TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE 37401
400 Chestnut Street Tower II

July 10, 1979

Director of Nuclear Reactor Regulation
Attention: Mr. S. A. Varga, Chief
Light Water Reactors Branch No. 4
Division of Project Management
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Varga:

In the Matter of the Application of) Docket No. 50-327
Tennessee Valley Authority)

The preservice ultrasonic examination of the Sequoyah unit 1 reactor vessel closure head revealed a flaw indication exceeding the ASME Boiler and Pressure Vessel Code Section XI, Division 1, IWB-3500, acceptance criteria. This deficiency was initially reported to NRC-OIE Region II Inspector C. R. McFarland on February 16, 1979, in accordance with 10 CFR 50.55(e). It was subsequently determined that the discontinuity would be acceptable throughout the operating life of the plant, and the deficiency was classified nonreportable under the requirements of 10 CFR 50.55(e).

As required by IWB-3600 of ASME Section XI, enclosed is information demonstrating compliance with current Section XI flaw acceptance criteria.

Enclosed are copies of the "Southwest Research Institute Supplemental Report 17-5339" (Enclosure 1), a memorandum from R. H. Dunham to H. S. Fox dated February 13, 1979, (Enclosure 2); a memorandum from R. H. Dunham to H. S. Fox dated April 5, 1979, with the "Sequoyah Nuclear Plant Analytical Evaluation of a Flaw in the Unit 1 Reactor

3001 SE 1/1

461 145

7907170124 A

Mr. S. A. Varga July 10, 1979

Pressure Vessel Closure Head CEB-CQS-79-1" report attached (Enclosure 3); and a memorandum from R. M. Pierce to G. G. Stack dated February 28, 1979, with the "Division of Construction Nonconforming Condition Report" (NCR) attached (Enclosure 4).

If you have any questions concerning this matter, please get in touch with D. L. Lambert at FTS 854-2581.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L M Mills by DSK

L. M. Mills, Manager
Nuclear Regulation and Safety

Enclosures

ENCLOSURE 1

PRELIMINARY EVALUATION OF SEQUOYAH UNIT 1 FLAW INDICATION

SUPPLEMENTAL REPORT
SwRI Project 17-5339

February 1979

Prepared for

Tennessee Valley Authority
505 Edney Building
Chattanooga, Tennessee 37401

Prepared by:

Andrew P. Pickett, P.E.

Approved by:

Clarence E. Lautzenheiser

Clarence E. Lautzenheiser
Vice President
Quality Assurance Systems
and Engineering Division

Reviewed by:

Donald W Deenavant for
Project Manager

7907170131 A

461 147

/

PRELIMINARY EVALUATION OF SEQUOYAH UNIT 1 FLAW INDICATION

1.0 Introduction

The preservice ultrasonic examination of Sequoyah Unit 1 reactor vessel closure head weld W09-10 revealed a flaw indication exceeding the acceptance standards of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section XI, Division 1, IWB-3500. Re-evaluation of the weld joint radiograph identified the indication as subject to exemption from IWB-3500 standards in accordance with Code Case N-209[1].

Code Case N-209 requires evaluation of the flaw indication by the IWB-3600 analytical procedures. This report describes a preliminary evaluation to determine the allowability of the indication and the potential effects of this flaw on operating procedures. The evaluation presented herein is based on the pressure vessel manufacturer's stress report[2].

A more detailed analysis and evaluation may be required to justify leaving this flaw indication in place. The final disposition of this indication and the justification for this disposition is to be established by others.

2.0 General Discussion of Potential Primary Coolant Boundary Failure at the Flaw Indication Location and the Consequences of Such Failure

The flaw location with respect to any structural discontinuities (such as a flange, nozzle, or lug) is such that the stresses at this section are about equal to the general primary membrane pressure stresses and the local thermal bending stresses (discussed as "skin effect stress" in the referenced stress report). The local surface area is not subjected to coolant injection flow cooling during postulated incidents (such as loss of coolant accidents) so that the increase in thermal stress at the flaw location, in response to emergency and faulted incident loadings, is expected to be less than the decrease in pressure stress at specific times after incident initiation. Neutron irradiation effects on material properties are negligible at this location.

The growth of a flaw through the coolant boundary at this location would result only in a steam leak (if unstable crack propagation is interdicted). This would not diminish the system capability for core submergence and cooling or safe shutdown in response to an emergency or faulted incident. System instrumentation would detect a steam leak.

---

[1]William McGaughey and Sam Wenk, Sequoyah Unit 1 Draft Field Notes, Circumferential Weld W09-10, Southwest Research Institute, January 31, 1979.

[2]"Analysis of the Main Closure Including Core Support Ledge," Rotterdam Stress Report, Document No. 30616-1105 (The Rotterdam Dockyard Company, September 22, 1975).

461 148

/

3.0 Fracture Mechanics Analysis

ASME Section XI, Division 1, Appendix A, A-1100, summarizes the analytical procedure to be used. This procedure was followed step-by-step, as described below.

(1) Ultrasonic and radiographic examinations evaluated by McGaughey and Wenk determined the actual flaw indication configuration. Figures 1 and 2 depict these results.

(2) The flaw indication was resolved into elliptical shape as depicted by Figure 3, Flaw Indication Characterization.

(3) The stresses at the flaw indication location were obtained from the manufacturer's stress report and posted in Table 1, Flaw Growth Prediction, for the various design conditions listed.

(4) The stress intensity factors for each condition were calculated and posted in Table 1 (see Figure 4, Sample Calculation).

(5) The necessary material properties were taken from the stress report.

(6) The analytical procedures described in A-5000, as appropriate, were used to determine the critical flaw parameters (see Table 1 and Figure 5, IWB-3600 Analysis).

(7) The flaw evaluation criteria of IWB-3600 were used to determine that the observed flaw indication is acceptable for continued operation provided that metal temperature exceeds the reference nil-ductility temperature (RT_{NDT}) by 120°F during the primary side hydrostatic test.

4.0 Conclusions

The fracture mechanics analyses performed using the conservative method of Section XI, Appendix A, the manufacturer's stress report, and the criteria of IWB-3600 indicate that:

(1) If any flaw growth occurs in response to the specified operating loadings, it would be negligible.

(2) Unstable crack propagation initiation from the defect is not credible if the metal temperature exceeds RT_{NDT} by 120°F during the primary side hydrostatic test. This is the highest stress/lowest metal temperature worst case condition postulated in the stress report.

The minimum critical flaw size (a_i) for emergency and faulted conditions has not been determined because of lack of information. There are two conditions to consider:

(1) Large steam line break.

(2) LOCA-ECC thermal shock.

461 149

Both of these conditions have been evaluated by Westinghouse on a generic basis and for specific reactor vessels.

For the preliminary evaluation, it can be noted that:

(1) The large steam line break minimum fluid temperature is 212°F. This is >200°F above RT_{NDT} for the material at this location. The fracture toughness at this temperature is sufficient to permit yield strength loading of a through wall crack without unstable propagation (see Figure 4).

(2) The flaw is located above any cold water injection location for LOCA-ECC event, and the consequent thermal shock would induce no higher stress than the large steam line break.

(3) Figure 5 is an example of the result of an overly conservative analysis which would be more severe than either condition. As can be seen, neither condition would result in unstable crack propagation.

461 150

TABLE 1

FLAW GROWTH PREDICTION

LOAD NO.	DESCRIPTION	No. of CYCLES	$\Delta\sigma_m$ Ksi	$\Delta\sigma_b$ Ksi	ΔK_I Ksi In.	da/dN Inches/Cycle	Δa Inches	REMARKS
1	Primary Side Hydrostatic Test	5	20.22	-1.98	20.33	2×10^{-6}	1×10^{-5}	3,105 psig @ 60°F
2	Primary Side Leak Test	50	16.22	-1.41	16.39	0.9×10^{-6}	4.5×10^{-5}	2,485 psig @ 400°F
3	Plant Heatup & Cooldown	200	14.65	-1.08	14.90	0.63×10^{-6}	1.26×10^{-4}	Normal Full Power (2235 psig @ 547°F)
4	Small Step Load Increase	2,000	2.69	-0.27	2.70	1.08×10^{-9}	2.17×10^{-6}	
5	Small Step Load Decrease	2,000	-2.69	-0.27	2.70	1.08×10^{-9}	2.17×10^{-6}	
6	Large Step Load Decrease	200	-3.07 -1.89	0.31 -0.47	3.08 1.76	1.77×10^{-9} 2.21×10^{-10}	3.54×10^{-7} 4.43×10^{-8}	
7	Loss of Load	80	-6.90	0.31	7.11	3.99×10^{-8}	3.19×10^{-6}	
8	Loss of Power	40	-2.30 -0.37	0.31 -0.07	2.27 0.36	5.68×10^{-10} 5.68×10^{-13}	2.27×10^{-8} 2.27×10^{-11}	
9	Loss of Flow	80	-2.86 1.93	0.28 -0.20	2.88 1.94	1.37×10^{-9} 3.12×10^{-10}	1.09×10^{-7} 2.50×10^{-8}	
10	Reactor Trip from Full Power	400	-0.58 1.93	0.06 -0.20	0.58 1.94	3.54×10^{-12} 3.12×10^{-10}	1.42×10^{-9} 1.25×10^{-7}	
11	Turbine Roll Test	10	10.59	-4.83	8.83	8.95×10^{-8}	8.95×10^{-7}	$0.001 > \Sigma\Delta a$ in any order
12	Steady State Fluctuations	-	±1.14	±0.11	1.15	4.45×10^{-11}		

$\Delta\sigma_m$ - Change in membrane stress
$\Delta\sigma_b$ - Change in bending stress
ΔK_I - Change in stress intensity factor
da/dN - Fatigue crack growth rate
Δa - Change in minor half diameter

POOR ORIGINAL

481 151

/

SAMPLE CALCULATION FLAW GROWTH INSERVICE

Loading No. 1 - Primary Side Hydrostatic Test @ 3,105 psig for 5 cycles @ 60°F.

From Stress Report

σ_{ys} = 50.07 ksi

σ_m = 20.22 ksi

σ_b = -1.98 ksi

From Section XI, Appendix A (1977 Edition)

Fig. A-3300-1, Q = 1.9

Fig. A-3300-2	Point 1	Point 2
	M_m = 1.035	1.025
Fig. A-3300-4		
	M_b = 0.47	0.27

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

$$= 20.22 \times 1.035 \sqrt{\pi} \sqrt{0.625/1.9} - 1.98 \times 0.47 \sqrt{\pi} \sqrt{0.625/1.9}$$

ΔK = 20.33 ksi $\sqrt{in}$

Fig. A-4300-1 (Summer 1977 Addenda)

da/dN = 2 micro-inches/cycle

Δa, 5~ = 1 x 10^{-5} inches

461 152

/

IWB-3600 ANALYSIS FOR HYDROTEST

A_f = 0.625 inches (see flaw growth inservice)

Assume $A_c^* = 0.7$ inches

$\sigma_m = 20.22 + 8 = 28.22$ ksi (1)

$\sigma_b = 1.98$ ksi

Then $K_{Ia}^* = 28.22 \times 1.035 \sqrt{\pi} \sqrt{0.7/1.87} - 1.98 \times 0.47 \sqrt{\pi} \sqrt{0.7/1.87}$

$= 30.67$ ksi $\sqrt{in}$

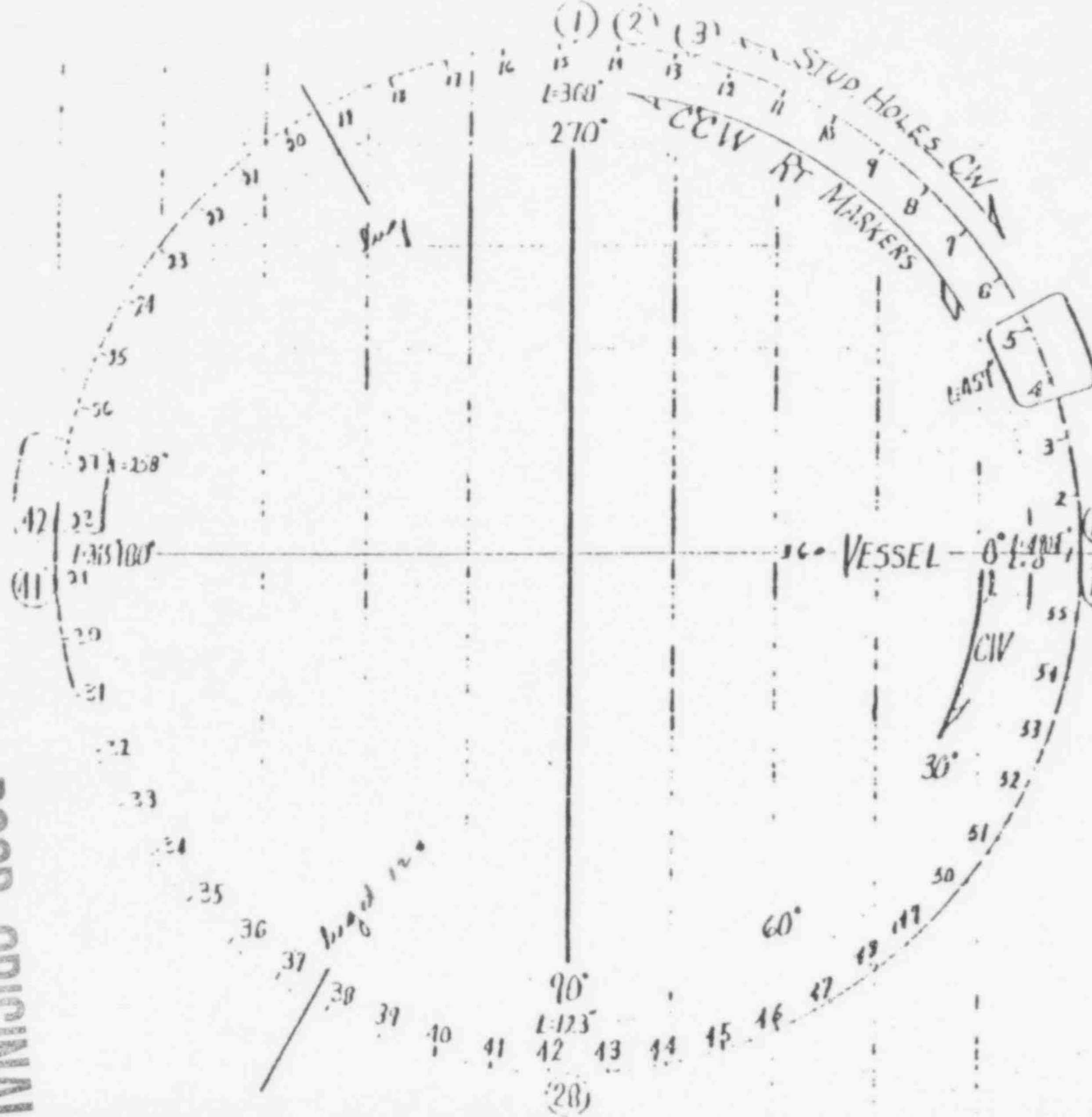
$K_{Ia} = 97$ required

Fig. A-4200-1

$(T - RT_{NDT})$°F required = 118°

(1) Assume 8 ksi residual stress

461 153



CORRELATION OF UT & RT INDICATIONS

UT LENGTH IS MEASURED CW FROM VESSEL 0° ON THE OUTSIDE SURFACE AT THE ℄ OF WELD 07-10 FOR 490⅝ IN.

RT MARKERS 1 THROUGH 55 ARE LAID OUT CCW FROM VESSEL 0°

THE ALLOWABLE UT INDICATION AT L=459" WAS CONFIRMED ON (14) RADIOGRAPH 4-5. THE INDICATION AT (15) L=258" WITH UT DIMENSIONS EXCEEDING ALLOWABLE LIMITS WAS FOUND TO BE AN ALLOWABLE INDICATION ON RADIOGRAPH 27-28.

