and one additional grouping exceeded the criteria when evaluated in accordance with IWA 3400-1.

The N5A nozzle was similarly indicated though the indications were not as numerous.

The indications are short, tight linear indications both grouped and random. They are both parallel and skewed with respect to the nozzle butter interface.

Both welds were examined ultrasonically using P-scan and manual techniques intended for use with multiple Inconel weld layers. P-scan showed three closely spaced indications in the circumferential direction (parallel with weld longitudinal axis) on the N5B nozzle. The N5A nozzle showed no circumferential indications. Manual axial examination of N5B showed seven axial indications with a concentration of indications at the circumferentially indicated area. N5A showed seven randomly spaced axial indications.

Some correlation appears to exist with respect to axial flaw location and O.D. Liquid Penetrant indications. Connection between the O.D. Liquid Penetrant indications and the axial U.T. has not been confirmed or disproven.

APPENDIX B

APPENDIX B

WELD OVERLAY PARAMETER INFORMATION

PRELIMINARY

---Preheat nozzle to 350°F - hold for ½ hour

LAYER 1 PARAMETERS

- Current: 120 Amps: 1/3 of time
  210 Amps: 2/3 of time
- Voltage: 11 Volts
- No oscillation
- Wire size 0.035" diameter Sandvik ER NI CR-3 wire
- Torch angle 90°
- Shield gas: Welding Grade Argon at 30 ft^3/hour
- Wire feed:
  - 30 inches/minute - 1/3 of the time
  - 43 inches/minute - 2/3 of the time
- Travel speed: 8.5 inches/minute
- Bead overlap was 50%
- Preheat and interpass 300°F to 400°F during entire layer
- Double down welding
- Heat input of 14,000 J/inch

LAYER 2 PARAMETERS

- Current: 140 Amps: 1/3 of time
  230 Amps: 2/3 of time
- Voltage: 11 Volts
- No oscillation
- Wire size: 0.035 inch diameter
- Torch angle - 90°
- Shield gas: Argon @ 30ft^3/hour
- Wire Feed
  - 51 inches/minute: 1/3 of time
  - 63 inches/minute: 2/3 of time
- Travel speed: 7 inches/minute
- Bead and interpass temperature 300°F to 400°F
- Heat input: 19,000 J/inch
- Double down welding
- Bead Overlap was 50%

LAYER 3 PARAMETERS

- o Current: 160 Amps: 1/3 of time
  250 Amps: 2/3 of time

- o Voltage: 11 Volts
- o Oscillation: 0.156 inches
  - o 0.2 second excursion
  - o Pulse synchronization
    - o 0.4 second dwell on each side of bead
- o Wire size: 0.035 inch
- o Torus angle: as Layer 1
- o Shield gas: as Layer 1
- o Wire feed:
  - o 56 inches/minute: 1/3 of time
  - o 69 inches/minute: 2/3 of time
- o Bead overlap: 50%
- o Heat input: 24,000 J/inch
- o Preheat and interpass temperature
  - o 300°F to 400°F

FOLLOWING THIRD LAYER

- o Hold preheat until postheat

Post heat -- 450°F to 500°F
Hold three hours and slow cool

Fill with tap water
- o used 3 gpm flow

Complete overlay with
- o second layer weld parameters

EXCEPT

- o Preheat and interpass temperatures are 70°F to 110°F
- o Can use orbital welding procedure or continue double down

APPENDIX C

PRELIMINARY

REPAIR OF IGSCC FLAWS IN THE CORE SPRAY SAFE-END TO NOZZLE WELDS AT VERMONT YANKEE NUCLEAR POWER PLANT

1.0 REFERENCES

1.1. General Electric Company Design Certification DC23A4322, "Reactor Vessel - Core Spray Safe End", for Vermont Yankee, August 12, 1985.

1.2. General Electric Company Stress Report 23A4904, "Core Spray Nozzle", for Reactor System - Vermont Yankee, December 13,1985.

