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DOCUMENT SUMMARY SHEET

DOCUMENT IDENTIFIER 32-1164054-01

TITLE OCONEE I UPPER SHELL FLAW EVALUATION

PREPARED BY:	REVIEWED BY:
NAME W.L. REDD	NAME G.L. WEATHERLY
SIGNATURE W L Redd	SIGNATURE G L Weatherly
TITLE SUPR. ENGR DATE 11-18-86	TITLE PRIN ENGR DATE 11/21/86
COST CENTER 367 REF. PAGE(S) NA	TM STATEMENT: REVIEWER INDEPENDENCE GLW

PURPOSE AND SUMMARY OF RESULTS:

THIS REVISION IS TO FORMALLY COLLECT, CORRECT AND PROVIDE DATA WHICH WAS PREVIOUSLY TRANSMITTED TO THE CUSTOMER (SUBSEQUENTLY SUBMITTED TO THE NRC) AS INFORMATION SUPPORTING THE FLAW EVALUATIONS.

IN LIEU OF NEGATING THE PREVIOUS ORIGINAL CALCULATIONS, WHICH STILL PROVIDE AN INDICATION OF THE AVAILABLE MARGINS (EVEN THOUGH THERE IS AN ERROR IN THE ECCENTRICITY, .75" WRONG; THE RESULTS ARE CONSERVATIVE) THIS REVISION ADDS TO THE PREVIOUS ISSUE.

THE PAGES CONTAINED HEREIN ADDRESS:

1) NEW LEFM CALCULATIONS FOR COMBINED INDICATIONS 3/4 & 18/19
2) POSTULATED SERVICE INDUCED GROWTH CALCULATIONS AND CODE ADJUSTED STRESSES
3) JUSTIFICATION FOR UNANALIZED TRANSIENTS
4) STRESS COMPONENTS AND METHOD OF DETERMINATION FOR LEFM ANALYSIS (FROM 32-1126593-00, REF. 8)

REF.: EVALUATION NUMBER 86-019, REV. 1

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE / VERSION / REV	CODE / VERSION / REV

INCLUDES A-1 thru A-7
B-1 " B-9

BWNP 20697 (6-85)

Babcock & Wilcox
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DOCUMENT SUMMARY SHEET

DOCUMENT IDENTIFIER 32-1164054-00

TITLE OCONEE I UPPER SHELL ASSY. FLAW EVALUATION

PREPARED BY:	REVIEWED BY:
NAME W.L. REDD	NAME G L WEATHERLY
SIGNATURE W.L. Redd	SIGNATURE G L Weatherly
TITLE SUPR. ENGR. DATE 4-24-86	TITLE ENGR IV DATE 4/24/86
COST CENTER 367 REF. PAGE(S) NA	TM STATEMENT: REVIEWER INDEPENDENCE

PURPOSE AND SUMMARY OF RESULTS:

The purpose of this calculation is to evaluate the three worst indications as reported in Evaluation Report #86-019 (Nos. 4,8 and 18/19 combined). Because of the concerns raised by the NRC with regards to confidence in the as-measured dimensions it was decided to increment each flaw addressed by ten percent (10 %) until it failed to meet acceptability. Having started this for flaw number 18/19 it was quickly seen that the changes in growth and crack arrest value was negligible, therefore it was decided to double each flaws initial size, determine its status and increment from this size. In each case the original flaw size, when doubled, using ASME Section XI, Appendix A, methodology, satisfied the requirements of IWB-3612. The end result was that each sub-surface flaw could be enlarged until it almost became a surface flaw and meet acceptability requirements.

The calculations contained within represent a variety of flaw sizes and cycles for each indication of concern as well as a very conservative evaluation of indication number 18/19 when it gets reclassified from a sub-surface to a surface indication. As can be seen from the various outputs considerable safety margin exist when compared to original flaw size and/or number of cycles to cause failure.

All of the results were obtained fom an IBM PC version of the B&W fully certified computer program FLEP (NPD-TM-5,April 1985)

Calculation 32-1126593-00 is the source calculation for the stresses used in this evaluation.

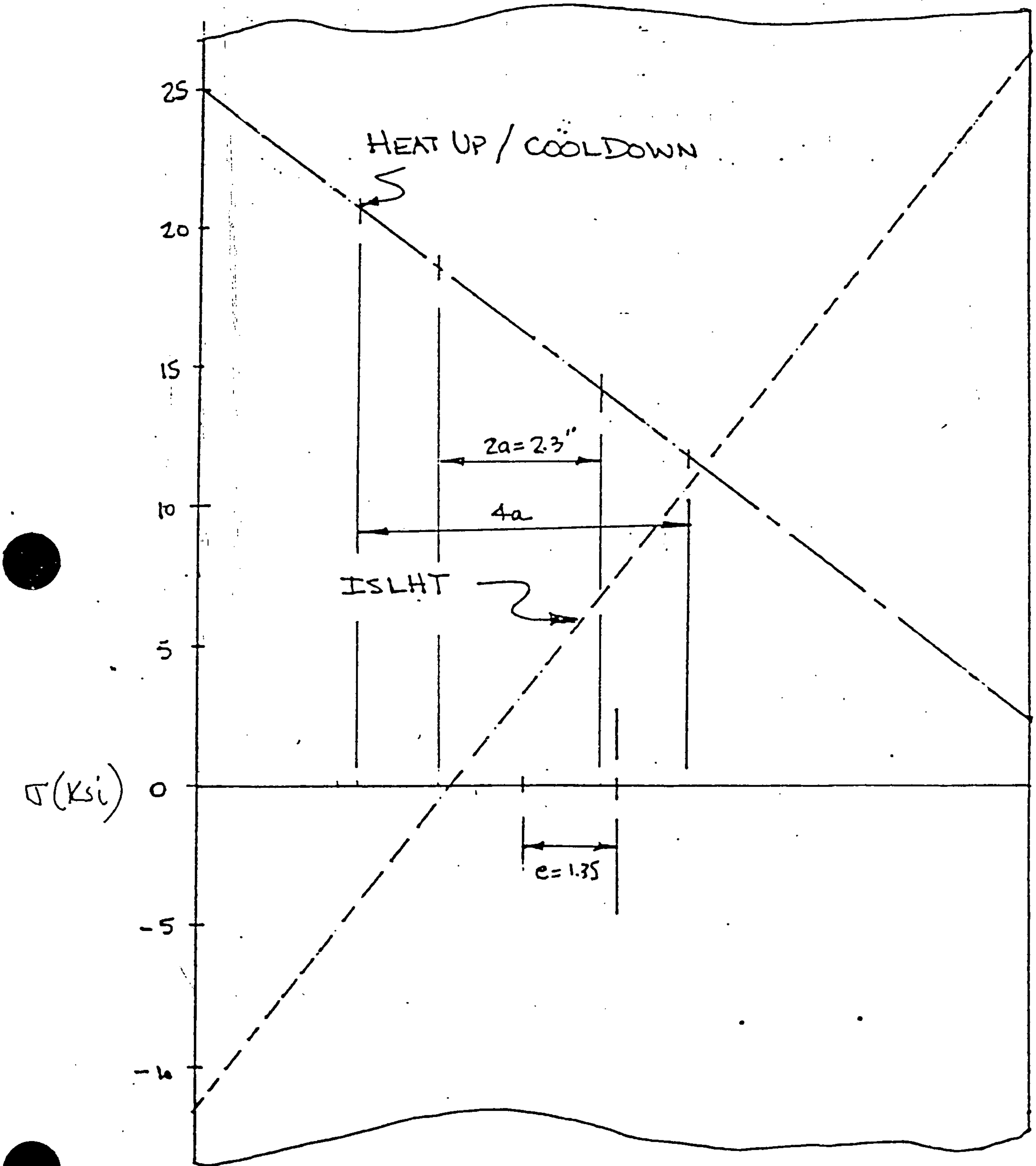
THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE / VERSION / REV	CODE / VERSION / REV

PAGE	DESCRIPTION	REV. LEVEL
ALL	ORIGINAL ISSUE	00
1	NEW CDS	01
2	REVISION DESCRIPTION	
23 thru 28, B1 thru B9	PAGES ADDED	

WHR ~~4/23/86~~ 11-18-86   GJW ~~4/24/86~~ 11/21/86

INDICATION # 18/19



WHR 4/23/86 AFW 4/24/86

73-1164054-00

ER 86-019 Indication No. 18/19 Combined

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.15000 IN

INITIAL FLAW LENGTH = 4.40000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.35000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

GUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	1.1500	1.1516
2	7.65	18.65	100.0	1.1516	1.1519

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.028

BENDING STRESS CORRECTION FACTOR MB = 0.333

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 28.15 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 7.10

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF 3000 ARE SATISFIED FOR THE FLAWED SECTION

WAM 4/23/86   SJW 4/24/86

$$K_I = \sigma_m M_m \sqrt{\pi}\sqrt{a/Q} + \sigma_b M_b \sqrt{\pi}\sqrt{a/Q}$$

$$da/dN = C_o(\Delta K)^n$$

$$= 2.67 \times 10^{-11} (\Delta K)^{3.726}$$

AFTER INTEGRATION :

$$a_f = \left\{ a_i^{-.863} - .863(2.67\times10^{-11})\left[(\Delta\sigma_m M_m + \Delta\sigma_b M_b)\sqrt{\pi/Q}\right]^{3.726} \Delta N \right\}^{-1.1587}$$

CORRELATION :

$$a_{f_1} = \left\{ (1.15)^{-.863} - 2.3\times10^{-11}\left[(13.65\times1.028 + 11.35\times.33)\sqrt{\pi/1.449}\right]^{3.726} 240 \right\}^{-1.1587}$$

$$= 1.1516 \text{ IN.}$$

$$a_{f_2} = \left\{ (a_{f_1})^{-.863} - 2.3\times10^{-11}\left[(7.65\times1.028 + 18.65\times.33)\sqrt{\pi/1.449}\right]^{3.726} 100 \right\}^{-1.1587}$$

$$= 1.1519 \text{ IN}$$

$$K_I = (13.65\times1.028 + 11.35\times.33)(\sqrt{\pi/1.449})\sqrt{1.1519} = 28.15 \text{ KSI}\sqrt{\text{IN}}$$

WHR 4/23/86 AFW 4/24/86

32-1164054-00

ER 86-019 Indication No. 18/19 Combined (100 % Increase in Size)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.30000 IN

INITIAL FLAW LENGTH = 8.80000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.35000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.3000	2.3097
2	7.65	18.65	100.0	2.3097	2.3117

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.133

BENDING STRESS CORRECTION FACTOR MB = 0.436

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 45.68 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 4.38

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF -3000 ARE SATISFIED FOR THE FLAWED SECTION

WHR 4/23/86 GJW 4/24/86

ER 86-019 Indication No. 18/19 Combined (Maximum Subsurface Indication)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 3.33500 IN

INITIAL FLAW LENGTH = 12.76000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.35000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

GUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	3.3350	3.3744
2	7.65	18.65	100.0	3.3744	3.3829

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.345

BENDING STRESS CORRECTION FACTOR MB = 0.550

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 66.64 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.00

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS NOT ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL
(1977 EDITION THROUGH SUMMER 1978 ADDENDA)

WHL · 4/23/86 AFW 4/24/86

ER 86-019 Indication No. 19/19 (96% of Maximum Subsurface)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 3.19000 IN

INITIAL FLAW LENGTH = 12.20500 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.35000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	3.1900	3.2222
2	7.65	18.65	100.0	3.2222	3.2291

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.306

BENDING STRESS CORRECTION FACTOR MB = 0.531

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 63.12 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.17

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF -3000 ARE SATISFIED FOR THE FLAWED SECTION

WM 4/24/86 GJW 4/24/86

ER 86-019 Indication No. 18/19 Combined (Treated as a Surface Indication)

FLAW TYPE : SURFACE

INITIAL FLAW DEPTH, (A) = 6.00000 IN

INITIAL FLAW LENGTH = 12.00000 IN

WALL THICKNESS = 12.00000 IN

KI CALCULATED AT PERIPHERY OF SURFACE FLAW WHERE BETA = 0.0 DEG

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.379E-09

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

F[illegible]GUE CRACK GROWTH :

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	6.0000	6.2243
2	7.65	18.65	100.0	6.2243	6.2591

FLAW SHAPE PARAMETER Q = 2.411

MEMBRANE STRESS CORRECTION FACTOR MM = 1.100

BENDING STRESS CORRECTION FACTOR MB = 0.298

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 52.54 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.81

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WM 4/23/86 [signature] 4/24/86

32-11 64054-00

ER 86-019 Indication No. 18/19 Combined (Treated as a Surface Indication)

FLAW TYPE : SURFACE

INITIAL FLAW DEPTH, (A) = 6.00000 IN

INITIAL FLAW LENGTH = 12.00000 IN

WALL THICKNESS = 12.00000 IN

KI CALCULATED AT PERIPHERY OF SURFACE FLAW WHERE BETA = 0.0 DEG

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.379E-09

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

[illegible]GUE CRACK GROWTH :

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	1800.0	6.0000	8.3046
2	7.65	18.65	100.0	8.3046	8.3664

FLAW SHAPE PARAMETER Q = 2.411

MEMBRANE STRESS CORRECTION FACTOR MM = 1.116

BENDING STRESS CORRECTION FACTOR MB = 0.298

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE. KI = 61.49 KSI ROOT INCH

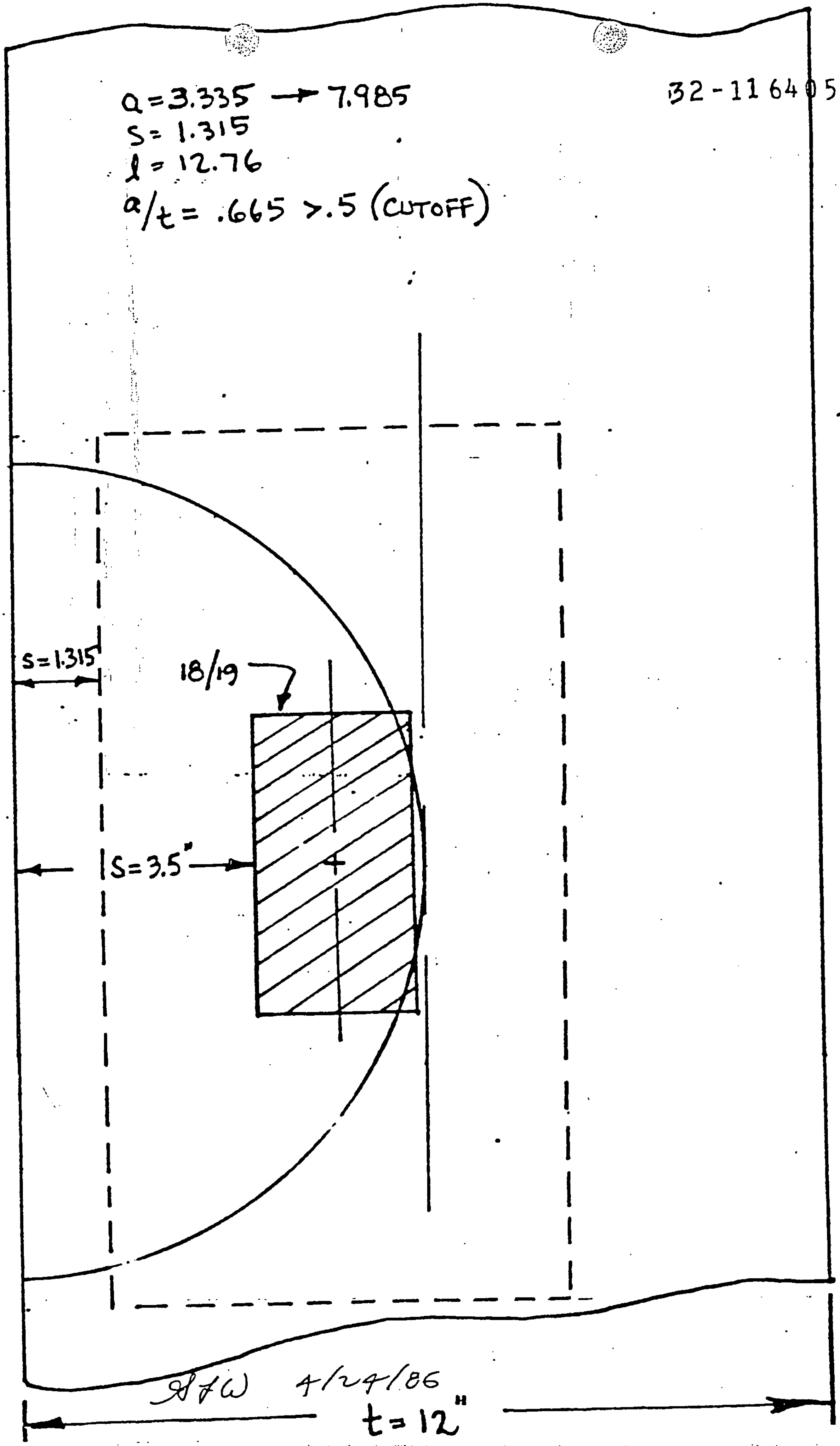
CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.25

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WM 4/23/86 GLW 4/24/86



a=3.335 → 7.985
S= 1.315
l= 12.76
a/t= .665 >.5 (CUTOFF)
32-1164054-00
S=1.315
18/19
S=3.5"
WHL 4/23/86
SJW 4/24/86
t= 12"

ER 86-019 Indication No. 18/19 Combined (Excess Cycles Evaluated)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.15000 IN

INITIAL FLAW LENGTH = 4.40000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.35000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	50000.0	1.1500	1.8211
2	7.65	18.65	100.0	1.8211	1.8220

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.078

BENDING STRESS CORRECTION FACTOR MB = 0.389

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 38.01 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

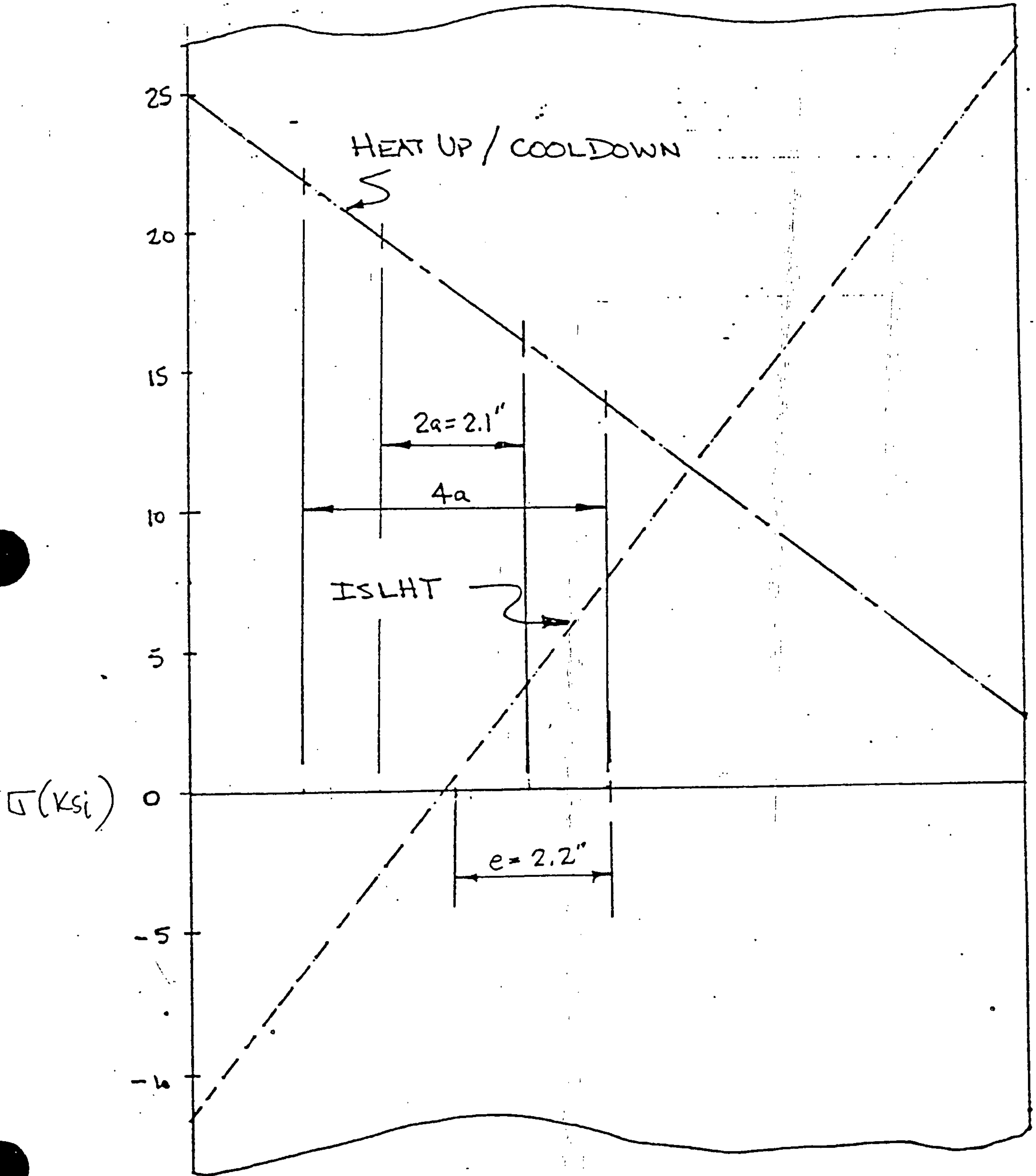
RATIO, KIA/KI = 5.26

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WHR 4/23/86   GJW 4/24/86

INDICATION #4



WM 4/23/86 GJW 4/24/86

ER 86-019 Indication No. 4

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.05000 IN

INITIAL FLAW LENGTH = 5.40000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.20000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

[illegible]GUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	1.0500	1.0525
2	7.65	18.65	100.0	1.0525	1.0531

FLAW SHAPE PARAMETER Q = 1.255

MEMBRANE STRESS CORRECTION FACTOR MM = 1.031

BENDING STRESS CORRECTION FACTOR MB = 0.475

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 31.60 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 6.33

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF [illegible]3000 ARE SATISFIED FOR THE FLAWED SECTION

[illegible] 4/23/86 [illegible] 4/24/86

ER 86-019 Indication No. 4 (100 % Increase in Size)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.10000 IN

INITIAL FLAW LENGTH = 10.80000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.20000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.1000	2.1145
2	7.65	18.65	100.0	2.1145	2.1182

FLAW SHAPE PARAMETER Q = 1.255

MEMBRANE STRESS CORRECTION FACTOR MM = 1.141

BENDING STRESS CORRECTION FACTOR MB = 0.572

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 50.82 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.94

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WBR 4/23/86 JJW 4/24/86

32-1164054-00

ER 86-019 Indication No. 4 (Maximum Subsurface Indication)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.73000 IN

INITIAL FLAW LENGTH = 14.04000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.20000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

...IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.7300	2.7661
2	7.65	18.65	100.0	2.7661	2.7756

FLAW SHAPE PARAMETER Q = 1.255

MEMBRANE STRESS CORRECTION FACTOR MM = 1.275

BENDING STRESS CORRECTION FACTOR MB = 0.643

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 65.11 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.07

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS NOT ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL (1977 EDITION THROUGH SUMMER 1978 ADDENDA)

WHR 4/23/86 DLW 4/24/86

ER 86-019 Indication No. 4 (97% of Maximum Subsurface)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.65000 IN

INITIAL FLAW LENGTH = 13.62900 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.20000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

FATIGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.6500	2.6819
2	7.65	18.65	100.0	2.6819	2.6904

FLAW SHAPE PARAMETER Q = 1.255

MEMBRANE STRESS CORRECTION FACTOR MM = 1.251

BENDING STRESS CORRECTION FACTOR MB = 0.635

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 63.02 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