SWRI 17-5339-004 SEQUOYAH 1

2FEB79 WCMcGaughey

FIGURE 1

461 154

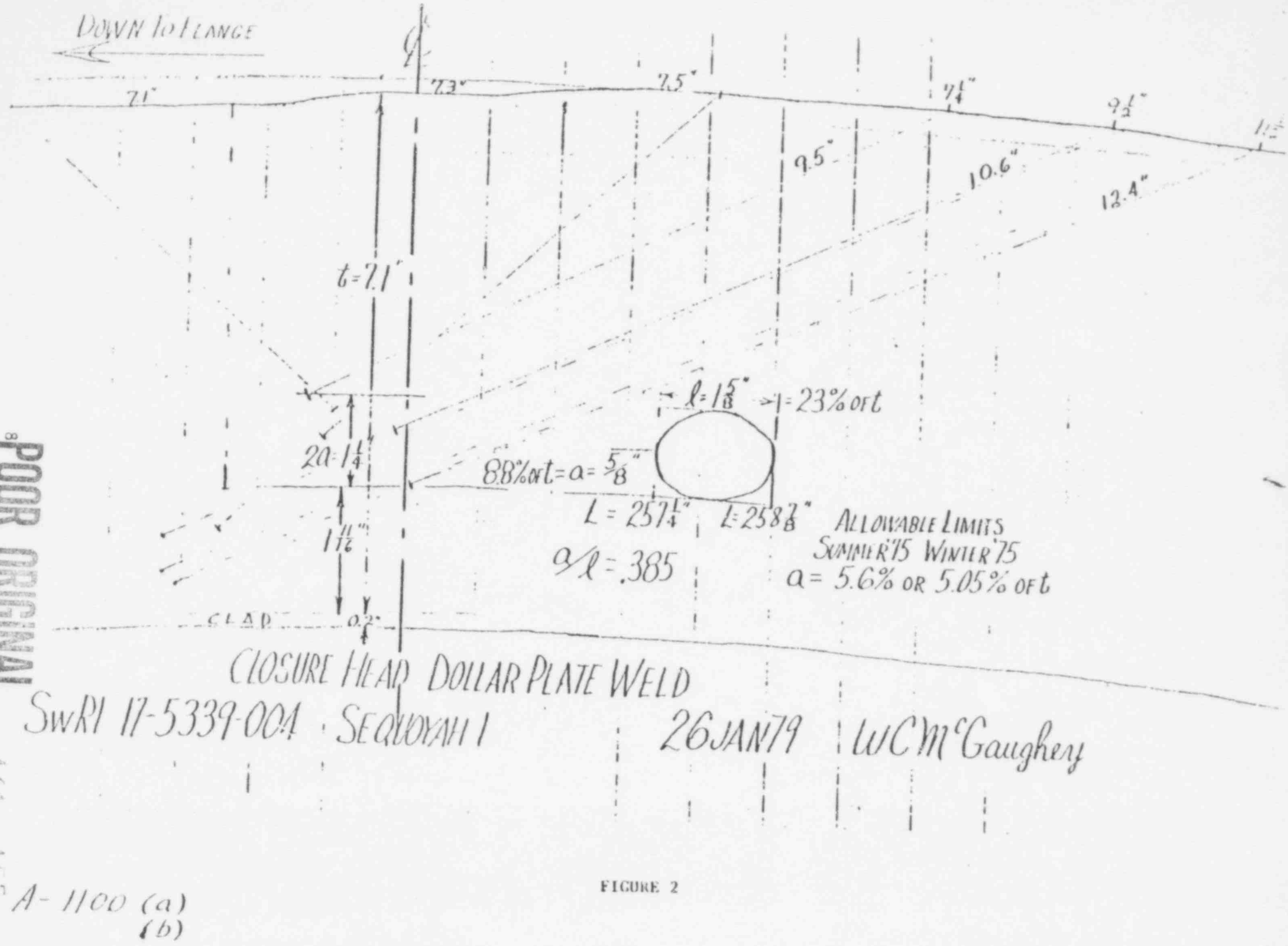
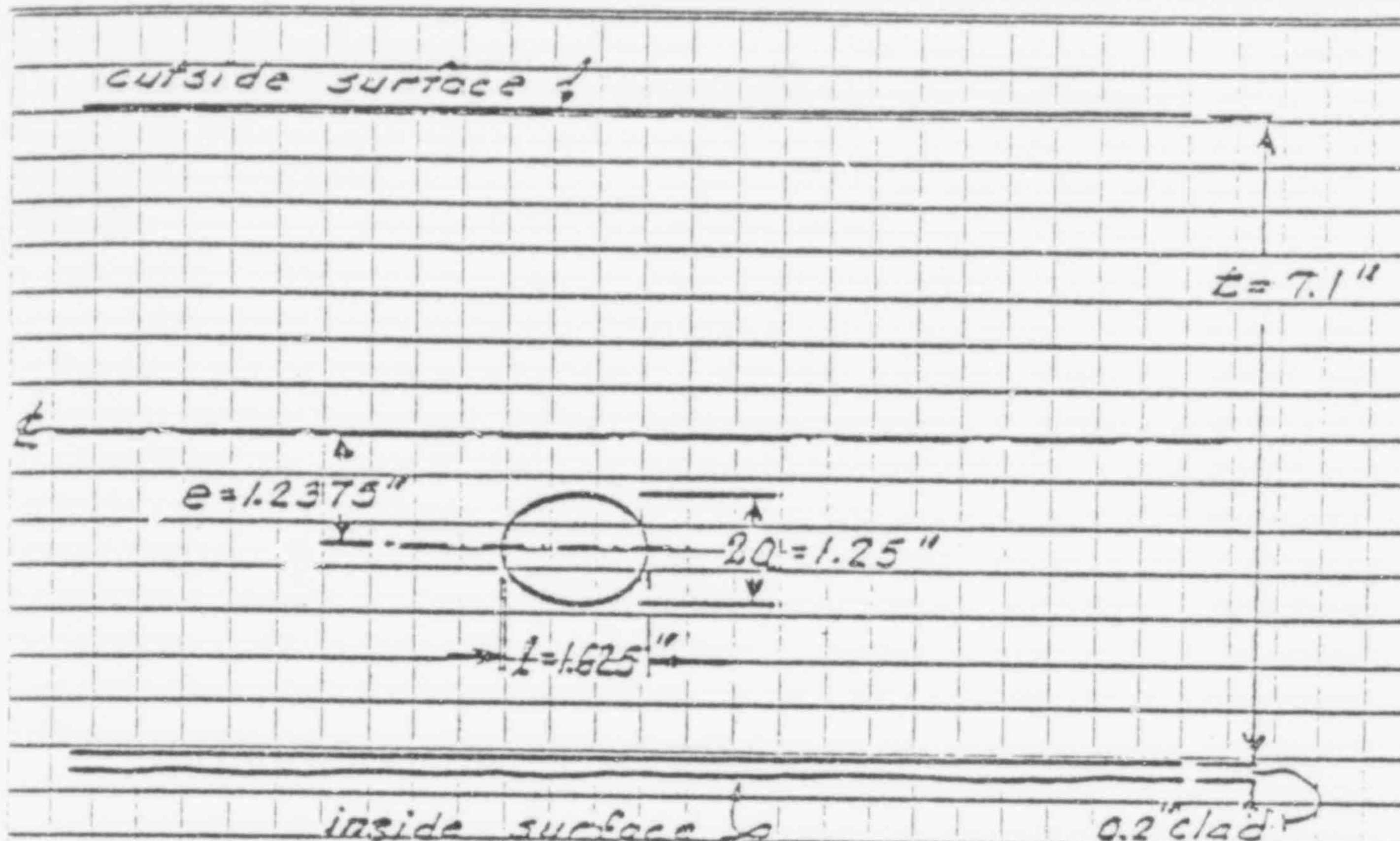


FIGURE 2

461 155

1



a = 0.625"

2e/t = 0.3486

a/l = 0.3246

2a/t = 0.1761

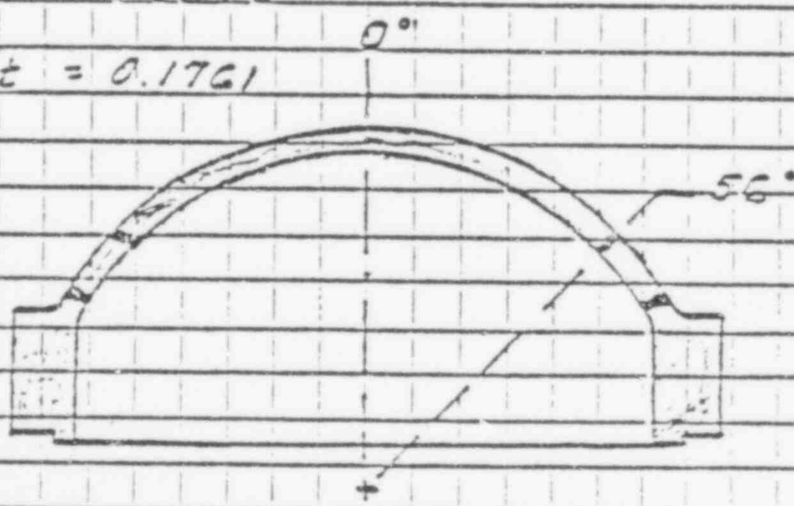
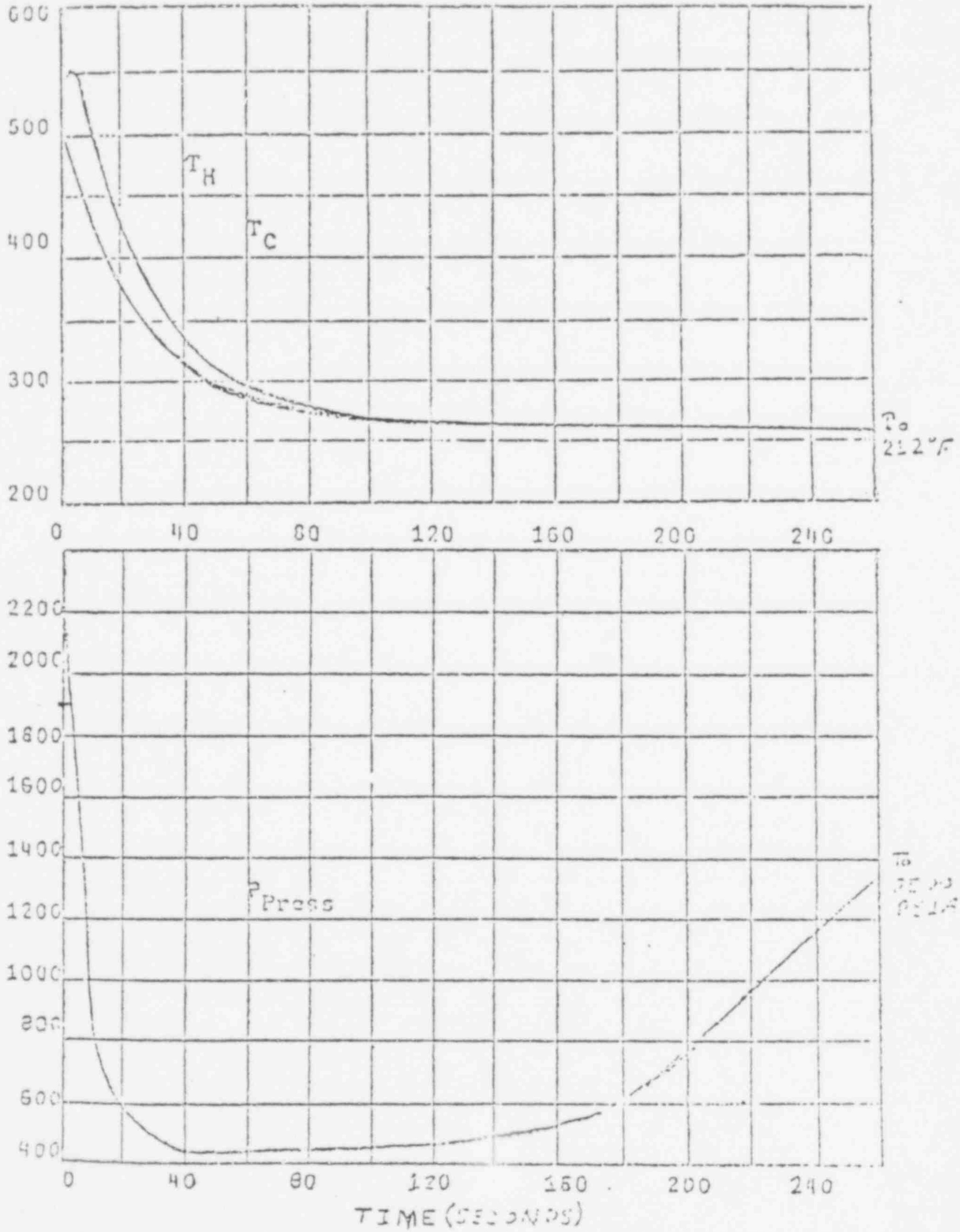


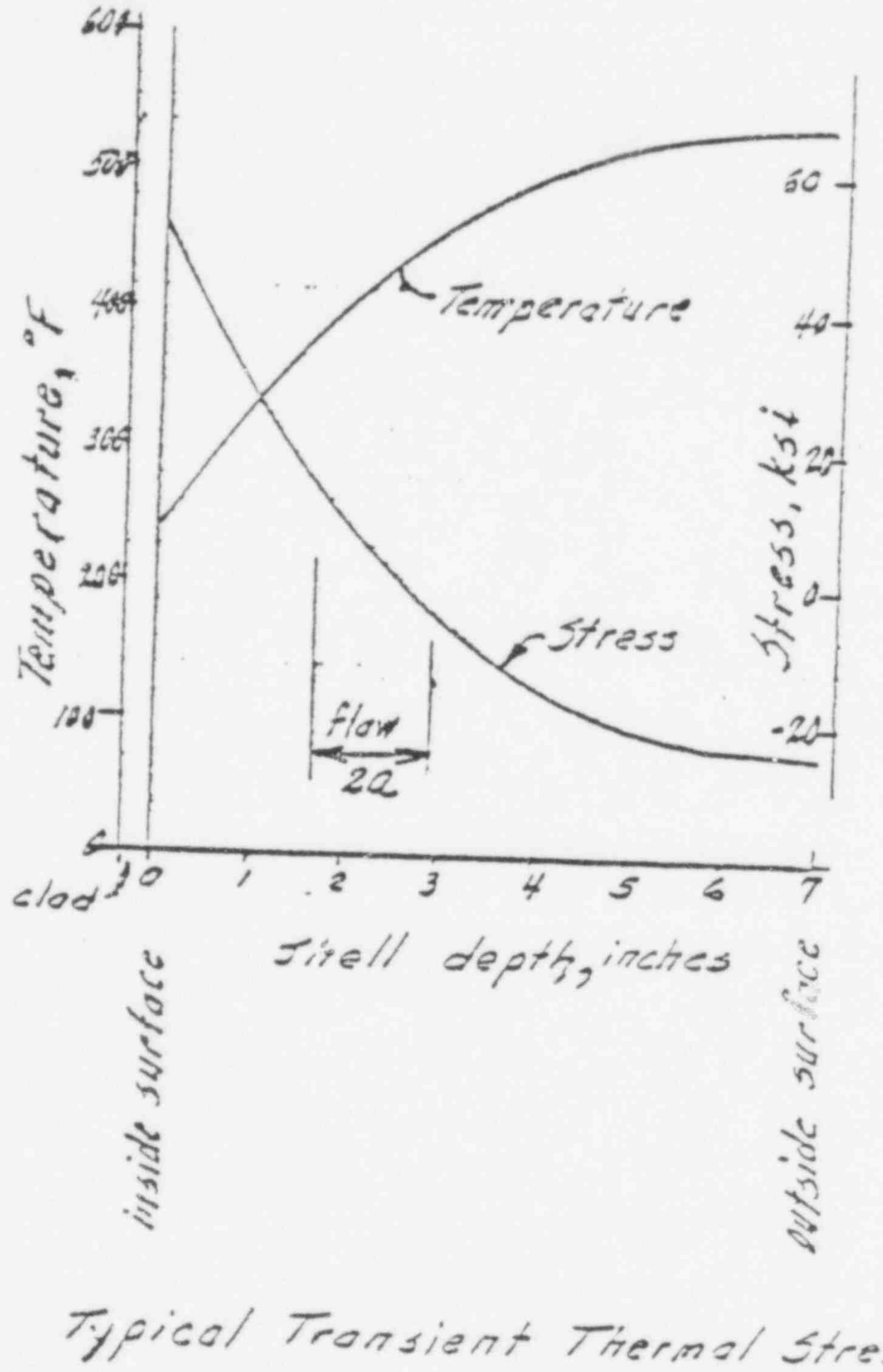
FIGURE 3

 7461 156

FIGURE 12
STEAM LINE BREAK FROM NO LOAD WITH NO RETURN TO POWER



POOR ORIGINAL 461 157



Typical Transient Thermal Stress Calculation Result

FIGURE 5

ENCLOSURE 2

TVA 64 (OS-9-65)

UNITED STATES GOVERNMENT

Memorandum

TENNESSEE VALLEY AUTHORITY

TO : H. S. Fox, Director of Power Production, 716 EB-C (2)

FROM : Roy H. Dunham, Director of Engineering Design, W11A9 C-K

DATE :

SUBJECT: SEQUOYAH NUCLEAR PLANT UNIT 1 - ASME SECTION XI FRACTURE MECHANICS EVALUATION OF A FLAW INDICATION IN THE REACTOR PRESSURE VESSEL CLOSURE HEAD

Reference conversations between E. A. Merrick (EN DES-MEB) and E. F. Harwell (P PROD).

On February 1, 1979, we received data from E. F. Harwell on an indication in the unit 1 reactor pressure vessel (RPV) closure head dollar plate to flange transition forging weld. The indication had been judged unacceptable to the requirements of ASME Section XI, and a decision was made to justify it to the requirements of ASME Code Case N-209. E. F. Harwell requested we perform an analytical evaluation of the flaw.

EN DES-CEB has performed that evaluation by application of procedures from Appendix A to ASME Code Section XI. Compliance with current Section XI flaw acceptance criteria has been demonstrated.

Our evaluation predicts that the existing subsurface planar flaw will grow to an elliptical crack with 2.69- and 2.07-inch major and minor diameters after 40 years of service under specified operating conditions. Applied stress intensification factors are calculated for the final crack dimensions and compared to allowable stress intensification factors from paragraph IWB-3612 of Section XI, thereby demonstrating compliance with the flaw acceptance criteria.

The complete evaluation will be released as report CEB-CQS-79-1 on approximately February 23, 1979, after completion of our internal review.

EN DES has the necessary expertise and component information inhouse to perform work of this nature in a timely responsive manner. This would be especially important for an operating plant. Consequently, we strongly recommend that you consider using EN DES to perform future evaluations rather than having the work performed outside of TVA.

We shall forward you copies of the report upon completion of the review cycle. EN DES engineers will be available to provide support for your presentation of the information on the NRC upon request.

Roy H. Dunham

POOR ORIGINAL

DRP:EAM:MGR

cc: R. G. Domer, W9C224 C-K
MEDS, E4B37 C-K
D. R. Patterson, W10C126 C-K
H. H. Mull, E7B24 C-K
R. M. Pierce, 204 GB-K (2)
G. G. Stack, Sequoyah CONST (4)
E. F. Thomas, 550 CST2-C

461 159

ENCLOSURE 3/

UNITED STATES GOVERNMENT

Memorandum

TENNESSEE VALLEY AUTHORITY

TO : H. S. Fox, Director of Power Production, 716 EB-C (2) C01 790410

FROM : Roy H. Dunham, Director of Engineering Design, W11A9 C-K

due in ARMS by 5/10

DATE :

SUBJECT: SEQUOYAH NUCLEAR PLANT UNIT 1 - ASME SECTION XI FRACTURE MECHANICS EVALUATION OF A FLAW INDICATION IN THE REACTOR PRESSURE VESSEL CLOSURE HEAD

C01790220709

Reference my memorandum to you dated February 13, 1979 (MEB 790214 353). Attachment 1 is the fracture mechanics evaluation report no. CEB-CQS-79-1 promised you in the referenced memorandum.

Attachment 2 (R. G. Domer's memorandum to D. R. Patterson dated March 19, 1979, CEB 790319 011) contains comments developed by our Civil Engineering Branch on Southwest Research Institute's evaluation of the indication in the reactor vessel head.

It is our position that report no. CEB-CQS-79-1 provides adequate assurance that the flaw indication is acceptable for the full service life of the unit 1 reactor vessel and that the Southwest Research Institute report basically substantiates this conclusion. It is our position that no repair is necessary for this indication. Finally, we do not recommend further faulted condition evaluation by Southwest Research Institute.

EN DES has the necessary expertise and component design information inhouse to perform work of this nature in a timely and responsive manner. This would be especially important for an operating plant. Consequently, we strongly recommend that you consider using EN DES to perform future evaluations rather than having the work performed outside of TVA.

EN DES engineers will be available upon request to provide support for your presentation of the information to the NRC.

Roy H. Dunham

Roy H. Dunham

DRP:EAM:MGR

Attachments

cc: R. G. Domer, W9D224 C-K
MEDS, E4B37 C-K
H. H. Mull, E7B24 C-K
D. R. Patterson, W10C126 C-K
R. M. Pierce, 204 GB-K (2)
G. G. Stack, Sequoyah CONST (4)
E. F. Thomas, 550 CST2-C

CHECK IF DIRECTOR'S OFFICE REVIEW REQ'D.

550 1. fr

BOD ✓

POOR ORIGINAL

823

97026/1 *Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan*

CEB-CGS-79-1

TENNESSEE VALLEY AUTHORITY

DIVISION OF ENGINEERING DESIGN
CIVIL ENGINEERING BRANCH

SEQUOYAH NUCLEAR PLANT

ANALYTICAL EVALUATION OF
A FLAW INDICATION IN THE
UNIT 1 REACTOR VESSEL CLOSURE HEAD

	Revision R0	R1	R2	R3	R4	R5
Prepared	J.R. Rockelley, P.E.					
Reviewed	RW Hickman					
Submitted	John S.B. Williams P.E.					
Recommended	R.G. Evans					
Approved	R.G. Klomer					

POOR ORIGINAL

461 161

Attachment #1

TENNESSEE VALLEY AUTHORITY

DIVISION OF ENGINEERING DESIGN
CIVIL ENGINEERING BRANCH

SEQUOYAH NUCLEAR PLANT

ANALYTICAL EVALUATION OF

A FLAW INDICATION IN THE

UNIT 1 REACTOR VESSEL CLOSURE HEAD

	Revision R0	R1	R2	R3	R4	R5
Prepared	J.K. Kochelle					
Reviewed	RW Holsman					
Submitted						
Recommended						
Approved						

461 162

POOR ORIGINAL

7907170140 A

SEQUOYAH NUCLEAR PLANT - ANALYTICAL EVALUATION OF A FLAW INDICATION IN THE UNIT 1 REACTOR VESSEL CLOSURE HEAD

Table of Contents

461 163

SEQUOYAH NUCLEAR PLANT - ANALYTICAL EVALUATION OF A FLAW INDICATION IN THE UNIT 1 REACTOR VESSEL CLOSURE HEAD

Introduction

A flaw indication has been found in the Sequoyah unit 1 reactor vessel closure head at the weld between the closure head dome (dollar plate) and ring. This flaw is of sufficient size to require analytical evaluation to satisfy section XI (reference 1) requirements for flaw acceptability.