1.3 Electric Power Research Institute Research Project EPRI 1566-1, "Stress Corrosion Cracking of Alloys 600 and 690 and Compatible Weld Metals in BWR Environments", Prepared by Southwest Research Institute, Second Interim Report, June, 1984.

2.0 PURPOSE

Flaws believed to be due to IGSCC were identified in the Inconel butter on the core spray safe end to nozzle weld at Vermont Yankee. The flaws were detected by ultrasonic and dye penetrant methods.

The purpose of this calculation is to document the design of a weld overlay repair at this location which will provide adequate safety margin at the repaired location for a period of at least 5 years.

Weld overlays applied to stainless steel piping are typically applied using 308L weld metal. This material has been shown to be highly resistant to IGSCC propagation. Flaws generally arrest at the overlay boundary. Weld material for repair of flawed Inconel piping is not generally immune to IGSCC propagation, however. The observed flaws at Vermont Yankee are in Inconel 182 weld material, for example. Consequently, weld overlay design using Inconel weld material must include allowance for continued crack growth.

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File Number YAEC-05-301

This calculation presents a design for weld overlay repair of the observed flaws based upon the requirements of ASME Section XI, paragraph IWB-3641, and upon location-specific stress information from references 1.1 & 1.2. For the purpose of overlay design, the flaws were assumed to be through the existing pipe wall, and to extend 360° circumferentially. The resulting overlay design was then evaluated for the possibility of degradation due to continued crack propagation. It is demonstrated that the integrity of the design overlay will not be reduced below Code levels for at least the design life of 5 years, when the beneficial effects of overlay application on the residual stress distribution are included in the evaluation.

3.0 STRESS DETERMINATION

In accordance with the requirements of Section XI, only primary membrane and primary bending stresses were considered in the overlay design. The values of these components were taken from reference 1.2.

OVERLAY DESIGN STRESS = $P_m + P_b$ = 8513 psi.

It is also necessary to demonstrate that the overlay thickness is not reduced below acceptable level during the life of the repair (5 years) due to IGSCC crack growth in the Inconel overlay material. For the crack growth calculations, thermal expansion is included in the stress sum above.

CRACK GROWTH STRESS = $P_m + P_b$ + THERMAL = 15088 psi.

4.0 WELD OVERLAY DESIGN

For the purpose of weld overlay design, the pipe wall thickness was taken as 0.939 ", as shown in reference 1.2. The required minimum length of the

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File Number YAEC-05-301

overlay is then

$L = 1.5 \times \sqrt{Rt}$,

where
R = outside radius of pipe = 6.72"
t = wall thickness = 0.939"

so

$L = 3.77"$

At least $0.75 \times \sqrt{Rt}$ of the length must be on each side of any flaw to provide adequate reinforcement. Since observed flaws are in the butter, an additional length of 1 " is included to account for the width of the weld crown. The final overlay length is therefore

L = 4.77", rounded to 5.0"

This length should be centered on the weld center-line.

The weld overlay required thickness based upon Section XI was determined using the program pc-CRACK. The pc-CRACK calculations are attached to this package. The required thickness is 0.34". This thickness is in addition to the thickness required by Code for a temper bead, as shown in figure 1.

5.0 WELD OVERLAY RESIDUAL STRESS DISTRIBUTIONS

Application of a weld overlay as indicated in figure 1 has been shown by finite element analysis to produce residual stress distributions through the pipe wall as shown in figure 2. In both the axial and circumferential directions, these distributions are highly compressive near the ID of the component, and become tensile near the outer surface of the overlay. These distributions are used in the crack growth calculations which are necessary to demonstrate that an Inconel weld overlay on the core spray safe end to nozzle weld will not be degraded below the design limit due to crack growth during the design life of the repair.