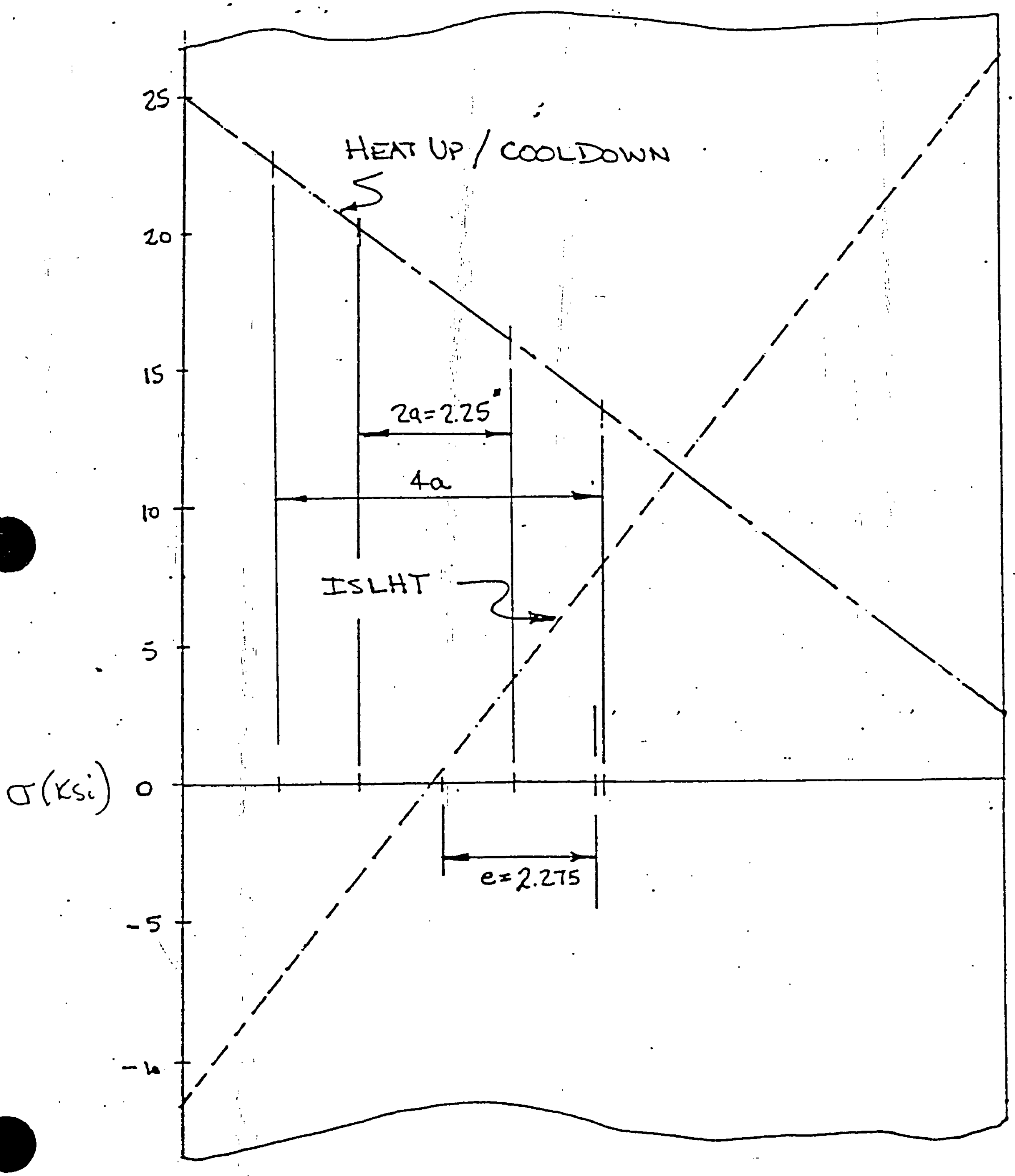
RATIO, KIA/KI = 3.17

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WHR 4/24/86 JJW 4/24/86

INDICATION # 8



WHR 4/23/86 GLW 4/24/86

ER 86-019 Indication No. 8

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.12500 IN

INITIAL FLAW LENGTH = 2.25000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.27500 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

GUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	1.1250	1.1259
2	7.65	18.65	100.0	1.1259	1.1261

FLAW SHAPE PARAMETER Q = 2.411

MEMBRANE STRESS CORRECTION FACTOR MM = 1.030

BENDING STRESS CORRECTION FACTOR MB = 0.495

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 23.97 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 8.34

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITION THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WM 4/23/86 GJW 4/24/86

ER 86-019 Indication No. 8 (100 % Increase in Size)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.25000 IN

INITIAL FLAW LENGTH = 4.50000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.27500 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

GUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.2500	2.2555
2	7.65	18.65	100.0	2.2555	2.2570

FLAW SHAPE PARAMETER Q = 2.411

MEMBRANE STRESS CORRECTION FACTOR MM = 1.174

BENDING STRESS CORRECTION FACTOR MB = 0.602

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 39.20 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 5.10

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WHR 4/23/86 JLW 4/24/86

ER 86-019 Indication No. 8 (Maximum Subsurface Indication)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.70000 IN

INITIAL FLAW LENGTH = 5.40000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.27500 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

FATIGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.7000	2.7102
2	7.65	18.65	100.0	2.7102	2.7129

FLAW SHAPE PARAMETER Q = 2.411

MEMBRANE STRESS CORRECTION FACTOR MM = 1.261

BENDING STRESS CORRECTION FACTOR MB = 0.650

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 46.24 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 4.33

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WMR 4/23/86 AFW 4/24/86

Babcock & Wilcox
a McDermott company
Nuclear Power Generation Division

PDS-21036.1 (9-81)

GENERAL CALCULATIONS

SUMMARY OF RESULTS

INDICATION #18/19

a_i =	1.15	2.30	3.335	3.19	6.0	6.0	1.15
ℓ =	4.4	8.80	12.76	12.205	12.0	12.0	4.40
e =	1.35	1.35	1.35	1.35	0	0	1.35
a_f =	1.1515	2.3090	3.3829	3.2291	6.2591	8.3664*	1.822**
K_{Ia}/K_I =	7.53	4.66	3.0	3.17	3.81	3.25	5.26

3.0 — DOESN'T MEET CRITERIA

*N = 1800 CYCLES
**N = 50000 CYCLES

INDICATION #4

a_i =	1.05	2.10	2.73	2.65
ℓ =	5.40	10.80	14.04	13.63
e =	2.20	2.20	2.20	2.20
a_f =	1.0531	2.1182	2.7756	2.6404
K_{Ia}/K_I =	6.33	3.94	3.03	3.17

3.03 — DOESN'T MEET CRITERIA

INDICATION #8

a_i =	1.125	2.25	2.70
ℓ =	2.25	4.50	5.40
e =	2.275	2.275	2.275
a_f =	1.1261	2.257	2.7129
K_{Ia}/K_I =	8.34	5.10	4.33

PREPARED BY WL Redd DATE 4-24-86 DOC. NO.
REVIEWED BY GFW DATE 4/24/86 PAGE NO. 22

ITEM 1

32-1164054-01

ER 86-019 Indication No. 3/4 Combined

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.05000 IN

INITIAL FLAW LENGTH = 7.60000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.66000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

FATIGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	1.0500	1.0524
2	7.65	18.65	100.0	1.0524	1.0529
3	2.86	2.86	18000.0	1.0529	1.0535

FLAW SHAPE PARAMETER Q = 1.122

MEMBRANE STRESS CORRECTION FACTOR MM = 1.024

BENDING STRESS CORRECTION FACTOR MB = 0.379

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 31.39 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 6.37

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WLR 11-18-86 SJW 11/21/86

Item 1

R2-1164054-01

ER 86-019 Indication No. 18/19 Combined

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.15000 IN

INITIAL FLAW LENGTH = 4.40000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.66000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

FATIGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	1.1500	1.1518
2	7.65	18.65	100.0	1.1518	1.1522
3	2.86	2.86	18000.0	1.1522	1.1527

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.030

BENDING STRESS CORRECTION FACTOR MB = 0.388

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 29.19 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 6.85

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

NLR 11-18-86 AJW 11/21/86

ITEM 2

ASSUMPTIONS:

1) SERVICE INDUCED GROWTH SINCE 1981
2) LINEAR (NON-CODE) GROWTH RATE
3) ORIGINAL MEASURED LENGTH USED

CYCLES CONTRIBUTING TO STRESS = 30 HU/CD
(5 YEARS x 240 CYC/40 YRS)

NEXT INSPECTION ≡ 18 MOS = 9 CYCLES

$da/dN = 1.15/30 = .038333$ IN/CYCLE

$a_f = a_i + \delta a = 1.15 + .038333(9) = 1.495$ IN

$K_I = (13.65 \times 1.052 + 11.35 \times .417)\sqrt{\pi}/1.721 \sqrt{1.495}$

$= 31.54$ KSI $\sqrt{IN}$

$K_{Ia}/K_I = 200/31.54 = 6.34 > 3.16$ OK!

AS PART OF THE REQUIREMENTS OF THE ASME, B & PV CODE, SECTION XI, SUBARTICLE IWB-3610, IT IS NECESSARY TO SHOW THAT THE PRIMARY STRESS LIMITS OF SECTION III, ARTICLE NB-3000 ARE SATISFIED ASSUMING A LOCAL AREA REDUCTION OF THE PRESSURE RETAINING MEMBRANE THAT IS EQUAL TO THE AREA OF THE DETECTED INDICATION(S).

THE CODE STRESS REPORT WAS UTILIZED TO:

1) SHOW THAT THE FLAWS WERE BEYOND THE REQUIRED AREA OF REINFORCEMENT FOR THE INLET AND OUTLET NOZZLE HENCE CONFIRMING ADDITIONAL THICKNESS EXIST BEYOND THAT REQUIRED AND,

2) EXTRACT THE PREVIOUSLY DETERMINED PRIMARY STRESSES TO ASSESS THE EFFECTS OF THE FLAWS ON THE CROSS SECTION

CALCULATED BELOW ARE THE CODE ADJUSTED STRESSES:

$$P_L = 12.7 \left(\frac{12}{12-2.99} \right) = 16.9 \text{ KSi} < 40 \text{ KSi ALLOWABLE}$$

$$P_L + P_b = 16.8 \left(\frac{12}{12-2.99} \right) = 22.4 \text{ KSi} < 40 \text{ KSi ALLOWABLE}$$

WLR 11-18-86 JJW 11/21/86

ITEM 3

JUSTIFICATION FOR UN-ANALIZED TRANSIENTS

A question was raised as to the effect of system transients in addition to the Heatup/Cooldown (HU/CD) and Inservice Leak and Hydrostatic Test (ISLHT) transients considered in the B&W analysis. The specific concern was whether some large cyclic transients, although not necessarily of high stress, could be significant to flaw evaluation.

It was noted by B&W that the flaw evaluations performed were in accordance with B&W's original stress report, which considered only the two transients (HU/CD and ISLHT) as significant in the flaw growth calculations. Review of the original stress report showed that other transients induce stresses less than the endurance limit stress, and thus do not affect the fatigue usage factor.

To address the question raised, the functional specification was reviewed with respect to transients with large numbers of cycles. Four transients fall into this category: 1) Power Loading/Unloading, 2) 10 percent Step Load Increase/Decrease, 3) Feed and Bleed, and 4) Miscellaneous. The temperature variation on the RV due to these transients is 20, 5, 0, and 0 degrees Fahrenheit respectively.

The effect of the most significant of these four transients, the Power Loading/Unloading transient, was evaluated. A thermal stress ($1.43E\alpha\Delta T$) of 5.7 ksi was assumed to vary linearly from the ID to the OD. This is a very conservative assumption since this stress is actually a surface stress which rapidly decays and probably has a zero value at the tips of the subsurface flaw. The transient membrane and bending stresses and cycles were input as a third transient into the FLEP (Section XI, Appendix A) flaw evaluation program. (This evaluation also includes a correction to the eccentricity as a result of recalculating the edge distance(s).)

The results of this calculation are attached for the worst case indication (ER 86-019 Indication No. 18/19 combined). A comparison of these results with and without the effect of the Power Loading/Unloading transient included, shows this transient to have an insignificant effect on the flaw evaluation.

Evaluations of the indications have been made using the Design, Normal and Upset transients as specifed in the Reactor Coolant System Functional Specification invoked on the Reactor Vessel.

This area of the Reactor Vessel, i.e., Closure Flange to Upper Nozzle Belt forging, is above the inlet and outlet nozzles and is remote from the core's fluence, hence its chemical properties remain constant.

Unanticipated transients which would require consideration from the standpoint of flaw growth such as Pressurized Thermal Shock (PTS), NRC Stylized, Rancho Seco, Main Steam Line Break (MSLB), Small Break LOCA and Control System Malfunctions have little, if any, impact on the area in which the postulated indications are assumed and would show larger margins of safety than have been determined because of the acceptability criteria (K_{Ia}/K_I must be greater than $\sqrt{2}$ vs. $\sqrt{10}$).

32-1164054-00

APPENDIX A

IBM PC PROGRAM FLEP

(PC VERSION OF NPD-TM-5)

JLW 4/24/86

```
      PROGRAM FLEP
      DIMENSION X1(15),Z1(9),Y1(15,9),X2(11),Z2(6),Y2(11,6),X3(13),Z3(6)
     *,Y3(13,6),X4(8),Z4(4),Y4(8,4),X5(13),Z5(6),Y5(13,6),X6(8),Z6(4),Y6
     *(8,4),SMR(20),SBR(20),XNCYCLE(20),TITLE(20),AI(20),AF(20),AI2(20),
     *AF2(20)
      REAL MM,MB,KI,KIA,MM2,MB2,KI2
C**** DATA INPUT FOR MM FACTOR FOR SURFACE FLAW
      DATA(X1(I),I=1,15)/.00,.05,.10,.15,.20,.25,.30,.35,.40,.45,.50,.55
     *,.60,.65,.70/
      DATA(Z1(I),I=1,9)/.00,.05,.10,.15,.20,.25,.30,.35,.50/
      DATA((Y1(K,L),L=1,9),K=1,15)/
     *1.112,1.105,1.100,1.100,1.100,1.100,1.100,1.100,1.100,
     *1.128,1.121,1.102,1.100,1.100,1.100,1.100,1.100,1.100,
     *1.188,1.149,1.121,1.110,1.100,1.100,1.100,1.100,1.100,
     *1.259,1.192,1.151,1.130,1.108,1.100,1.100,1.100,1.100,
     *1.367,1.257,1.195,1.158,1.125,1.112,1.104,1.100,1.100,
     *1.514,1.346,1.253,1.195,1.151,1.130,1.114,1.100,1.100,
     *1.703,1.452,1.320,1.238,1.182,1.151,1.127,1.100,1.100,
     *1.956,1.584,1.406,1.294,1.221,1.179,1.143,1.100,1.100,
     *9.000,1.739,1.508,1.354,1.264,1.208,1.162,1.100,1.100,
     *9.000,1.930,1.631,1.428,1.318,1.244,1.186,1.100,1.100,
     *9.000,9.000,1.776,1.523,1.381,1.283,1.214,1.100,1.100,
     *9.000,9.000,1.934,1.646,1.452,1.328,1.242,1.100,1.100,
     *9.000,9.000,9.000,1.800,1.543,1.385,1.274,1.104,1.104,
     *9.000,9.000,9.000,1.975,1.644,1.443,1.309,1.110,1.110,
     *9.000,9.000,9.000,9.000,1.765,1.514,1.359,1.117,1.117/
C**** DATA INPUT FOR MB FACTOR FOR SURFACE FLAW WITH BETA=0. DEG
      DATA(X2(I),I=1,11)/.00,.05,.10,.15,.20,.25,.30,.35,.40,.45,.50/
      DATA(Z2(I),I=1,6)/.0,.1,.2,.3,.4,.5/
      DATA((Y2(K,L),L=1,6),K=1,11)/
     *1.101,1.076,1.067,1.042,1.031,1.023,
     *1.059,1.024,0.995,0.979,0.965,0.950,
     *1.037,0.977,0.927,0.912,0.897,0.879,
     *1.034,0.934,0.869,0.848,0.828,0.806,
     *1.045,0.895,0.810,0.781,0.758,0.734,
     *1.072,0.862,0.758,0.718,0.693,0.662,
     *1.117,0.836,0.709,0.658,0.620,0.590,
     *1.178,0.820,0.665,0.597,0.550,0.514,
     *1.256,0.815,0.626,0.548,0.485,0.444,
     *1.356,0.829,0.591,0.481,0.412,0.371,
     *1.478,0.866,0.561,0.420,0.343,0.298/
C**** DATA INPUT FOR MM FACTOR FOR SUBSURFACE FLAW AT POINT 1
      DATA(X3(I),I=1,13)/.00,.05,.10,.15,.20,.25,.30,.35,.40,.45,.50,.55
     *,.60/
      DATA(Z3(I),I=1,6)/.15,.25,.35,.45,.55,.65/
      DATA((Y3(K,L),L=1,6),K=1,13)/
     *1.010,1.037,1.080,1.139,1.234,1.366,
     *1.010,1.038,1.081,1.144,1.247,1.380,
     *1.011,1.041,1.085,1.152,1.264,1.402,
     *1.012,1.043,1.091,1.165,1.285,1.430,
     *1.013,1.046,1.099,1.179,1.308,1.466,
     *1.014,1.050,1.111,1.196,1.336,1.524,
     *1.015,1.054,1.123,1.216,1.368,1.587,
     *1.018,1.062,1.136,1.243,1.407,9.000,
     *1.022,1.070,1.151,1.274,1.463,9.000,
     *1.028,1.082,1.170,1.308,9.000,9.000,
     *1.033,1.095,1.190,1.346,9.000,9.000,
     *1.041,1.112,1.212,1.390,9.000,9.000,
     *1.052,1.132,1.238,1.443,9.000,9.000/
C**** DATA INPUT FOR MB FACTOR FOR SUBSURFACE FLAW AT POINT 1
      DATA(X4(I),I=1,8)/.0,.1,.2,.3,.4,.5,.6,.7/
      DATA(Z4(I),I=1,4)/.1,.3,.5,.7/
      DATA((Y4(K,L),L=1,4),K=1,8)/
```

B2-1164054-00

```
*0.155,0.252,0.361,0.474,
*0.261,0.361,0.474,0.618,
*0.365,0.468,0.590,0.748,
*0.471,0.577,0.706,0.894,
*0.568,0.687,0.832,9.000,
*0.671,0.816,0.984,9.000,
*0.765,0.961,9.000,9.000/
C**** DATA INPUT FOR MM FACTOR FOR SUBSURFACE FLAW AT POINT 2
      DATA(X5(I),I=1,13)/.00,.05,.10,.15,.20,.25,.30,.35,.40,.45,.50,.55
     *,.60/
      DATA(Z5(I),I=1,6)/.15,.25,.35,.45,.55,.65/
      DATA((Y5(K,L),L=1,6),K=1,13)/
     *1.010,1.037,1.080,1.139,1.232,1.361,
     *1.010,1.037,1.077,1.134,1.231,1.361,
     *1.011,1.038,1.077,1.132,1.232,1.363,
     *1.012,1.039,1.080,1.135,1.237,1.367,
     *1.013,1.039,1.084,1.141,1.244,1.373,
     *1.014,1.041,1.089,1.149,1.253,1.382,
     *1.015,1.042,1.094,1.157,1.264,1.393,
     *1.016,1.047,1.104,1.172,1.277,9.000,
     *1.016,1.052,1.112,1.191,1.293,9.000,
     *1.018,1.061,1.125,1.212,9.000,9.000,
     *1.021,1.072,1.139,1.237,9.000,9.000,
     *1.028,1.086,1.156,1.266,9.000,9.000,
     *1.037,1.105,1.179,1.298,9.000,9.000/
C**** DATA INPUT FOR MB FACTOR FOR SUBSURFACE FLAW AT POINT 2
      DATA(X6(I),I=1,8)/.0,.1,.2,.3,.4,.5,.6,.7/
      DATA(Z6(I),I=1,4)/.1,.3,.5,.7/
      DATA((Y6(K,L),L=1,4),K=1,8)/
     *-.050,-.158,-.258,-.382,
     *0.045,-.054,-.158,-.281,
     *0.152,0.055,-.050,-.171,
     *0.255,0.163,0.052,-.065,
     *0.358,0.268,0.159,0.058,
     *0.458,0.373,0.272,0.185,
     *0.570,0.490,0.398,0.313,
     *0.671,0.608,0.526,0.435/
      READ 5,NFLAW
      DO  10 K=1,NFLAW
      READ 15,(TITLE(I),I=1,20)
      PRINT 20,(TITLE(I),I=1,20)
      READ 25,NTYPE,A,XLL,E,T,BETA,NTRAN,SM,SB
      READ 30,TEMP,SYIELD,RTNDT,C,XN,KI,KIA
      READ 35,(SMR(I),SBR(I),XNCYCLE(I),I=1,NTRAN)
      IF(NTYPE.EQ.2) GO TO 40
      PRINT 45
      GO TO 50
   40 PRINT 55
   50 PRINT 60,A,XLL,T
      IF(NTYPE.EQ.1) GO TO 75
      PRINT 80,E
      GO TO 85
   75 PRINT 90,BETA
   85 PRINT 95,TEMP,RTNDT
      WKI=KI
      IF(KI.NE.0.0) GO TO 281
      PRINT 105,SYIELD
      PRINT 110,C
      PRINT 120,XN
      PRINT 125,SM,SB
      LL=1
      A1=A
      XL=XLL
      X=A/XLL
      IF(X.GT.0.5) GO TO 135
```

```
  140 IF(NTYPE.EQ.2) GO TO 145
C**** DETERMINE MM FACTOR FOR SURFACE FLAW
      KEY=1
      XX=A1/T
      ZZ=A1/XL
      DO 150 I1=1,15
  150 IF(X1(I1).GE.XX) GO TO 155
      GO TO 135
  155 IP1=I1
      II1=I1-1
      DO 160 J1=1,9
  160 IF(Z1(J1).GE.ZZ) GO TO 165
      GO TO 135
  165 JP1=J1
      JJ1=J1-1
      DX1=(XX-X1(II1))/(X1(IP1)-X1(II1))
      DZ1=(ZZ-Z1(JJ1))/(Z1(JP1)-Z1(JJ1))
      IF(Y1(II1,JJ1).GT.2.) GO TO 135
      IF(Y1(IP1,JJ1).GT.2.) GO TO 135
      IF(Y1(II1,JP1).GT.2.) GO TO 135
      IF(Y1(IP1,JP1).GT.2.) GO TO 135
      YA1=Y1(II1,JJ1)+DX1*(Y1(IP1,JJ1)-Y1(II1,JJ1))
      YB1=Y1(II1,JP1)+DX1*(Y1(IP1,JP1)-Y1(II1,JP1))
      MM=YA1+DZ1*(YB1-YA1)
      IF(BETA.EQ.90.) GO TO 175
C**** DETERMINE MB FACTOR FOR SURFACE FLAW AT BETA=0 DEGREES
      IF(LL.EQ.1) GO TO 200
      IF(XX.GT.0.25) GO TO 215
      GO TO 205
  215 IF(ZZ.GT.0.1) GO TO 205
  200 DO 180 I2=1,11
  180 IF(X2(I2).GE.XX) GO TO 185
      GO TO 135
  185 IP2=I2
      II2=I2-1
      DO 190 J2=1,6
  190 IF(Z2(J2).GE.ZZ) GO TO 195
      GO TO 135
  195 JP2=J2
      JJ2=J2-1
      DX2=(XX-X2(II2))/(X2(IP2)-X2(II2))
      DZ2=(ZZ-Z2(JJ2))/(Z2(JP2)-Z2(JJ2))
      YA2=Y2(II2,JJ2)+DX2*(Y2(IP2,JJ2)-Y2(II2,JJ2))
      YB2=Y2(II2,JP2)+DX2*(Y2(IP2,JP2)-Y2(II2,JP2))
      MB=YA2+DZ2*(YB2-YA2)
      GO TO 205
C**** DETERMINE MB FACTOR FOR SURFACE FLAW AT BETA=90 DEGREES
  175 IF(LL.GT.1) GO TO 205
      IF(XX.GT.0.5) GO TO 135
      IF(ZZ.GT.0.3) GO TO 135
      IF(ZZ.LT.0.2) GO TO 135
      DX2=(XX-0.0)/(0.5-0.0)
      DZ2=(ZZ-0.2)/(0.3-0.2)
      YA2=0.821+DX2*(0.805-0.821)
      YB2=0.956+DX2*(0.892-0.956)
      MB=YA2+DZ2*(YB2-YA2)
      GO TO 205
C**** DETERMINE MM FACTOR FOR SUBSURFACE FLAW AT POINT 1
  145 XX=2.*E/T
      ZZ=2.*A1/T
      DO 220 I3=1,13
  220 IF(X3(I3).GE.XX) GO TO 225
      GO TO 135
  225 IP3=I3
      II3=I3-1
```

```
  230 IF(Z3(J3).GE.ZZ) GO TO 235
      GO TO 135
  235 JP3=J3
      JJ3=J3-1
      DX3=(XX-X3(II3))/(X3(IP3)-X3(II3))
      DZ3=(ZZ-Z3(JJ3))/(Z3(JP3)-Z3(JJ3))
      IF(Y3(II3,JJ3).GT.2.) GO TO 135
      IF(Y3(IP3,JJ3).GT.2.) GO TO 135
      IF(Y3(II3,JP3).GT.2.) GO TO 135
      IF(Y3(IP3,JP3).GT.2.) GO TO 135
      YA3=Y3(II3,JJ3)+DX3*(Y3(IP3,JJ3)-Y3(II3,JJ3))
      YB3=Y3(II3,JP3)+DX3*(Y3(IP3,JP3)-Y3(II3,JP3))
      MM=YA3+DZ3*(YB3-YA3)
C**** DETERMINE MB FACTOR FOR SUBSURFACE FLAW AT POINT 1
      DO 240 I4=1,8
  240 IF(X4(I4).GE.XX) GO TO 245
      GO TO 135
  245 IP4=I4
      II4=I4-1
      DO 250 J4=1,4
  250 IF(Z4(J4).GE.ZZ) GO TO 255
      GO TO 135
  255 JP4=J4
      JJ4=J4-1
      DX4=(XX-X4(II4))/(X4(IP4)-X4(II4))
      DZ4=(ZZ-Z4(JJ4))/(Z4(JP4)-Z4(JJ4))
      IF(Y4(II4,JJ4).GT.2.) GO TO 135
      IF(Y4(IP4,JJ4).GT.2.) GO TO 135
      IF(Y4(II4,JP4).GT.2.) GO TO 135
      IF(Y4(IP4,JP4).GT.2.) GO TO 135
      YA4=Y4(II4,JJ4)+DX4*(Y4(IP4,JJ4)-Y4(II4,JJ4))
      YB4=Y4(II4,JP4)+DX4*(Y4(IP4,JP4)-Y4(II4,JP4))
      MB=YA4+DZ4*(YB4-YA4)
C**** DETERMINE FINAL FLAW SIZE
  205 AI(1)=A
      DO 265 I=1,NTRAN
      D1=SMR(I)*MM*1.77245/(Q**0.5)
      D2=SBR(I)*MB*1.77245/(Q**0.5)
      D=D1+D2
      IF(D.LT.0.0) D=0.0
      F=(2.-XN)/2.
      AF(I)=(AI(I)**F+F*C*(D)**XN*XNCYCLE(I))**(1/F)
  265 AI(I+1)=AF(I)
      IF(AF(NTRAN).LT.(1.01*A1)) GO TO 270
      A1=AF(NTRAN)
      XL=AF(NTRAN)*XLL/A
      LL=LL+1
      GO TO 140
  270 IF(NTYPE.EQ.1) GO TO 271
C**** DETERMINE MM FACTOR FOR SUBSURFACE FLAW AT POINT 2
      A1=A
  217 ZZ=2.*A1/T
      DO 221 I5=1,13
  221 IF(X5(I5).GE.XX) GO TO 226
      GO TO 135
  226 IP5=I5
      II5=I5-1
      DO 231 J5=1,6
  231 IF(Z5(J5).GE.ZZ) GO TO 236
      GO TO 135
  236 JP5=J5
      JJ5=J5-1
      DX5=(XX-X5(II5))/(X5(IP5)-X5(II5))
      DZ5=(ZZ-Z5(JJ5))/(Z5(JP5)-Z5(JJ5))
      IF(Y5(II5,JJ5).GT.2.) GO TO 135
```