This report documents our analytical evaluation of the flaw.

Conclusions

1. The subject subsurface planar flaw will grow from its present size (see page 2) to an elliptical crack of the dimensions shown on page 40 after 40 years of service under the specified operating conditions.

2. The applied stress intensification factors for normal, upset, and faulted conditions with the final crack size are less than allowable stress intensity factors from section XI, IWB-3612 (see page 41). This proves acceptability of the flaw for continued service.

Discussion

This evaluation is based on the procedures of appendix A of section XI. Additional guidance was obtained from reference 5. Stress information was taken from the vessel stress report (reference 2).

Crack growth is predicted for 10-year intervals up to 40 years. An equal number of cycles for each specified operating condition is assumed for each interval.

The final fracture toughness evaluation is based on a 3105 psi hydrotest at 133 F as the limiting condition. Future hydrostatic tests will actually be conducted at higher temperatures. This and other conservative assumptions are noted in the body of the report.

A conservative faulted condition fracture toughness evaluation was also conducted to verify that the hydrotest at 133 F is the limiting condition.

Characterization Of Existing Flaw (Initial Condition)

IWA-3320 - Ref 1

Subsurface Planar Flaw

Fig IWA-3320-1 $\quad S = 1\tfrac{11}{16}'' = 1.6875''$, $a = \tfrac{5}{8}'' = .625''$ $\Big\}$ $S > a$ (Neglect Clad.)

Orientation and Location

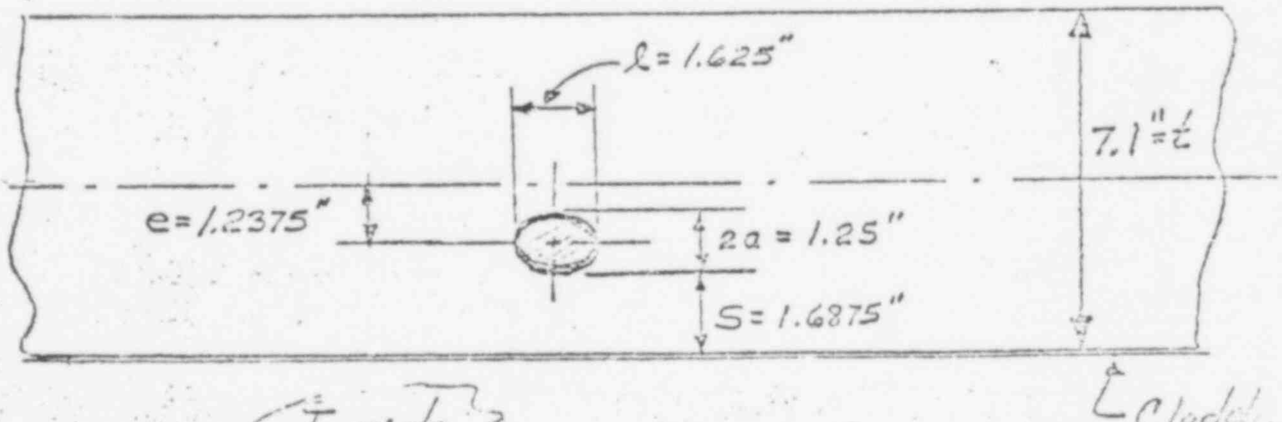
(See Sketch)

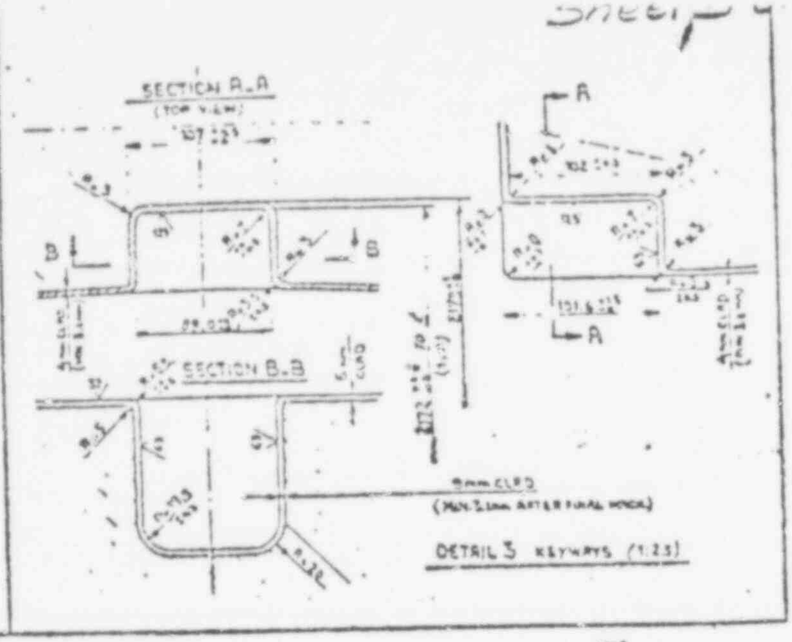
$a = \tfrac{5}{8}'' = .625''$, $l = 1\tfrac{5}{8} = 1.625''$ $\Big\}$ $a/l = .3846$

$t = 7.1''$, $a/t = \frac{.625}{7.1} = 0.088 = 8.8\%$

Flaw Lies In R-Θ Plane ie ⊥ To Meridional Str.

Location Is At Weld Between Closure Hd. Dome & R.





A							
B							
C							
D							
E							
F							
KOORD PLAW	1		1	1	1	1	
MACH AFD	5		5	5	5	5	
APPARATENAFD	6		7	5	4	4	
LASTECHNOL	2		2	2	2	2	
KWAL ZORG	7		7	5	6	6	
MR BROWN	—	—	—			1	
MR GOODWIN	1	1	—		1	1	
LUDERS	3	3	3		3	3	
MR HAY	1	1	1				
MR BECKWITH			1				
WIJZ.	H	J	K	G	D	C	

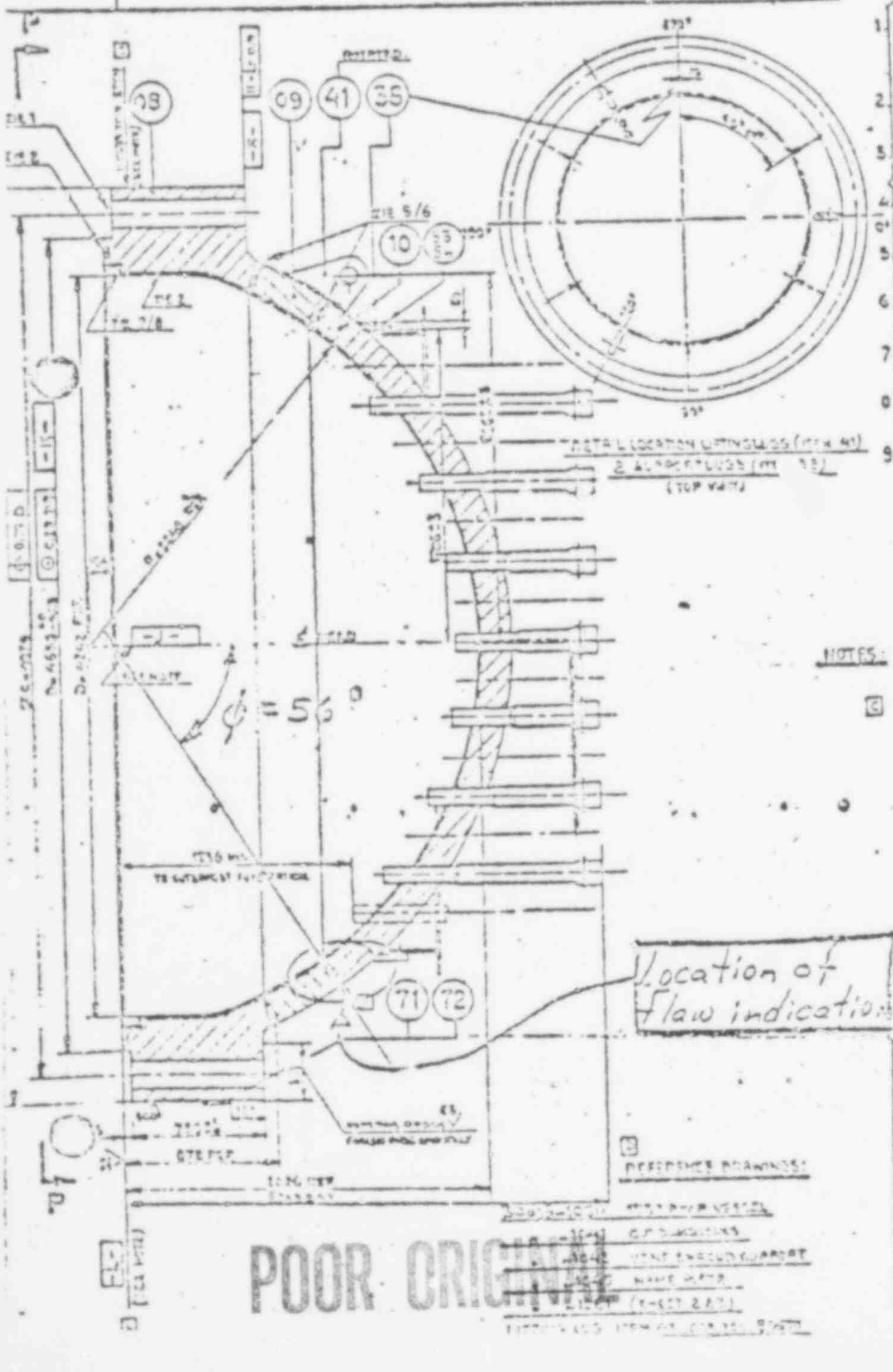
FABRICAGE VOLGORDE:

1. VOORDRAAIEN VAN DEKSELFLENS LEG 00 EN VOORBOREN VAN 54 BOUTGATEN
2. CLADDEN VAN LEG 06 + OPLASSEN VAN PAKKINGVLAK
3. LASSEN VAN HULPSHIRT AAN CAP LEG 10
4. CLADDEN EN VOORBEWERKEN VAN GATEN IN CAP LEG 10
5. MACH BEWERKING LASKANTEN LEG 10, 09 EN 03
6. LASSEN VAN RONDNADEN 03+09 EN 09+10 (LET OP STAND DER GATEN VAN REGELSTAAFDOORV.)
7. VOORBEWERKING SLOTS + CLADDEN (ZIE DETAIL 3)
8. MACH EINDBEWERKING SLOTS, BOUTGATEN, C.R.D. HOLES EN PAKKINGVLAK
9. INLASSEN VAN REGELSTAAFPIJPEN

OPMERKINGEN:

NOTES:

CENTERLINE IS DEFINED AS A VERTICAL LINE PASSING THRU ...
THE INTERSECTION OF THE KEY WAY/ AXIS (AS FABRICATED) TO ...
IS DEFINED AS THE BASIC REFERENCE FOR THE CLOSURE HEAD
FOR VENT PIPE AND WELDING C.R.D. HOUSINGS SEE ...



	72	4		
	71	1	NAME PLATE	
POS NR	AANT.	BENAMING		MATERIAAL

DE ROTTERDAMSCHE DROOGDOK
AFD. N.S.

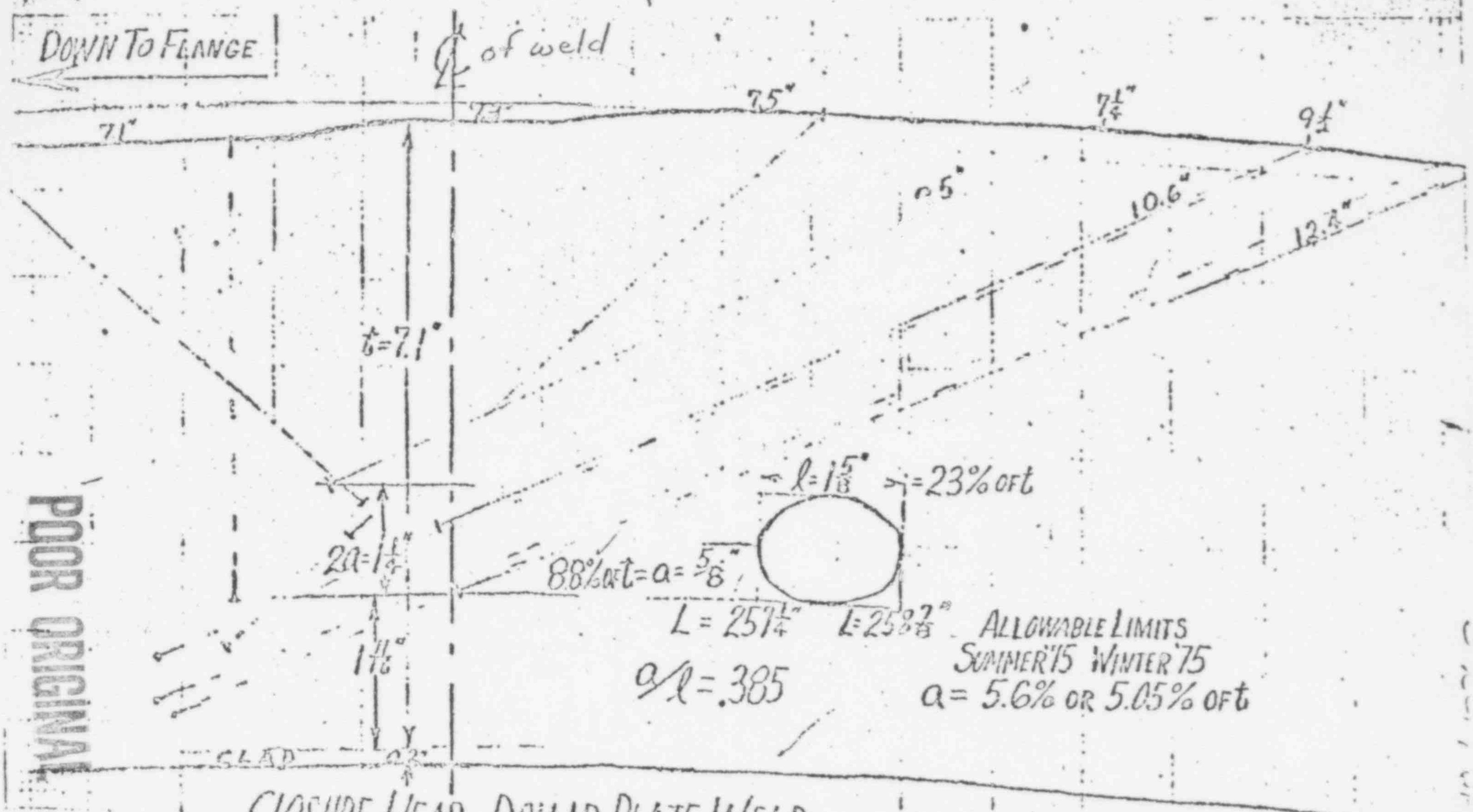
CLOSURE HEAD ASSEMBLY

461 166

X 4254

To: Ed Merrick, W10D 188 C

From: Fonda Harwell, SE



CLOSURE HEAD DOLLAR PLATE WELD

SwRI 17-5339-004 SEQUOYAH I 26JAN79 W.C. McGaughey

POOR ORIGINAL

Acceptability

IWB-3430, IWB-3510, Table IWB-3510-1 Ref 1

$$\text{Allowable } a/t = 4.6 + \left(\frac{.3846-.35}{.40-.35}\right)(5.2-4.6) = \underline{5.015\%}$$

$$\text{Flaw } a/t = \underline{8.8\%} > \text{Allowable}$$

→ Analytical Evaluation Required Per IWB-3600 (Ref 1)

Analytical Evaluation Of Indication - General Procedure

- Apply Appendix A procedures to determine a_f for Normal and Upset conditions specified by E-Spec.* Determine a_f for 10 year intervals.
- At the end of specified 40 year interval evaluate fracture toughness for applied stress intensity factor as described in IWB-3612, for Normal, Upset and Faulted Conditions.

→ * A total of 10^7 cycles of steady state fluxuations to the limit ($\pm$100 psi) are assumed for fatigue evaluat. This assumption was also made by RDM for their code fatigue evaluation in the stress report. ←

TVA 11030 (WM-7-75)

461 168

Material Properties

- Closure Head Dome – A533 B, CL.1

RT_{NDT} = −17 °F (Insignifigant Irradiation Effects)
(See next page)

Temp (°F) =	100	200	300	400	500	600
σ_Y (ksi)	50.	47.1	45.2	44.5	43.2	42.0

(Ref

K_{IC} and K_{Ia} ⇒ Section XI, Fig A-4200-1* Ref 1

*Assume Upper Shelf K_{IC} and K_{Ia} = 200 ksi $\sqrt{in}$

da/dN Curve ⇒ Section XI (Fig A-4300-1)

- Closure Head Ring – A 508, CL.2

RT_{NDT} = +5 °F (Insignifigant Irradiation Effects)
(See Next Page)

Other Properties Same As For Closure Head Dome

- Weld Between Closure Head Dome and Ring

Same As Ring.

TABLE 5.2-30

SEQUOYAH NO. 1 REACTOR VESSEL TOUGHNESS DATA

COMPONENT	Material Grade	Cu (%)	P (%)	NDTT (°F)	MINIMUM 50 ft-lb/35 mil temp. Long. (°F)	Trans. (°F)	RT_{NDT} (°F)	MINIMUM IMPACT ENERGY at highest test temp. Long.	Trans.
Clos. Hd. Dome	A533B,Cl.1	-	-	-40	2	43*	-17	103.7**	
Clos. Hd. Ring	A508,Cl.2	-	-	+ 5	35.5	56.3*	+ 5	125.6**	
Hd. Flange	A508,Cl.2	-	-	-40	-58	- 28*	-40	117.5**	
Vessel Flange	A508,Cl.2	-	-	-49	-63	- 57*	-49	157.8**	
Inlet Nozzle	A508,Cl.2	-	-	-58	25	50*	-10	85.2**	
Inlet Nozzle	A508,Cl.2	-	-	-40	32	72.5*	+12.5	92.7**	
Inlet Nozzle	A508,Cl.2	-	-	-22	- 4	20*	-22	112.9**	
Inlet Nozzle	A508,Cl.2	-	-	-67	8.6	63.6*	+ 3.6	78.3**	
Outlet Nozzle	A508,Cl.2	-	-	-49	17.6	39*	-21	85.2**	
Outlet Nozzle	A508,Cl.2	-	-	-58	30	60*	0	75.5**	
Outlet Nozzle	A508,Cl.2	-	-	-58	16	22*	-30	108.3**	
Outlet Nozzle	A508,Cl.2	-	-	-49	- 4	15*	-45	123.3**	
Upper Shell	A508,Cl.2	-	-	-40	43	70*	+10	74.8**	
Inter. Shell	A508,Cl.2	0.15	.011	- 4	10	100	+40	116	64
Lower Shell	A508,Cl.2	0.13	.015	+ 5	75	133	+73	109	51
Trans. Ring	A508,Cl.2	-	-	+ 5	26.5	44.5*	+ 5	82.4**	
Bot. Hd. Ring	A533B,Cl.1	-	-	-31	23	48*	-12	103.7**	
Bot. Hd. Ring	A533B,Cl.1	-	-	-31	23	48*	-12	103.7**	
Bot. Hd. Ring	A533B,Cl.1	-	-	-13	35.5	NA	≤60[a]	62.8**	
Bot. Hd. Ring	A533B,Cl.1	-	-	-31	39	57*	- 3	86.4**	
Bot. Hd. Ring	A533B,Cl.1	-	-	-49	-24	- 3*	-49	114**	
Bot. Hd. Ring	A533B,Cl.1	-	-	-58	-13	+ 3*	-57	120.4**	
Bot. Hd. Ring	A533B,Cl.1	-	-	-59	-67	11*	-53	137.7**	
Bot. Hd.	A533B,Cl.1	-	-	-40	—	- 4	-40	—	116.9$
Weld	Weld	.25	NA	-22	--	41	-19	—	85.8$
HAZ	WELD HAZ	--	--						

* Estimated (77 ft-lb/54 mil temp. for longitudinal data).