6.0 STRESS INTENSITY CALCULATIONS

The residual stress distributions in figure 2 were input to the program pc-CRACK. Using these distributions together with Vermont Yankee geometry information, the program was then used to calculate stress intensity as a function of crack depth. A similar calculation was performed assuming an applied stress of 15.088 ksi, factored by the ratio of the pipe wall thickness to the overlay repaired thickness. That is,

APPLIED STRESS = 15.088 X (PIPE WALL/(PIPE WALL+OVERLAY)

The results of these calculations are shown in figure 3. In this figure, stress intensity is plotted against crack depth into the composite (pipe + overlay) wall for a 0.5" total thickness overlay. Note that the figure demonstrates that the net stress intensity ($K_{applied} + K_{residual}$) remains negative well beyond the flaw depth corresponding to the original pipe wall thickness. This demonstrates that no IGSCC crack growth would be anticipated for this weld overlay design.

7.0 CRACK GROWTH CALCULATIONS

Inconel 82 and 182 behave similarly to stainless steel with regard to IGSCC. Some of the available data on Inconel IGSCC crack growth rates is presented in figure 4 (reference 1.3), which also presents stainless steel data. A crack growth correlation which bounds the available data is

$$da/dt = 1.078 \times 10^{-8} K^{2.26}$$

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Checked by/date An-Yu Kuo / 4-30-86
File Number Y4EC-05-301
Page 4 of 12

where :

da/dt is in units of inches / hour
K is the stress intensity in units of ksi-√inches

Crack growth calculations were performed assuming an initial crack which was through the original pipe wall. The residual stresses , applied stresses, and crack growth correlation described above were input to a pc-CRACK calculation. As discussed in the previous section, the combined stress intensity K is negative for flaw depths greater than the original wall thickness. Review of the crack growth correlation above leads to a prediction of no growth due to IGSCC over the life of the repair. The integrity of the overlay is not expected to be degraded during this period.

8.0 CONCLUSION

The overlay design in figure 1 meets the requirements of Section XI. Analysis shows that a through wall flaw would be arrested by the residual stress benefits of the weld overlay application. Because of the uncertainty associated with flaw definition, it is recommended that re-inspection and re-evaluation of the repairs be performed after 1 cycle of operation , to confirm the acceptability of the repairs for subsequent cycles.