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```
      IF(Y5(II5,JP5).GT.2.) GO TO 135
      IF(Y5(IP5,JP5).GT.2.) GO TO 135
      YA5=Y5(II5,JJ5)+DX5*(Y5(IP5,JJ5)-Y5(II5,JJ5))
      YB5=Y5(II5,JP5)+DX5*(Y5(IP5,JP5)-Y5(II5,JP5))
      MM2=YA5+DZ5*(YB5-YA5)
C**** DETERMINE MB FACTOR FOR SUBSURFACE FLAW AT POINT 2
      DO 241 I6=1,8
  241 IF(X6(I6).GE.XX) GO TO 246
      GO TO 135
  246 IP6=I6
      II6=I6-1
      DO 251 J6=1,4
  251 IF(Z6(J6).GE.ZZ) GO TO 256
      GO TO 135
  256 JP6=J6
      JJ6=J6-1
      DX6=(XX-X6(II6))/(X6(IP6)-X6(II6))
      DZ6=(ZZ-Z6(JJ6))/(Z6(JP6)-Z6(JJ6))
      YA6=Y6(II6,JJ6)+DX6*(Y6(IP6,JJ6)-Y6(II6,JJ6))
      YB6=Y6(II6,JP6)+DX6*(Y6(IP6,JP6)-Y6(II6,JP6))
      MB2=YA6+DZ6*(YB6-YA6)
C**** DETERMINE FINAL FLAW SIZE FOR POINT 2 ON SUBSURFACE FLAW
      AI2(1)=A
      DO 266 I=1,NTRAN
      D1=SMR(I)*MM2*1.77245/(Q**0.5)
      D2=SBR(I)*MB2*1.77245/(Q**0.5)
      D=D1+D2
      IF(D.LT.0.0) D=0.0
      F=(2.-XN)/2.
      AF2(I)=(AI2(I)**F+F*C*(D)**XN*XNCYCLE(I))**(1/F)
  266 AI2(I+1)=AF2(I)
      IF(AF2(NTRAN).LT.(1.01*A1)) GO TO 271
      A1=AF2(NTRAN)
      GO TO 217
C**** DETERMINE STRESS INTENSITY FACTOR, KI
  271 KI=SM*MM*1.77245*(AF(NTRAN)/Q)**0.5 + SB*MB*1.77245*(AF(NTRAN)/Q)*
     1*0.5
      IF(KI.LT.0.0) KI=0.0001
      IF(NTYPE.EQ.1) GO TO 281
      KI2=SM*MM2*1.77245*(AF2(NTRAN)/Q)**0.5 + SB*MB2*1.77245*(AF2(NTRAN
     1)/Q)**0.5
      IF(KI2.LT.0.0) KI2=0.0001
      IF(KI.GT.KI2) GO TO 280
      KEY=3
      KI=KI2
      MM=MM2
      MB=MB2
      DO 279 I=1,NTRAN
      AI(I)=AI2(I)
  279 AF(I)=AF2(I)
      GO TO 281
  280 KEY=2
C**** DETERMINE CRACK ARREST STRESS INTENSITY FACTOR, KIA
  281 IF(KIA.NE.0.) GO TO 285
      KIA=1.233*(2.71828**(0.0145*(TEMP-RTNDT+160.))) + 26.78
      IF(KIA.LT.200.) GO TO 285
      KIA=200.
C**** DETERMINE RATIO OF KIA TO KI
  285 RATIO=KIA/KI
      IF(WKI.NE.0.0) GO TO 304
      IF(KEY-2)286,287,288
  286 PRINT 130
      GO TO 289
  287 PRINT 131
      GO TO 289
```

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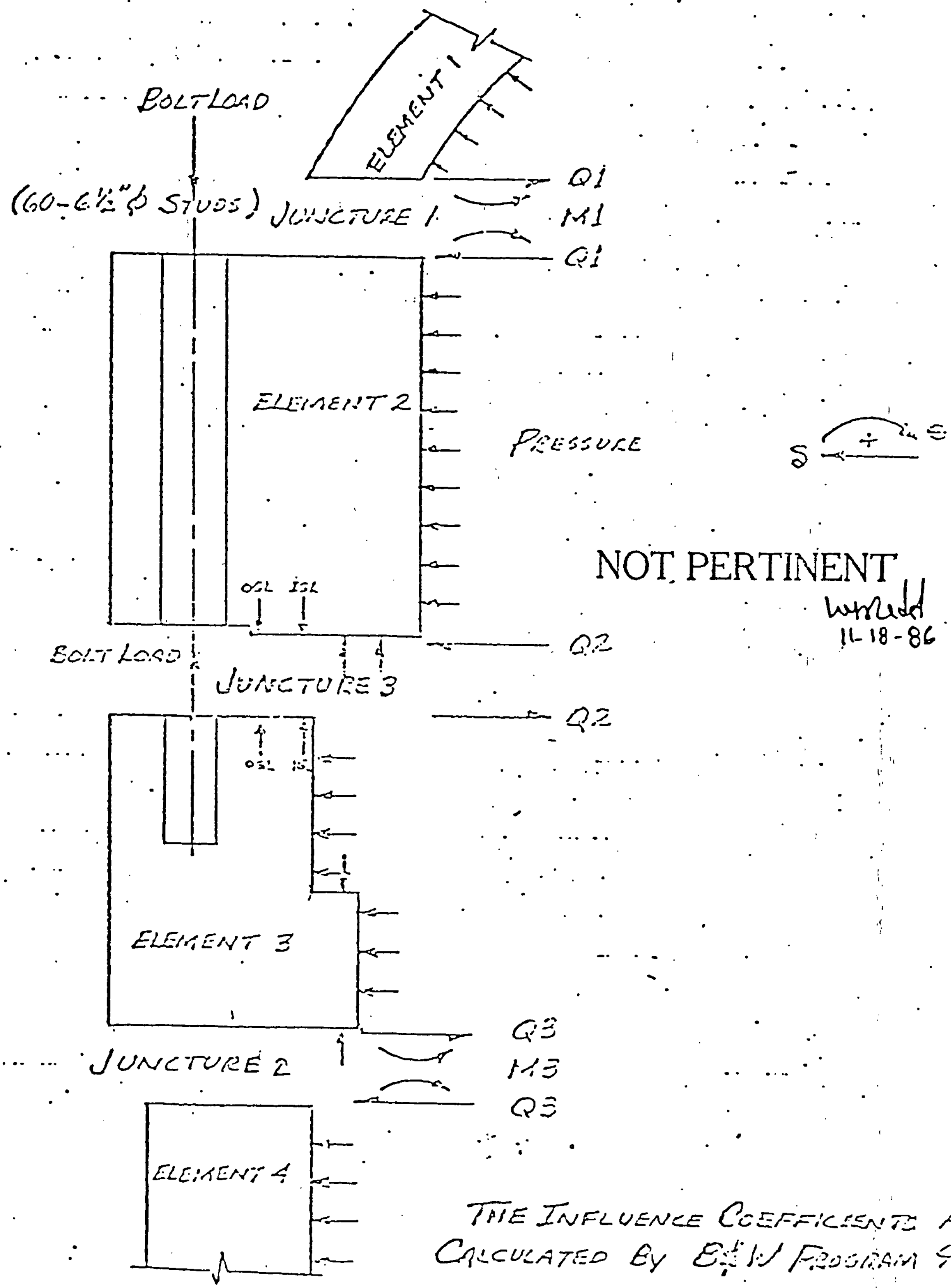
```
289 PRINT 133
    PRINT 275,(I,SMR(I),SBR(I),XNCYCLE(I),AI(I),AF(I),I=1,NTRAN)
    PRINT 290,Q,MM,MB
304 PRINT 305,KI
    PRINT 310,KIA
    PRINT 315,RATIO
    PRINT 320
    IF(RATIO.GE.3.16) GO TO 325
    PRINT 330
    GO TO 10
325 PRINT 340
 10 CONTINUE
    GO TO 350
135 PRINT 355
350 CONTINUE
  5 FORMAT(I5)
 15 FORMAT(20A4)
 20 FORMAT(//,20A4//)
 25 FORMAT(4X,I1,5F10.0,3X,I2,2F10.0)
 30 FORMAT(3F10.0,E10.0,3F10.0)
 35 FORMAT(3F10.0)
 45 FORMAT(1H0,'FLAW TYPE : SURFACE')
 55 FORMAT(1H0,'FLAW TYPE : SUBSURFACE')
 60 FORMAT(1H0,'INITIAL FLAW DEPTH, (A) = ',F10.5,' IN '//' INITIAL FL
   1AW LENGTH = ',F10.5,' IN '//' WALL THICKNESS = ',F10.5,' IN ')
 80 FORMAT(1H0,'ECCENTRICITY OF SUBSURFACE FLAW = ',F10.5,' IN ')
 90 FORMAT(1H0,'KI CALCULATED AT PERIPHERY OF SURFACE FLAW WHERE BETA
   1= ',F5.1,' DEG ')
 95 FORMAT(1H0,'CRACK TIP TEMPERATURE = ',F6.1,' F '//' REFERENCE NIL
   1DUCTILITY TEMPERATURE = ',F6.1,' F ')
105 FORMAT(1H0,'YIELD STRENGTH = ',F7.2,' KSI ')
110 FORMAT(1H0,'SCALING CONSTANT USED IN PARIS EQUATION = ',E10.3)
120 FORMAT(1H0,'EXPONENT USED IN PARIS EQUATION = ',F7.3)
125 FORMAT(1H0,'MEMBRANE STRESS = ',F7.2,' KSI '//1X,'BENDING STRESS =
   1 ',F7.2,' KSI ')
130 FORMAT(1H0,'FATIGUE CRACK GROWTH : ')
131 FORMAT(1H0,'FATIGUE CRACK GROWTH :  POINT 1 LOCATION IS CRITICAL')
132 FORMAT(1H0,'FATIGUE CRACK GROWTH :  POINT 2 LOCATION IS CRITICAL')
133 FORMAT(1H0,4X,'TRANSIENT     STRESS RANGES (KSI)     NO. OF     FL
   1AW DEPTH (IN)'/5X,'NO.          MEMBRANE   BENDING     CYCLES
   2  INITIAL   FINAL'//)
275 FORMAT(1H ,6X,I3,9X,F7.2,3X,F7.2,4X,F10.1,2X,F9.4,F9.4)
290 FORMAT(1H0,'FLAW SHAPE PARAMETER Q = ',F7.3//' MEMBRANE STRESS COR
   1RECTION FACTOR MM = ',F7.3//' BENDING STRESS CORRECTION FACTOR MB
   1= ',F7.3)
305 FORMAT(1H0,'STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = ',
   1F7.2,' KSI ROOT INCH ')
310 FORMAT(1H0,'CRACK ARREST STRESS INTENSITY FACTOR, KIA = ',F7.2,' K
   1SI ROOT INCH ')
315 FORMAT(1H0,'RATIO, KIA/KI = ',F7.2)
320 FORMAT(1H0,'ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16
   1')
330 FORMAT(1H0,'THIS FLAW IS NOT ACCEPTABLE PER SECTION XI OF THE ASME
   1 BOILER AND PRESSURE VESSEL CODE '/' (1977 EDITION THROUGH SUMMER
   21978 ADDENDA) ')
340 FORMAT(1H0,'THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOI
   1LER AND PRESSURE VESSEL CODE '/' (1977 EDITON THROUGH SUMMER 1978
   2ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF'/' NB-3000 ARE SAT
   3ISFIED FOR THE FLAWED SECTION ')
355 FORMAT(1H0,'PARAMETER OUTSIDE TABULATED VALUES, EXECUTION TERMINAT
   1ED')
    STOP
    END
```

ITEM 4

APPENDIX B

STRESS COMPONENTS AND METHOD OF DETERMINATION

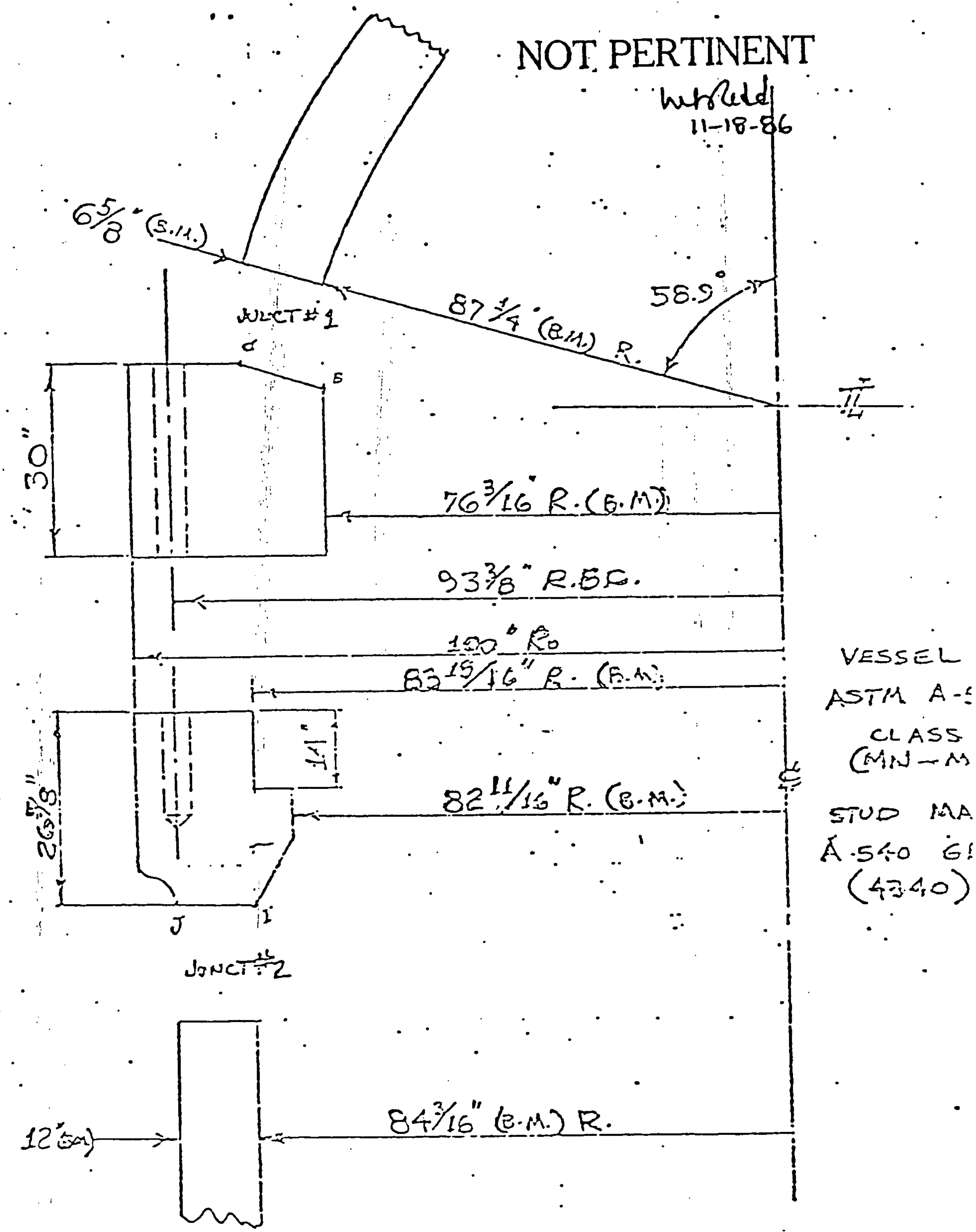


NOT PERTINENT
wrredd
11-18-86

THE INFLUENCE COEFFICIENTS ARE CALCULATED BY B&W PROGRAM 910

WLR 11-18-86 JfW 11/21/86

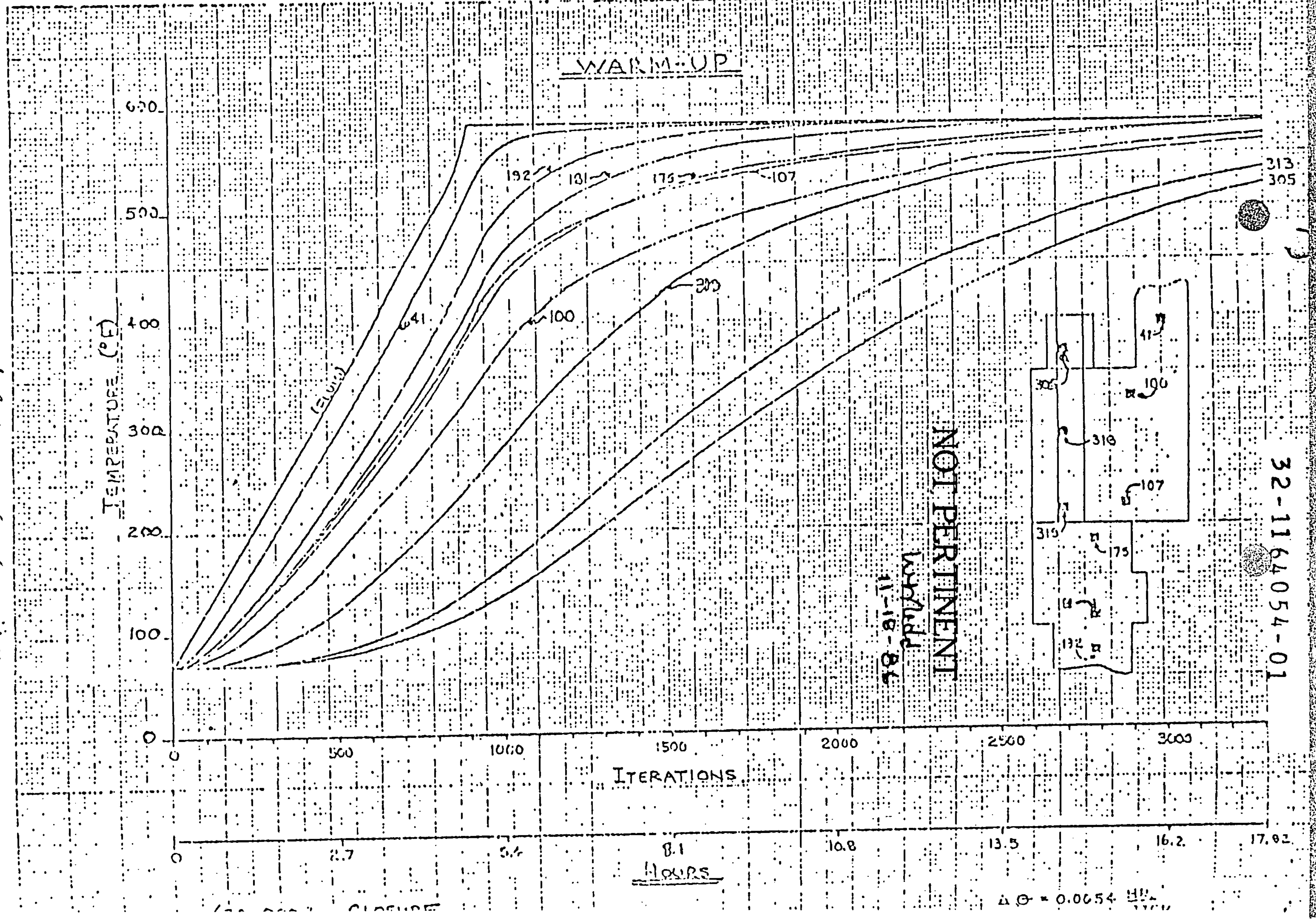
NOT PERTINENT



WLR 11-18-86 [illegible] 11/21/86

NO. 340-M DIETZGEN GRAPH PAPER MILLIMETER

EUGENE DIETZGEN CO. MADE IN U. S. A.



32-1164054-01

WLR 11-18-86

11/21/86

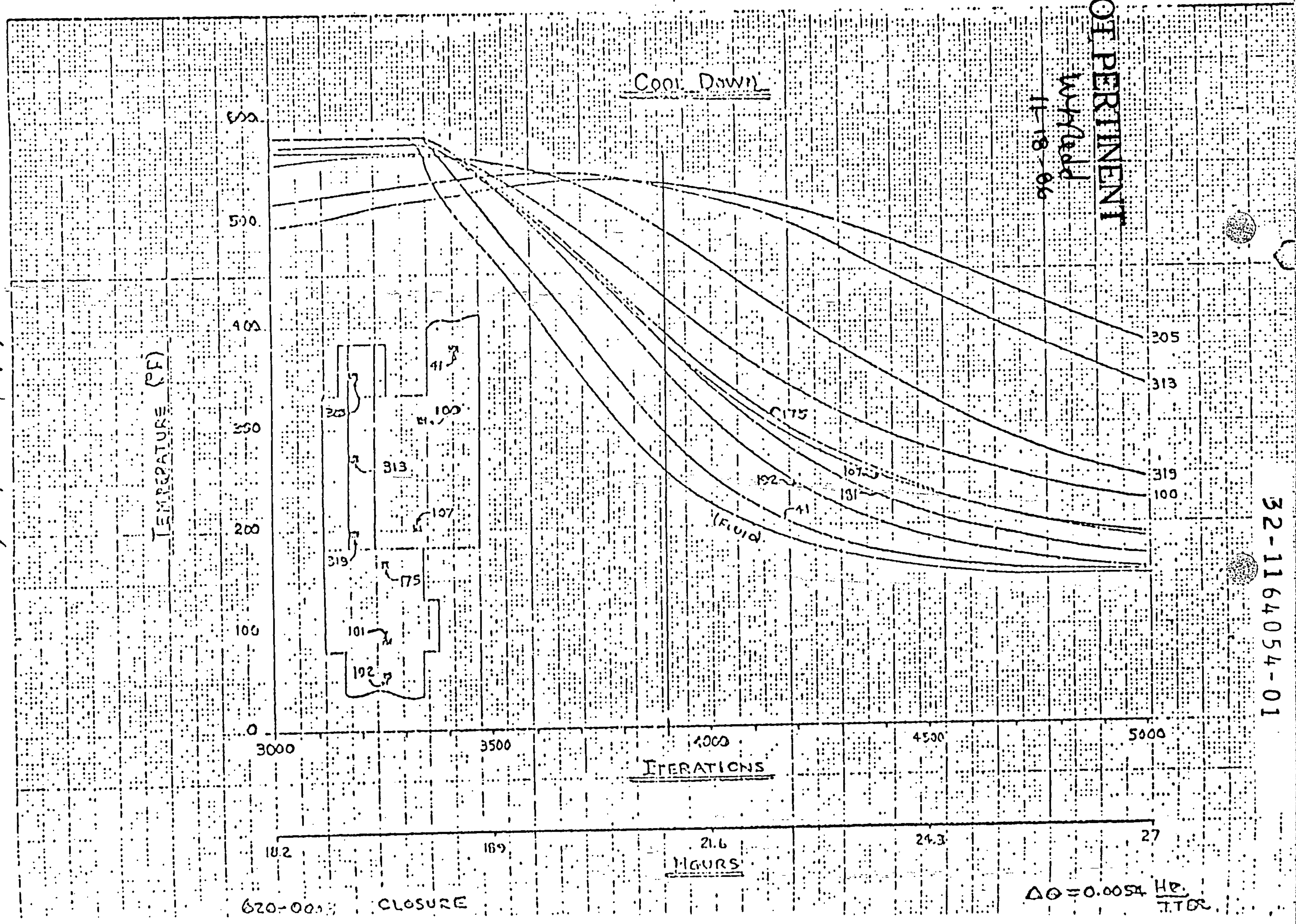
B4

NOT PERTINENT
WHTodd
11-18-86

WLR 11-18-86

JCW 11/21/86

32-1164054-01



35

TIMES FOR ANALYSIS

32-1164054-01

BASED ON THE TIME-TEMPERATURE HISTORIES THE FOLLOWING TIMES WERE CHOSEN FOR ANALYSIS BASED ON THE MAXIMUM AXIAL GRADIENTS BETWEEN THE PLOTTED POINTS. THIS WILL GIVE THE TIMES OF MAXIMUM MISMATCH DEFLECTION BETWEEN ADJACENT ELEMENTS, AND THUS THE TIMES OF MAXIMUM STRESS. THE TIMES CHOSEN ARE:

HEATUP		STEADY STATE		COOLDOWN	
ITER.	TIME	ITER.	TIME	ITER.	TIME
825	4.455 hr	3330	17.820 hr	3900	21.0
920	4.968 hr			4020	21.7
950	5.130 hr			4080	22.0
1030	5.562 hr			4200	22.6
1110	5.994 hr			4320	23.5
1400	7.560 hr			4500	24.3
				4660	25.1

THE FOLLOWING PAGES SHOW THE PROGRAM OUTPUT FOR THE ABOVE CRITICAL TIMES.

NOT PERTINENT
wrredd
11-18-86

WLR 11-18-86 AJW 11/21/86

WLR 11-18-86

gf 11/18/86

NOT PERTINENT
WRRedd
11-18-86

INPUT DATA

JUNCTURE NO. 2

STRESS CONCENTRATION FACTORS

INSIDE		OUTSIDE	
BENDING	TENSION	BENDING	TENSION
1.470	1.490	1.570	1.700

INPUT STRESSES (IN KSI)

CASE	ITER	LONGITUDINAL INSIDE	LONGITUDINAL OUTSIDE	CIRCUMFERENTIAL INSIDE	CIRCUMFERENTIAL OUTSIDE	RADIAL INSIDE	RADIAL OUTSIDE	LONGITUDINAL FREE THERMAL INSIDE	LONGITUDINAL FREE THERMAL OUTSIDE	CIRCUMFERENTIAL FREE THERMAL INSIDE	CIRCUMFERENTIAL FREE THERMAL OUTSIDE	
1	0	-19.4	19.4	-5.2	6.4	0.0	0.0	0.0	0.0	0.0	0.0	BOLT-UP
2	1	-10.5	26.9	8.6	17.7	-2.5	0.0	0.0	0.0	0.0	0.0	BOLT-UP & PRESSURE
3	2	-11.1	31.5	11.4	21.4	-3.1	0.0	0.0	0.0	0.0	0.0	BOLT-UP & HYDRO PRESSURE
4	825	-19.5	33.8	-1.4	13.1	-2.2	0.0	-32.6	17.4	-32.6	17.4	HEAT-UP
5	920	-20.5	34.8	-2.5	12.6	-2.2	0.0	-34.6	19.6	-36.6	19.6	HEAT-UP
6	950	-21.3	35.6	-3.0	12.7	-2.2	0.0	-33.3	19.2	-33.3	19.2	HEAT-UP
7	1030	-22.2	36.6	-3.2	13.1	-2.2	0.0	-26.1	16.1	-26.1	16.1	HEAT-UP
8	1110	-22.6	36.9	-0.6	15.6	-2.2	0.0	-20.7	13.0	-20.7	13.0	HEAT-UP
9	1400	-22.0	36.3	-1.1	14.9	-2.2	0.0	-9.6	6.1	-9.6	6.1	HEAT-UP
10	3330	-13.4	27.7	6.4	16.8	-2.2	0.0	-0.4	0.3	-0.4	0.3	STEADY STATE
11	3920	-11.5	11.5	2.3	8.8	0.0	0.0	20.0	-15.8	20.0	-15.8	COOLDOWN
12	4020	-10.1	10.1	3.0	8.7	0.0	0.0	24.8	-14.7	24.8	-14.7	COOLDOWN
13	4080	-9.7	9.7	3.2	8.6	0.0	0.0	23.3	-13.8	23.3	-13.8	COOLDOWN
14	4200	-9.0	9.0	3.3	8.3	0.0	0.0	20.4	-12.3	20.4	-12.3	COOLDOWN
15	4320	-8.6	8.6	3.1	7.8	0.0	0.0	15.6	-9.8	15.6	-9.8	COOLDOWN
16	4500	-8.9	8.9	2.3	7.3	0.0	0.0	11.2	-7.0	11.2	-7.0	COOLDOWN
17	4660	-9.4	9.4	1.6	7.0	0.0	0.0	8.6	-5.4	8.6	-5.4	COOLDOWN

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DEFINITION OF CASES ON PREVIOUS PAGE

1	BOLT UP AT ROOM TEMPERATURE (R.T.)
2	BOLT UP + PRESSURE = 2500 psi @ R.T.
3	BOLT UP + PRESSURE = 3125 psi @ R.T.
4→9	HEAT UP
10	STEADY STATE
11→17	COOLDOWN

STRESS DETERMINATION

A) HEAT UP / COOLDOWN

MAXIMUM STRESS TENDING TO OPEN THE INDICATIONS IS ON O.D. HALF OF VESSEL SECTION AND OCCURS AT ELEVATED TEMPERATURES, HOWEVER, INDICATIONS BEING EVALUATED ARE IN I.D. HALF ($<t/2$) WHERE COOLDOWN STRESSES ARE MAXIMUM.

$$\sigma_\ell)_{inside} = \underset{(\text{BOLT UP @ TEMP})}{\sigma_{cooldown}} + \sigma_{THERMAL} + \left(\sigma_{\substack{\text{BOLT UP}\\ +P=2500}} - \sigma_{\text{BOLT UP}}\right)\frac{P_{OPER}}{P_D=2500}$$

$$= -11.5 + 28.8 + [-10.5-(-19.4)]\,2185/2500$$

$$= -11.5 + 28.8 + 7.8$$

$$= 25.1 \text{ ksi}$$

$$\sigma_\ell)_{outside} = 11.5 - 15.8 + 6.6$$

$$= 2.3 \text{ ksi}$$

B) INSERVICE LEAK

$$\sigma_\ell)_{Inside} = \sigma_{BOLT\ UP} + (\sigma_{\substack{BOLT\ UP\\ +P=2500}} - \sigma_{BOLT\ UP}) \frac{P_{LEAK}}{P_{DES}}$$

$$= -19.4 + [-10.5 - (-19.4)]\ 2350/2500$$

$$= -11.0 \text{ ksi}$$

$$\sigma_\ell)_{outside} = 19.4 + (26.9 - 19.4)\ 2350/2500$$

$$= 26.5 \text{ ksi}$$

* COMPRESSIVE THERMAL STRESSES IGNORED

Babcock & Wilcox
a McDermott company

DOCUMENT SUMMARY SHEET

DOCUMENT IDENTIFIER 32-1164054-01

TITLE OCONEE I UPPER SHELL FLAW EVALUATION

PREPARED BY:	REVIEWED BY:
NAME W.L. REDD	NAME G.L. WEATHERLY
SIGNATURE W L Redd	SIGNATURE G L Weatherly
TITLE SUPR. ENGR DATE 11-18-86	TITLE PRIN ENGR DATE 11/21/86
COST CENTER 367 REF. PAGE(S) NA	TM STATEMENT: REVIEWER INDEPENDENCE GLW

PURPOSE AND SUMMARY OF RESULTS:

THIS REVISION IS TO FORMALLY COLLECT, CORRECT AND PROVIDE DATA WHICH WAS PREVIOUSLY TRANSMITTED TO THE CUSTOMER (SUBSEQUENTLY SUBMITTED TO THE NRC) AS INFORMATION SUPPORTING THE FLAW EVALUATIONS.

IN LIEU OF NEGATING THE PREVIOUS ORIGINAL CALCULATIONS, WHICH STILL PROVIDE AN INDICATION OF THE AVAILABLE MARGINS (EVEN THOUGH THERE IS AN ERROR IN THE ECCENTRICITY, .75" WRONG, THE RESULTS ARE CONSERVATIVE) THIS REVISION ADDS TO THE PREVIOUS ISSUE.

THE PAGES CONTAINED HEREIN ADDRESS:

1) NEW LEFM CALCULATIONS FOR COMBINED INDICATIONS 3/4 & 18/19
2) POSTULATED SERVICE INDUCED GROWTH CALCULATIONS AND CODE ADJUSTED STRESSES
3) JUSTIFICATION FOR UNANALIZED TRANSIENTS
4) STRESS COMPONENTS AND METHOD OF DETERMINATION FOR LEFM ANALYSIS (FROM 32-1126593-00, REF. 8)

REF.: EVALUATION NUMBER 86-019, REV. 1

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE / VERSION / REV	CODE / VERSION / REV

INCLUDES A-1 thru A-7
B-1 " B-9

Babcock & Wilcox
a McDermott company

DOCUMENT SUMMARY SHEET

DOCUMENT IDENTIFIER 32-1164054-00

TITLE OCONEE I UPPER SHELL ASSY. FLAW EVALUATION

PREPARED BY:		REVIEWED BY:	
NAME	W. L. REDD	NAME	G L WEATHERLY
SIGNATURE	W L Redd	SIGNATURE	G L Weatherly
TITLE	SUPR. ENGR. DATE 4-24-86	TITLE	ENGR IV DATE 4/24/86
COST CENTER	367 REF. PAGE(S) NA	TM STATEMENT: REVIEWER INDEPENDENCE	

PURPOSE AND SUMMARY OF RESULTS:

The purpose of this calculation is to evaluate the three worst indications as reported in Evaluation Report #86-019 (Nos. 4,8 and 18/19 combined). Because of the concerns raised by the NRC with regards to confidence in the as-measured dimensions it was decided to increment each flaw addressed by ten percent (10 %) until it failed to meet acceptability. Having started this for flaw number 18/19 it was quickly seen that the changes in growth and crack arrest value was negligible, therefore it was decided to double each flaws initial size, determine its status and increment from this size. In each case the original flaw size, when doubled, using ASME Section XI, Appendix A, methodology, satisfied the requirements of IWB-3612. The end result was that each sub-surface flaw could be enlarged until it almost became a surface flaw and meet acceptability requirements.

The calculations contained within represent a variety of flaw sizes and cycles for each indication of concern as well as a very conservative evaluation of indication number 18/19 when it gets reclassified from a sub-surface to a surface indication. As can be seen from the various outputs considerable safety margin exist when compared to original flaw size and/or number of cycles to cause failure.

All of the results were obtained fom an IBM PC version of the B&W fully certified computer program FLEP (NPD-TM-5, April 1985)

Calculation 32-1126593-00 is the source calculation for the stresses used in this evaluation.

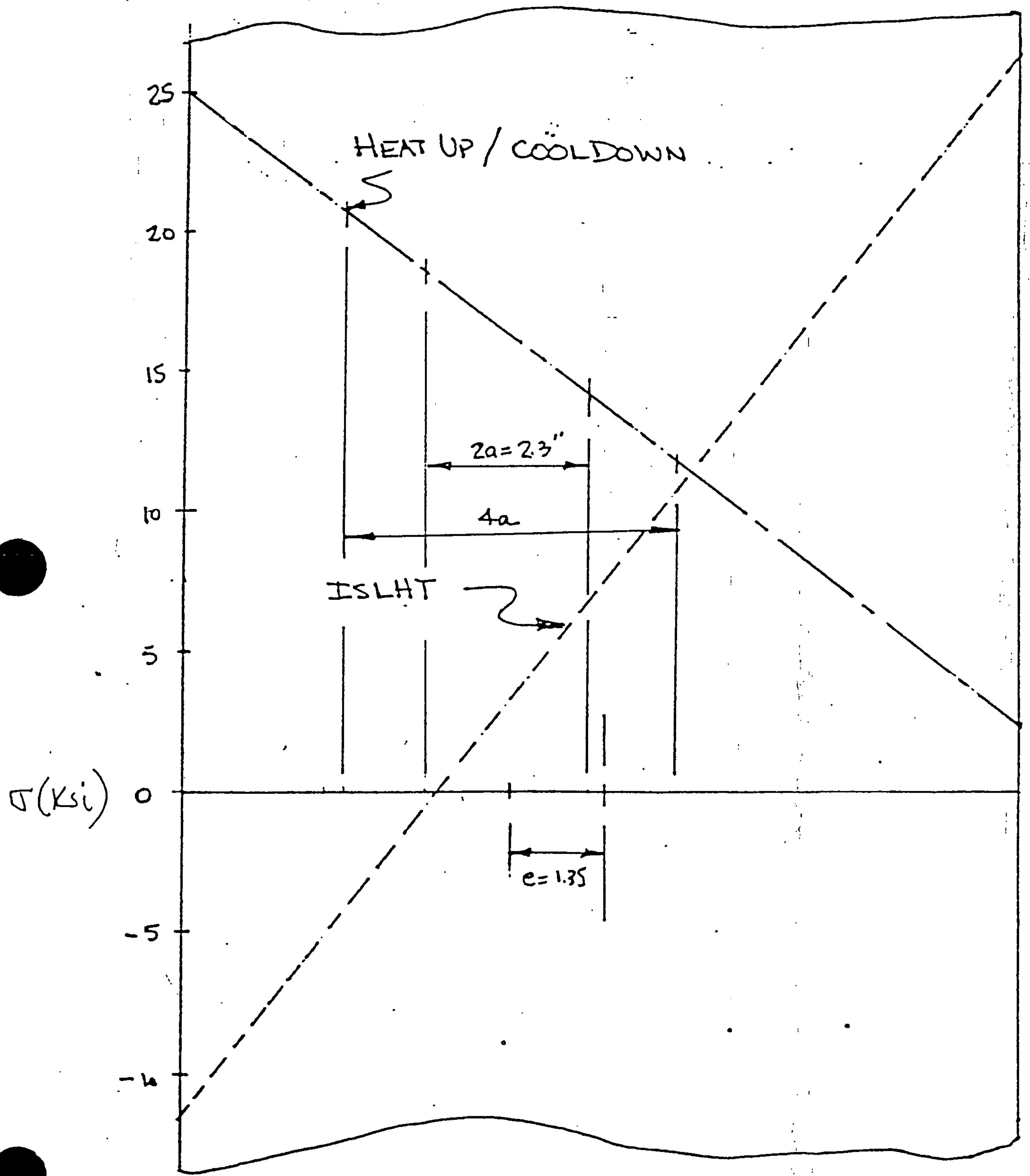
THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:

CODE / VERSION / REV	CODE / VERSION / REV

PAGE	DESCRIPTION	REV. LEVEL
ALL	ORIGINAL ISSUE	00
1	NEW CDS	01
2	REVISION DESCRIPTION	
23 thru 28, B1 thru B9	PAGES ADDED	

WHR ~~4/23/86~~ 11-18-86 GJW ~~4/24/86~~ 11/21/86

INDICATION # 18/19



WM 4/23/86 AFW 4/24/86

ER 86-019 Indication No. 18/19 Combined

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.15000 IN

INITIAL FLAW LENGTH = 4.40000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.35000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	1.1500	1.1516
2	7.65	18.65	100.0	1.1516	1.1519

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.028

BENDING STRESS CORRECTION FACTOR MB = 0.333

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 28.15 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 7.10

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF 3000 ARE SATISFIED FOR THE FLAWED SECTION

WAH 4/23/86 JJW 4/24/86

$$K_I = \sigma_m M_m \sqrt{\pi}\sqrt{a/Q} + \sigma_b M_b \sqrt{\pi}\sqrt{a/Q}$$

$$da/dN = C_o(\Delta K)^n$$

$$= 2.67 \times 10^{-11} (\Delta K)^{3.726}$$

AFTER INTEGRATION:

$$a_f = \left\{a_i^{-.863} - .863(2.67\times10^{-11})\left[(\Delta\sigma_m M_m + \Delta\sigma_b M_b)\sqrt{\pi/Q}\right]^{3.726} \Delta N\right\}^{-1.1587}$$

CORRELATION:

$$a_{f_1} = \left\{(1.15)^{-.863} - 2.3\times10^{-11}\left[(13.65\times1.028 + 11.35\times.33)\sqrt{\pi/1.449}\right]^{3.726} 240\right\}^{-1.1587}$$

$$= 1.1516 \text{ IN.}$$

$$a_{f_2} = \left\{(a_{f_1})^{-.863} - 2.3\times10^{-11}\left[(7.65\times1.028 + 18.65\times.33)\sqrt{\pi/1.449}\right]^{3.726} 100\right\}^{-1.1587}$$

$$= 1.1519 \text{ IN}$$

$$K_I = (13.65\times1.028 + 11.35\times.33)(\sqrt{\pi/1.449})\sqrt{1.1519} = 28.15 \text{ KSI}\sqrt{\text{IN}}$$

WHR 4/23/86 AFW 4/24/86

32-1164054-00

ER 86-019 Indication No. 18/19 Combined (100 % Increase in Size)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.30000 IN

INITIAL FLAW LENGTH = 8.80000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.35000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

GUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.3000	2.3097
2	7.65	18.65	100.0	2.3097	2.3117

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.133

BENDING STRESS CORRECTION FACTOR MB = 0.436

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 45.68 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 4.38

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF -3000 ARE SATISFIED FOR THE FLAWED SECTION

WHR 4/23/86 GJW 4/24/86

ER 86-019 Indication No. 18/19 Combined (Maximum Subsurface Indication)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 3.33500 IN

INITIAL FLAW LENGTH = 12.76000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.35000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

[illegible]GUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	3.3350	3.3744
2	7.65	18.65	100.0	3.3744	3.3829

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.345

BENDING STRESS CORRECTION FACTOR MB = 0.550

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 66.64 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.00

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS NOT ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL
(1977 EDITION THROUGH SUMMER 1978 ADDENDA)

WHL - 4/23/86 AFW 4/24/86

ER 86-019 Indication No. 18/19 (96% of Maximum Subsurface)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 3.19000 IN

INITIAL FLAW LENGTH = 12.20500 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.35000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

[illegible]IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	3.1900	3.2222
2	7.65	18.65	100.0	3.2222	3.2291

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.306

BENDING STRESS CORRECTION FACTOR MB = 0.531

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 63.12 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.17