** Percent shear was not reported. The number given in the table is the minimum impact energy value at the highest test temperature (568°F). No transverse upper shelves were estimated because the longitudinal upper shelves were not reached at the test temperatures. The longitudinal upper shelf could be estimated conservatively as 115 ft-lb based on data from Watts Bar Units 1 and 2 vessels which are also being built by the Rotterdam Dockyard Co.

$ The percent shear was reported for weld and HAZ. The number shown is the true upper shelf.

a Estimated conservatively as 60°F or less.

Evaluation of Existing Flaw For Hydrotest Conditions

$P = 3105$ psig
$T = 73 + 60 = 133°F$
$a_f = .625"$ $\quad \sigma_y = 50$ ksi
$T - RT_{NDT} = 133 - 5 = 128°F$

$K_{Ia} = 105$ ksi $\sqrt{in}$, $K_{Ic} = 200$ ksi $\sqrt{in}$ (Fig A-4200-1)

Stress Condition

Ref: Stress Report 30616-1105, Page B.3-14 and 15

Membrane = 11.24 $\frac{kgf}{mm^2}$
Bending = −4.05 "
Inside = 7.19 "
Outside = 15.30 "

} Design Condition Stresses $p = 1.75 \frac{Kgf}{cm^2}$

Pressure Used In Analysis = (1.75)(1422) = 2488.5 psi

Hydrotest Stresses in Ksi, Factor = $(1.422)\left(\frac{3105}{2488.5}\right)$ =

$\sigma_m = (11.24)(1.774) = +19.94$ Ksi

$\sigma_b = (-4.05)(1.774) = -7.18$ Ksi (Compressive to Insi

Stress Intensity Factor

Article A-3000

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

Fig A-3300-1

$\frac{\sigma_m + \sigma_b}{\sigma_{ys}} = \frac{19.94 - 7.18}{50.0} = .255$; $a/\ell = .385$; $Q = 1.9$

Ref Fig A-3300.2

$2a/t = \frac{(2)(.625)}{7.1} = 0.176$

$e = 1.2375$, $\frac{2e}{t} = \frac{(2)(1.2375)}{7.1} = 0.349$

$M_m \cong \underline{1.02}$ @ Pt_1 and Pt_2

Ref Fig A-3300-4

$M_{b_{1i}} = .45$ @ Pt 1 (Toward Inside Of Vessel)

$M_{b_2} = .25$ @ Pt 2 (Toward Outside Of Vessel)

Calculate K_I

$K_{I_{2max}} = (19.94)(1.02)\sqrt{\pi}\sqrt{\frac{.625}{1.95}} + (-7.18)(.25)\sqrt{\pi}\sqrt{\frac{.6}{1.}}$

$= 20.41 - 1.82 = \underline{18.59 \text{ Ksi}\sqrt{in}}$ (to Outside)

$K_{I_1} = (19.94)(1.02)\sqrt{\pi}\sqrt{\frac{.625}{1.95}} + (-7.18)(.45)\sqrt{\pi}\sqrt{\frac{.625}{1.9}}$

$= 20.41 - 3.28 = \underline{17.13 \text{ Ksi}\sqrt{in}}$ (to Inside)

Compare K_I to K_{Ia} Allowable

Ref IWB-3612

$K_{Ia}/\sqrt{10} = \frac{105}{\sqrt{10}} = \underline{33.2} > K_{I_{max}} = \underline{18.59}$

Conclusion: Existing Flaw Meets Criteria @ T = 133°F

Minimum Hydro Test Temperature Corresponds To
$K_{Ia} = (18.59)(\sqrt{10}) = 58.8 \text{ Ksi}\sqrt{in}$

$\therefore T_{min} = 70 + RT_{NDT} = 70 + 5 = \underline{75°F}$ for present fl

TVA 11030 (WM-7-75)

461 172

Stress Cycles At $\phi = 63.2°$ - From RDM Stress Report

1. Primary Side Hydro - (2 Occurences in 10 years ← Conserv

Condition	Mean Stress (Ksi)	Bending Stress (Ksi)
Zero	0	0
Preload	+1.37	-26.12
Hydrotest	+20.23	-22.42

2. Primary Side Leak Test - (13 Occurences in 10 years)

Condition	Mean Stress (Ksi)	Bending Stress (
Zero	0	0
Preload	+1.23	-23.40
Heatup @ 12600 sec	+15.59	-24.39
Heatup @ 13080 sec	+15.59	-23.58
Heatup @ 14040 sec	+15.63	-21.50
Heatup @ 15000 sec	+15.67	-20.63
Heatup @ 18000 sec	+15.80	-19.98
Heatup @ 21000 sec	+15.88	-19.78
Leak Test @ 2485 psi	+16.23	-19.18
Cooldown @ 12600 sec	+4.11	-17.11
Cooldown @ 13080 sec	+4.11	-18.00
Cooldown @ 14040 sec	+4.07	-19.95
Cooldown @ 15000 sec	+4.01	-20.62
Cooldown @ 18000 sec	+3.85	-20.22
Cooldown @ 21000 sec	+3.75	-20.68 ?

TVA 11030 (WM-7-75)

3. Plant Heatup and Cooldown (50 Occurences in 10 Years)

Condition	Mean Stress (Ksi)	Bending Stress (ksi)
Preload	+1.23	-~~23~~.40
Heatup @ 17280 sec	+13.84	-25.16
Heatup @ 18000 sec	+13.85	-23.52
Heatup @ 19080 sec	+13.92	-21.25
Heatup @ 21600 sec	+13.92	-20.42
Heatup @ 23400 sec	+14.06	-20.19
Heatup @ 25200 sec	+14.13	-20.01
Heatup @ 28800 sec	+14.22	-19.67
Heatup @ 32400 sec	+14.31	-19.30
Normal Full Power @ 2225 psi	+14.65	-18.80
Cooldown @ 17280 sec	+4.19	-15.55
Cooldown @ 18000 sec	+4.18	-17.23
Cooldown @ 19080 sec	+4.10	-19.31
Cooldown @ 21600 sec	+4.02	-19.91
Cooldown @ 23400 sec	+3.95	-20.08
Cooldown @ 25200 sec	+3.88	-20.15
Cooldown @ 28800 sec	+3.80	-20.26
Cooldown @ 32400 sec	+3.68	-19.44

4. Small Step Load Increase (500 Occurences in 10 Years)

Condition	Mean Stress (ksi)	Bending Stress (k
Normal Full Power	+14.65	-18.80
First Peak	+15.25	-18.41
Second Peak	+15.46	-17.37

5. Small Step Load Decrease (500 Occurences in 10 years)

Condition	Mean Stress (Ksi)	Bending Stress
Normal Full Power	+14.65	-18.80
First Peak	+13.89	-20.22
Second Peak	+13.76	-19.43

TVA 11030 (WM-7-75)

6. Large Step Load Decrease (50 Occurences in 10 years)

Condition	Mean Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-18.80
First T Peak	+13.87	-20.41
Pressure Peak	+12.78	-19.39
Second T Peak	+14.75	-17.70

7. Loss of Load (20 Occ ences in 10 years)

Condition	Mean Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-18.80
First T Peak	+13.66	-22.30
Second T Peak	+10.51	-19.75

8. Loss of Power (10 Occurences in 10 years)

Condition	Mean Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-18.80
First T Peak	+12.61	-20.27
Pressure Peak	+14.34	-18.64
Second T Peak	+16.25	-18.36

9. Loss of Flow (20 Occurences in 10 years)

Condition	Mean Stress (ksi)	Bending Stress (
Normal Full Power	+14.65	-18.80
First T Peak	+12.59	-20.47
Second T Peak	+13.27	-18.04

10. Reactor Trip From Full Power (100 Occurences in 10 Years

Condition	Mean Stress (ksi)	Bending Stress (
Normal Full Power	+14.65	-18.80
First T Peak	+13.78	-19.20
Second T Peak	+13.24	-18.05

11. Turbine Roll Test (3 Occurences in 10 years)

Condition	Mean Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-18.80
Test	+15.69	-11.34

12. Steady State Fluxuations (2.5×10^6 Occurences in 10 years)

Condition	Mean Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-18.80
First T Peak	+14.21	-18.82
Second T Peak	+14.55	-18.25

Relationship Between Stresses at $\phi = 56°$ And $\phi = 63.2°$

Design Condition (P = 2485 psi)

(Stresses for 10 locations from $\phi = 66.8°$ to $\phi = 56°$ given in RDM stress rep.

$\phi = 63.2°$
$$\sigma_m = (11.37)(1.422) = 16.17 \text{ Ksi}$$
$$\sigma_b = (-12.61)(1.422) = -17.93 \text{ Ksi}$$

$\phi = 56°$
$$\sigma_m = (11.24)(1.422) = 15.98 \text{ Ksi}$$
$$\sigma_b = (-4.05)(1.422) = -5.76 \text{ Ksi}$$

Preload For Design (P = 0)

(Stresses at $\phi = 66.8°, 65.6°, 64.4°,$ and $63.2°$ given in RDM stress repo

$\phi = 63.2°$
$$\sigma_m = (.86)(1.422) = +1.22 \text{ Ksi}$$
$$\sigma_b = (-16.46)(1.422) = -23.41 \text{ Ksi}$$

$\phi = 56°$ (estimate)
$$\sigma_m = +1.22 \text{ Ksi}$$
$$\sigma_b = (-5.76)(1.13) = -6.51 \text{ Ksi}$$

ϕ (°) $\Rightarrow$	66.8	65.6	64.4	63.2	62.0	60.8	59.6	58.4	57.2	5
$\left(\frac{\sigma_{b\,preload}}{\sigma_{b\,design}}\right) \Rightarrow$	1.390	1.364	1.334	1.305	1.28	1.25	1.22	1.19	1.16	1.
	From Stress Report				Extrapolated					

Hydrotest Condition (p = 3105 psi)

$\phi = 63.2°$
$$\sigma_m = (14.22)(1.422) = 20.22 \text{ Ksi}$$
$$\sigma_b = (-15.77)(1.422) = -22.42 \text{ Ksi}$$

$\phi = 56°$ (estimate)
$$\sigma_m = (15.98)\left(\frac{3105}{2485}\right) = 19.97 \text{ Ksi (use 20.0}$$
$$\sigma_b = (-5.76)\left(\frac{3105}{2485}\right) = -7.20 \text{ Ksi}$$

Preload For Hydrotest (p=0)

$\phi = 63.2°$ $\sigma_m = (.96)(1.422) = +1.37$ Ksi
$\sigma_b = (-18.37)(1.422) = -26.12$ Ksi

$\phi = 56°$ (est.) $\sigma_m = +1.37$ Ksi
$\sigma_b = (-6.51)\left(\frac{3105}{2485}\right) = -8.13$ Ksi

Normal Operating Full Power (p = 2235 psi)

$\phi = 63.2°$ $\sigma_m = (10.30)(1.422) = 14.65$ Ksi
$\sigma_b = (-13.22)(1.422) = -18.80$ Ksi

$\phi = 56°$ (est) $\sigma_m = 14.65$ Ksi
$\sigma_b = (-6.51) + (6.51-5.76)\left(\frac{2235}{2485}\right) = -6.15$ Ksi

Pressure = 385 psi

$\phi = 63.2°$ (est) $\sigma_m = 3.75$ Ksi (From RDM Stress Report)
$\sigma_b = -23.41 + (23.41-17.93)\left(\frac{385}{2485}\right) = -22.56$

$\phi = 56°$ (est) $\sigma_m = 3.75$ Ksi
$\sigma_b = -6.51 + (6.51-5.76)\left(\frac{385}{2485}\right) = -6.39$

General Relationship For Design and Operating Conditions

Membrane Stress Relationship

$\boxed{\sigma_{m_{56}} = \sigma_{m_{63.2}}}$ (Conservative)

Bending Stress Relationship

Pressure and Preload

$\sigma_{P/b_{56}} = -6.51 + (6.51-5.76)\left(\frac{P}{2485}\right) = -6.51 + 0.75\left(\frac{P}{2485}\right)$

$\sigma_{P/b_{63.2}} = -23.41 + (23.41-17.93)\left(\frac{P}{2485}\right) = -23.41 + 5.48\left(\frac{P}{2485}\right)$

Bending Stress Relationship* (Continued)

Thermal

$$\sigma_T)_{b56} = \sigma_T)_{b63.2} \quad \text{(Conservative)}$$

$$\boxed{(\sigma_p + \sigma_T)_{b56} = (\sigma_p + \sigma_T)_{b63.2} + 16.90 - 4.73\left(\frac{P}{2485}\right)} \quad \text{(General Relations}$$

For $P = 0$ (Preload for Design and Operation)

$$\sigma_{b56} = \sigma_{b63.2} + 16.90 = -23.41 + 16.90 = \underline{-6.51 \text{ ksi}}$$

For $P = 2485$ (Design)

$$\sigma_{b56} = \sigma_{b63.2} + 16.90 - 4.73 = -17.93 + 16.90 - 4.73 = \underline{-5.76 \text{ ksi}}$$

For $P = 2235$ Normal Full Power

$$\sigma_{b56} = \sigma_{b63.2} + 16.90 - (4.73)\left(\frac{P}{2485}\right)$$

$$= -18.80 + 16.90 - 4.25 = \underline{-6.15 \text{ ksi}}$$

For $P = 385$

$$\sigma_{b56} = \sigma_{b63.2} + 16.90 - (4.73)\left(\frac{385}{2485}\right)$$

$$= \underline{\sigma_{b63.2} + 16.16}$$

* Note: P subscript indicates pressure and preload str
T subscript indicates thermal stress.

461 179

Stress Cycles At $\phi = 56.0°$

1. Primary Side Hydrostatic Test

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Zero	0	0
Preload	+1.37	-8.13
Hydrotest	+20.22	-7.20

2. Primary Side Leak Test

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Zero	0	0
Preload	+1.23	-6.51
Heatup @ 12600 sec	+15.59	-12.22
Heatup @ 13080 sec	+15.59	-11.42
Heatup @ 14040 sec	+15.63	-9.32
Heatup @ 15000 sec	+15.67	-8.46
Heatup @ 18000 sec	+15.80	-7.81
Heatup @ 21000 sec	+15.88	-7.61
Leak Test @ 2435 psi	+16.23	-7.01
Cooldown @ 12600 sec	+4.11	-0.95
Cooldown @ 13080 sec	+4.11	-1.84
Cooldown @ 14040 sec	+4.07	-3.79
Cooldown @ 15000 sec	+4.01	-4.46
Cooldown @ 18000 sec	+3.85	-4.66
Cooldown @ 21000 sec	+3.75	-4.52

TVA 11030 (V/M-7-75)

3. Plant Heatup and Cooldown

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Preload	+1.23	-6.51
Heatup @ 17280 sec	+13.84	-12.51
Heatup @ 18000 sec	+13.85	-10.87
Heatup @ 19080 sec	+13.92	-8.60
Heatup @ 21600 sec	+13.92	-7.77
Heatup @ 23400 sec	+14.06	-7.54
Heatup @ 25200 sec	+14.13	-7.36
Heatup @ 28800 sec	+14.22	-7.02
Heatup @ 32400 sec	+14.31	-6.65
Normal Full Power	+14.65	-6.15
Cooldown @ 17280 sec	+4.19	+0.61
Cooldown @ 18000 sec	+4.18	-1.07
Cooldown @ 19080 sec	+4.10	-3.15
Cooldown @ 21600 sec	+4.02	-3.75
Cooldown @ 23400 sec	+3.95	-3.92
Cooldown @ 25200 sec	+3.88	-3.99
Cooldown @ 28800 sec	+3.80	-4.10
Cooldown @ 32400 sec	+3.68	-3.28

4. Small Step Load Increase

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-6.15
First Peak p=2295	+15.25	-5.88
Second Peak p=2170	+15.46	-4.60

5. Small Step Load Decrease

Condition	Membrane Stress (ksi)	Bending Stress
Normal Full Power	+14.65	-6.15
First Peak p=2310	+13.89	-7.72
Second Peak p=2155	+13.76	-6.63

6. Large Step Load Decrease

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-6.15
First Peak p=2335	+13.87	-7.95
Pressure Peak p=1960	+12.78	-6.22
Second Peak p=2135	+14.75	-4.86

7. Loss of Load

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-6.15
First Peak p=2535	+13.66	-10.32
Second Peak p=1605	+10.51	-7.77

8. Loss of Power

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-6.15
First Peak p=2065	+12.61	-7.30
Pressure Peak p=2160	+14.34	-5.85
Second Peak p=2485	+16.25	-6.19

9. Loss of Flow

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-6.15
First Peak p=2110	+12.59	-7.59
Second Peak p=1865	+13.27	-4.69

10. Reactor Trip From Full Power

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	-6.15
First Peak p=2335	+13.78	-6.74
Second Peak p=1960	+13.24	-4.88

11. Turbine Roll Test

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	∓6.15
Test p= 1932	+15.69	+1.88

12. Steady State Fluxuations

Condition	Membrane Stress (ksi)	Bending Stress (ksi)
Normal Full Power	+14.65	∓6.15
First Peak p=2335	+14.21	-6.36
Second Peak p=2135	+14.55	-5.41

Crack Growth For First 10 Years Of Service

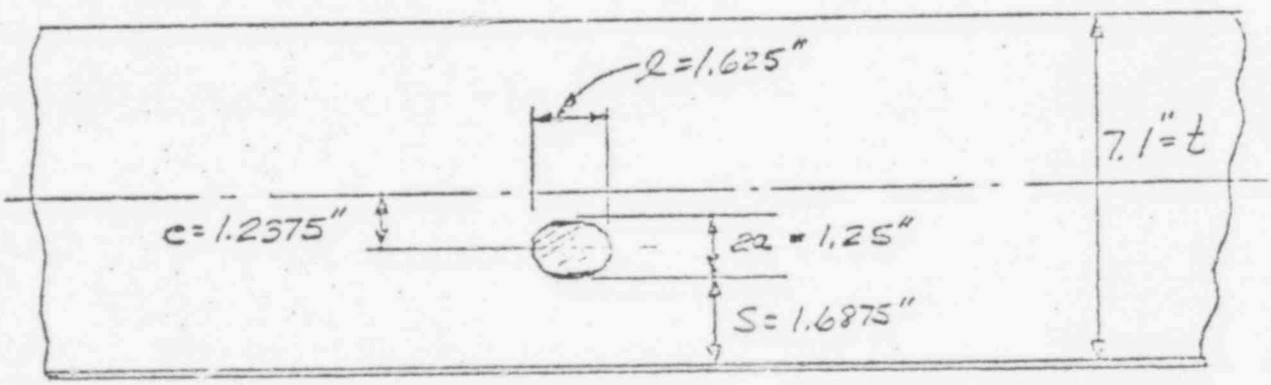
Assumptions

1. Use da/dN curve from Section XI, Appendix A, Fig A 4300-1

$$da/dN = (.0267)(10^{-3})\,\Delta K_I^{3.726}$$

2. Determine ΔK_I for each normal and upset operating condition at $\phi = 56°$.

3. Use initial properties for crack size.



$a = .625"$ $\qquad a/t = 0.088 = 8.8\%$ $\qquad 2a/t = 0.176$

$l = 1.625"$

$e = 1.2375"$ $\qquad a/l = 0.3846$

$t = 7.1"$

Primary Side Hydrostatic Test

1. Preload Condition

$\sigma_m = +1.37\ ksi$, $\sigma_b = -8.13\ ksi$, $T = 70°F$, $\sigma_y = 50\ ksi$