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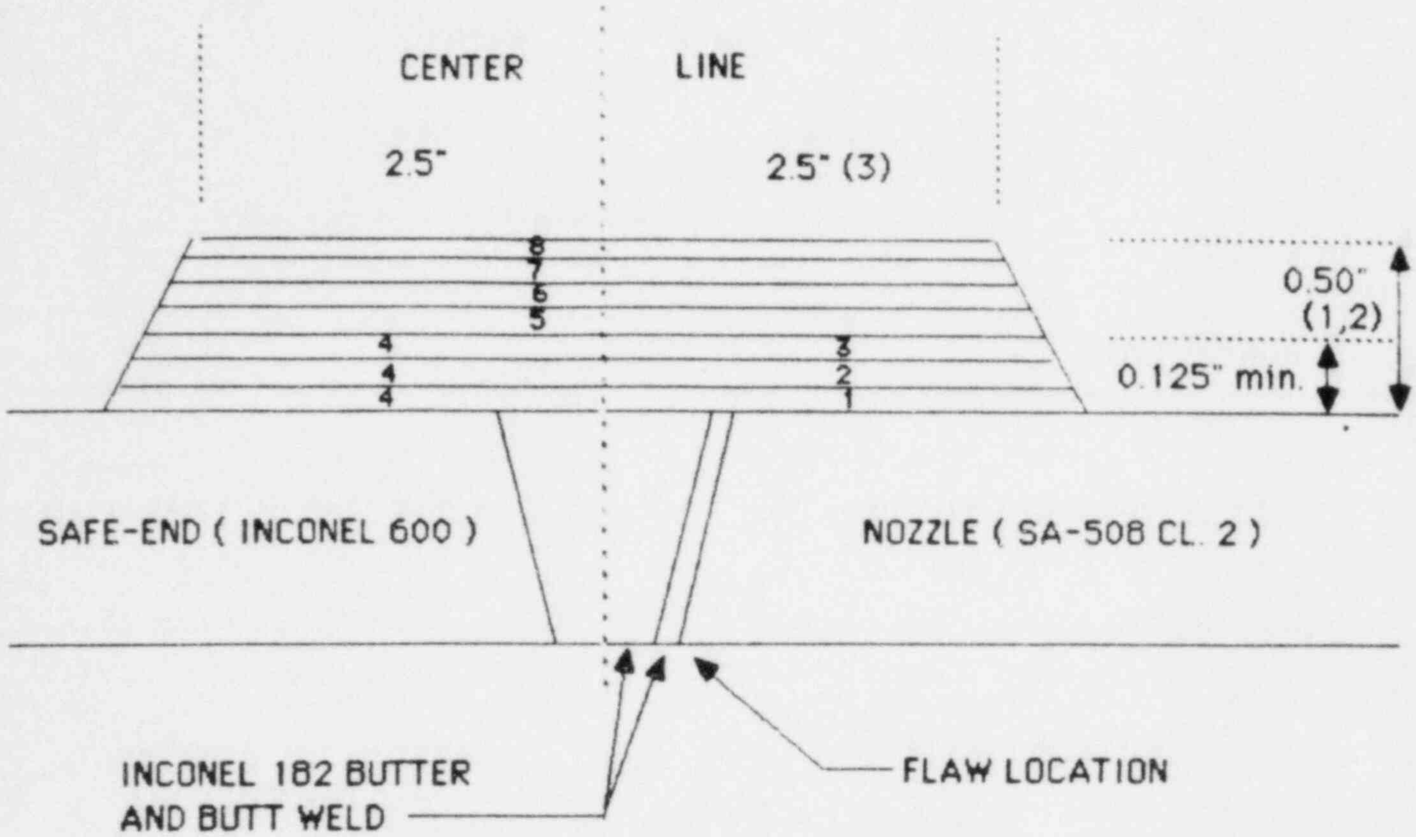
File Number YAEC-05-301

Figure 1



WELD OVERLAY DESIGN
VERMONT YANKEE CORE SPRAY
SAFE END TO NOZZLE WELD (4)

NOTES:
1. OVERALL WELD OVERLAY DESIGN THICKNESS IS 0.50".
2. WELD HEAT INPUT TO BE APPLIED IN THE SEQUENCE SHOWN IN ACCORDANCE WITH PARAMETERS GIVEN IN THE LETTER FROM A.J. GIANNUZZI TO JOHN HOFFMAN, DATED APRIL 11, 1986 (AJG-86-025). WELD SEQUENCE TO BE PERFORMED IN ACCORDANCE WITH AJG-86-025, OR ALTERNATIVELY, IN ACCORDANCE WITH THE LETTER DATED MAY 1, 1986 (AJG-86-031, SAME CORRESPONDENTS).
3. FULL THICKNESS OF OVERLAY MUST EXTEND AT LEAST 1.9" BEYOND THE BUTTER-NOZZLE INTERFACE.
4. THIS DESIGN ASSUMES BENEFICIAL RESIDUAL STRESS DISTRIBUTION DUE TO OVERLAY APPLICATION.