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF [illegible]-3000 ARE SATISFIED FOR THE FLAWED SECTION

WJM 4/24/86 GJW 4/24/86

32-1164054-00

ER 86-019 Indication No. 19/19 Combined (Treated as a Surface Indication)

FLAW TYPE : SURFACE

INITIAL FLAW DEPTH, (A) = 6.00000 IN

INITIAL FLAW LENGTH = 12.00000 IN

WALL THICKNESS = 12.00000 IN

KI CALCULATED AT PERIPHERY OF SURFACE FLAW WHERE BETA = 0.0 DEG

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.379E-09

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

FATIGUE CRACK GROWTH :

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	6.0000	6.2243
2	7.65	18.65	100.0	6.2243	6.2591

FLAW SHAPE PARAMETER Q = 2.411

MEMBRANE STRESS CORRECTION FACTOR MM = 1.100

BENDING STRESS CORRECTION FACTOR MB = 0.298

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 52.54 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.81

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WAM 4/23/86 AJW 4/24/86

32-1164054-00

ER 86-019 Indication No. 18/19 Combined (Treated as a Surface Indication)

FLAW TYPE : SURFACE

INITIAL FLAW DEPTH, (A) = 6.00000 IN

INITIAL FLAW LENGTH = 12.00000 IN

WALL THICKNESS = 12.00000 IN

KI CALCULATED AT PERIPHERY OF SURFACE FLAW WHERE BETA = 0.0 DEG

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.379E-09

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

[illegible]IGUE CRACK GROWTH :

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	1800.0	6.0000	8.3046
2	7.65	18.65	100.0	8.3046	8.3664

FLAW SHAPE PARAMETER Q = 2.411

MEMBRANE STRESS CORRECTION FACTOR MM = 1.116

BENDING STRESS CORRECTION FACTOR MB = 0.298

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE. KI = 61.49 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.25

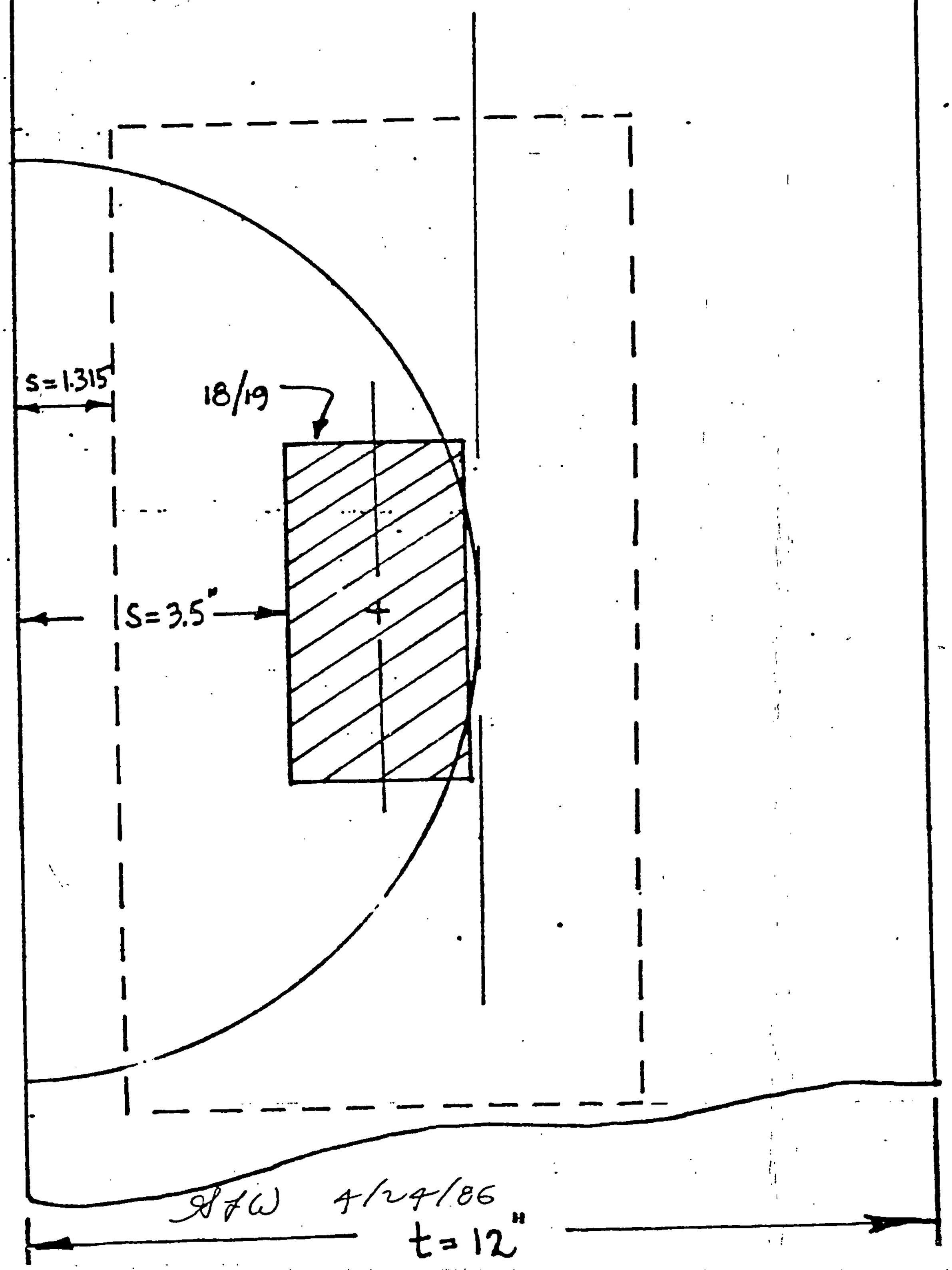
ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF [illegible]-3000 ARE SATISFIED FOR THE FLAWED SECTION

WM 4/23/86 GLW 4/24/86

32-1164054-00

$a = 3.335 \rightarrow 7.985$
$s = 1.315$
$l = 12.76$
$a/t = .665 > .5$ (CUTOFF)



WAL
4/23/86

[signature] 4/24/86

ER 86-019 Indication No. 18/19 Combined (Excess Cycles Evaluated)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.15000 IN

INITIAL FLAW LENGTH = 4.40000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.35000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

FATIGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	50000.0	1.1500	1.8211
2	7.65	18.65	100.0	1.8211	1.8220

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.078

BENDING STRESS CORRECTION FACTOR MB = 0.389

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 38.01 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

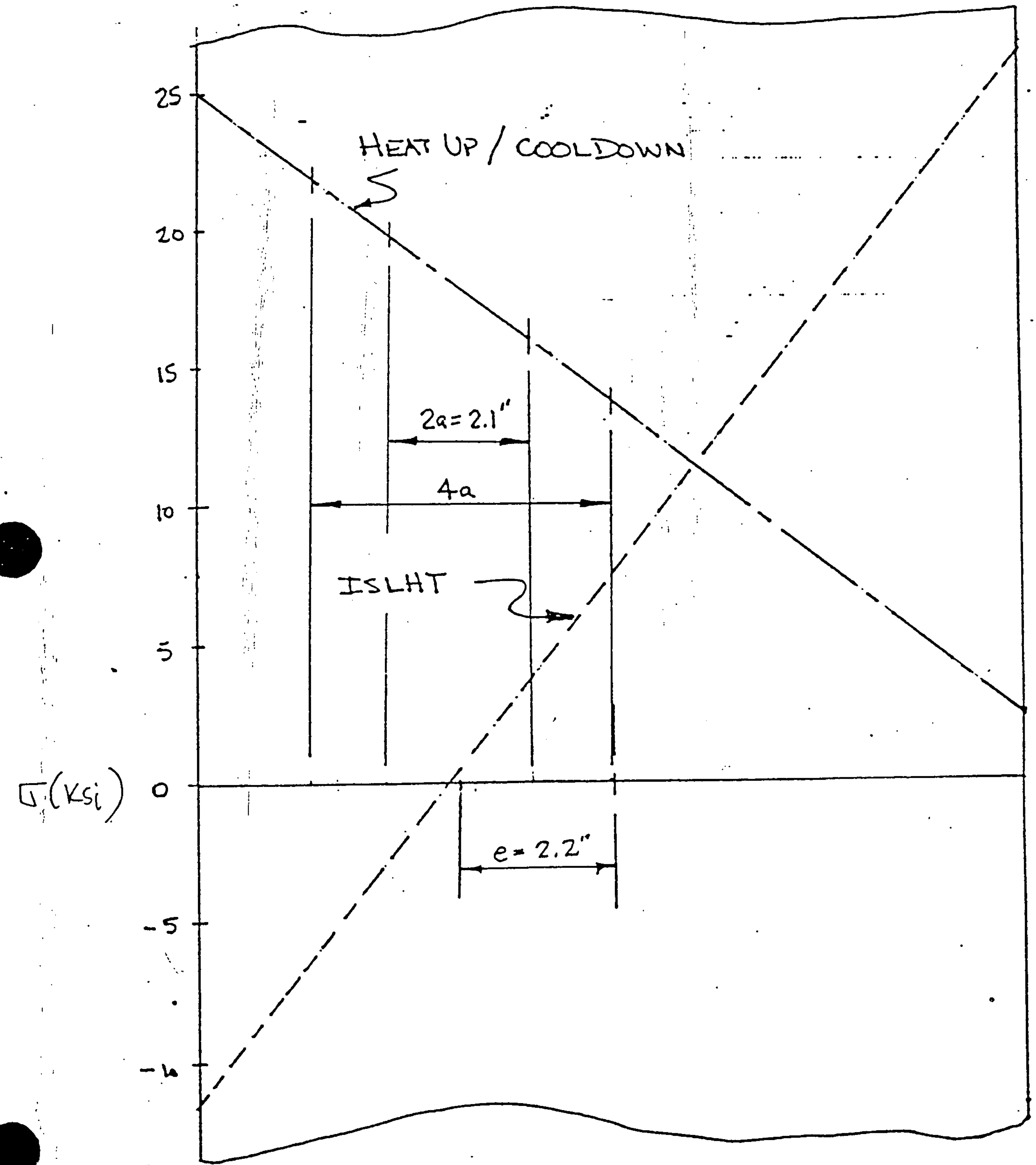
RATIO, KIA/KI = 5.26

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WM 4/23/86 DJW 4/24/86

INDICATION #4



WM 4/23/86   AFW 4/24/86

ER 86-019 Indication No. 4

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.05000 IN

INITIAL FLAW LENGTH = 5.40000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.20000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

GUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	1.0500	1.0525
2	7.65	18.65	100.0	1.0525	1.0531

FLAW SHAPE PARAMETER Q = 1.255

MEMBRANE STRESS CORRECTION FACTOR MM = 1.031

BENDING STRESS CORRECTION FACTOR MB = 0.475

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 31.60 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 6.33

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF 3000 ARE SATISFIED FOR THE FLAWED SECTION

WHM 4/23/86 JTW 4/24/86

ER 86-019 Indication No. 4 (100 % Increase in Size)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.10000 IN

INITIAL FLAW LENGTH = 10.80000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.20000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.1000	2.1145
2	7.65	18.65	100.0	2.1145	2.1182

FLAW SHAPE PARAMETER Q = 1.255

MEMBRANE STRESS CORRECTION FACTOR MM = 1.141

BENDING STRESS CORRECTION FACTOR MB = 0.572

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 50.82 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.94

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WBR 4/23/86 DJW 4/24/86

ER 86-019 Indication No. 4 (Maximum Subsurface Indication)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.73000 IN

INITIAL FLAW LENGTH = 14.04000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.20000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

[illegible]IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT	STRESS RANGES (KSI)		NO. OF	FLAW DEPTH (IN)	
NO.	MEMBRANE	BENDING	CYCLES	INITIAL	FINAL
1	13.65	11.35	240.0	2.7300	2.7661
2	7.65	18.65	100.0	2.7661	2.7756

FLAW SHAPE PARAMETER Q = 1.255

MEMBRANE STRESS CORRECTION FACTOR MM = 1.275

BENDING STRESS CORRECTION FACTOR MB = 0.643

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 65.11 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 3.07

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS NOT ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL
(1977 EDITION THROUGH SUMMER 1978 ADDENDA)

WHR 4/23/86 GLW 4/24/86

ER 86-019 Indication No. 4 (97% of Maximum Subsurface)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.65000 IN

INITIAL FLAW LENGTH = 13.62900 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.20000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.6500	2.6819
2	7.65	18.65	100.0	2.6819	2.6904

FLAW SHAPE PARAMETER Q = 1.255

MEMBRANE STRESS CORRECTION FACTOR MM = 1.251

BENDING STRESS CORRECTION FACTOR MB = 0.635

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 63.02 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

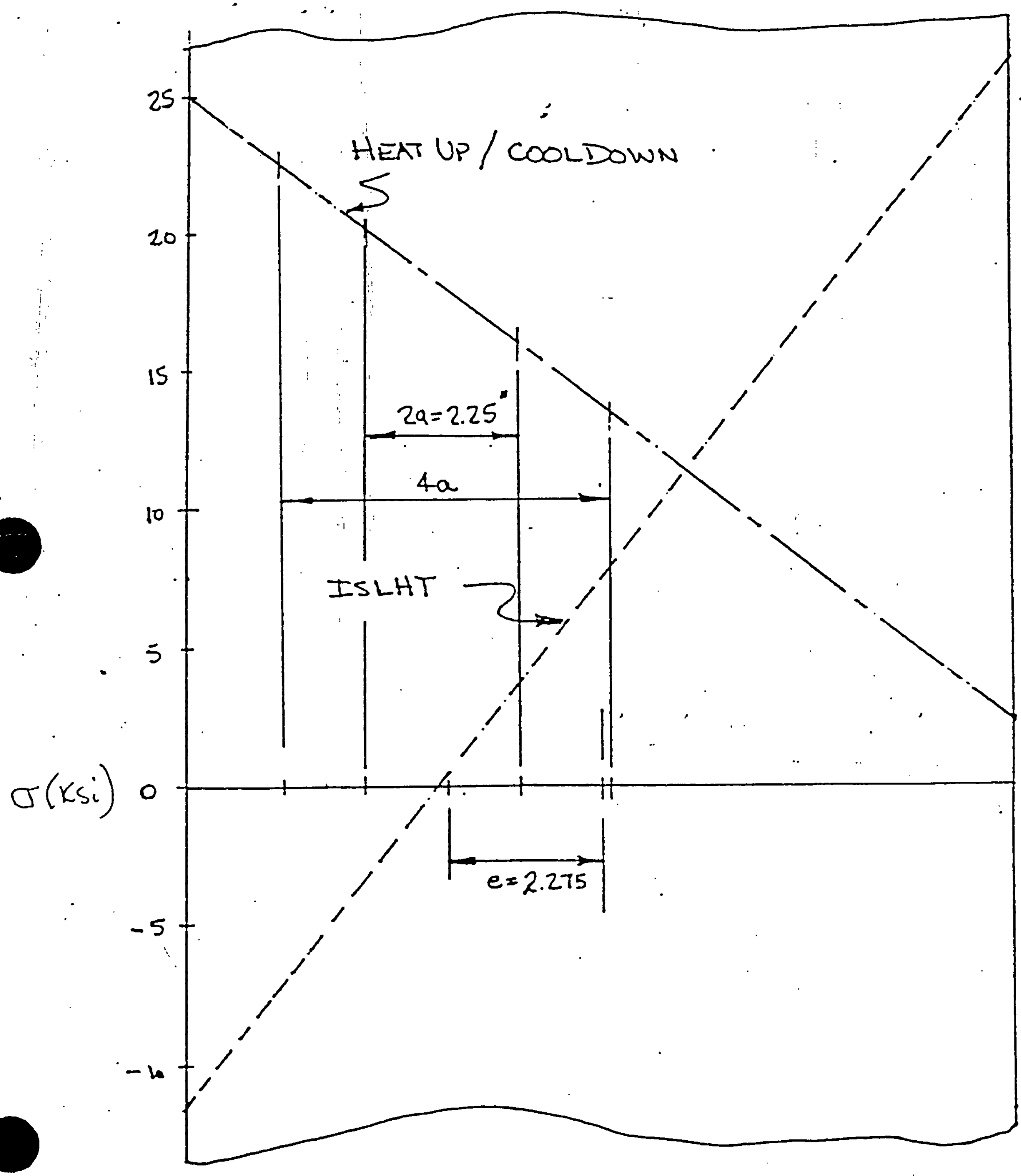
RATIO, KIA/KI = 3.17

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF B-3000 ARE SATISFIED FOR THE FLAWED SECTION

WHR 4/24/86 GJW 4/24/86

INDICATION # 8



WHR 4/23/86 DFW 4/24/86

ER 86-019 Indication No. 8

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.12500 IN

INITIAL FLAW LENGTH = 2.25000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.27500 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

[illegible]IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	1.1250	1.1259
2	7.65	18.65	100.0	1.1259	1.1261

FLAW SHAPE PARAMETER Q = 2.411

MEMBRANE STRESS CORRECTION FACTOR MM = 1.030

BENDING STRESS CORRECTION FACTOR MB = 0.495

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 23.97 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 8.34

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITION THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF [illegible]-3000 ARE SATISFIED FOR THE FLAWED SECTION

Wm 4/23/86 AJW 4/24/86

ER 86-019 Indication No. 8 (100 % Increase in Size)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.25000 IN

INITIAL FLAW LENGTH = 4.50000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.27500 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

[illegible]IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.2500	2.2555
2	7.65	18.65	100.0	2.2555	2.2570

FLAW SHAPE PARAMETER Q = 2.411

MEMBRANE STRESS CORRECTION FACTOR MM = 1.174

BENDING STRESS CORRECTION FACTOR MB = 0.602

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 39.20 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 5.10

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF [illegible]-3000 ARE SATISFIED FOR THE FLAWED SECTION

WHR 4/23/86 AFW 4/24/86

ER 86-019 Indication No. 8 (Maximum Subsurface Indication)

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 2.70000 IN

INITIAL FLAW LENGTH = 5.40000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 2.27500 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

[illegible]IGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	2.7000	2.7102
2	7.65	19.65	100.0	2.7102	2.7129

FLAW SHAPE PARAMETER Q = 2.411

MEMBRANE STRESS CORRECTION FACTOR MM = 1.261

BENDING STRESS CORRECTION FACTOR MB = 0.650

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 46.24 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 4.33

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WHR 4/23/86 AFW 4/24/86

Babcock & Wilcox
a McDermott company
Nuclear Power Generation Division

PDS-21036.1 (9-81)

GENERAL CALCULATIONS

SUMMARY OF RESULTS

INDICATION #18/19

a_i =	1.15	2.30	3.335	3.19	6.0	6.0	1.15
ℓ =	4.4	8.80	12.76	12.205	12.0	12.0	4.40
e =	1.35	1.35	1.35	1.35	0	0	1.35
a_f =	1.1515	2.3090	3.3829	3.2291	6.2591	8.3664*	1.822**
K_{Ia}/K_I =	7.53	4.66	3.0	3.17	3.81	3.25	5.26

3.0 — DOESN'T MEET CRITERIA

* N = 1800 CYCLES
** N = 5000 CYCLES

INDICATION #4

a_i =	1.05	2.10	2.73	2.65
ℓ =	5.40	10.80	14.04	13.63
e =	2.20	2.20	2.20	2.20
a_f =	1.0531	2.1182	2.7756	2.6904
K_{Ia}/K_I =	6.33	3.94	3.03	3.17

3.03 — DOESN'T MEET CRITERIA

INDICATION #8

a_i =	1.125	2.25	2.70
ℓ =	2.25	4.50	5.40
e =	2.275	2.275	2.275
a_f =	1.1261	2.257	2.7129
K_{Ia}/K_I =	8.34	5.10	4.33

PREPARED BY WL Redd DATE 4-24-86 DOC. NO.
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ITEM 1

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ER 86-019 Indication No. 3/4 Combined

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.05000 IN

INITIAL FLAW LENGTH = 7.60000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.66000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

FATIGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	1.0500	1.0524
2	7.65	18.65	100.0	1.0524	1.0529
3	2.86	2.86	18000.0	1.0529	1.0535

FLAW SHAPE PARAMETER Q = 1.122

MEMBRANE STRESS CORRECTION FACTOR MM = 1.024

BENDING STRESS CORRECTION FACTOR MB = 0.379

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 31.39 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 6.37

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

WLR 11-18-86 SJW 11/21/86

Item 1

Z2-1164054-01

ER 86-019 Indication No. 18/19 Combined

FLAW TYPE : SUBSURFACE

INITIAL FLAW DEPTH, (A) = 1.15000 IN

INITIAL FLAW LENGTH = 4.40000 IN

WALL THICKNESS = 12.00000 IN

ECCENTRICITY OF SUBSURFACE FLAW = 1.66000 IN

CRACK TIP TEMPERATURE = 275.0 F

REFERENCE NIL DUCTILITY TEMPERATURE = 20.0 F

YIELD STRENGTH = 50.00 KSI

SCALING CONSTANT USED IN PARIS EQUATION = 0.267E-10

EXPONENT USED IN PARIS EQUATION = 3.726

MEMBRANE STRESS = 13.65 KSI

BENDING STRESS = 11.35 KSI

FATIGUE CRACK GROWTH : POINT 1 LOCATION IS CRITICAL

TRANSIENT NO.	STRESS RANGES (KSI) MEMBRANE	BENDING	NO. OF CYCLES	FLAW DEPTH (IN) INITIAL	FINAL
1	13.65	11.35	240.0	1.1500	1.1518
2	7.65	18.65	100.0	1.1518	1.1522
3	2.86	2.86	18000.0	1.1522	1.1527

FLAW SHAPE PARAMETER Q = 1.449

MEMBRANE STRESS CORRECTION FACTOR MM = 1.030

BENDING STRESS CORRECTION FACTOR MB = 0.388

STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = 29.19 KSI ROOT INCH

CRACK ARREST STRESS INTENSITY FACTOR, KIA = 200.00 KSI ROOT INCH

RATIO, KIA/KI = 6.85

ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16

THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOILER AND PRESSURE VESSEL CODE (1977 EDITON THROUGH SUMMER 1978 ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF NB-3000 ARE SATISFIED FOR THE FLAWED SECTION

NLR 11-18-86 AJW 11/21/86

ITEM 2

ASSUMPTIONS:

1) SERVICE INDUCED GROWTH SINCE 1981
2) LINEAR (NON-CODE) GROWTH RATE
3) ORIGINAL MEASURED LENGTH USED

CYCLES CONTRIBUTING TO STRESS = 30 HU/CD
(5 YEARS x 240 CYC/40 YRS)

NEXT INSPECTION ≡ 18 MOS = 9 CYCLES

$da/dN = 1.15/30 = .038333$ IN/CYCLE

$a_f = a_i + \delta a = 1.15 + .038333(9) = 1.495$ IN

$K_I = (13.65 \times 1.052 + 11.35 \times .417)\sqrt{\pi}/1.721 \sqrt{1.495}$

$= 31.54$ KSI$\sqrt{\text{IN}}$

$K_{Ia}/K_I = 200/31.54 = 6.34 > 3.16$ OK!

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AS PART OF THE REQUIREMENTS OF THE ASME, B & PV CODE, SECTION XI, SUBARTICLE IWB-3610, IT IS NECESSARY TO SHOW THAT THE PRIMARY STRESS LIMITS OF SECTION III, ARTICLE NB-3000 ARE SATISFIED ASSUMING A LOCAL AREA REDUCTION OF THE PRESSURE RETAINING MEMBRANE THAT IS EQUAL TO THE AREA OF THE DETECTED INDICATION(S).

THE CODE STRESS REPORT WAS UTILIZED TO:

1) SHOW THAT THE FLAWS WERE BEYOND THE REQUIRED AREA OF REINFORCEMENT FOR THE INLET AND OUTLET NOZZLE HENCE CONFIRMING ADDITIONAL THICKNESS EXIST BEYOND THAT REQUIRED AND;

2) EXTRACT THE PREVIOUSLY DETERMINED PRIMARY STRESSES TO ASSESS THE EFFECTS OF THE FLAWS ON THE CROSS SECTION

CALCULATED BELOW ARE THE CODE ADJUSTED STRESSES:

$$P_L = 12.7 \left(\frac{12}{12-2.99}\right) = 16.9 \text{ ksi} < 40 \text{ ksi ALLOWABLE}$$

$$P_L + P_b = 16.8 \left(\frac{12}{12-2.99}\right) = 22.4 \text{ ksi} < 40 \text{ ksi ALLOWABLE}$$

WLR 11-18-86 JJW 11/21/86

Babcock & Wilcox
a McDermott company
Nuclear Power Generation Division

32-1164054-01

PDS-21036.1 (9-81)

GENERAL CALCULATIONS

ITEM 3

JUSTIFICATION FOR UN-ANALIZED TRANSIENTS

A question was raised as to the effect of system transients in addition to the Heatup/Cooldown (HU/CD) and Inservice Leak and Hydrostatic Test (ISLHT) transients considered in the B&W analysis. The specific concern was whether some large cyclic transients, although not necessarily of high stress, could be significant to flaw evaluation.

It was noted by B&W that the flaw evaluations performed were in accordance with B&W's original stress report, which considered only the two transients (HU/CD and ISLHT) as significant in the flaw growth calculations. Review of the original stress report showed that other transients induce stresses less than the endurance limit stress, and thus do not affect the fatigue usage factor.

To address the question raised, the functional specification was reviewed with respect to transients with large numbers of cycles. Four transients fall into this category: 1) Power Loading/Unloading, 2) 10 percent Step Load Increase/Decrease, 3) Feed and Bleed, and 4) Miscellaneous. The temperature variation on the RV due to these transients is 20, 5, 0, and 0 degrees Fahrenheit respectively.

The effect of the most significant of these four transients, the Power Loading/Unloading transient, was evaluated. A thermal stress (1.43E $\alpha \Delta T$) of 5.7 ksi was assumed to vary linearly from the ID to the OD. This is a very conservative assumption since this stress is actually a surface stress which rapidly decays and probably has a zero value at the tips of the subsurface flaw. The transient membrane and bending stresses and cycles were input as a third transient into the FLEP (Section XI, Appendix A) flaw evaluation program. (This evaluation also includes a correction to the eccentricity as a result of recalculating the edge distance(s).)

The results of this calculation are attached for the worst case indication (ER 86-019 Indication No. 18/19 combined). A comparison of these results with and without the effect of the Power Loading/Unloading transient included, shows this transient to have an insignificant effect on the flaw evaluation.

PREPARED BY WLR	DATE 11-18-86	DOC. NO.
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Evaluations of the indications have been made using the Design, Normal and Upset transients as specifed in the Reactor Coolant System Functional Specification invoked on the Reactor Vessel.

This area of the Reactor Vessel, i.e., Closure Flange to Upper Nozzle Belt forging, is above the inlet and outlet nozzles and is remote from the core's fluence, hence its chemical properties remain constant.

Unanticipated transients which would require consideration from the standpoint of flaw growth such as Pressurized Thermal Shock (PTS), NRC Stylized, Rancho Seco, Main Steam Line Break (MSLB), Small Break LOCA and Control System Malfunctions have little, if any, impact on the area in which the postulated indications are assumed and would show larger margins of safety than have been determined because of the acceptability criteria (K_{Ia}/K_I must be greater than $\sqrt{2}$ vs. $\sqrt{10}$).

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APPENDIX A

IBM PC PROGRAM FLEP

(PC VERSION OF NPD-TM-5)

GLW 4/24/86