$\frac{\sigma_m + \sigma_b}{\sigma_y} = \frac{1.37 + 8.13}{50} = 0.19$, $a/l = 0.3846$

$Q = 1.9$ (Fig A-3300-1)

$\frac{2a}{t} = 0.176$, $\frac{2e}{t} = \frac{(2)(1.2375)}{7.1} = 0.3486$

$M_m = 1.02$ @ Pt. 1 and 2 (Fig A 3300-2)

$M_{b_1} = .45$, $M_{b_2} = .25$ (Fig A 3300-4)

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

stet 1.016 AKR 2-5-79 conservative

$= \sigma_m M_m \sqrt{\frac{(\pi)(.625)}{1.9}} + \sigma_b M_b \sqrt{\frac{(\pi)(.625)}{1.9}} = 1.033 (\sigma_m M_m + \sigma_b M_b)$

$K_{I_1} = (1.033)[(1.37)(1.02) + (-8.13)(.45)] = -2.34\ ksi\sqrt{in}$

$K_{I_2} = (1.033)[(1.37)(1.02) + (-8.13)(.25)] = -.66\ ksi\sqrt{in}$

2. Test Condition ($p = 3105\ psi$)

$\sigma_m = +20.22\ ksi$, $\sigma_b = -7.20\ ksi$, $T = 113°F$, $\sigma_y = 50\ ksi$

$\frac{\sigma_m + \sigma_b}{\sigma_y} = \frac{20.22 + 7.20}{50} = 0.55$, $a/l = 0.3846$

$Q = 1.9$ (Fig A-3300-1) , $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$

$K_{I_1} = 1.033[(20.22)(1.02) + (-7.20)(.45)] = +17.96\ ksi\sqrt{in}$

$K_{I_2} = 1.033[(20.22)(1.02) + (-7.20)(.25)] = +19.45\ ksi\sqrt{in}$

3. $\Delta K_I = 17.96 - (-2.34) = \underline{20.30}\ ksi\sqrt{in} = \Delta K_{I_1}$

4. Growth (micro-inches/cycle)

$$da/dN = (.0267)(10^{-3})(\Delta K_I)^{3.726}$$

$$= (.0267)(10^{-3})(20.30)^{3.726} = 1.987 \text{ in}$$

Primary Side Leak Test

1. Preload

$\sigma_m = +1.23$ Ksi, $\sigma_b = -6.51$ Ksi, $T = 70°F$, $\sigma_y = 50$ ksi

$\frac{\sigma_m + \sigma_b}{\sigma_y} = \frac{1.23 + 6.51}{50} = .19$, $a/\ell = 0.3846$, $Q = 1.9$

$M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$

$K_{I_1} = 1.033[(1.23)(1.02) + (-6.51)(.45)] = -1.73$ ksi $\sqrt{in}$

$K_{I_2} = 1.033[(1.23)(1.02) + (-6.51)(.25)] = -.39$ Ksi $\sqrt{in}$

2. Heatup @ 12600 sec.

$\sigma_m = 15.59$ Ksi, $\sigma_b = -12.22$ Ksi, $T \cong T_{fluid} - 50 = 350°F$, $\sigma_y =$

$\frac{\sigma_m + \sigma_b}{\sigma_y} = \frac{15.59 + 12.29}{\sigma_y} = .62$ $a/\ell = 0.3846$

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$

$K_{I_1} = 1.033[(15.59)(1.02) + (-12.22)(.45)] = +10.75$ ksi $\sqrt{in}$

$K_{I_2} = 1.033[(15.59)(1.02) + (-12.22)(.25)] = +13.27$ ksi $\sqrt{in}$

3. Leak Test @ 2485 psi

$\sigma_m = 16.23$ Ksi, $\sigma_b = -7.01$ Ksi, $T = T_{fluid} = 400°F$, $\sigma_y = 44.5$ ksi

$\frac{\sigma_m + \sigma_b}{\sigma_y} = \frac{16.23 + 7.01}{44.5} = 0.52$, $a/l = 0.3846$, $Q = 1.9$

$M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$

$K_{I_1} = 1.033\left[(16.23)(1.02) + (-7.01)(.45)\right] = +13.84$ Ksi $\sqrt{in}$

$K_{I_2} = 1.033\left[(16.23)(1.02) + (-7.01)(.25)\right] = \underline{+15.29}$ Ksi $\sqrt{in}$

4. Cooldown @ 18000 sec.

$\sigma_m = 3.85$ Ksi, $\sigma_b = -4.66$ Ksi, $T \cong T_{fluid} = 70°F$, $\sigma_y = 50$ ksi

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$

$K_{I_1} = 1.033\left[(3.85)(1.02) + (-4.66)(.45)\right] = +1.89$ Ksi $\sqrt{in}$

$K_{I_2} = 1.033\left[(3.85)(1.02) + (-4.66)(.25)\right] = +2.85$ Ksi $\sqrt{in}$

5. Growth (micro inches/cycle)

$da/dN = (.0267)(10^{-3})(\Delta K_I)^{3.726}$

$\Delta K_I = 15.29 - (-.39) = 15.68$ Ksi $\sqrt{in} = \Delta K_{I_2}$

$da/dN = (.0267)(10^{-3})(15.68)^{3.726} = \underline{.7522}$

Plant Heatup and Cooldown

1. Preload Condition

Same as for Leak Test

$K_{I_1} = -1.73 \text{ ksi}\sqrt{in}$, $K_{I_2} = -.39 \text{ ksi}\sqrt{in}$

2. Heatup @ 17280 sec

$\sigma_m = 13.84 \text{ ksi}$, $\sigma_b = -12.51 \text{ ksi}$, $T \cong T_{fluid} - 50° = 547 - 50 \cong 500°$

$\sigma_y = 43.2 \text{ ksi}$, $\frac{\sigma_m + \sigma_b}{\sigma_y} = \frac{13.84 + 12.51}{43.2} = .61$

$Q = 1.90$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$

$K_{I_1} = (1.033)\left[(13.84)(1.02) + (-12.51)(.45)\right] = +8.77 \text{ ksi}\sqrt{in}$

$K_{I_2} = (1.033)\left[(13.84)(1.02) + (-12.51)(.25)\right] = +11.35 \text{ ksi}\sqrt{in}$

3. Normal Full Power ($p = 2235$ psi)

$\sigma_m = 14.65 \text{ ksi}$, $\sigma_b = -6.15 \text{ ksi}$, $T = 547°F$, $\sigma_y = 42.6$ k

$\frac{\sigma_m + \sigma_b}{\sigma_y} = \frac{14.65 + 6.15}{42.6} = 0.49$

$Q = 1.90$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$

$K_{I_1} = 1.033\left[(14.65)(1.02) + (-6.15)(.45)\right] = +12.58 \text{ ksi}$

$K_{I_2} = 1.033\left[(14.65)(1.02) + (-6.15)(.25)\right] = +13.85 \text{ ksi}$

TVA 11030 (WM-7-75)

461 188

4. Cooldown @ 28800 sec

$\sigma_m = 3.80\,ksi$, $\sigma_b = -4.10\,ksi$, $T = 70°F$, $\sigma_y = 50\,ksi$

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$

$K_{I_1} = 1.033[(3.80)(1.02) + (-4.10)(.45)] = +2.10\,ksi\sqrt{in}$

$K_{I_2} = 1.033[(3.80)(1.02) + (-4.10)(.25)] = +2.95\,ksi\sqrt{in}$

5. Growth (micro inches/cycle)

$da/dN = (0.0267)(10^{-3})(\Delta K_I)^{3.726}$

$\Delta K_I = 12.58 - (-1.73) = 14.31\,ksi\sqrt{in} = \Delta K_{I_1}$

$da/dN = (0.0267)(10^{-3})(14.31)^{3.726} = \underline{0.540}$

Small Step Load Increase

1. Normal Full Power

See previous calc. $K_{I_1} = +12.58$ ksi $\sqrt{in}$, $K_{I_2} = 13.85$ ksi $\sqrt{in}$

2. First Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 15.25$ ksi, $\sigma_b = -5.8$

$K_{I_1} = 1.033\left[(15.25)(1.02) + (-5.88)(.45)\right] = 13.34$ ksi $\sqrt{in}$

$K_{I_2} = 1.033\left[(15.25)(1.02) + (-5.88)(.25)\right] = 14.55$ ksi $\sqrt{in}$

3. Second Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 15.46$, $\sigma_b = -4.$

$K_{I_1} = 1.033\left[(15.46)(1.02) + (-4.60)(.45)\right] = 14.15$ ksi $\sqrt{in}$

$K_{I_2} = 1.033\left[(15.46)(1.02) + (-4.60)(.25)\right] = 15.10$ ksi $\sqrt{in}$

4. Crack Growth (micro inches/cycle)

$da/dN = (.0267)(10^{-3})\,\Delta K_I^{3.726}$

$\Delta K_{I_1} = 14.15 - 12.58 = 1.57$, $\Delta K_{I_2} = 15.10 - 13.85 = 1.25$

$da/dN = (0.0267)(10^{-3})(1.57)^{3.726} = \underline{0.143\,(10^{-3})}$

461 190

Small Step Load Decrease

1. Normal Full Power

See Previous Calc. $K_{I_1} = +12.58$ ksi$\sqrt{in}$, $K_{I_2} = 13.85$ ksi$\sqrt{in}$

2. First Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 13.89$, $\sigma_b = -7.7$

$K_{I_1} = 1.033[(13.89)(1.02) + (-7.72)(.45)] = 11.05$ ksi$\sqrt{in}$

$K_{I_2} = 1.033[(13.89)(1.02) + (-7.72)(.25)] = 12.64$ ksi$\sqrt{in}$

3. Second Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 13.76$, $\sigma_b = -6.$

$K_{I_1} = 1.033[(13.76)(1.02) + (-6.63)(.45)] = 11.42$ ksi$\sqrt{in}$

$K_{I_2} = 1.033[(13.76)(1.02) + (-6.63)(.25)] = 12.79$ ksi$\sqrt{in}$

4. Crack Growth

$da/dN = (.0267)(10^{-3})(\Delta K_I)^{3.726}$

$\Delta K_{I_1} = 12.58 - 11.05 = 1.53$; $\Delta K_{I_2} = 13.85 - 12.64 = 1.21$

$da/dN = (0.0267)(10^{-3})(1.53)^{3.726} = \underline{0.130(10^{-3})}$

461 191

TVA 11030 (WM-7-75)

Large Step Load Decrease

1. Normal Full Power

From Previous Calc. $K_{I_1} = 12.58 \text{ Ksi}\sqrt{in}$, $K_{I_2} = 13.85 \text{ Ksi}\sqrt{in}$

2. First Peak

$\sigma_m = 13.87 \text{ Ksi}$, $\sigma_b = -7.95 \text{ Ksi}$

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$

$K_{I_1} = 1.033[(13.87)(1.02) + (-7.95)(.45)] = 10.92 \text{ Ksi}\sqrt{in}$

$K_{I_2} = 1.033[(13.87)(1.02) + (-7.95)(.25)] = 12.56 \text{ Ksi}\sqrt{in}$

2. Pressure Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 12.78 \text{ Ksi}$, $\sigma_b = -6.22$

$K_{I_1} = 1.033[(12.78)(1.02) + (-6.22)(.45)] = 10.57 \text{ Ksi}\sqrt{in}$

$K_{I_2} = 1.033[(12.78)(1.02) + (-6.22)(.25)] = 11.86 \text{ Ksi}\sqrt{in}$

3. Second Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 14.75 \text{ Ksi}$, $\sigma_b = -4.$

$K_{I_1} = (1.033)[(14.75)(1.02) + (-4.86)(.45)] = 13.28 \text{ Ksi}\sqrt{in}$

$K_{I_2} = (1.033)[(14.75)(1.02) + (-4.86)(.25)] = 14.29 \text{ Ksi}\sqrt{in}$

4. Crack Growth (Micro Inches / Cycle)

$\Delta K_{I_1} = 13.28 - 10.57 = 2.71$, $\Delta K_{I_2} = 14.29 - 11.86 = 2.43$

$da/dN = (.0267)(10^{-3})(\Delta K_I)^{3.726} = \underline{1.096\,(10^{-3})}$

Loss of Load

1. Normal Full Power

From Previous Calc. $K_{I_1} = 12.58$ Ksi $\sqrt{in}$, $K_{I_2} = 13.85$ Ksi $\sqrt{in}$

2. First Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 13.66$ ksi, $\sigma_b = -10.32$ ksi

$K_{I_1} = 1.033[(13.66)(1.02) + (-10.32)(.45)] = 9.60$ ksi $\sqrt{in}$

$K_{I_2} = 1.033[(13.66)(1.02) + (-10.32)(.25)] = 11.73$ ksi $\sqrt{in}$

3. Second Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 10.51$ ksi, $\sigma_b = -7.77$ ksi

$K_{I_1} = 1.033[(10.51)(1.02) + (-7.77)(.45)] = 7.46$ ksi $\sqrt{in}$

$K_{I_2} = 1.033[(10.51)(1.02) + (-7.77)(.25)] = 9.07$ ksi $\sqrt{in}$

4. Crack Growth (Micro Inches/cycle)

$\Delta K_{I_1} = 12.58 - 7.46 = 5.12$; $\Delta K_{I_2} = 13.85 - 9.07 = 4.78$

$da/dN = (0.0267)(10^{-3})(\Delta K_I)^{3.726} = \underline{11.73(10^{-3})}$

TVA 11030 (WK-7-75)

461 193

Loss of Power

1. Normal Full Power

From Previous Calc. $K_{I_1} = 12.58$ ksi$\sqrt{in}$, $K_{I_2} = 13.85$ ksi$\sqrt{in}$

2. First Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 12.61$ ksi, $\sigma_b = -7.30$ ksi$\sqrt{in}$

$K_{I_1} = 1.033\left[(12.61)(1.02) + (-7.30)(.45)\right] = 9.89$ ksi$\sqrt{in}$

$K_{I_2} = 1.033\left[(12.61)(1.02) + (-7.30)(.25)\right] = 11.40$ ksi$\sqrt{in}$

3. Pressure Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 14.34$ ksi, $\sigma_b = -5.85$

$K_{I_1} = 1.033\left[(14.34)(1.02) + (-5.85)(.45)\right] = 12.39$ ksi$\sqrt{in}$

$K_{I_2} = 1.033\left[(14.34)(1.02) + (-5.85)(.25)\right] = 13.60$ ksi$\sqrt{in}$

4. Second Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma = 16.25$ ksi, $\sigma_b = -6.19$

$K_{I_1} = 1.033\left[(16.25)(1.02) + (-6.19)(.45)\right] = 14.24$ ksi$\sqrt{in}$

$K_{I_2} = 1.033\left[(16.25)(1.02) + (-6.19)(.25)\right] = 15.52$ ksi$\sqrt{in}$

5. Crack Growth

$\Delta K_{I_1} = 14.24 - 9.89 = 4.35$, $\Delta K_{I_2} = 15.52 - 11.40 = 4.12$

$da/dN = 0.0267\,(\Delta K_I)^{3.726} = \underline{6.370(10^{-3})}$

Loss of Flow

1. Normal Full Power

From Previous Calc. $K_{I_1} = 12.58\ Ksi\sqrt{in}$, $K_{I_2} = 13.85\ Ksi\sqrt{in}$

2. First Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 12.59\ ksi$, $\sigma_b = -7.59\ ksi$

$$K_{I_1} = 1.033\left[(12.59)(1.02) + (-7.59)(.45)\right] = 9.74\ Ksi\sqrt{in}$$

$$K_{I_2} = 1.033\left[(12.59)(1.02) + (-7.59)(.25)\right] = 11.31\ Ksi\sqrt{in}$$

3. Second Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, σ_m 3.27 ksi, $\sigma_b = -4.69$

$$K_{I_1} = (1.033)\left[(13.27)(1.02) + (-4.69)(.45)\right] = 11.80\ Ksi\sqrt{in}$$

$$K_{I_2} = (1.033)\left[(13.27)(1.02) + (-4.69)(.25)\right] = 12.77\ Ksi\sqrt{in}$$

4. Crack Growth (Micro-Inches/Cycle)

$\Delta K_{I_1} = 12.58 - 9.74 = 2.84$, $\Delta K_{I_2} = 13.85 - 11.31 = 2.54$

$$da/dN = 0.0267\left(\Delta K_I\right)^{3.726} = \underline{1.305\left(10^{-3}\right)}$$

Reactor Trip From Full Power

1. Normal Full Power

From Previous Calc. $K_{I_1} = 12.58\ ksi\sqrt{in}$, $K_{I_2} = 13.85\ ksi\sqrt{in}$

2. First Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 13.78\ ksi$, $\sigma_b = -6.74\ ksi$

$K_{I_1} = 1.033\left[(13.78)(1.02) + (-6.74)(.45)\right] = 11.39\ ksi\sqrt{in}$

$K_{I_2} = 1.033\left[(13.78)(1.02) + (-6.74)(.25)\right] = 12.78\ ksi\sqrt{in}$

3. Second Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 13.24\ ksi$, $\sigma_b = -4.88$

$K_{I_1} = 1.033\left[(13.24)(1.02) + (-4.88)(.45)\right] = 11.68\ ksi\sqrt{in}$

$K_{I_2} = 1.033\left[(13.24)(1.02) + (-4.88)(.25)\right] = 12.69\ ksi\sqrt{in}$

4. Crack Growth (Micro Inches/cycle)

$\Delta K_{I_1} = 12.58 - 11.39 = 1.19$; $\Delta K_{I_2} = 13.85 - 12.69 = 1.16\ ksi\sqrt{in}$

$da/dN = 0.0267\,(\Delta K_I)^{3.726} = \underline{.0512\,(10^{-3})}$

461 196

Turbine Roll Test

1. Normal Full Power

From Previous Calc. $K_{I_1} = 12.58$ ksi$\sqrt{in}$, $K_{I_2} = 13.85$ ksi$\sqrt{in}$

2. Roll Test

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 15.69$ ksi, $\sigma_b = +1.88$

$$K_{I_1} = 1.033\left[(15.69)(1.02) + (+1.88)(.45)\right] = 17.41 \text{ ksi}\sqrt{in}$$

$$K_{I_2} = 1.033\left[(15.69)(1.02) + (+1.88)(.25)\right] = 17.02 \text{ ksi}\sqrt{in}$$

3. Crack Growth (Micro-Inches/Cycle)

$\Delta K_{I_1} = 17.41 - 12.58 = 4.83$; $\Delta K_{I_2} = 17.02 - 13.85 = 3.17$

$$da/dN = (0.0267)(\Delta K_I)^{3.726} = \underline{9.44(10^{-3})}$$

Steady State Fluxuations

1. Normal Full Power

From Previous Calc. $K_{I_1} = 12.58 \text{ ksi}\sqrt{\text{in}}$, $K_{I_2} = 13.85 \text{ ksi}\sqrt{\text{in}}$