DESIGN NUMBER: YAEC-05-01 REVISION: 1 DATE: 5-2-86

PREPARED BY/DATE H L Durst , 5-2-86

REVIEWED BY/DATE An-Yu Kuo , 5-2-86

pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 1.1

WELD OVERLAY SIZING EVALUATION

WELD OVERLAY SIZING FOR CIRCUMF. CRACK,WROUGHT/CAST STAINLESS

VERMONT YANKEE CORE SPRAY WELD OVERLAY

WALL THICKNESS= 0.9390
MEMBRANE STRESS= 3662.3000
BENDING STRESS= 4851.0000
STRESS RATIO= 0.4921
ALLOWABLE STRESS=17300.0000
FLOW STRESS=51900.0000

	L/CIRCUM					
	0.00	0.10	0.20	0.30	0.40	0.50
FINAL A/T	0.7500	0.7500	0.7500	0.7500	0.7500	0.7373
OVERLAY THICKNESS	0.3130	0.3130	0.3130	0.3130	0.3130	0.3346

END OF pc-CRACK

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File No. YAEC-05-301
Page 7 of 12

Checked by: AYK 4-30-86
File No. YAEC-05-301
Page 8 of 12

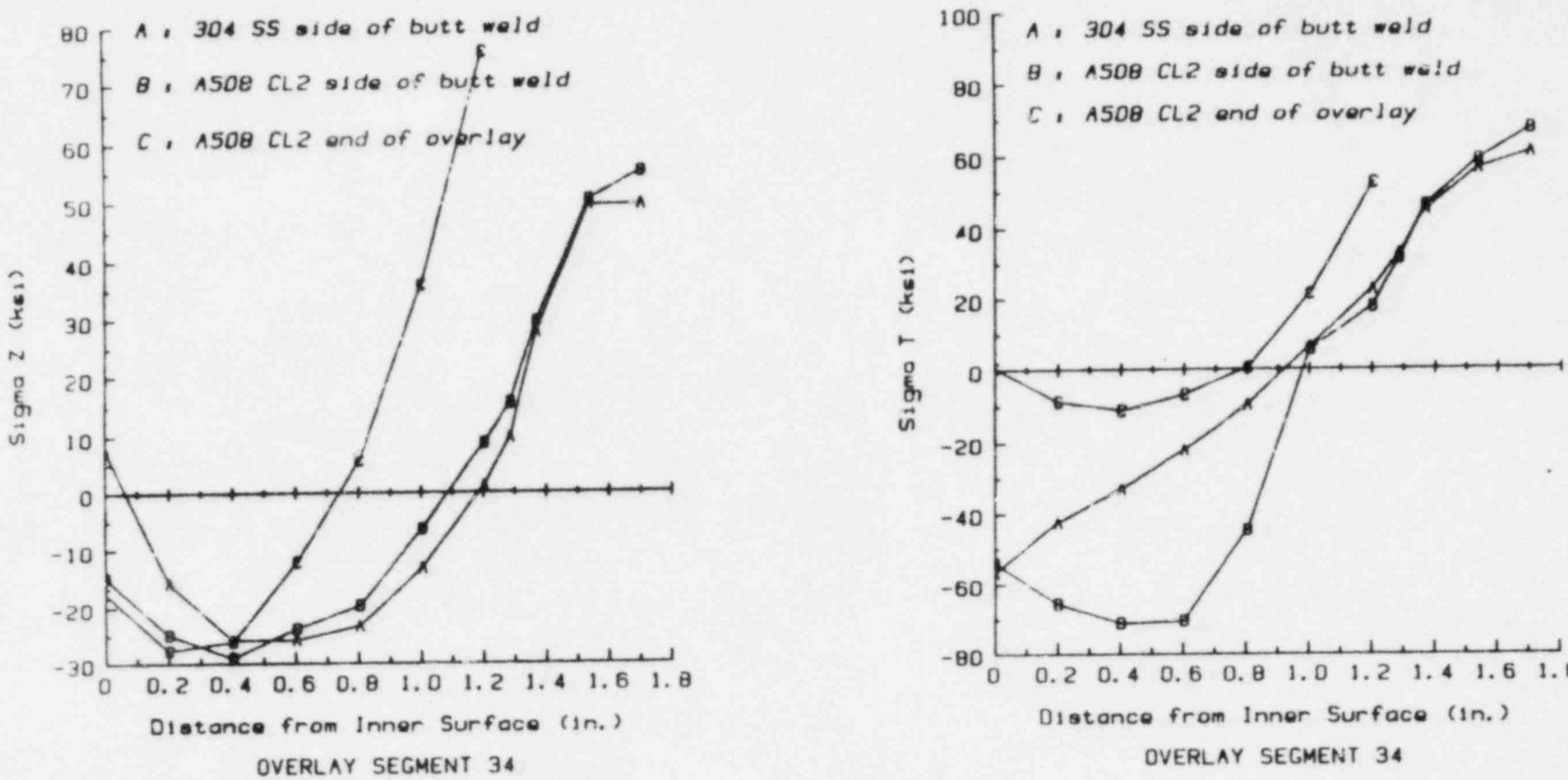

FIGURE 2. Finite Element Results: Residual Stresses After Weld Overlay

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pc-CRACK
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LINEAR ELASTIC FRACTURE MECHANICS EVALUATION

VERMONT YANKEE CORE SPRAY : RESIDUAL AND FACTORED APPLIED STRESSES

CRACK MODEL:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

WALL THICKNESS= 1.4400