```
      PROGRAM FLEP
      DIMENSION X1(15),Z1(9),Y1(15,9),X2(11),Z2(6),Y2(11,6),X3(13),Z3(6)
     *,Y3(13,6),X4(8),Z4(4),Y4(8,4),X5(13),Z5(6),Y5(13,6),X6(8),Z6(4),Y6
     *(8,4),SMR(20),SBR(20),XNCYCLE(20),TITLE(20),AI(20),AF(20),AI2(20),
     *AF2(20)
      REAL MM,MB,KI,KIA,MM2,MB2,KI2
C**** DATA INPUT FOR MM FACTOR FOR SURFACE FLAW
      DATA(X1(I),I=1,15)/.00,.05,.10,.15,.20,.25,.30,.35,.40,.45,.50,.55
     *,.60,.65,.70/
      DATA(Z1(I),I=1,9)/.00,.05,.10,.15,.20,.25,.30,.35,.50/
      DATA((Y1(K,L),L=1,9),K=1,15)/
     *1.112,1.105,1.100,1.100,1.100,1.100,1.100,1.100,1.100,
     *1.128,1.121,1.102,1.100,1.100,1.100,1.100,1.100,1.100,
     *1.188,1.149,1.121,1.110,1.100,1.100,1.100,1.100,1.100,
     *1.259,1.192,1.151,1.130,1.108,1.100,1.100,1.100,1.100,
     *1.367,1.257,1.195,1.158,1.125,1.112,1.104,1.100,1.100,
     *1.514,1.346,1.253,1.195,1.151,1.130,1.114,1.100,1.100,
     *1.703,1.452,1.320,1.238,1.182,1.151,1.127,1.100,1.100,
     *1.956,1.584,1.406,1.294,1.221,1.179,1.143,1.100,1.100,
     *9.000,1.739,1.508,1.354,1.264,1.208,1.162,1.100,1.100,
     *9.000,1.930,1.631,1.428,1.318,1.244,1.186,1.100,1.100,
     *9.000,9.000,1.776,1.523,1.381,1.283,1.214,1.100,1.100,
     *9.000,9.000,1.934,1.646,1.452,1.328,1.242,1.100,1.100,
     *9.000,9.000,9.000,1.800,1.543,1.385,1.274,1.104,1.104,
     *9.000,9.000,9.000,1.975,1.644,1.443,1.309,1.110,1.110,
     *9.000,9.000,9.000,9.000,1.765,1.514,1.359,1.117,1.117/
C**** DATA INPUT FOR MB FACTOR FOR SURFACE FLAW WITH BETA=0. DEG
      DATA(X2(I),I=1,11)/.00,.05,.10,.15,.20,.25,.30,.35,.40,.45,.50/
      DATA(Z2(I),I=1,6)/.0,.1,.2,.3,.4,.5/
      DATA((Y2(K,L),L=1,6),K=1,11)/
     *1.101,1.076,1.067,1.042,1.031,1.023,
     *1.059,1.024,0.995,0.979,0.965,0.950,
     *1.037,0.977,0.927,0.912,0.897,0.879,
     *1.034,0.934,0.869,0.848,0.828,0.806,
     *1.045,0.895,0.810,0.781,0.758,0.734,
     *1.072,0.862,0.758,0.718,0.693,0.662,
     *1.117,0.836,0.709,0.658,0.620,0.590,
     *1.178,0.820,0.665,0.597,0.550,0.514,
     *1.256,0.815,0.626,0.548,0.485,0.444,
     *1.356,0.829,0.591,0.481,0.412,0.371,
     *1.478,0.866,0.561,0.420,0.343,0.298/
C**** DATA INPUT FOR MM FACTOR FOR SUBSURFACE FLAW AT POINT 1
      DATA(X3(I),I=1,13)/.00,.05,.10,.15,.20,.25,.30,.35,.40,.45,.50,.55
     *,.60/
      DATA(Z3(I),I=1,6)/.15,.25,.35,.45,.55,.65/
      DATA((Y3(K,L),L=1,6),K=1,13)/
     *1.010,1.037,1.080,1.139,1.234,1.366,
     *1.010,1.038,1.081,1.144,1.247,1.380,
     *1.011,1.041,1.085,1.152,1.264,1.402,
     *1.012,1.043,1.091,1.165,1.285,1.430,
     *1.013,1.046,1.099,1.179,1.308,1.466,
     *1.014,1.050,1.111,1.196,1.336,1.524,
     *1.015,1.054,1.123,1.216,1.368,1.587,
     *1.018,1.062,1.136,1.243,1.407,9.000,
     *1.022,1.070,1.151,1.274,1.463,9.000,
     *1.028,1.082,1.170,1.309,9.000,9.000,
     *1.033,1.095,1.190,1.346,9.000,9.000,
     *1.041,1.112,1.212,1.390,9.000,9.000,
     *1.052,1.132,1.238,1.443,9.000,9.000/
C**** DATA INPUT FOR MB FACTOR FOR SUBSURFACE FLAW AT POINT 1
      DATA(X4(I),I=1,8)/.0,.1,.2,.3,.4,.5,.6,.7/
      DATA(Z4(I),I=1,4)/.1,.3,.5,.7/
      DATA((Y4(K,L),L=1,4),K=1,8)/
```

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```
     *0.155,0.252,0.361,0.494,
     *0.261,0.361,0.474,0.618,
     *0.365,0.468,0.590,0.748,
     *0.471,0.577,0.706,0.894,
     *0.568,0.687,0.832,9.000,
     *0.671,0.816,0.984,9.000,
     *0.765,0.961,9.000,9.000/
C**** DATA INPUT FOR MM FACTOR FOR SUBSURFACE FLAW AT POINT 2
      DATA(X5(I),I=1,13)/.00,.05,.10,.15,.20,.25,.30,.35,.40,.45,.50,.55
     *,.60/
      DATA(Z5(I),I=1,6)/.15,.25,.35,.45,.55,.65/
      DATA((Y5(K,L),L=1,6),K=1,13)/
     *1.010,1.037,1.080,1.139,1.232,1.361,
     *1.010,1.037,1.077,1.134,1.231,1.361,
     *1.011,1.038,1.077,1.132,1.232,1.363,
     *1.012,1.039,1.080,1.135,1.237,1.367,
     *1.013,1.039,1.084,1.141,1.244,1.373,
     *1.014,1.041,1.089,1.149,1.253,1.382,
     *1.015,1.042,1.094,1.157,1.264,1.393,
     *1.016,1.047,1.104,1.172,1.277,9.000,
     *1.016,1.052,1.112,1.191,1.293,9.000,
     *1.018,1.061,1.125,1.212,9.000,9.000,
     *1.021,1.072,1.139,1.237,9.000,9.000,
     *1.028,1.086,1.156,1.266,9.000,9.000,
     *1.037,1.105,1.179,1.298,9.000,9.000/
C**** DATA INPUT FOR MB FACTOR FOR SUBSURFACE FLAW AT POINT 2
      DATA(X6(I),I=1,8)/.0,.1,.2,.3,.4,.5,.6,.7/
      DATA(Z6(I),I=1,4)/.1,.3,.5,.7/
      DATA((Y6(K,L),L=1,4),K=1,8)/
     *-.050,-.158,-.258,-.382,
     *0.045,-.054,-.158,-.281,
     *0.152,0.055,-.050,-.171,
     *0.255,0.163,0.052,-.065,
     *0.358,0.268,0.159,0.058,
     *0.458,0.373,0.272,0.185,
     *0.570,0.490,0.398,0.313,
     *0.671,0.608,0.526,0.435/
      READ 5,NFLAW
      DO  10 K=1,NFLAW
      READ 15,(TITLE(I),I=1,20)
      PRINT 20,(TITLE(I),I=1,20)
      READ 25,NTYPE,A,XLL,E,T,BETA,NTRAN,SM,SB
      READ 30,TEMP,SYIELD,RTNDT,C,XN,KI,KIA
      READ 35,(SMR(I),SBR(I),XNCYCLE(I),I=1,NTRAN)
      IF(NTYPE.EQ.2) GO TO 40
      PRINT 45
      GO TO 50
   40 PRINT 55
   50 PRINT 60,A,XLL,T
      IF(NTYPE.EQ.1) GO TO 75
      PRINT 80,E
      GO TO 85
   75 PRINT 90,BETA
   85 PRINT 95,TEMP,RTNDT
      WKI=KI
      IF(KI.NE.0.0) GO TO 281
      PRINT 105,SYIELD
      PRINT 110,C
      PRINT 120,XN
      PRINT 125,SM,SB
      LL=1
      A1=A
      XL=XLL
      X=A/XLL
      IF(X.GT.0.5) GO TO 135
```

```
  140 IF(NTYPE.EQ.2) GO TO 145
C**** DETERMINE MM FACTOR FOR SURFACE FLAW
      KEY=1
      XX=A1/T
      ZZ=A1/XL
      DO 150 I1=1,15
  150 IF(X1(I1).GE.XX) GO TO 155
      GO TO 135
  155 IP1=I1
      II1=I1-1
      DO 160 J1=1,9
  160 IF(Z1(J1).GE.ZZ) GO TO 165
      GO TO 135
  165 JP1=J1
      JJ1=J1-1
      DX1=(XX-X1(II1))/(X1(IP1)-X1(II1))
      DZ1=(ZZ-Z1(JJ1))/(Z1(JP1)-Z1(JJ1))
      IF(Y1(II1,JJ1).GT.2.) GO TO 135
      IF(Y1(IP1,JJ1).GT.2.) GO TO 135
      IF(Y1(II1,JP1).GT.2.) GO TO 135
      IF(Y1(IP1,JP1).GT.2.) GO TO 135
      YA1=Y1(II1,JJ1)+DX1*(Y1(IP1,JJ1)-Y1(II1,JJ1))
      YB1=Y1(II1,JP1)+DX1*(Y1(IP1,JP1)-Y1(II1,JP1))
      MM=YA1+DZ1*(YB1-YA1)
      IF(BETA.EQ.90.) GO TO 175
C**** DETERMINE MB FACTOR FOR SURFACE FLAW AT BETA=0 DEGREES
      IF(LL.EQ.1) GO TO 200
      IF(XX.GT.0.25) GO TO 215
      GO TO 205
  215 IF(ZZ.GT.0.1) GO TO 205
  200 DO 180 I2=1,11
  180 IF(X2(I2).GE.XX) GO TO 185
      GO TO 135
  185 IP2=I2
      II2=I2-1
      DO 190 J2=1,6
  190 IF(Z2(J2).GE.ZZ) GO TO 195
      GO TO 135
  195 JP2=J2
      JJ2=J2-1
      DX2=(XX-X2(II2))/(X2(IP2)-X2(II2))
      DZ2=(ZZ-Z2(JJ2))/(Z2(JP2)-Z2(JJ2))
      YA2=Y2(II2,JJ2)+DX2*(Y2(IP2,JJ2)-Y2(II2,JJ2))
      YB2=Y2(II2,JP2)+DX2*(Y2(IP2,JP2)-Y2(II2,JP2))
      MB=YA2+DZ2*(YB2-YA2)
      GO TO 205
C**** DETERMINE MB FACTOR FOR SURFACE FLAW AT BETA=90 DEGREES
  175 IF(LL.GT.1) GO TO 205
      IF(XX.GT.0.5) GO TO 135
      IF(ZZ.GT.0.3) GO TO 135
      IF(ZZ.LT.0.2) GO TO 135
      DX2=(XX-0.0)/(0.5-0.0)
      DZ2=(ZZ-0.2)/(0.3-0.2)
      YA2=0.821+DX2*(0.805-0.821)
      YB2=0.956+DX2*(0.892-0.956)
      MB=YA2+DZ2*(YB2-YA2)
      GO TO 205
C**** DETERMINE MM FACTOR FOR SUBSURFACE FLAW AT POINT 1
  145 XX=2.*E/T
      ZZ=2.*A1/T
      DO 220 I3=1,13
  220 IF(X3(I3).GE.XX) GO TO 225
      GO TO 135
  225 IP3=I3
      II3=I3-1
```

```
230 IF(Z3(J3).GE.ZZ) GO TO 235
    GO TO 135
235 JP3=J3
    JJ3=J3-1
    DX3=(XX-X3(II3))/(X3(IP3)-X3(II3))
    DZ3=(ZZ-Z3(JJ3))/(Z3(JP3)-Z3(JJ3))
    IF(Y3(II3,JJ3).GT.2.) GO TO 135
    IF(Y3(IP3,JJ3).GT.2.) GO TO 135
    IF(Y3(II3,JP3).GT.2.) GO TO 135
    IF(Y3(IP3,JP3).GT.2.) GO TO 135
    YA3=Y3(II3,JJ3)+DX3*(Y3(IP3,JJ3)-Y3(II3,JJ3))
    YB3=Y3(II3,JP3)+DX3*(Y3(IP3,JP3)-Y3(II3,JP3))
    MM=YA3+DZ3*(YB3-YA3)
C**** DETERMINE MB FACTOR FOR SUBSURFACE FLAW AT POINT 1
    DO 240 I4=1,8
240 IF(X4(I4).GE.XX) GO TO 245
    GO TO 135
245 IP4=I4
    II4=I4-1
    DO 250 J4=1,4
250 IF(Z4(J4).GE.ZZ) GO TO 255
    GO TO 135
255 JP4=J4
    JJ4=J4-1
    DX4=(XX-X4(II4))/(X4(IP4)-X4(II4))
    DZ4=(ZZ-Z4(JJ4))/(Z4(JP4)-Z4(JJ4))
    IF(Y4(II4,JJ4).GT.2.) GO TO 135
    IF(Y4(IP4,JJ4).GT.2.) GO TO 135
    IF(Y4(II4,JP4).GT.2.) GO TO 135
    IF(Y4(IP4,JP4).GT.2.) GO TO 135
    YA4=Y4(II4,JJ4)+DX4*(Y4(IP4,JJ4)-Y4(II4,JJ4))
    YB4=Y4(II4,JP4)+DX4*(Y4(IP4,JP4)-Y4(II4,JP4))
    MB=YA4+DZ4*(YB4-YA4)
C**** DETERMINE FINAL FLAW SIZE
205 AI(1)=A
    DO 265 I=1,NTRAN
    D1=SMR(I)*MM*1.77245/(Q**0.5)
    D2=SBR(I)*MB*1.77245/(Q**0.5)
    D=D1+D2
    IF(D.LT.0.0) D=0.0
    F=(2.-XN)/2.
    AF(I)=(AI(I)**F+F*C*(D)**XN*XNCYCLE(I))**(1/F)
265 AI(I+1)=AF(I)
    IF(AF(NTRAN).LT.(1.01*A1)) GO TO 270
    A1=AF(NTRAN)
    XL=AF(NTRAN)*XLL/A
    LL=LL+1
    GO TO 140
270 IF(NTYPE.EQ.1) GO TO 271
C**** DETERMINE MM FACTOR FOR SUBSURFACE FLAW AT POINT 2
    A1=A
217 ZZ=2.*A1/T
    DO 221 I5=1,13
221 IF(X5(I5).GE.XX) GO TO 226
    GO TO 135
226 IP5=I5
    II5=I5-1
    DO 231 J5=1,6
231 IF(Z5(J5).GE.ZZ) GO TO 236
    GO TO 135
236 JP5=J5
    JJ5=J5-1
    DX5=(XX-X5(II5))/(X5(IP5)-X5(II5))
    DZ5=(ZZ-Z5(JJ5))/(Z5(JP5)-Z5(JJ5))
    IF(Y5(II5,JJ5).GT.2.) GO TO 135
```

```
      IF(Y5(II5,JP5).GT.2.) GO TO 135
      IF(Y5(IP5,JP5).GT.2.) GO TO 135
      YA5=Y5(II5,JJ5)+DX5*(Y5(IP5,JJ5)-Y5(II5,JJ5))
      YB5=Y5(II5,JP5)+DX5*(Y5(IP5,JP5)-Y5(II5,JP5))
      MM2=YA5+DZ5*(YB5-YA5)
C**** DETERMINE MB FACTOR FOR SUBSURFACE FLAW AT POINT 2
      DO 241 I6=1,8
  241 IF(X6(I6).GE.XX) GO TO 246
      GO TO 135
  246 IP6=I6
      II6=I6-1
      DO 251 J6=1,4
  251 IF(Z6(J6).GE.ZZ) GO TO 256
      GO TO 135
  256 JP6=J6
      JJ6=J6-1
      DX6=(XX-X6(II6))/(X6(IP6)-X6(II6))
      DZ6=(ZZ-Z6(JJ6))/(Z6(JP6)-Z6(JJ6))
      YA6=Y6(II6,JJ6)+DX6*(Y6(IP6,JJ6)-Y6(II6,JJ6))
      YB6=Y6(II6,JP6)+DX6*(Y6(IP6,JP6)-Y6(II6,JP6))
      MB2=YA6+DZ6*(YB6-YA6)
C**** DETERMINE FINAL FLAW SIZE FOR POINT 2 ON SUBSURFACE FLAW
      AI2(1)=A
      DO 266 I=1,NTRAN
      D1=SMR(I)*MM2*1.77245/(Q**0.5)
      D2=SBR(I)*MB2*1.77245/(Q**0.5)
      D=D1+D2
      IF(D.LT.0.0) D=0.0
      F=(2.-XN)/2.
      AF2(I)=(AI2(I)**F+F*C*(D)**XN*XNCYCLE(I))**(1/F)
  266 AI2(I+1)=AF2(I)
      IF(AF2(NTRAN).LT.(1.01*A1)) GO TO 271
      A1=AF2(NTRAN)
      GO TO 217
C**** DETERMINE STRESS INTENSITY FACTOR, KI
  271 KI=SM*MM*1.77245*(AF(NTRAN)/Q)**0.5 + SB*MB*1.77245*(AF(NTRAN)/Q)*
     1*0.5
      IF(KI.LT.0.0) KI=0.0001
      IF(NTYPE.EQ.1) GO TO 281
      KI2=SM*MM2*1.77245*(AF2(NTRAN)/Q)**0.5 + SB*MB2*1.77245*(AF2(NTRAN
     1)/Q)**0.5
      IF(KI2.LT.0.0) KI2=0.0001
      IF(KI.GT.KI2) GO TO 280
      KEY=3
      KI=KI2
      MM=MM2
      MB=MB2
      DO 279 I=1,NTRAN
      AI(I)=AI2(I)
  279 AF(I)=AF2(I)
      GO TO 281
  280 KEY=2
C**** DETERMINE CRACK ARREST STRESS INTENSITY FACTOR, KIA
  281 IF(KIA.NE.0.) GO TO 285
      KIA=1.233*(2.71828**(0.0145*(TEMP-RTNDT+160.))) + 26.78
      IF(KIA.LT.200.) GO TO 285
      KIA=200.
C**** DETERMINE RATIO OF KIA TO KI
  285 RATIO=KIA/KI
      IF(WKI.NE.0.0) GO TO 304
      IF(KEY-2)286,287,288
  286 PRINT 130
      GO TO 289
  287 PRINT 131
      GO TO 289
```