2. First Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 14.21 \text{ ksi}$, $\sigma_b = -6.36 \text{ ksi}$

$$K_{I_1} = 1.033\left[(14.21)(1.02) + (-6.36)(.45)\right] = 12.02 \text{ ksi}\sqrt{\text{in}}$$

$$K_{I_2} = (1.033)\left[(14.21)(1.02) + (-6.36)(.25)\right] = 13.33 \text{ ksi}\sqrt{\text{in}}$$

3. Second Peak

$Q = 1.9$, $M_m = 1.02$, $M_{b_1} = .45$, $M_{b_2} = .25$, $\sigma_m = 14.55 \text{ ksi}$, $\sigma_b = -5.41$

$$K_{I_1} = 1.033\left[(14.55)(1.02) + (-5.41)(.45)\right] = 12.82 \text{ ksi}\sqrt{\text{in}}$$

$$K_{I_2} = 1.033\left[(14.55)(1.02) + (-5.41)(.25)\right] = 13.93 \text{ ksi}\sqrt{\text{in}}$$

4. Crack Growth (Micro-Inches/Cycle)

$\Delta K_{I_1} = 12.82 - 12.02 = 0.80$, $\Delta K_{I_2} = 13.93 - 13.33 = .60$

$$da/dN = 0.0267\ (\Delta K)^{3.726} = \underline{0.0116\ (10^{-3})}$$

461 198

Total Crack Growth After 10 Years

Operational Cycle	No. of Cycles	da/dN micro-inches/cycle	da (micro-i
Primary Side Hydrotest	2	1.987	3.97[illegible]
Primary Side Leak Test	13	.759	9.867
Plant Heatup and Cooldown	50	.540	27.00[illegible]
Small Step Load Increase	500	.143 (10^{-3})	.072
Small Step Load Decrease	~~500~~	.130 (10^{-3})	.065
Large Step Load Decrease	50	1.096 (10^{-3})	.05[illegible]
Loss of Load	20	11.73 (10^{-3})	.23[illegible]
Loss of Power	10	6.390 (10^{-3})	.064
Loss of Flow	20	1.304 (10^{-3})	.026
Reactor Trip From Full Power	100	.0512 (10^{-3})	.005
Turbine Roll Test	3	9.44 (10^{-3})	.02[illegible]
Steady State Fluxuations	$2.5(10)^6$	0.0116 (10^{-3})	29.0[illegible]
			70.4

→ Conservatively multiply calculated growth by 10^3 ←

$a_{f_{10}} = (70.4)(10^{-3}) + (.625) = \underline{.695''}$

Assuming $a/\ell = 0.3846$, $\ell_{f_{10}} = \frac{.695}{.3846} = \underline{1.808''}$

Determine Factors For New Crack Size $(a_{f_{10}}, \ell_{f_{10}})$

Flaw Shape Factor ⇒ $Q = 1.9$ (Fig A-3300-1) No Change

Membrane Stress Correction Factor, M_m (Fig A-3300-2)

$2a/t = \frac{(2)(.695)}{7.1} = .196$, $2a/t = \frac{(2)(1.2375)}{7.1} = 0.3486$

$M_{m_1} = 1.03$, $M_{m_2} = 1.02$ Very slight change, Neglect

Bending Stress (Fig A 3300-4)

$2a/t = 0.3486$, $a/t = .196$, $M_{b_1} = .45$, $M_{b_2} = .25$ No change

$\sqrt{\frac{\pi a}{Q}} = \sqrt{\frac{\pi(.695)}{1.9}} = \underline{1.072}$

461 199

TVA 11030 (WM-7-75)

Total Crack Growth After 20 Years

$$da_{20} = d_{a_{10}} + d_{a_{10}}\left(\frac{1.072}{1.033}\right)^{3.726} = 70.4 + (1.148)70.4 = 151.2$$

$$a_{f_{20}} = .1512 + .625 = \underline{.776}''$$

$$\ell_{20} = \frac{.776}{.3846} = \underline{2.01}''$$

Determine Factors For New Crack Size $(a_{f_{20}}, \ell_{20})$

Flaw Shape Factor ⇒ $Q = 1.9$ (Fig A-3300-1) No Change

Membrane Stress Correction Factor, M_m (Fig A-3300-2)

$$\frac{2a}{t} = \frac{(2)(.776)}{7.1} = .219,\quad \frac{2a}{\ell} = 0.3486$$

$M_{m_1} = 1.04$, $M_{m_2} = 1.03$ ≅2% change Neglect

Bending Stress (Fig A3300-4)

$M_{b_1} = .45$, $M_{b_2} = .25$ No Change

$$S_{20} = 1.6875 - .1512 = 1.536'' \Rightarrow a_{f_{20}} = .776''$$

$$\sqrt{\frac{\pi a}{Q}} = \sqrt{\frac{(\pi)(.776)}{1.9}} = \underline{1.133}$$

TVA 11030 (WM-7-75)

461 200

Total Crack Growth After 30 Years

$$d_{a_{30}} = da_{20} + \left(\frac{1.133}{1.033}\right)^{3.726} da_{10} = 151.2 + (1.411)\,70.4 = 250.5$$

$$a_{f_{30}} = .2505 + .625 = \underline{.876''}$$

$$\ell_{30} = \frac{.876}{.3846} = \underline{2.28''}$$

Determine Factors For New Crack Size $(a_{f_{30}}, \ell_{30})$

Flaw Shape Factor $\Rightarrow Q = 1.9$ (Fig A-3300-1) No Change

Membrane Stress Correction Factor, M_m (Fig A-3300-2)

$$2a/t = \frac{(2)(.876)}{7.1} = .247 \quad , \quad 2a/t = 0.3486$$

$M_{m_1} = 1.06$, $M_{m_2} = 1.04$ $\approx 4\%$ Change - Neglect

Bending Stress Correction Factor (Fig A-3300-?)

$M_{b_1} = .48$, $M_{b_2} = .25$ $\approx 8\%$ Change - Neglect

$$S_{30} = 1.6875 - .2505 = 1.437'' > a_{f_{30}} = 0.876''$$

$$\sqrt{\frac{a\pi}{Q}} = \sqrt{\frac{(.876)\pi}{1.9}} = \underline{1.203}$$

TVA 11030 (WM-7-75)

Total Crack Growth After 40 years

$$da_{40} = da_{30} + da_{10}\left(\frac{1.203}{1.033}\right)^{3.726} = 250.5 + 70.4(1.764) = 374.7$$

$$a_{f40} = .375 + .625 = 1.000''$$

$$l_{40} = \frac{1.000}{.3846} = 2.60''$$

Determine Factors For New Crack Size (a_{f40}, l_{40})

Flaw Shape Factor $\Rightarrow Q = 1.9$ (Fig A-3300-1) No Change

Membrane Stress Correction Factor, M_m (Fig A-3300-2)

$$2a/t = \frac{(2)(1.000)}{7.1} = .282, \quad 2a/t = 0.3486$$

$$M_{m_1} = 1.07, \quad M_{m_2} = 1.05 \qquad \approx 5\% \text{ change}$$

Bending Stress Correction Factor, M_b (Fig A3300-4)

$$M_{b_1} = .50, \quad M_{b_2} = .21 \qquad \approx 16\% \text{ change}$$

$$S_{40} = 1.6875 - .375 = 1.313'' > a = 1.000''$$

$$\sqrt{\frac{\pi a}{Q}} = \sqrt{\frac{(\pi)(1.00)}{1.9}} = \underline{1.285}$$

Adjusted* Crack Growth After 40 Years

$$da_{40a} = da_{30} + da_{10}\left(\frac{1.286}{1.033}\right)^{3.726} = 250.5 + (70.4)(2.26) = 409.6$$

$$a_{f40a} = .410 + .625 = \boxed{1.035''} \leftarrow$$

$$l_{40a} = \frac{1.035}{.3846} = \boxed{2.691''} \leftarrow$$

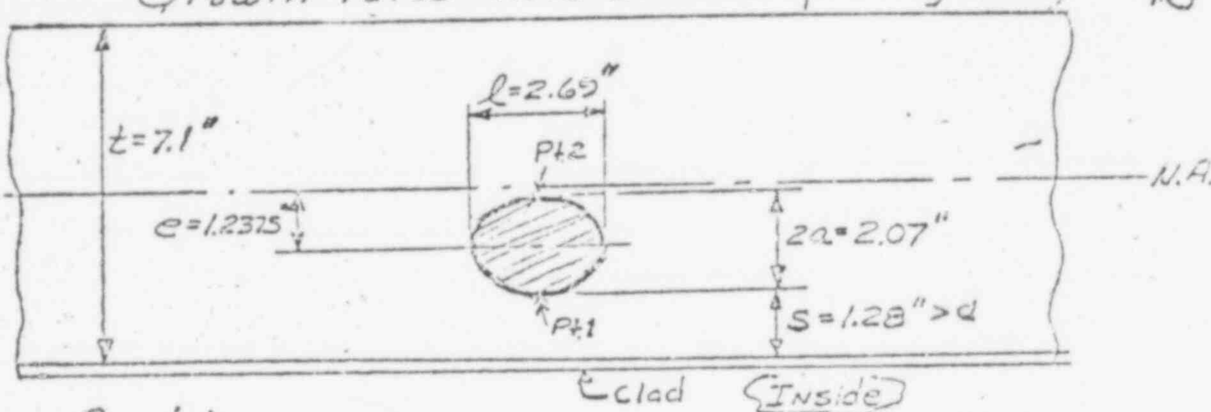
$$S_{40a} = 1.6875 - .410 = \boxed{1.278''} > \underline{a = 1.035''}$$

461 202

*Considers iteration step of stress correction factor variations.

Fracture Toughness Evaluation With Final Crack Size ($a_{f_{40a}}$)

Geometry (The final crack size will not exceed this limit: Growth rates have been multiplied by 1000; See pg.



Stress Condition

Evaluate for Hydrotest Condition: $\sigma_m = 20.22$ Ksi
(Temperature = 73+60 = 133°F) $\sigma_b = -7.20$ Ksi
($p = 3105$ psi)

Allowable Stress Intensity Factor

Ref. IWB-3612 : $K_{I_{all.}} = K_{Ia}/\sqrt{10}$

$T - RT_{NDT} = 133 - 5 = 128°F$ (Conservative - Future Hydrotests will be conducted at higher temperatures - E.R.Wier.

From Fig (A-4200-1) : $K_{Ia} = 105$ Ksi $\sqrt{in}$, $K_{Ic} = 200$ Ksi $\sqrt{in}$

$K_{I_{all}} = 105/\sqrt{10} = 33.2$ Ksi $\sqrt{in}$

Applied Stress Intensification Factor

Flaw Shape Factor, Q

$Q = 1.9$ (Fig A-3300-1) From Previous Calc.

Membrane Stress Correction Factor, M_m (Fig A-3300-2)

$2a/t = \frac{(2)(1.035)}{7.1} = .292$, $2e/t = 0.3486$

$M_{m_1} = 1.09 \quad , M_{m_2} = 1.07$

Bending Stress Correction Factor, M_b (Fig A3300-4)

$M_{b_1} = .50 \quad , M_{b_2} = .21$

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

$$K_{I_1} = (20.22)(1.09)\sqrt{\frac{(\pi)(1.035)}{1.9}} + (-7.20)(.50)\sqrt{\frac{(\pi)(1.035)}{1.9}}$$

$$= 28.83 - 4.71 = \underline{24.12 \text{ ksi}\sqrt{in}} < K_{I_{all}} = \underline{33.2 \text{ ksi}\sqrt{in}}$$

$$K_{I_2} = (20.22)(1.07)\sqrt{\frac{(\pi)(1.035)}{1.9}} + (-7.20)(.21)\sqrt{\frac{(\pi)(1.035)}{1.9}}$$

$$= 28.30 - 1.98 = \underline{26.32 \text{ ksi}\sqrt{in}} < K_{I_{all}} = \underline{33.2 \text{ ksi}\sqrt{in}}$$

Conclusions

1. The hydrotest condition produces the highest stress intensity factor at the evaluated crack for normal and upset conditions.
2. The requirements of section XI paragraph IWB-3612 are satisfied for a hydrotest, performed after 40 years of specified service conditions, at a test temperature of 133°F. This test temperature is based on the requirement of $T_{test} = (RT_{NDT})_{max} + 60 = 73 + 60 = 133°F$.
3. For all other significant* normal and upset conditions the temperature is sufficiently high ($\geq 105°F$) to justify use of the 200 ksi$\sqrt{in}$ upper shelf values of K_{IC} and K_{Ia}. This results in an allowable of $200/\sqrt{10}$ = 63.2 ksi$\sqrt{in}$, compared to the 133°F allowable of 33.2 ksi$\sqrt{in}$. (For faulted conditions $K_{I_{all}} = 200/\sqrt{2} = 141.4$ ksi$\sqrt{in}$)

POOR ORIGINAL

* Conditions with $K_I \leq 30/\sqrt{10} = 9.5$ ksi$\sqrt{in}$ are not considered significant. They are acceptable regardless of temperature. (See Fig A-4200-1)

61 204

TVA 11030 (M-7-75)

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [illegible] DATE 2-26-79 CHECKED BY [illegible] DATE 3-7-79

FRACTURE TOUGHNESS EVALUATION WITH FINAL CRACK SIZE - FAULTED CONDITION

FOR GEOMETRY SEE SHEET 40.

STRESS CONDITION

FAULTED CONDITION FROM WESTINGHOUSE EQUIPMENT SPEC 678777 (REF 3) PAGES 6 & 19. PAGE 19 IS INCLUDED IN THIS REPORT AS SHEET 43.

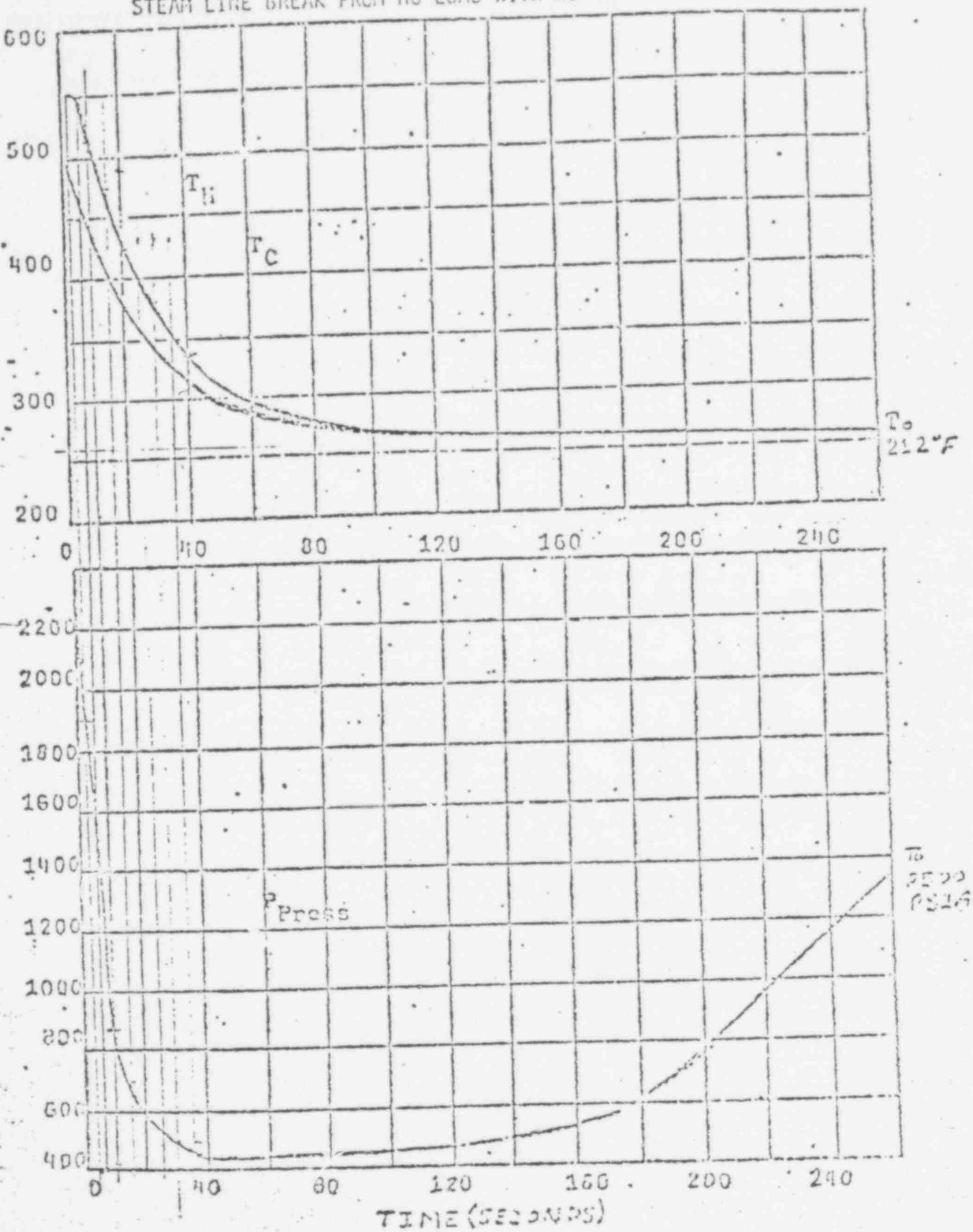
FIND STRESS AT LOCATION OF FLAW DUE TO TEMPERATURE TRANSIENT. SINCE REF 6 PAGE 842 DESCRIBES THE STRESS IN A SPHERICAL SHELL AS A FUNCTION OF THE METAL TEMPERATURE, THE TEMPERATURE PROFILE OF THE SHELL THICKNESS MUST FIRST BE ESTABLISHED.

TEMPERATURE EVALUATION

POOR ORIGINAL

SINCE THE INSIDE SURFACE OF THE SHELL IS IMMERSED IN WATER,

FIGURE 12
STEAM LINE BREAK FROM NO LOAD WITH NO RETURN TO POWER



PCOR ORIGINAL

461 206

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH
COMPUTED BY AWR DATE 2-26-79 CHECKED BY JWR DATE 3-7-79

IT WILL START TO COOL RELATIVELY SLOWLY AT T= 4 SECONDS, WHEN THE WATER TEMPERATURE BEGINS TO DROP. NO SIGNIFICANT HEAT IS LOST UNTIL THE PRESSURE IS BELOW THE SATURATION PRESSURE FOR THE METAL TEMPERATURE AND BOILING COMMENCES.