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
VY144OL	-13.6306	-112.8590	214.8675	-70.7868
VYCGAPL	9.7810	0.0000	0.0000	0.0000

CRACK DEPTH	STRESS INTENSITY FACTOR CASE VY144OL	CASE VYCGAPL
0.0230	-4.51	2.92
0.0461	-6.98	4.15
0.0691	-9.25	5.10
0.0922	-11.44	5.92
0.1152	-13.57	6.64
0.1382	-15.67	7.31
0.1613	-17.83	7.97
0.1843	-19.99	8.62
0.2074	-22.14	9.25
0.2304	-24.26	9.86
0.2534	-26.35	10.46
0.2765	-28.41	11.05
0.2995	-30.49	11.66
0.3226	-32.61	12.29
0.3456	-34.68	12.93
0.3686	-36.71	13.56
0.3917	-38.67	14.20
0.4147	-40.58	14.83
0.4378	-42.47	15.50
0.4608	-44.48	16.28
0.4838	-46.41	17.06
0.5069	-48.26	17.86
0.5299	-50.02	18.66
0.5530	-51.69	19.47
0.5760	-53.25	20.28
0.5990	-54.86	21.16
0.6221	-56.36	22.04
0.6451	-57.76	22.93
0.6682	-59.05	23.83

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File No. YAEC-05-301
Page 9 of 12

0.6912	-60.21	24.74
0.7142	-61.25	25.66
0.7373	-62.37	26.65
0.7603	-63.42	27.67
0.7834	-64.34	28.70
0.8064	-65.12	29.74
0.8294	-65.77	30.79
0.8525	-66.26	31.86
0.8755	-66.49	32.98
0.8986	-66.42	34.15
0.9216	-66.17	35.33
0.9446	-65.72	36.53
0.9677	-65.07	37.74
0.9907	-64.22	38.96
1.0138	-63.29	40.23
1.0368	-62.53	41.59
1.0598	-61.52	42.98
1.0829	-60.27	44.37
1.1059	-58.76	45.78
1.1290	-57.00	47.21
1.1520	-54.97	48.65