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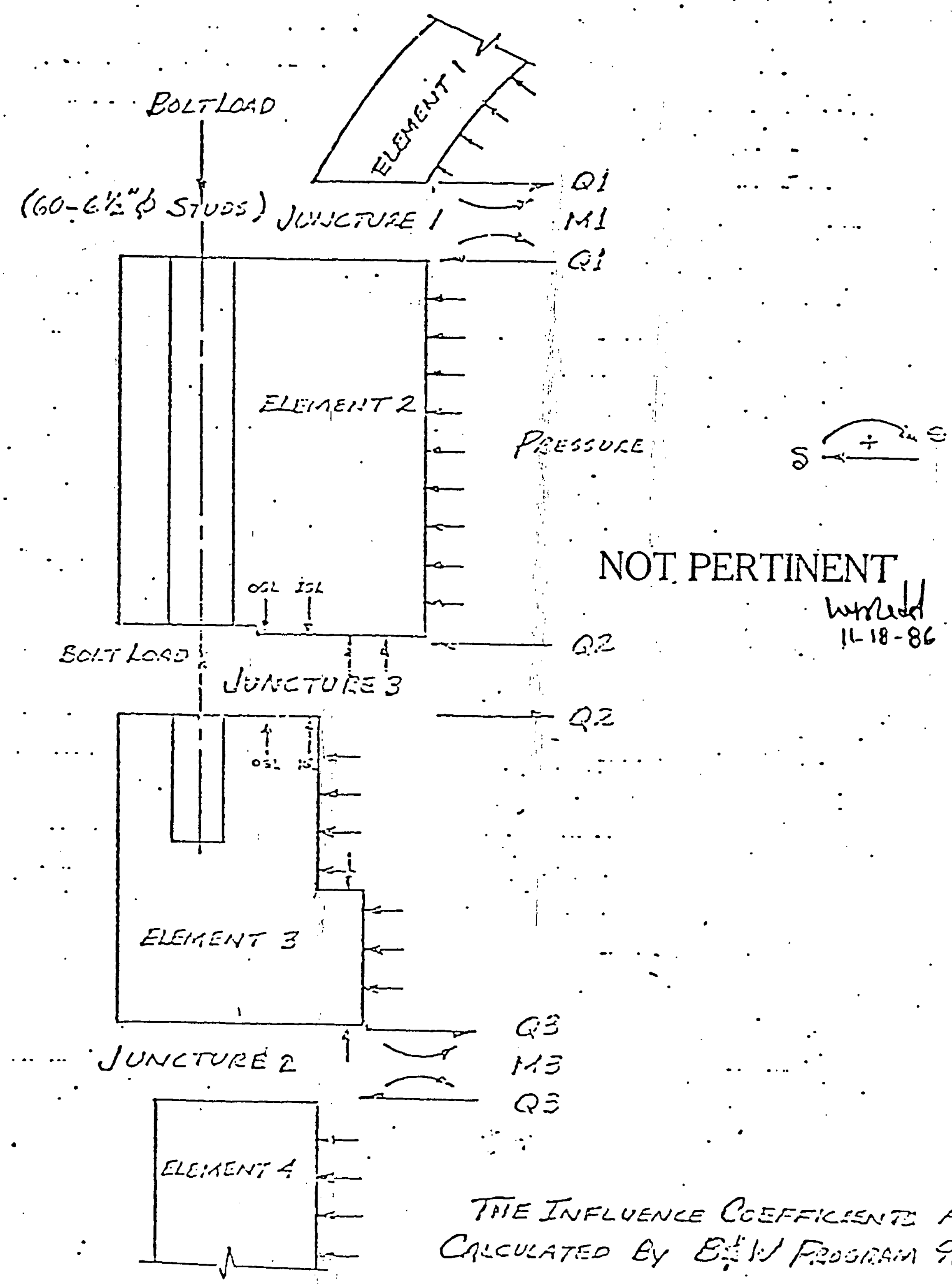
```
 289 PRINT 133
     PRINT 275,(I,SMR(I),BR(I),XNCYCLE(I),AI(I),AF(I),I=1,NTRAN)
     PRINT 290,Q,MM,MB
 304 PRINT 305,KI
     PRINT 310,KIA
     PRINT 315,RATIO
     PRINT 320
     IF(RATIO.GE.3.16) GO TO 325
     PRINT 330
     GO TO 10
 325 PRINT 340
  10 CONTINUE
     GO TO 350
 135 PRINT 355
 350 CONTINUE
   5 FORMAT(I5)
  15 FORMAT(20A4)
  20 FORMAT(//,20A4//)
  25 FORMAT(4X,I1,5F10.0,3X,I2,2F10.0)
  30 FORMAT(3F10.0,E10.0,3F10.0)
  35 FORMAT(3F10.0)
  45 FORMAT(1H0,'FLAW TYPE : SURFACE')
  55 FORMAT(1H0,'FLAW TYPE : SUBSURFACE')
  60 FORMAT(1H0,'INITIAL FLAW DEPTH, (A) = ',F10.5,' IN '//' INITIAL FL
    1AW LENGTH = ',F10.5,' IN '//' WALL THICKNESS = ',F10.5,' IN ')
  80 FORMAT(1H0,'ECCENTRICITY OF SUBSURFACE FLAW = ',F10.5,' IN ')
  90 FORMAT(1H0,'KI CALCULATED AT PERIPHERY OF SURFACE FLAW WHERE BETA
    1= ',F5.1,' DEG ')
  95 FORMAT(1H0,'CRACK TIP TEMPERATURE = ',F6.1,' F '//' REFERENCE NIL
    1DUCTILITY TEMPERATURE = ',F6.1,' F ')
 105 FORMAT(1H0,'YIELD STRENGTH = ',F7.2,' KSI ')
 110 FORMAT(1H0,'SCALING CONSTANT USED IN PARIS EQUATION = ',E10.3)
 120 FORMAT(1H0,'EXPONENT USED IN PARIS EQUATION = ',F7.3)
 125 FORMAT(1H0,'MEMBRANE STRESS = ',F7.2,' KSI '//1X,'BENDING STRESS =
    1 ',F7.2,' KSI ')
 130 FORMAT(1H0,'FATIGUE CRACK GROWTH : ')
 131 FORMAT(1H0,'FATIGUE CRACK GROWTH :  POINT 1 LOCATION IS CRITICAL')
 132 FORMAT(1H0,'FATIGUE CRACK GROWTH :  POINT 2 LOCATION IS CRITICAL')
 133 FORMAT(1H0,4X,'TRANSIENT     STRESS RANGES (KSI)     NO. OF     FL
    1AW DEPTH (IN)'/5X,'NO.          MEMBRANE   BENDING      CYCLES
    2  INITIAL   FINAL'//)
 275 FORMAT(1H ,6X,I3,9X,F7.2,3X,F7.2,4X,F10.1,2X,F9.4,F9.4)
 290 FORMAT(1H0,'FLAW SHAPE PARAMETER Q = ',F7.3//' MEMBRANE STRESS COR
    1RECTION FACTOR MM = ',F7.3//' BENDING STRESS CORRECTION FACTOR MB
    1= ',F7.3)
 305 FORMAT(1H0,'STRESS INTENSITY FACTOR USING FINAL FLAW SIZE, KI = ',
    1F7.2,' KSI ROOT INCH ')
 310 FORMAT(1H0,'CRACK ARREST STRESS INTENSITY FACTOR, KIA = ',F7.2,' K
    1SI ROOT INCH ')
 315 FORMAT(1H0,'RATIO, KIA/KI = ',F7.2)
 320 FORMAT(1H0,'ACCEPTANCE CRITERIA : KIA/KI MUST BE GREATER THAN 3.16
    1')
 330 FORMAT(1H0,'THIS FLAW IS NOT ACCEPTABLE PER SECTION XI OF THE ASME
    1 BOILER AND PRESSURE VESSEL CODE '/' (1977 EDITION THROUGH SUMMER
    21978 ADDENDA) ')
 340 FORMAT(1H0,'THIS FLAW IS ACCEPTABLE PER SECTION XI OF THE ASME BOI
    1LER AND PRESSURE VESSEL CODE '/' (1977 EDITON THROUGH SUMMER 1978
    2ADDENDA), PROVIDED THE PRIMARY STRESS LIMITS OF'/' NB-3000 ARE SAT
    3ISFIED FOR THE FLAWED SECTION ')
 355 FORMAT(1H0,'PARAMETER OUTSIDE TABULATED VALUES, EXECUTION TERMINAT
    1ED')
      STOP
      END
```