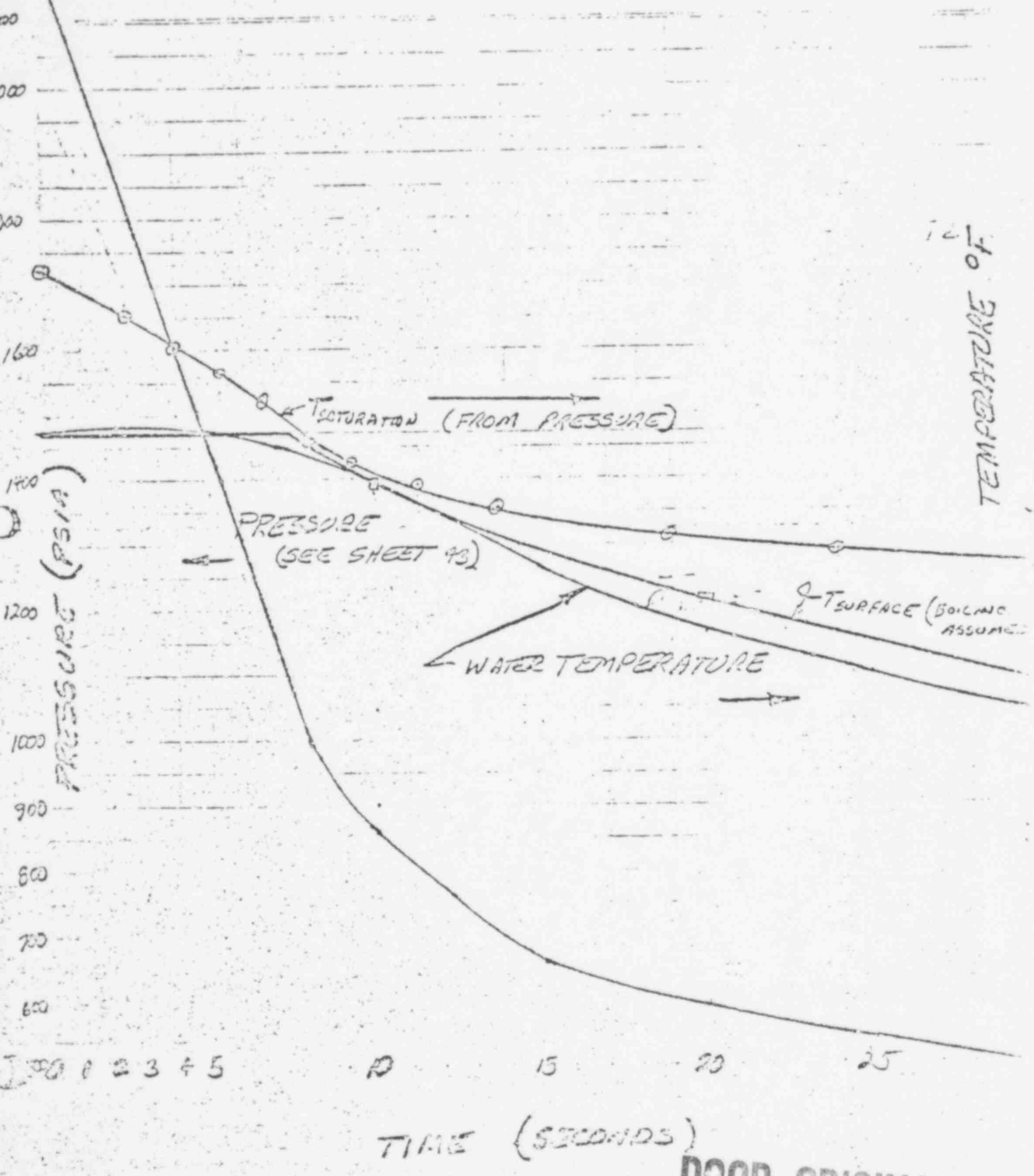
FROM THAT POINT (T=8 SECONDS) THE ASSUMPTION WAS MADE THAT THE SHELL WOULD BE COOLED BY BOILING SUBCOOLED WATER. THE FIGURE ON SHEET 45 SHOWS THAT THE SURFACE TEMPERATURE OF THE METAL NEVER REACHES THE BOILING POINT (SATURAT TEMPERATURE) OF THE WATER FOR THE ASSUMED CONDITIONS. FIGURE 20 ON PAGE 13-24 OF REF 7 GIVES THE HEAT FLOW FOR [illegible] OF

POOR ORIGINAL 461 207

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET 45 OF 60

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [illegible] DATE 3/7/79 CHECKED JKR DATE 3-7-79



POOR ORIGINAL

461 208

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [illegible] DATE 2-26-79 CHECKED BY JKR DATE 3-7-79

SUBCOOLED WATER AS A FUNCTION OF TWO QUANTITIES a) THE DIFFERENCE BETWEEN METAL SURFACE TEMPERATURE AND SATURATION TEMPERATURE, & b) THE DEGREE OF SUBCOOL OF THE WATER. ASSUMING THE CONDITIONS AT T = 10 SECONDS, T_{WALL} IS ABOUT 550°F, T_{SAT} = 525°F (REF 7 Pg 2-90 P = 850 PSIA), $T_{WATER} \approx 510°F$

$T_{WALL} - T_{SAT} = \Delta T_{SAT} = 550°F - 525°F = 25°F$

$T_{SAT} - T_{WATER} = 525 - 510°F = \Delta T_{SUB} = 15°F$

(USE 25° IN FIG 20)

$q \approx 10^5$ BTU/HR FT^2

IN ORDER TO FIND THE TEMPERATURE PROFILE FROM FIGURE 22 ON PAGES 3-39, 40 & 41 OF REF 7 AN EQUIVALENT FILM COEFICIENT (h) MUST BE FOUND.

POOR ORIGINAL

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [signature] DATE 2-26-79 CHECKED BY DATE 3-7-79

$$q = h\,(T_{WALL} - T_{WATER})$$

$$h = \frac{q}{(T_{WALL} - T_{WATER})} = \frac{10^5 \ BTU/HR\ FT^2}{550-510 \ {}^\circ F} = 2500 \frac{BTU}{HR\ FT^2\ {}^\circ F}$$

SINCE THE STRESS INCREASES WITH HEAT LOSS RATE & REF 8 LISTS $500 < h < 1000$ ON PAGE 4-98 & SHEET 44a SHOWS THAT THE RESULTING SURFACE TEMP. IS BELOW THE SATURATION TEMP. THIS IS A VERY CONSERVATIVE FIGURE $\left(2500 \frac{BTU}{HR\ FT^2\ {}^\circ F}\right)$ TO USE.

ASSUME THE WATER TEMPERATURE DROPS INSTANTLY TO T_2 SO THAT FIGURE 3-22 (REF 7) CAN BE USED.

$$\frac{h\delta}{K} = \frac{500\,(7.1)}{26.7\,(12)} = 55.4 \quad \text{UNITLESS}$$

$$\frac{\alpha\theta}{\delta^2} = \frac{.4198/3600}{7.1^2/144} \times \theta\ \text{SEC} = 3.33 \times 10^{-4}\,\theta$$

461 210

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [illegible] DATE 2-27-79 CHECKED BY AKR DATE 3-7-79

x/δ ↓	θ sec	10	20	30	40	50	60
	$\frac{\alpha\theta}{\delta^2}$	3.33×10^{-3}	6.66×10^{-3}	.01	.0133	.0166	.02
0		.81	.86	.88	.90	.92	.92
.02		.62	.72	.77	.81	.82	.84
.1		.15	.30	.42	.45	.52	.56
.4		0	0	.01	.015	.02	.05
1		0	0	0	0	0	0

461 211

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR PROJECT SEQUOYAH

COMPUTED BY [illegible] DATE 3-7-79 CHECKED BY JKR DATE 3-7-79

x/δ	θ	70	80	90	100	110	120	150
	$\frac{\alpha\theta}{\delta}$	.0233	.0266	.0299	.0333	.0366	.04	.05

$t-t_o / t_a-t_o$

0	.92	.93	.935	.94	.945	.95	.96
.02	.84	.86	.87	.875	.88	.885	.90
.1	.58	.61	.63	.65	.67	.68	.72
.4	.05	.07	.09	.10	.12	.14	.18
1	0	0	0	0	0	0	.01

TEMPERATURE

t_o	280	275	273	270	269	268	267
0	302	294	291	287	284	282	278
.02	323	313	309	305	303	300	295
.1	393	387	375	368	362	358	34[illegible]
.4	536	530	525	522	516	510	49[illegible]
1	550	550	550	550	550	550	5[illegible]

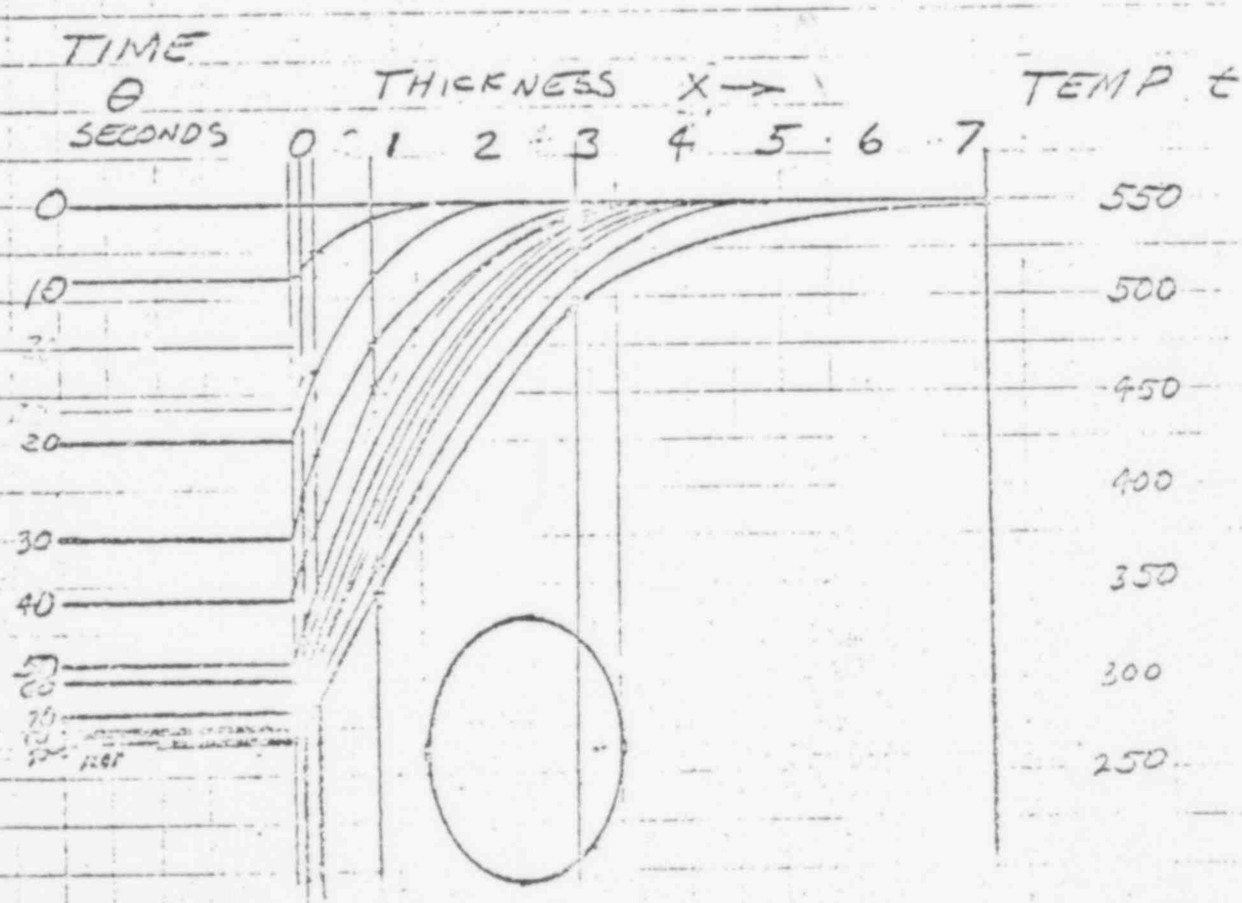
461 212

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY RWP DATE 7-22-79 CHECKED BY JKR DATE 8-7-79

TEMPERATURE PROFILE

		TEMPERATURE					
x/δ	x	θ=10	20	30	40	50	60
		t_{WATER} = 510	425	375	340	310	300
0	0	518	442	396	361	329	320
.02	.14	525	460	415	380	353	340
.1	.71	544	512	476	455	425	410
.4	2.84	550	550	548	547	545	537
1	21	550	550	550	550	550	550



FIRST EVALUATE THE STRESS AT ... SIZE

OF ... AT ...

461 213

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT

COMPUTED BY [illegible] DATE 2-23-79 CHECKED BY JKR DATE 5-6-79

FROM REF 6 PAGE 842

$$\sigma_H = \frac{2\alpha E}{1-\mu}\left[\frac{2r^3+r_i^3}{2(r_o^3-r_i^3)}\left(\frac{1}{r^3}\right)\int_{r_i}^{r_o} Tr^2dr + \frac{1}{2r^3}\int_{r_i}^{r} Tr^2dr - \frac{T}{2}\right]$$

$$\sigma_r = \frac{2\alpha E}{1-\mu}\left[\frac{r^3-r_i^3}{r_o^3-r_i^3}\left(\frac{1}{r^3}\right)\int_{r_i}^{r_o} Tr^2dr - \frac{1}{r^3}\int_{r_i}^{r} Tr^2dr\right]$$

$r_i = 88.35$

$r_o = 95.45$

@ $\theta = 40$ SEC FIND σ_H AT $r = 88.35 + 1.28 = 89.63$

& @ $r = 89.63 + 2.07 = 91.70$ & $r = 88.35$ & $r = 95.45$

EXPRESS T AS A FUNCTION OF r.

$r = 88.35$ TO 88.49, $T = 360 + \frac{19}{.14}(r - 88.35)$

$r = 88.49$ TO 89.06, $T = 380 + \frac{75}{.57}(r - 88.49)$

$r = 89.06$ TO 91.19, $T = 455 + \frac{92}{2.13}(r - 89.06)$

$r = 91.19$ TO 95.45; $T = 547 + \frac{3}{4.26}(r - 91.19)$

POOR ORIGINAL

461 214

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT

[illegible] 2-23-79 JWR 3-7-79

COMPUTED BY DATE CHECKED BY DATE

$$\sigma_H = \frac{2(8.16\times10^{-6})28\times10^6}{1-.3}\left[\frac{2r^3+88.35^3}{2(95.45^3-88.35^3)r^3}\left\{\int_{88.35}^{88.49}\left(3[illegible]+\frac{19}{.14}[r-88.35]\right)r^2dr\right.\right.$$

$$+\int_{88.49}^{89.06}\left(385+\frac{75}{.57}[r-88.49]\right)r^2dr+\int_{89.06}^{91.19}\left(455+\frac{92}{2.13}(r-89.06)\right)r^2dr+$$

$$\left.\int_{91.19}^{95.45}\left(548+\frac{3}{4.26}[r-91.19]\right)r^2dr\right\}+\frac{1}{2r^3}\int_{88.35}^{r}Tr^2dr-\frac{T}{2}\Bigg]$$

@ $r = r_i = 88.35$

$$\sigma_H = 652.8\left[\frac{2(88.35^3)+88.35^3}{2(95.45^3-88.35^3)88.35^3}\left\{\int_{88.35}^{88.49}\left(3[illegible]r^2+135.7[illegible]r^3-11990r^2\right)dr\right.\right.$$

$$+\int_{88.49}^{89.06}\left([illegible]r^2+131.58r^3-11693r^2\right)dr+\int_{89.06}^{91.19}\left[[illegible]r^2+43.19r^3-3847r^2\right]dr$$

$$\left.+\int_{91.19}^{95.45}\left[5[illegible]r^2+.70[illegible]r^3-61[illegible]r^2\right]dr\right\}+0-\frac{361}{2}\Bigg]$$

$$\sigma_H = 652.8\left[\frac{3}{2(17981)}\left\{\left[-3076r^3+35[illegible]\right]_{88.35}^{88.49}+\left[[illegible]r^3+32.9[illegible]\right]\right.\right.$$

$$+\left[[illegible]\right]^{91.19}_{89.06}\left[[illegible]\right]$$

461 215

SUBJECT: FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY 2-23-79 DATE CHECKED BY JKR DATE 3-7-79

$$\sigma_H = 652.8\left[8.334\times10^{-6}\left\{-3876\left(88.49^3-88.35^3\right)+33.98\left(88.49^4-88.35^4\right)\right.\right.$$

$$+3754\left(89.06^3-88.49^3\right)+32.9\left(89.06^4-88.49^4\right)-1081\left(91.19^3-89.06^3\right)$$

$$\left.\left.+10.8\left(91.19^4-89.06^4\right)+161\left(95.45^3-91.19^3\right)+.176\left(95.45^4-91.19^4\right)\right\}-100.5\right]$$

$$\sigma_{H_{r=88.35}} = 652.8\left[8.334\times10^{-6}\left\{-12.73\times10^6+13.13\times10^6-53.59\times10^6\right.\right.$$

$$\left.+52.482\times10^6-53.70\times10^6+67.37\times10^6+17.93\times10^6+7.\ldots\right\}$$

$$\left.-100.5\right]$$

$$\sigma_{H_{r=88.35}} = 52{,}520 \text{ PSI}$$

@ $r = 89.63$ = RADIUS AT POINT 1

$$\sigma_H = 652.8\left[\frac{2(89.63^3)+88.35^3}{2(95.45^3-88.35^3)\,89.63^3}\left\{31.39\times10^6\right\} - \frac{1}{2(89.63^3)}\int_{88.35}^{89.63} T r^2\right.$$

$$\left.-\left\{\frac{1554+33.30\left[89.63-89.06\right]}{2}\right\}\right]$$

$$\sigma_H = 652.8\left[257.9-239.01+6.979\times10^{-7}\left\{\int_{88.35}^{88.49}\left[221+\frac{19}{.14}(r-88.35)\right]\ldots\right.\right.$$

$$+\int_{88.49}^{89.06}\left[390+\frac{75}{.57}(r-88.49)\right]r^2\,dr + \int_{89.06}^{\ldots}\left(\ldots\;\ldots 06\right)r^2\,dr\Big\}$$

POOR ORIGINAL

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [illegible] 2-23-79 DATE CHECKED BY RKR 3-7-79 DATE

$$\sigma_H = 652.8\Big[18.06 + 6.944\times10^{-7}\Big\{-3.876[88.49^3-88.35^3]$$
$$+33.92[88.49^4-88.35^4]-3758[89.06^3-88.49^3]$$
$$+32.89[89.06^4-88.49^4]-1131[89.63^3-89.06^3]$$
$$+10.80[89.63^4-89.06^4]\Big\}\Big]$$

$\sigma_H = 13079$ PSI

$r = 89.63$

@ $r = 91.70$ = RADIUS OF PT Z

$$\sigma_H = 652.8\left[\frac{2(91.7^3)+88.35^3}{2(95.95^3-88.35^3)\,91.7^3}\left\{31.31\times10^6\right\} - \frac{547+\frac{3}{4.26}(91.7-}{2}\right.$$

$$+\frac{1}{2(91.7^3)}\left\{\int_{88.35}^{88.49}\left[361+\frac{19}{.14}(r-88.35)\right]r^2dr + \int_{88.49}^{89.06}\left[330+\frac{75}{.57}(r-88.49)\right]\right.$$

$$+\int_{89.06}^{91.19}\left[455+\frac{92}{2.13}(r-89.06)\right]r^2dr + \int_{91.19}^{91.70}\left[547+\frac{13}{4.26}(r-91.19)\right]r^2d$$