END OF pc-CRACK

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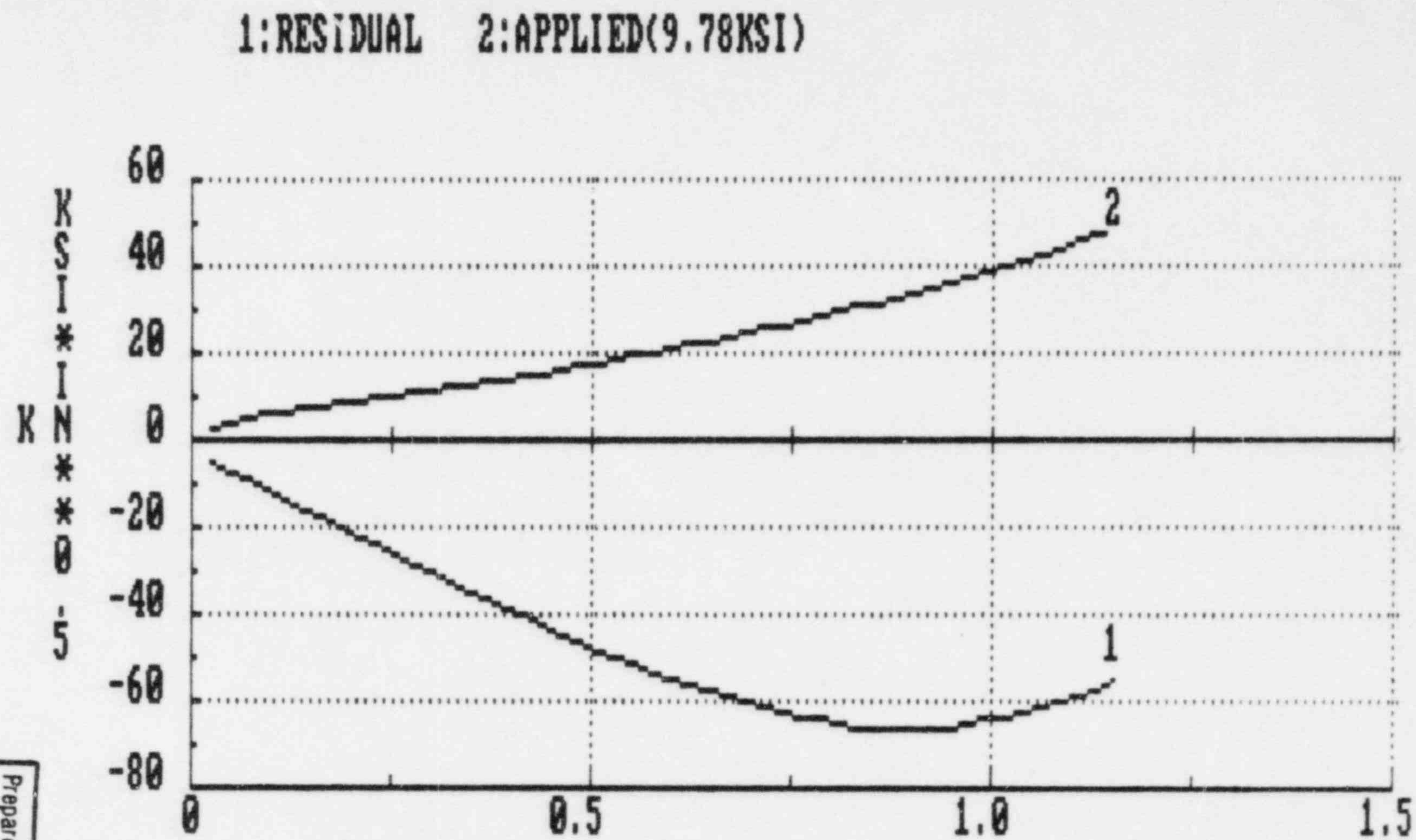
File No. _YAEC-05-301_
Page _10_ of _12_