ITEM 4

APPENDIX B

STRESS COMPONENTS AND METHOD OF DETERMINATION



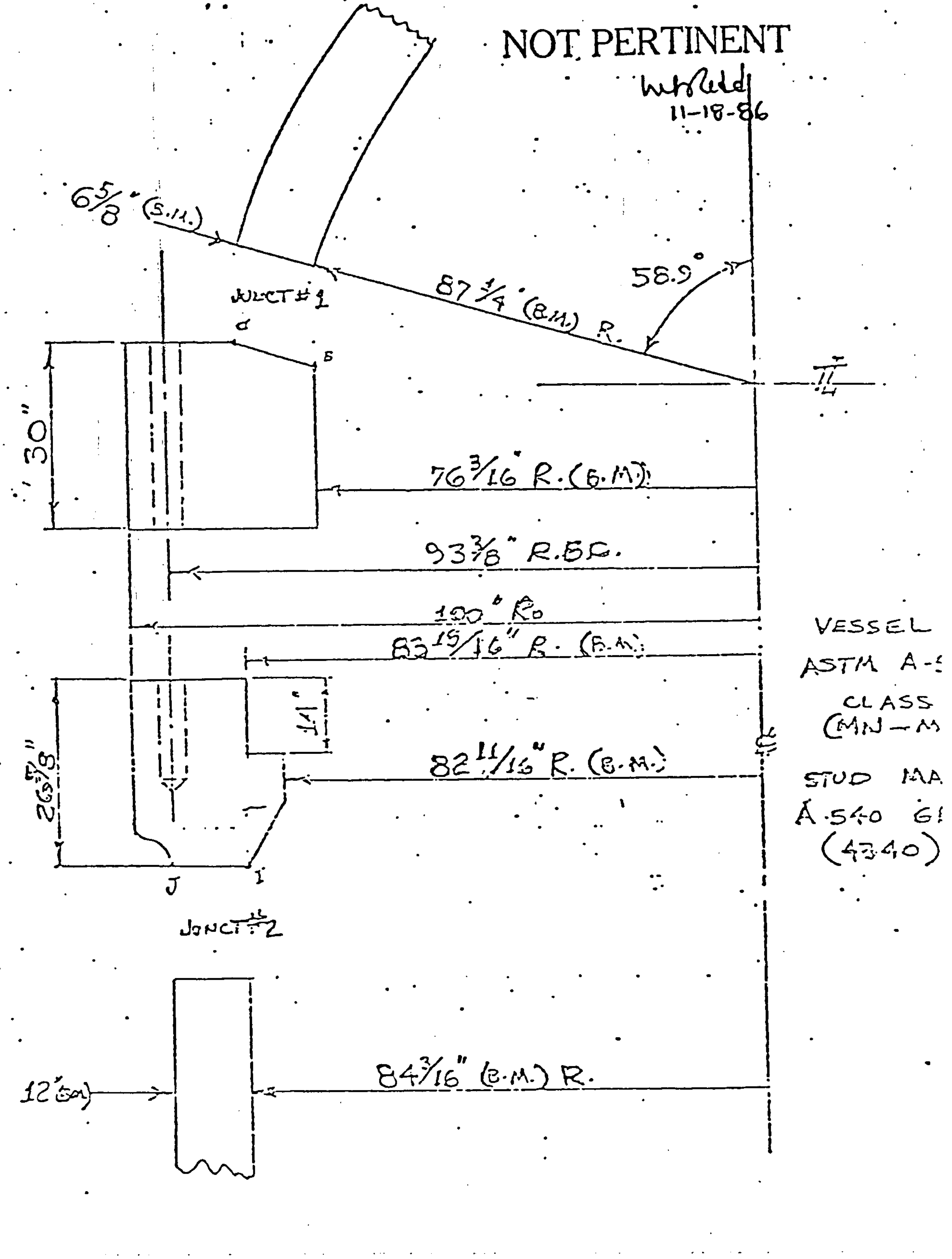
NOT PERTINENT
WHRedd
11-18-86

THE INFLUENCE COEFFICIENTS ARE CALCULATED BY B&W PROGRAM 970

WLR 11-18-86 JFW 11/21/86

32-1164054-01

NOT PERTINENT



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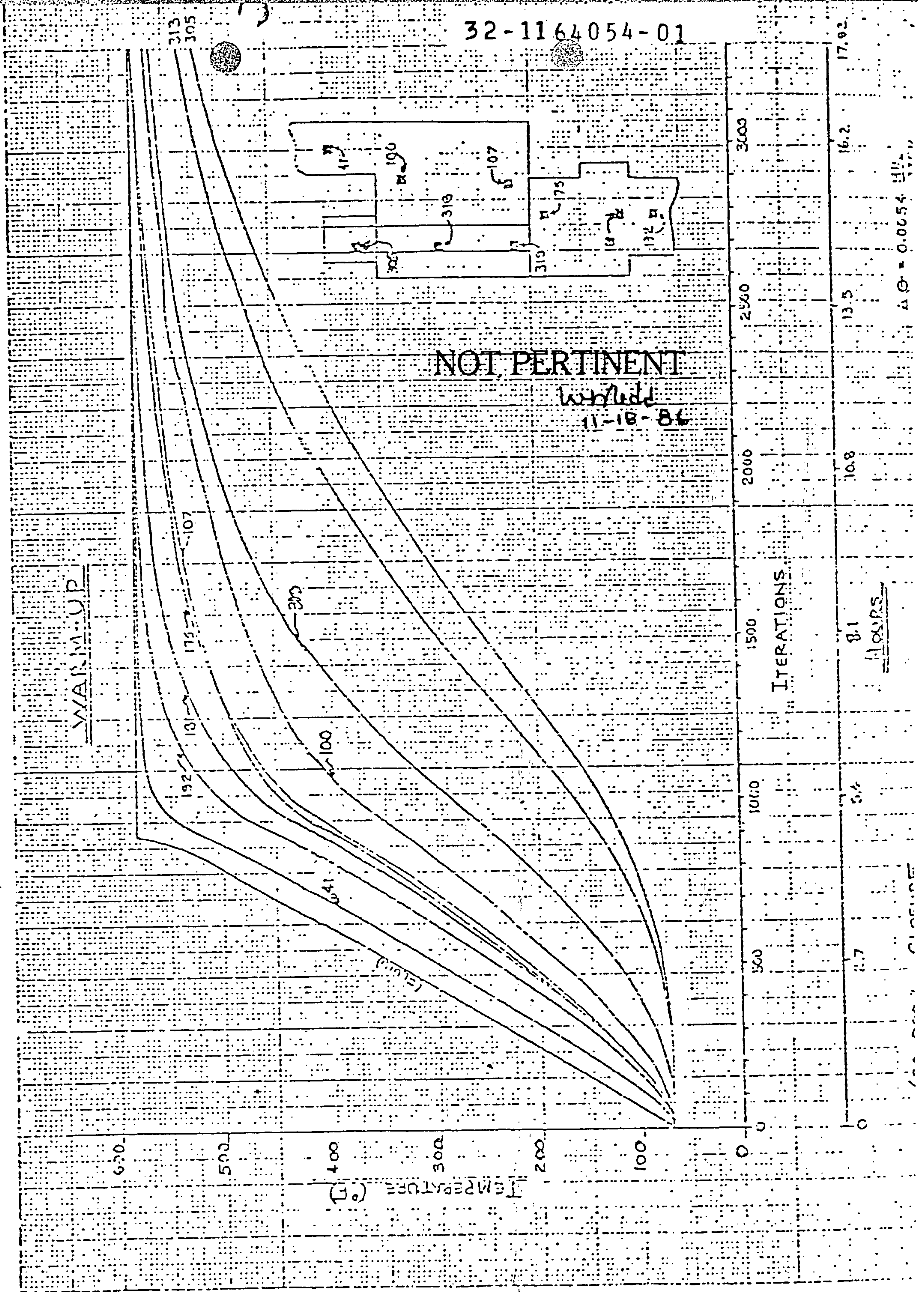
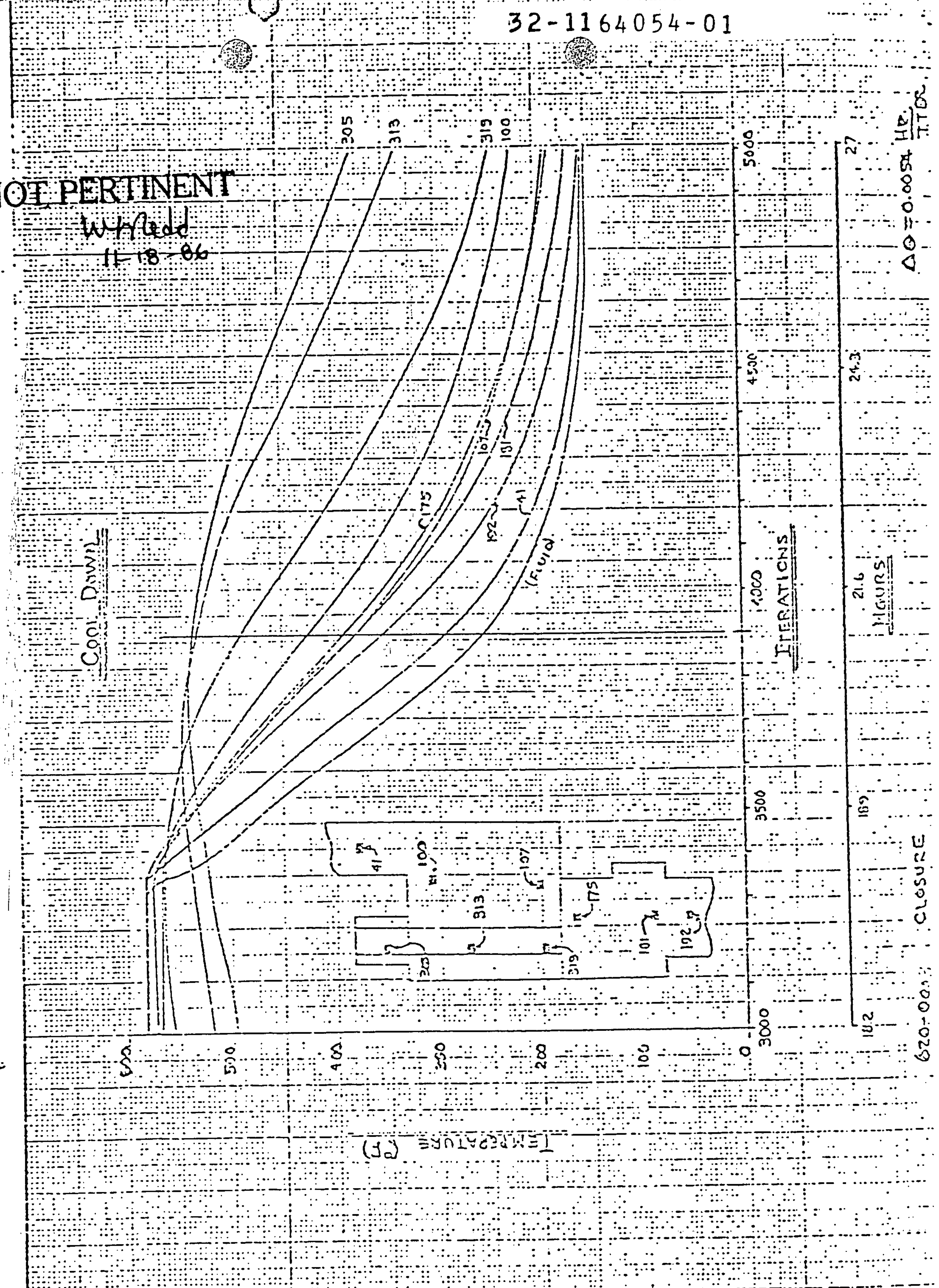


NOT PERTINENT
W.R. Redd
11-18-86

WLR 11-18-86 AJW 11/21/86

32-1164054-01

NOT PERTINENT
W. Redd
11-18-86



WLR 11-18-86

SJW 11/21/86

TIMES FOR ANALYSIS

BASED ON THE TIME-TEMPERATURE HISTORIES THE FOLLOWING TIMES WERE CHOSEN FOR ANALYSIS BASED ON THE MAXIMUM AXIAL GRADIENTS BETWEEN THE PLOTTED POINTS. THIS WILL GIVE THE TIMES OF MAXIMUM MISMATCH DEFLECTION BETWEEN ADJACENT ELEMENTS, AND THUS THE TIMES OF MAXIMUM STRESS, THE TIMES CHOSEN ARE:

HEATUP		STEADY STATE		COOLDOWN	
ITER.	TIME	ITER.	TIME	ITER.	TIME
825	4.455 hr	3330	17.820 hr	3900	21.0
920	4.968 hr			4020	21.7
950	5.130 hr			4080	22.0
1030	5.562 hr			4200	22.6
1110	5.994 hr			4320	23.5
1400	7.530 hr			4500	24.3
				4660	25.1

THE FOLLOWING PAGES SHOW THE PROGRAM OUTPUT FOR THE ABOVE CRITICAL TIMES.

NOT PERTINENT
wmedd
11-18-86

WLR 11-18-86 AFW 11/21/86

WLR 11-18-86
11/18/86

NOT PERTINENT
[signature]
11-18-86

INPUT DATA

JUNCTURE NO. 2

STRESS CONCENTRATION FACTORS

INSIDE		OUTSIDE	
BENDING	TENSION	BENDING	TENSION
1.470	1.490	1.570	1.700

INPUT STRESSES (IN KSI)

CASE	ITER	LONGITUDINAL INSIDE	LONGITUDINAL OUTSIDE	CIRCUMFERENTIAL INSIDE	CIRCUMFERENTIAL OUTSIDE	RADIAL INSIDE	RADIAL OUTSIDE	LONGITUDINAL FREE THERMAL INSIDE	LONGITUDINAL FREE THERMAL OUTSIDE	CIRCUMFERENTIAL FREE THERMAL INSIDE	CIRCUMFERENTIAL FREE THERMAL OUTSIDE	
1	0	-19.4	19.4	-5.2	6.4	0.0	0.0	0.0	0.0	0.0	0.0	BOLT-UP
2	1	-10.5	26.9	8.6	17.7	-2.5	0.0	0.0	0.0	0.0	0.0	BOLT-UP & PRESSURE
3	2	-11.1	31.5	11.4	21.4	-3.1	0.0	0.0	0.0	0.0	0.0	BOLT-UP & HYDRO PRESSURE
4	825	-19.5	33.8	-1.4	13.1	-2.2	0.0	-32.6	17.4	-32.6	17.4	HEAT-UP
5	920	-20.5	34.8	-2.5	12.6	-2.2	0.0	-36.6	19.6	-36.6	19.6	
6	950	-21.3	35.6	-3.0	12.7	-2.2	0.0	-33.3	19.2	-33.3	19.2	
7	1030	-22.2	36.6	-3.2	13.1	-2.2	0.0	-26.1	16.1	-26.1	16.1	
8	1110	-22.6	35.9	-0.6	15.6	-2.2	0.0	-20.7	13.0	-20.7	13.0	
9	1400	-22.0	36.3	-1.1	14.9	-2.2	0.0	-9.6	6.1	-7.6	6.1	
10	3330	-13.4	27.7	6.4	16.8	-2.2	0.0	-0.4	0.3	-0.4	0.3	STEADY STATE
11	[illegible]	-11.5	11.5	2.3	8.8	0.0	0.0	20.0	-15.8	20.0	-15.8	COOLDOWN
12	4020	-10.1	10.1	3.0	8.7	0.0	0.0	24.8	-14.7	24.8	-14.7	
13	4080	-9.7	9.7	3.2	8.6	0.0	0.0	23.3	-13.8	23.3	-13.8	
14	4200	-9.0	9.0	3.3	8.3	0.0	0.0	20.4	-12.3	20.4	-12.3	
15	4120	-8.6	8.6	3.1	7.8	0.0	0.0	15.6	-9.8	15.6	-9.8	
16	4500	-8.9	8.9	2.3	7.3	0.0	0.0	11.2	-7.0	11.2	-7.0	
17	4660	-9.4	9.4	1.6	7.0	0.0	0.0	8.6	-5.4	8.6	-5.4	

32-1164054-01

DEFINITION OF CASES ON PREVIOUS PAGE

1	BOLT UP AT ROOM TEMPERATURE (R.T.)
2	BOLT UP + PRESSURE = 2500 psi @ R.T.
3	BOLT UP + PRESSURE = 3125 psi @ R.T.
4→9	HEAT UP
10	STEADY STATE
11→17	COOLDOWN

STRESS DETERMINATION

A) HEAT UP / COOLDOWN

MAXIMUM STRESS TENDING TO OPEN THE INDICATIONS IS ON O.D. HALF OF VESSEL SECTION AND OCCURS AT ELEVATED TEMPERATURES, HOWEVER, INDICATIONS BEING EVALUATED ARE IN I.D. HALF ($<t/2$) WHERE COOLDOWN STRESSES ARE MAXIMUM.

$$\sigma_l)_{inside} = \underset{\text{(BOLT UP @ TEMP)}}{\sigma_{cooldown}} + \sigma_{THERMAL} + \left(\sigma_{\substack{BOLT\ UP \\ +P=2500}} - \sigma_{BOLT\ UP}\right) \frac{P_{OPER}}{P_D = 2500}$$

$$= -11.5 + 28.8 + [-10.5 - (-19.4)]\ 2185/2500$$

$$= -11.5 + 28.8 + 7.8$$

$$= 25.1 \text{ KSI}$$

$$\sigma_l)_{outside} = 11.5 - 15.8 + 6.6$$

$$= 2.3 \text{ KSI}$$

B) INSERVICE LEAK

$$\sigma_\ell)_{Inside} = \sigma_{BOLT\ UP} + \left(\sigma_{BOLT\ UP\ +P=2500} - \sigma_{BOLT\ UP}\right) \frac{P_{LEAK}}{P_{DES}}$$

$$= -19.4 + [-10.5 - (-19.4)]\ 2350/2500$$

$$= -11.0 \text{ ksi}$$

$$\sigma_\ell)_{outside} = 19.4 + (26.9 - 19.4)\ 2350/2500$$

$$= 26.5 \text{ ksi}$$

* COMPRESSIVE THERMAL STRESSES IGNORED

BABCOCK & WILCOX
NUCLEAR POWER GENERATION DIVISION
VOLUMETRIC EXAMINATION EVALUATION REPORT

BWNP-20525-I(11-81)

EVALUATION NUMBER: 86-019, REV. 1

METHOD: UT ✓ RT ___

FILE NO. OR REFERENCE:

WELD NO. OR IDENTIFICATION: RV FLANGE TO SHELL WELD #1RPV-WR19

APPLICABLE CODE YEAR AND ADDENDA: ASME SECTION XI 1980 EDITION THRU WINTER 1980 ADDENDA

DATE OF INITIAL EXAMINATION: 3-18-86 RE-EXAMINATION:

REPORTABLE INDICATION NUMBER(S): 0 THRU 21

COMMENTS:

ORIGINATOR: HOWARD STOPPLEMANN LEVEL: II DATE: 20 MARCH 1986

PRELIMINARY DISPOSITION

ACCEPTANCE STANDARD: IWB 3510-1

COMMENTS: THIS REVISION IS A SUPPLEMENT TO THE INITIAL EVALUATION REPORT #86-019. IT CONTAINS A REVISED EVALUATION OF INDICATIONS #3/#4 COMBINED AND #18/#19 COMBINED AND SUPERCEDES THE INITIAL EVALUATIONS.
ATTACHMENT - A CONTAINS THE REVISED CALCULATIONS.
ATTACHMENT - B CONTAINS B&W DRAWING #128704E9

☐ ACCEPTABLE INDICATION NUMBER(S)
☑ REJECTABLE INDICATION NUMBER(S) 3/4, 18/19

LEVEL III: George R. Stromer LVL III UT DATE: 11/18-86

FRACTURE MECHANICS ANALYSIS ☑ YES ☐ NO DOCUMENT NUMBER

FINAL DISPOSITION

COMMENTS: Acceptable per B&W Doc ID# 32-1164054-01 Fracture Analysis Report. Indicates flaws 3/4, & 18/19 acceptable for further service.

☑ ACCEPTABLE INDICATION NUMBER(S) 3-4, 18-19
☐ REJECTABLE INDICATION NUMBER(S)

LEVEL III: George R. Stromer LVL III UT DATE: 11/24/86

FIGURE NO. B01.030.001A

ER # 86-019, REV. 1 NOV. 12, 1986

APPLICABLE DIMENSIONS FROM B&W DRAWING #128704, REV. 9

* RADIUS TO FLANGE INCLUDING CLAD = 83.75"
* RADIUS TO BASE METAL AT INDICATION LOCATION = 84.0625"
* BASE METAL THICKNESS AT WELD = 12.0"

INDICATION #3/#4

* DISTANCE BETWEEN BOLT HOLE ℄'s AT INDICATION #3/#4

2(83.75" + 4.3") = 176.10" DIAMETER AT INDICATION #3/#4

$$\frac{176.1 \times \pi}{60} = 9.22''$$

$\ell = 9.22'' - 1.6'' = 7.6''$ $a/t = 1.05/12 = 8.8\%$

$2a = 5.7'' - 3.6'' = 2.1''$ $a/\ell = 1.05/7.6 = .14$

$S = 3.6'' - .312'' = 3.29''$

$$e = \frac{12 - 2.1}{2} - 3.29 = 1.66''$$

INDICATION #18/#19

$\ell = 11.96'' - 7.56'' = 4.4''$ $a/t = 1.15/12 = 9.6\%$

$2a = 5.80 - 3.50 = 2.30''$ $a/\ell = 1.15/4.4 = .26$

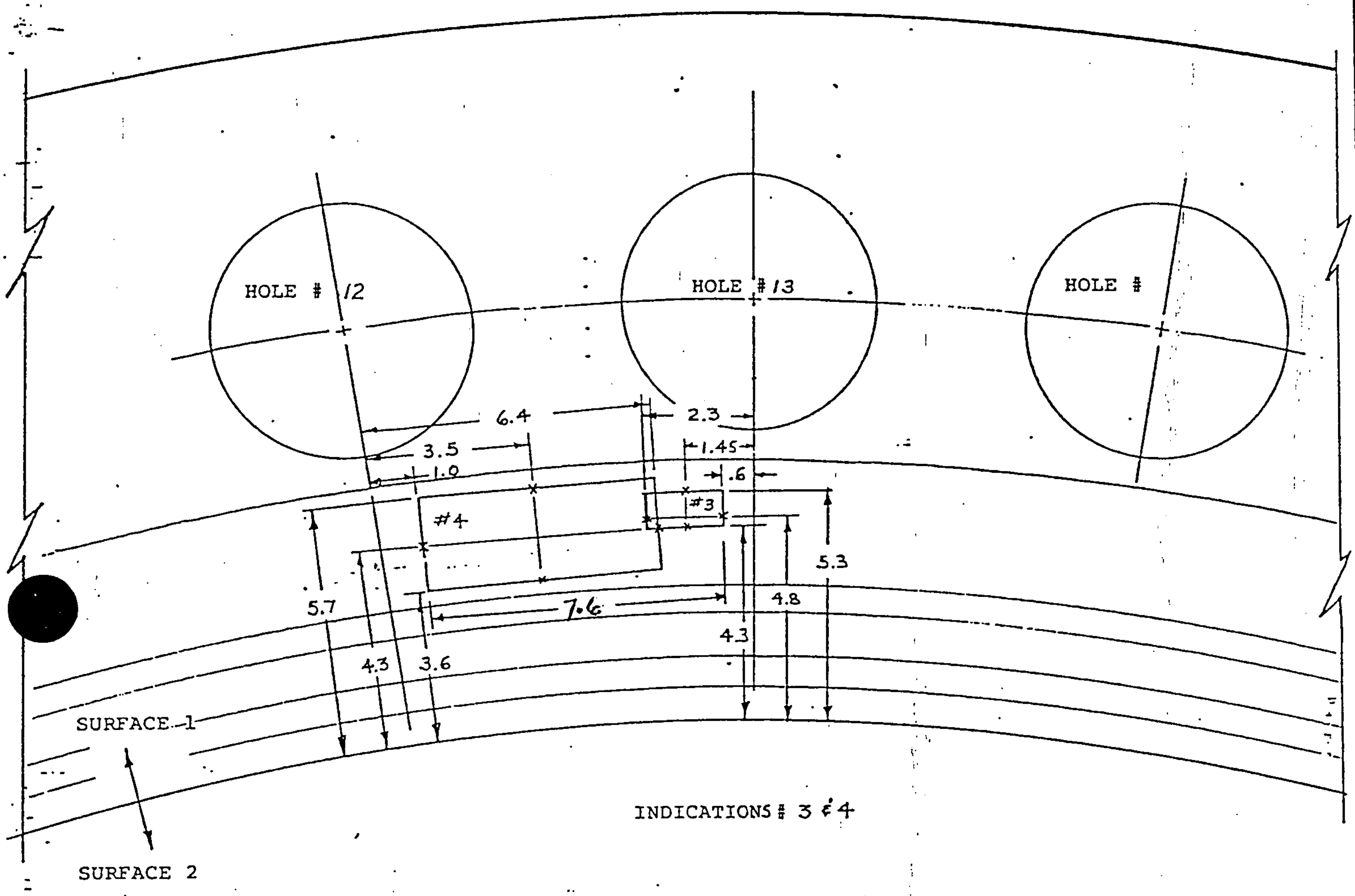
$S = 3.50 - .312 = 3.19''$

$$e = \frac{12 - 2.3}{2} - 3.19 = 1.66''$$

ALL OF THE INITIAL CALCULATIONS FOUND IN ER #86-019 ARE BASED ON AN OFFSET OF .75" (RADIAL) FROM THE FLANGE SURFACE TO THE BASE METAL AT THE LOCATION OF THE INDICATIONS. THIS VALUE WAS USED IN ERROR. THE CORRECT RADIAL OFFSET IS .312" BASED ON B&W DRAWING #128704E9. THE CORRECT VALUE HAS BEEN USED IN THE REVISED CALCULATION OF INDICATIONS #3/4 AND #18/19. THESE COMBINED INDICATIONS REPRESENT THE WORST CASE CONDITIONS AND BOUND ALL OF THE OTHER RECORDED INDICATIONS.