K VS A FOR 0.5" OVERLAY WITH FACTORED APPLIED STRESS

Figure 3

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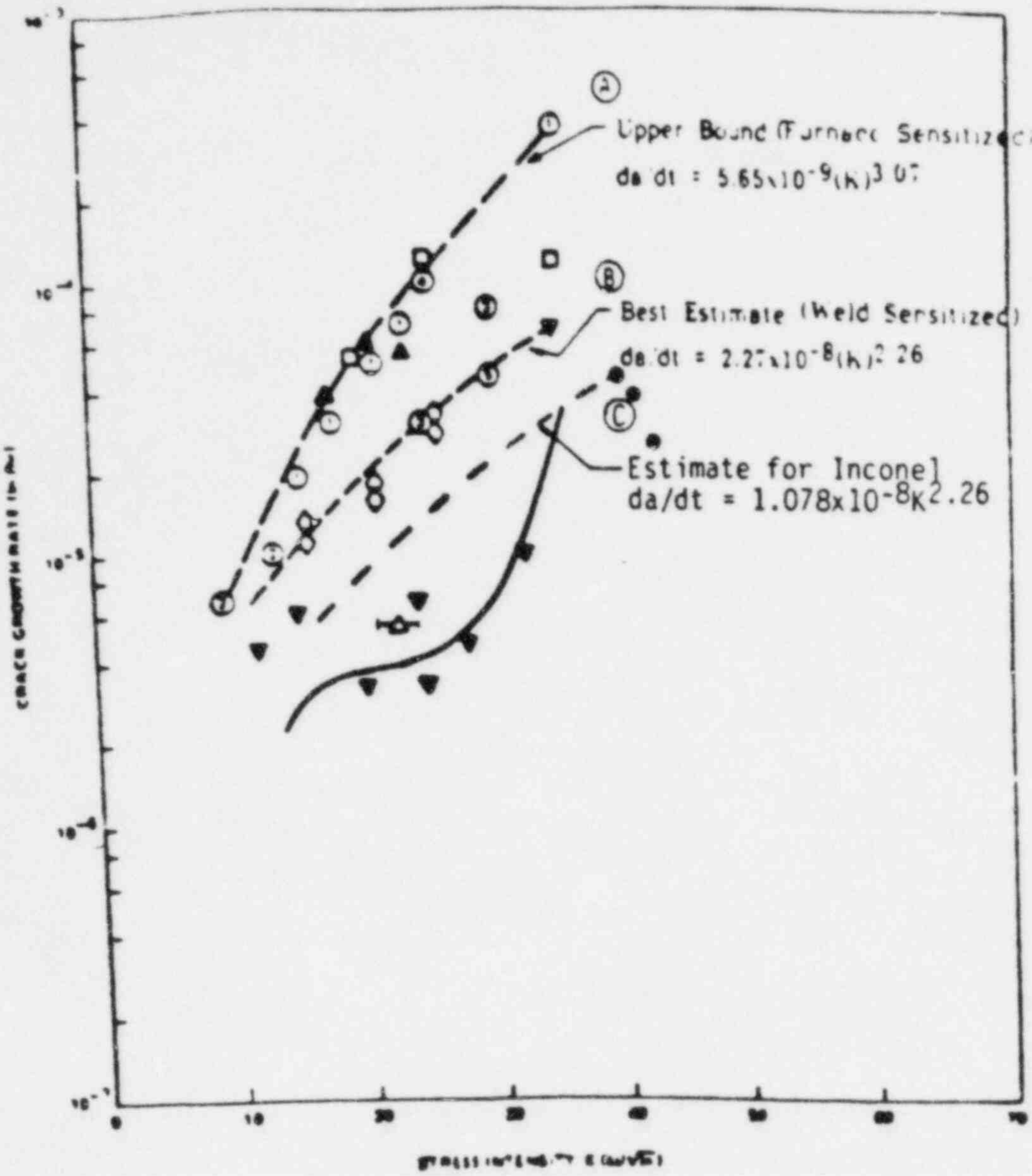
File No. YAEC-05-301
Page 11 of 12



Crack Growth Rate Curves to be Used in Flaw Evaluation Analysis and Supporting Data (From EPRI NP-2472)

- Inconel at 288°C in 7ppm O_2, 1ppm H_2SO_4 (EPRI-1566-2, Interim Report)

FIGURE 4

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File No. YAEC-05-301
Page 12 of 12