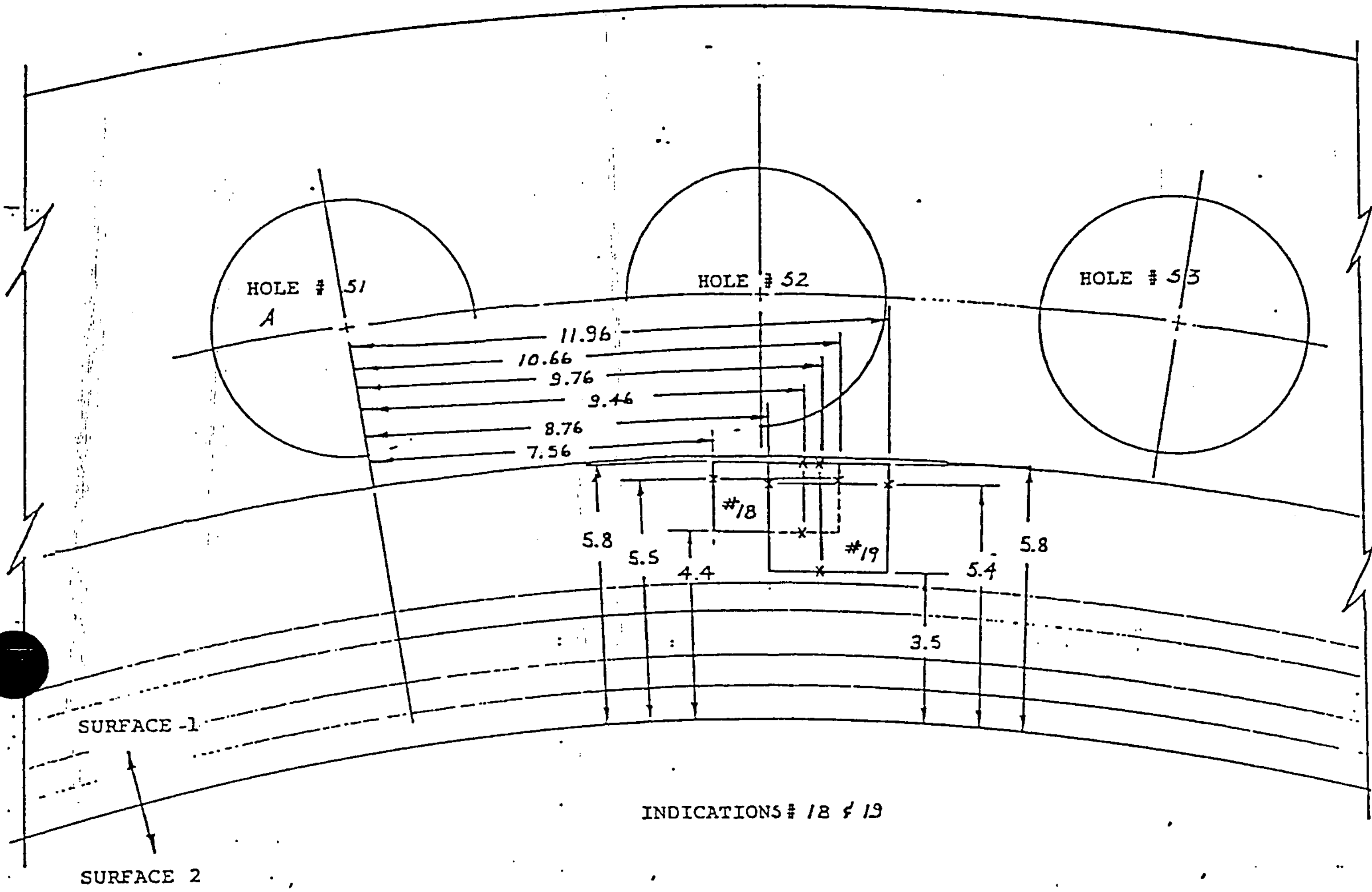
THE ERROR DOES NOT AFFECT ANY OF THE CALCULATIONS USED TO DETERMINE INDICATION ACCEPTABILITY PER IWA-3000 AND IWB-3000. IT WOULD AFFECT THE ECCENTRICITY VALUE USED IN THE FRACTURE MECHANICS CALCULATIONS. USING THE CORRECT RADIAL OFFSET VALUE (.312") PLACES THE INDICATIONS CLOSER TO THE SECTION MID-PLANE WHICH MAKES THE PREVIOUS FRACTURE ANALYSIS MORE CONSERVATIVE. THE FRACTURE ANALYSIS HAS BEEN REVISED BASED ON THE NEW "e" VALUES FOR INDICATIONS #3/4 AND #18/19

M. G. Hacker 11/12/86



NOTE: X = Transducer Centerline Location

DUKE POWER COMPANY
OCONEE UNIT #1
WELD NO.: 1RPV-WR19
FIGURE NO.: B01.030.001A
CONT. NO.: 580-2034-12-02
DWG. BY W.D. MINTON 4-23-86
REV. 1 - 11/24/86

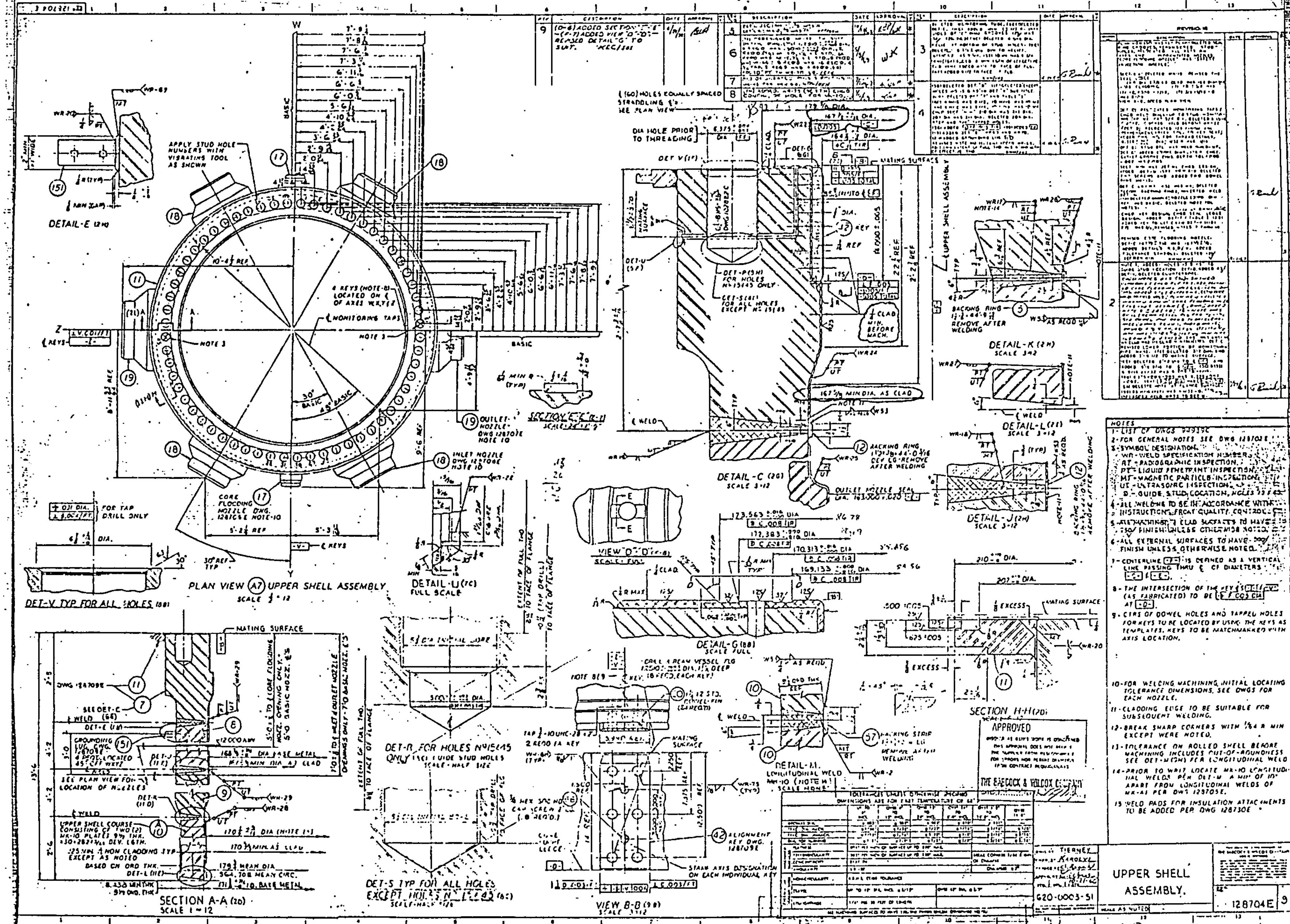


INDICATIONS # 18 & 19

NOTE: X = Transducer Centerline Location

DUKE POWER COMPANY
OCONEE UNIT #1
WELD NO.: 1RPY-WR19
FIGURE NO.: B01.030.001A
CONT. NO.: 580-2034-12-02

ATTACHMENT "B"



MICROFILMED BY
B & W LYNCHBURG, VA.

5 19 -71

BABCOCK & WILCOX
NUCLEAR POWER GENERATION DIVISION
VOLUMETRIC EXAMINATION EVALUATION REPORT

BWNP-20525-1(11-81)

EVALUATION NUMBER: 86-019, REV. 1

METHOD: UT ✓ RT ____

FILE NO. OR REFERENCE:

WELD NO. OR IDENTIFICATION: RV FLANGE TO SHELL WELD #1RPV-WR19

APPLICABLE CODE YEAR AND ADDENDA: ASME SECTION XI 1980 EDITION THRU WINTER 1980 ADDENDA

DATE OF INITIAL EXAMINATION: 3-18-86 RE-EXAMINATION:

REPORTABLE INDICATION NUMBER(S): 0 THRU 21

COMMENTS:

ORIGINATOR: HOWARD STOPPLEMANN LEVEL: II DATE: 20 MARCH 1986

PRELIMINARY DISPOSITION

ACCEPTANCE STANDARD: IWB 3510-1

COMMENTS: THIS REVISION IS A SUPPLEMENT TO THE INITIAL EVALUATION REPORT #86-019. IT CONTAINS A REVISED EVALUATION OF INDICATIONS #3/#4 COMBINED AND #18/#19 COMBINED AND SUPERCEDES THE INITIAL EVALUATIONS.
ATTACHMENT - A CONTAINS THE REVISED CALCULATIONS.
ATTACHMENT - B CONTAINS B&W DRAWING #128704 E 9

☐ ACCEPTABLE INDICATION NUMBER(S)

☑ REJECTABLE INDICATION NUMBER(S) 3/4, 18/19

LEVEL III: George R. Stromer LvIII UT DATE: 11/18-86

FRACTURE MECHANICS ANALYSIS ☑ YES ☐ NO DOCUMENT NUMBER

FINAL DISPOSITION

COMMENTS: Acceptable per B&W Doc ID# 32-1164054-01 Fracture Analysis Report. Indicates flaws 3/4, & 18/19 acceptable for further service.

☑ ACCEPTABLE INDICATION NUMBER(S) 3-4, 18-19

☐ REJECTABLE INDICATION NUMBER(S)

LEVEL III: George R. Stromer LvIII UT DATE: 11/24/86

FIGURE NO. B01.030.001A

ER # 86-019, REV. 1 NOV. 12, 1986

APPLICABLE DIMENSIONS FROM B&W DRAWING #128704, REV. 9

* RADIUS TO FLANGE INCLUDING CLAD = 83.75"
* RADIUS TO BASE METAL AT INDICATION LOCATION = 84.0625"
* BASE METAL THICKNESS AT WELD = 12.0"

INDICATION #3/#4

* DISTANCE BETWEEN BOLT HOLE ℄'S AT INDICATION #3/#4

$2(83.75" + 4.3") = 176.10"$ DIAMETER AT INDICATION #3/#4

$$\frac{176.1 \times \pi}{60} = 9.22"$$

$\ell = 9.22" - 1.6" = 7.6"$

$2a = 5.7" - 3.6" = 2.1"$

$S = 3.6" - .312" = 3.29"$

$e = \frac{12 - 2.1}{2} - 3.29 = 1.66"$

$a/t = 1.05/12 = 8.8\%$

$a/\ell = 1.05/7.6 = .14$

INDICATION #18/#19

$\ell = 11.96" - 7.56" = 4.4"$

$2a = 5.80 - 3.50 = 2.30"$

$S = 3.50 - .312 = 3.19"$

$e = \frac{12 - 2.3}{2} - 3.19 = 1.66"$

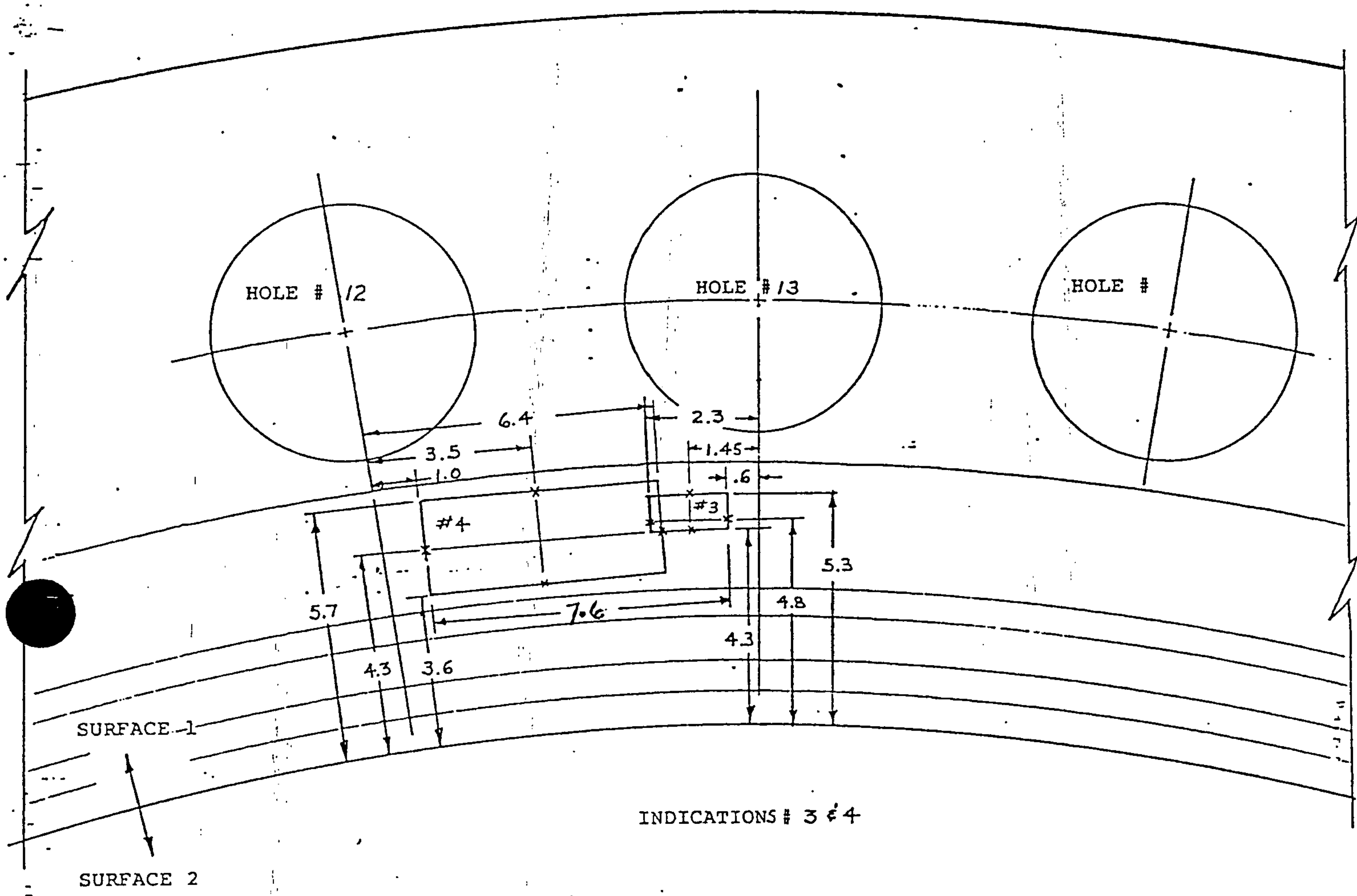
$a/t = 1.15/12 = 9.6\%$

$a/\ell = 1.15/4.4 = .26$

ALL OF THE INITIAL CALCULATIONS FOUND IN ER #86-019 ARE BASED ON AN OFFSET OF .75" (RADIAL) FROM THE FLANGE SURFACE TO THE BASE METAL AT THE LOCATION OF THE INDICATIONS. THIS VALUE WAS USED IN ERROR. THE CORRECT RADIAL OFFSET IS .312" BASED ON B&W DRAWING #128704E9. THE CORRECT VALUE HAS BEEN USED IN THE REVISED CALCULATION OF INDICATIONS #3/4 AND #18/19. THESE COMBINED INDICATIONS REPRESENT THE WORST CASE CONDITIONS AND BOUND ALL OF THE OTHER RECORDED INDICATIONS.

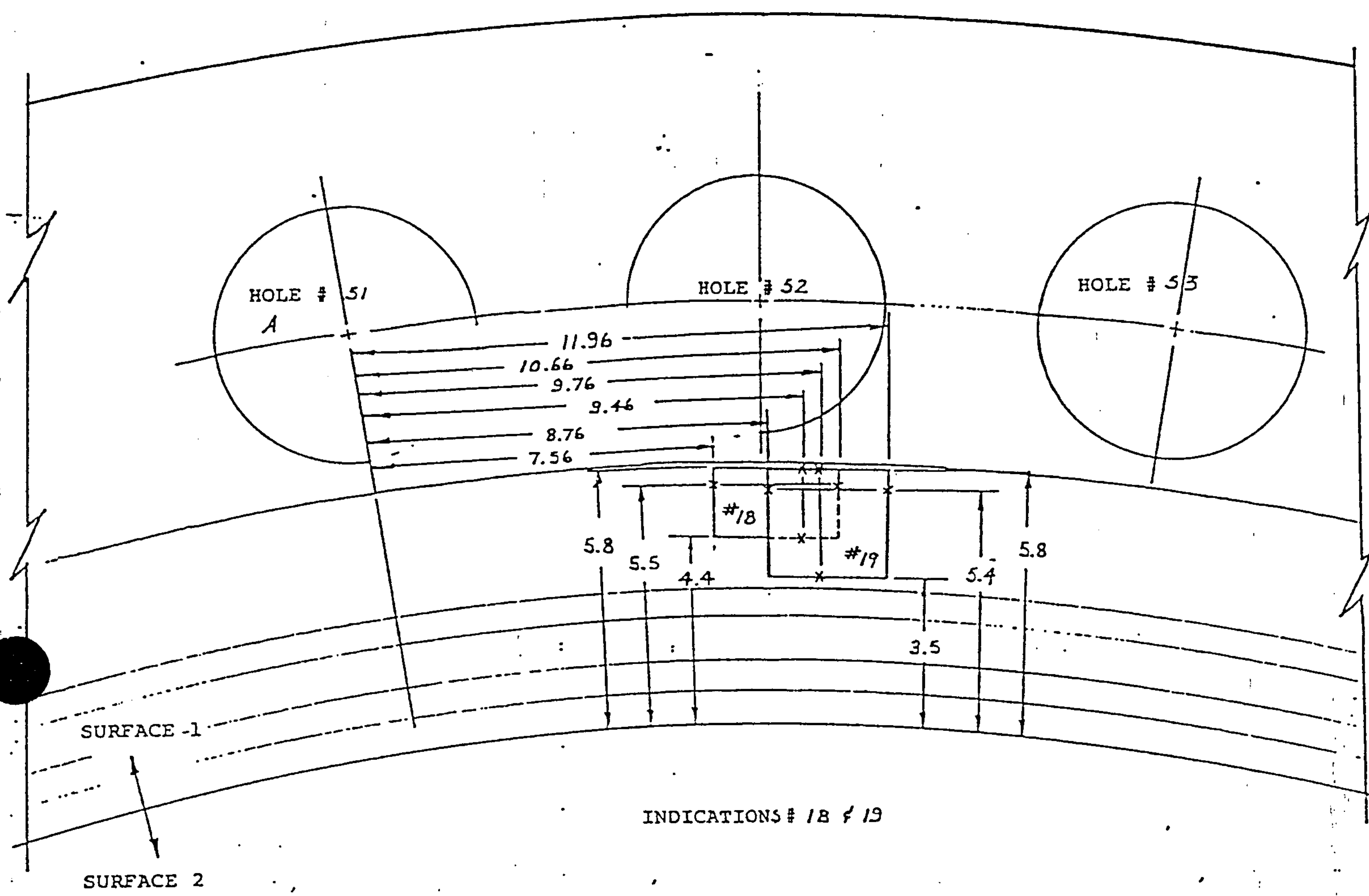
THE ERROR DOES NOT AFFECT ANY OF THE CALCULATIONS USED TO DETERMINE INDICATION ACCEPTABILITY PER IWA-3000 AND IWB-3000. IT WOULD AFFECT THE ECCENTRICITY VALUE USED IN THE FRACTURE MECHANICS CALCULATIONS. USING THE CORRECT RADIAL OFFSET VALUE (.312") PLACES THE INDICATIONS CLOSER TO THE SECTION MID-PLANE WHICH MAKES THE PREVIOUS FRACTURE ANALYSIS MORE CONSERVATIVE. THE FRACTURE ANALYSIS HAS BEEN REVISED BASED ON THE NEW "e" VALUES FOR INDICATIONS #3/4 AND #18/19

M. G. Hocker 11/12/86



NOTE: X = Transducer Centerline Location

DUKE POWER COMPANY
OCONEE UNIT #1
WELD NO.: 1RPV-WR19
FIGURE NO.: B01.030.001A
CONT. NO.: 580-2034-12-02
DWG. BY W.D. MINTON 4-23-86
REV. 1 - 11/24/86

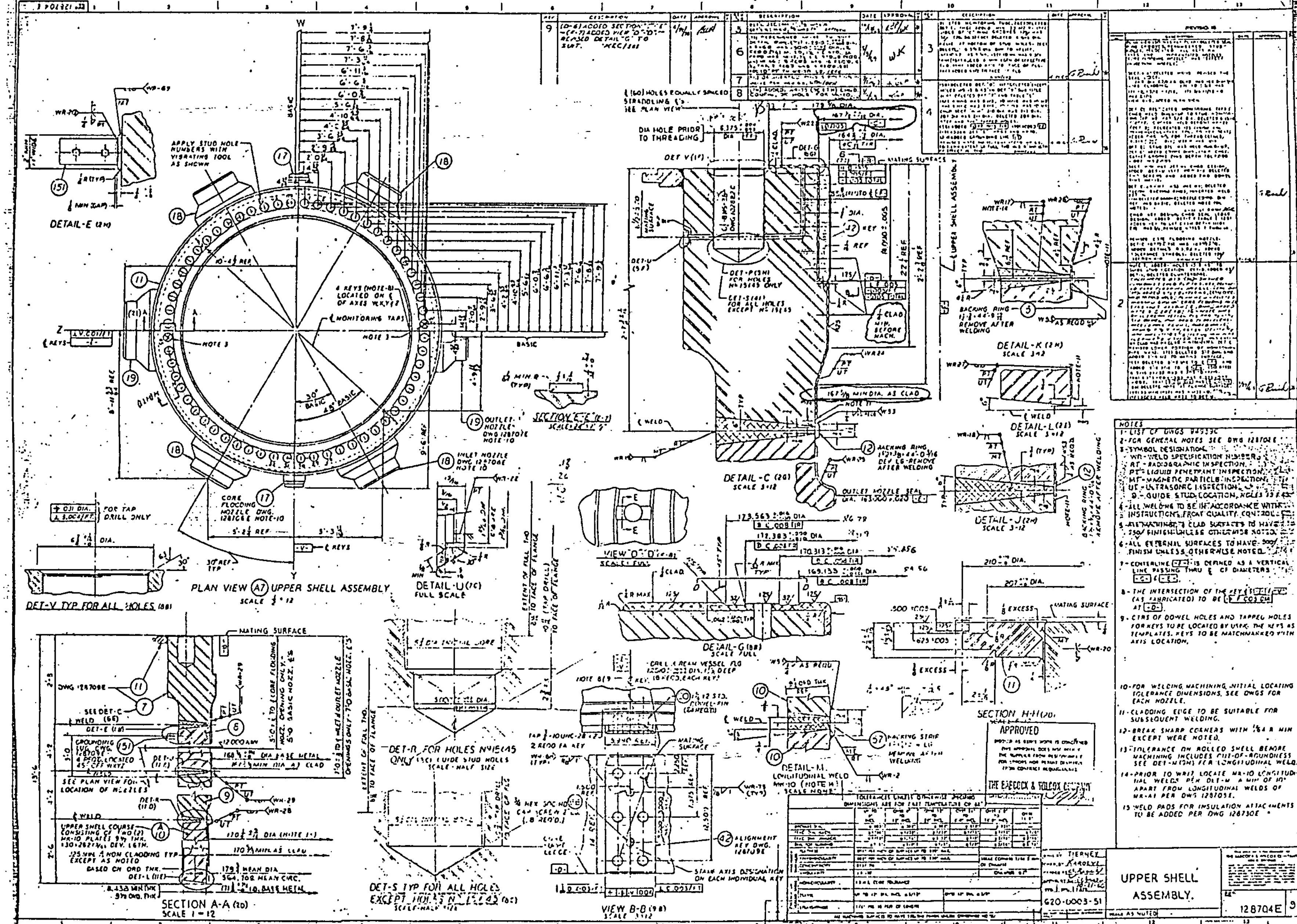


INDICATIONS # 18 & 19

NOTE: X = Transducer Centerline Location

DUKE POWER COMPANY
OCONEE UNIT #1
WELD NO.: 1RPV-WR19
FIGURE NO.: B01.030.001A
CONT. NO.: 580-2034-12-02

ATTACHMENT "B"



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