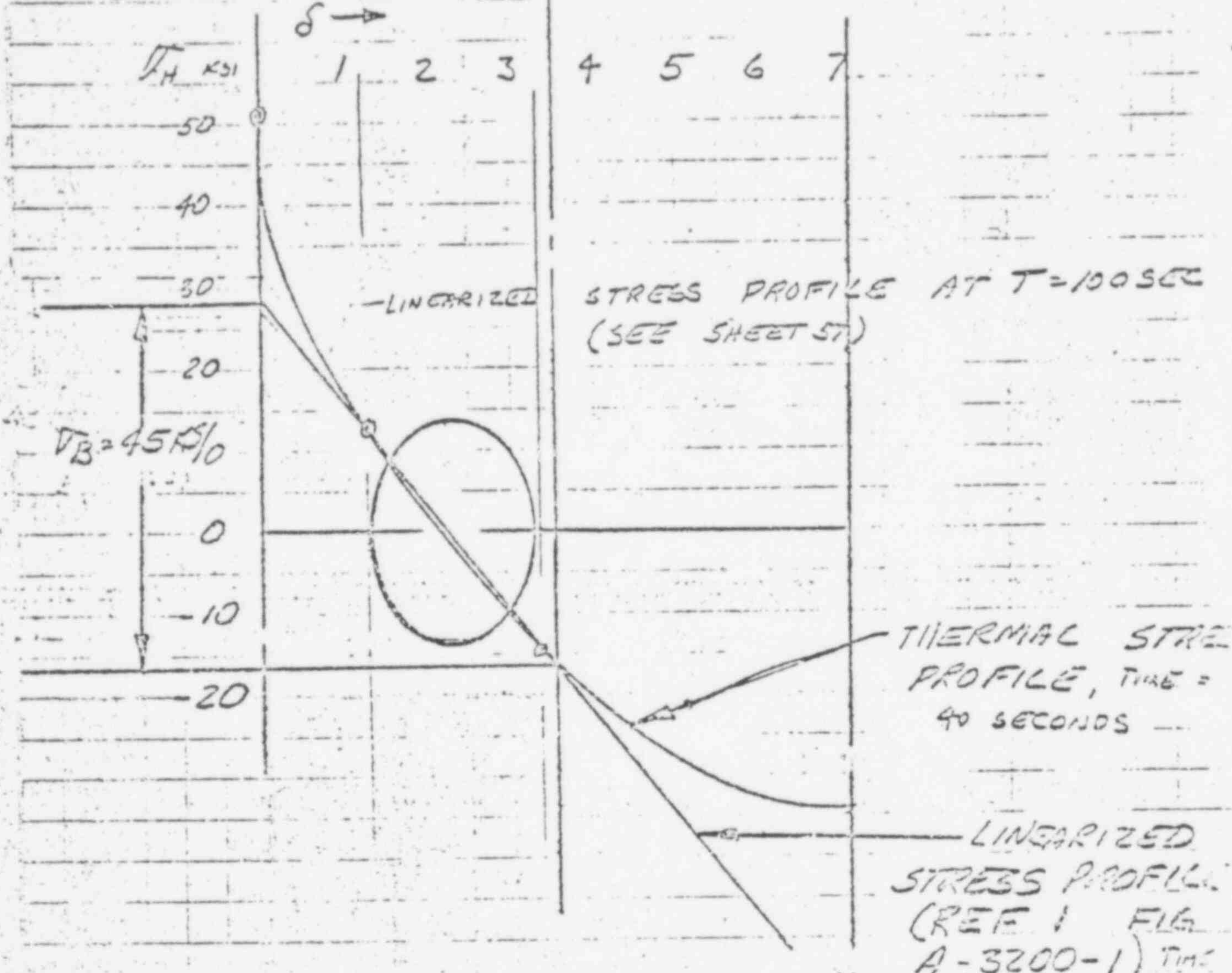
$$\sigma_H = 652.8\Big[-21.92 + 6.484\times10^{-7}\Big\{-3875.5[88.49^3-88.35^3]$$
$$+ [illegible].93[88.49^4-88.35^4]-3757[89.06^3-88.49^3] +$$
$$[illegible][89.06^4-88.49^4]-1131[91.19^3-89.06^3] +$$
$$[91.19^4-89.06^4]-140.[illegible][91.7^3-91.19^3]+.30[91.7^4-91.$$
$$= -14756 \text{ psi}$$

POOR ORIGINAL 461 217

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY RWH DATE 2-23-79 CHECKED BY JHR DATE 3-7-79

STRESS PROFILE T = 40 SEC



COMBINED STRESS (FAULTED)

@ TIME = 40 SECONDS

P = 450 PSI

		σ_M	σ_B
$\sigma_M = \frac{Pr}{t} = \frac{450\ (91)}{7.1} =$		5768	0
PRELOAD (SH 14)		1,220	-6,510
TEMPERATURE		17,[illegible]	65,000
COMBINED		[illegible]	[illegible]490

POOR ORIGINAL

461 218

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH
COMPUTED BY [initials] 2-23-79 DATE CHECKED BY JKR DATE 3-7-79

APPLIED STRESS INTENSIFICATION FACTOR K_I

$$\frac{\sigma_m + \sigma_b}{\sigma_{YS}} = \frac{-10,000 + 38490}{44,900} = .63$$ REF 1 FIG A-3300-1

$a/\ell = .38$

$Q_1 = 1.8$

STRESS CORRECTION FACTORS

$2a/t = .292$, $\frac{2e}{t} = .3486$

MEMBRANE STRESS CORRECTION FACTOR

$M_{m_1} = 1.09$ FIG A 3300-2

$M_{m_2} = 1.07$

$M_{b_1} = .50$ FIG A 3300-4

$M_{b_2} = .21$

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

-4.69 $K_{I_1} = -10.00 (1.09)\sqrt{\frac{\pi(1.035)}{1.8}} + 38.5(.5)(1.34) = 11.23$ Ksi√in

$K_{I_2} = -10.00 (1.07)(1.34) + 38.5(.21)(1.34) = -3.5$ Ksi√in

POOR ORIGINAL

461 219

TVA 489H (EN DES-2-78) TENNESSEE VALLEY AUTHORITY SHEET

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [illegible] DATE 3-8-79 CHECKED BY [illegible] DATE 3-8-79

SINCE @ $\theta = 100$ SEC THE SLOPE OF THE TEMPERATURE ACROSS THE FLAW IS AT ABOUT ITS MAXIMUM.

EXPRESS T AS f(r)

$r = 88.35$ TO 88.49 $T = 287 + \frac{18}{.14}(r - 88.35)$

$r = 88.49$ TO 89.06 $T = 305 + \frac{63}{.57}(r - 88.49)$

$r = 89.06$ TO 91.19 $T = 368 + \frac{154}{2.13}(r - 89.06)$

$r = 91.19$ TO 95.45 $T = 522 + \frac{34}{4.26}(r - 91.19)$

@ $r = 89.63$

$$\sigma_H = \frac{2\alpha E}{1-\mu}\left[\frac{2r^3 + r_i^3}{2(r_o^3 - r_i^3)r^3}\int_{r_i}^{r_o} T r^2 dr + \frac{1}{2r^3}\int_{r_i}^{r} T r^2 dr - \frac{T}{2}\right]$$

$$= 652.8\left[\frac{2(89.63^3) + 88.35^3}{2(95.45^3 - 88.35^3)89.63^3}\left\{\int_{88.35}^{88.49}\left[287 + \frac{18}{.14}(r - 88.35)\right]r^2 dr + \right.\right.$$

$$\int_{88.49}^{89.06}\left(305 + \frac{63}{.57}[r - 88.49]\right)r^2 dr + \int_{89.06}^{91.19}\left(368 + \frac{154}{2.13}[r - 89.06]\right)r^2 dr +$$

$$\left.\int_{91.19}^{95.45}\left(522 + \frac{34}{4.26}[r - 91.19]\right)r^2 dr\right\} + \frac{1}{2r^3}\int_{88.35}^{89.63} T r^2 dr - \left.\frac{T}{2}\right]$$

461 220

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [illegible] DATE 3-7-79 CHECKED BY JKR DATE 3-8-79

$$V_H = 652.8\left[8.217\times10^{-6}\left\{\left[287-11369\right]\frac{r^3}{3} + 128.6\frac{r^4}{4}\right]_{88.35}^{88.49} + \left[-3158\, r^3 + 27.63\, r^4\right]_{88.49}^{89.06} + \left[18.08\, r^4 - 2023\, r^3\right]_{89.06}^{91.19} + \right.$$

$$\left.\left[1.995\, r^4 - 68.6\, r^3\right]_{91.19}^{95.45}\right\} + \frac{1}{2(89.63)^3}\left\{32.15\, r^4 - 36\ 1\, r^3\Big|_{88}^{8} + \left[27.63\, r^4 - 3158\, r^3\right]_{88.49}^{89.06} + \left[18.08\, r^4 - 2023\, r^3\right]_{89.06}^{89.63}\right\} + \frac{363 + \frac{[illegible]}{2.[illegible]}}{2}$$

$$V_H = 652.8\left[8.217\times10^{-6}\left\{32.15(88.49^4-88.35^4) - 3691(88.49^3-88.35^3)\right.\right.$$

$$+ 27.63(89.06^4-88.49^4) - 3158(89.06^3-88.49^3) + 18.08(91.19^4 - [illegible]$$

$$- 2023(91.19^3-89.06^3) + 1.995(95.45^4-91.19^4) - 68.6([illegible]$$

$$+ \frac{1}{2(89.63)^3}\left\{32.15(88.49^4-88.35^4) - 3691(88.49^3-88.35^3)\right.$$

$$+ [illegible].63(89.06^4-88.49^4) - 3158(89.06^3-88.49^3)$$

$$\left.\left. + [illegible].08(89.63^4-89.06^4) - 2023(89.63^3-89.06^3)\right\} + 205\right]$$

POOR ORIGINAL

461 221

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [illegible] DATE 3-7-79 CHECKED BY AKR DATE 3-8-79

$$\sigma_H = 652.8\Big[8.217\times10^{-6}\{12.45\times10^6 - 12.12\times10^6 + 44.07\times10^6 - 42.56\times10^6 + 112.78\times10^6 - 105.00\times10^6 + 27.69\times10^6 - 7.64\times10^6\}$$

$$+ .694\times10^{-6}\{12.45\times10^6 - 12.12\times10^6 + 44.07\times10^6 - 42.56\times10^6 + 29.40\times10^6 - 27.61\times10^6\} - 205\Big]$$

$$= 652.8\big[243.39 + 2.52 - 205\big] = 26,705 \text{ PSI}.$$

AT $r = 91.7$

$$\sigma_H = 652.8\left[\frac{2(91.7^3) + 88.35^3}{2(95.45^3 - 88.35^3)\,91.7^3}\left\{29.62\times10^6\right\} + \frac{1}{2(91.7^3)}\Big\{12.45\times10^6 - 12.12\times10^6 + 44.07\times10^6 - 42.56\times10^6 + 112.78\times10^6 - 105\times10^6 + 1.995\underbrace{(91.7^4 - 91.19^4)}_{3.112\times10^6} - 68.6\underbrace{(91.7^2 - 9[illegible])}_{.878}\Big\} - \frac{526}{2}\right]$$

$$\sigma_H = 652.8\left[8.091\times10^{-6}(29.62\times10^6) + [illegible]([illegible]\times10^6) - 2[illegible]\right]$$

$$\sigma_H = -11190 \text{ PSI}$$

POOR ORIGINAL

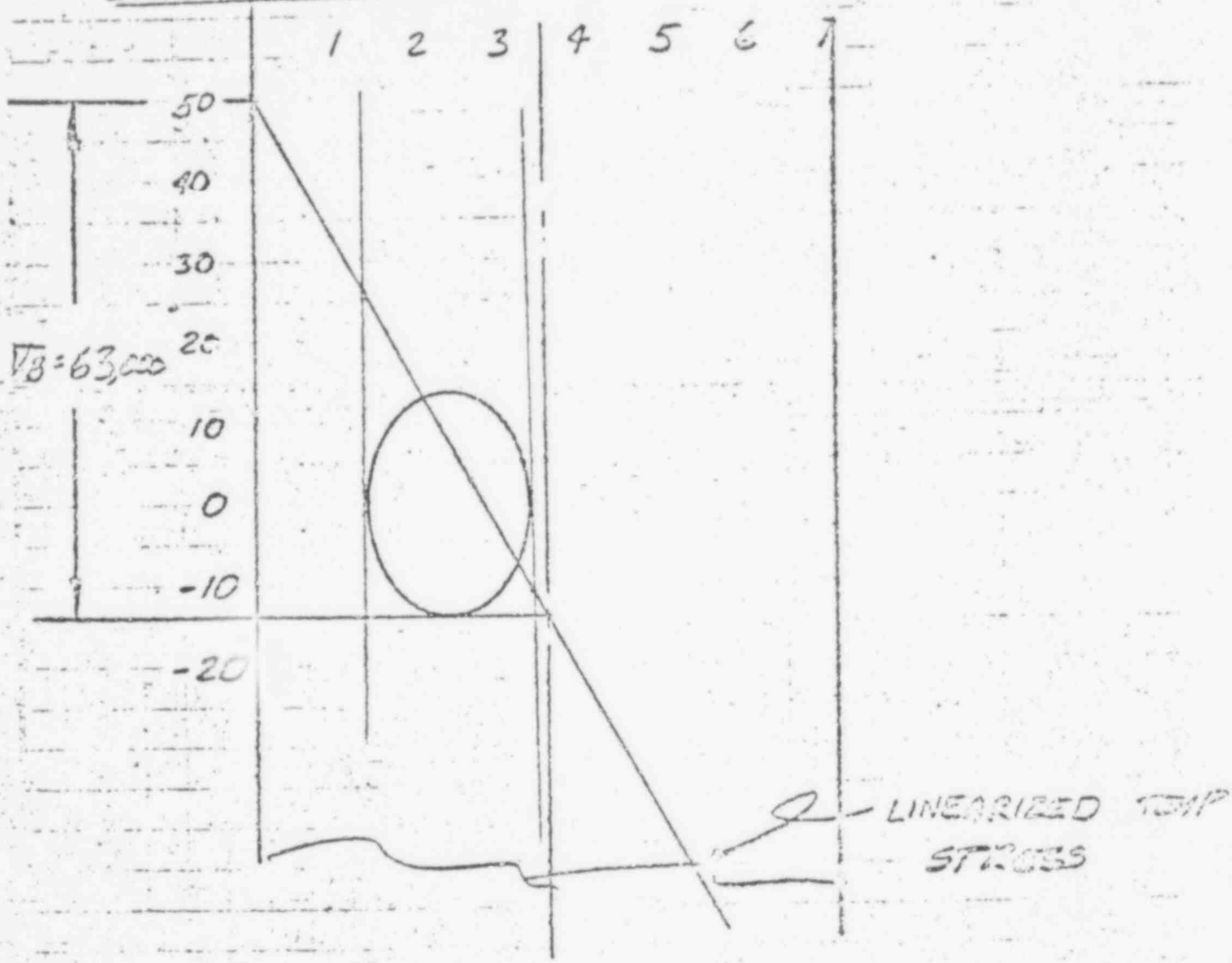
461 222

TVA 439Q (EN DES-3-77) TENNESSEE VALLEY AUTHORITY SHEET 57 OF

SUBJECT FLAW INDICATION IN UNIT 1 REACT. 2 VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [illegible] DATE 2-23-79 CHECKED BY MKR DATE 3-7-79

STRESS PROFILE @ T = 100 SEC



POOR ORIGINAL

461 223

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY RDH DATE 2-23-79 CHECKED BY DATE

COMBINED STRESS (FAULTED)

@ TIME = 100 SECONDS

	σ_m	σ_B
$P = 455$ PSI		
$\sigma_m = \frac{Pr}{t} = \frac{455(91)}{7.1} =$	5832 PSI	0
PRELOAD	1,220	-6510
TEMPERATURE	-14,000	63,000
COMBINED	-6948	56490

APPLIED STRESS INTENSIFICATION FACTOR TERMS

$$\frac{\sigma_m + \sigma_B}{\sigma_{ys}} = \frac{-6948 + 56490}{44,900} = 1.1$$

USE 1.0 CURVE DUE TO PREVIOUS CONSERVATISM

$Q = 1.7$

$K_{I} = -10.00\,(1.03)(1.38) + 56.5\,(.5)(1.29) = 23.94$

POOR ORIGINAL

SUBJECT FLAW INDICATION IN UNIT 1 REACTOR VESSEL HEAD PROJECT SEQUOYAH

COMPUTED BY [illegible] DATE 2-27-79 CHECKED BY JKR DATE 3-8-79

ALLOWABLE STRESS INTENSITY FACTOR

$K_{I_{ALL}} = K_{IA} / \sqrt{2}$ FAULTED REF 1 IWB-3612b

$T - RT_{NDT} = 400 - 5 = 395$ $T = 100$

$K_{IA} = 200$

$K_{IALL} = 200 / \sqrt{2} = 141.42$

$K_I = 23.94 < K_{IALL} = 141.42$

CONCLUSION

FAULTED CONDITION IS NOT CRITICAL.

HEAT TRANSFER CALCULATIONS WERE BASED ON IMMERSION IN WATER AT END TEMP RATHER THAN LETTING WATER TEMP. DROP WITH TIME.

AT $\theta = 100$ SEC THE STRESS AT FLAW IS NEAR ENOUGH TO MAXIMUM TO SHOW THAT THE FAULTED CONDN IS NOT CRITICAL.

POOR ORIGINAL

461 225

References

1. ASME Boiler and Pressure Vessel Code-Section XI, Division 1, "Rules For Inservice Inspection Of Nuclear Power Plant Components", 1977 Edition with addenda through Summer 1978.

2. The Rotterdam Dockyard Company (RDM) - Stress Report For Sequoyah Reactor Vessels, Document No. 30616-1105, "Analysis of The Main Closure Including Core Support Ledge".

3. Westinghouse Equipment Specifications 676413, Revision 1, and 678777, Revision 2 for the Sequoyah Unit 1 and 2 Reactor Vessels

4. ASME Boiler and Pressure Vessel Code - Section III, Division 1, "Appendices", 1977 Edition with addenda through Summer 1978.

5. EPRI NP-719-SR Special Report August 1978 - Flaw Evaluation Procedures: ASME Section XI" - Prepared by ASME Section XI Task Group on Flaw Evaluation

6. Engineering Design - Joseph H. Faupel, John Wiley & Sons - 19[illegible]

7. Handbook of Heat Transfer - W.M. Rohsenow and J.P. Hartnett, McGraw-Hill Publishing Co., 1963.

8. Standard Handbook for Mechanical Engineers - Baumeister and Marks, 7th Edition, McGraw-Hill Publishing Co., 1966.

POOR ORIGINAL

461 226

64 (03-9-63)

UNITED STATES GOVERNMENT

Memorandum

CEB '790319 011

TENNESSEE VALLEY AUTHORITY

TO : D. R. Patterson, Chief, Mechanical Engineering Branch, W10C126 C-K

FROM : R. G. Domer, Chief, Civil Engineering Branch, W9D224 C-K

DATE : MAR 1 9 1979

SUBJECT: SEQUOYAH NUCLEAR PLANT - ANALYTICAL EVALUATION OF A FLAW INDICATION IN THE UNIT 1 REACTOR VESSEL CLOSURE HEAD

Reference: My memorandum to you dated March 19, 1979 (CEB 790321 018).

MEB'79 03 22 000

We have reviewed the attached letter and enclosure entitled, "Preliminary Evaluation of Sequoyah 1 Flaw Indication," Supplemental Report SwRI Project 17-5339, February 1979 (attachment). We have reached the following conclusions based upon this review and our report, CEB-CQS-79-1, which was transmitted to you by the referenced memorandum.

Conclusions

1. Crack growth for the 40-year service life of the vessel will be small. Our report predicts a very conservative upper bound limit to this growth by multiplying the specified number of event cycles by 1000 and by considering 2.5 billion steady-state pressure fluxuations of 100 psi. The SwRI report predicts growth for the specified number of events and does not evaluate growth for steady-state fluxuations. The basic methodology applied and growth rates calculated in these reports are in reasonable agreement.

2. For fracture toughness, a low temperature hydrotest at 3105 psig would produce the most critical condition relative to code acceptance limits. Our report demonstrates acceptability for this condition for a minimum metal temperature of 133 F, assuming the conservative upper bound crack size after 40 years of service. The SwRI report suggests in section 3.0(7) a minimum metal temperature of 120 + 5 = 125 F. Both reports are in substantial agreement on this conclusion.

3. SwRI did not perform a faulted condition fracture toughness evaluation, but they raised a question and suggested that more evaluation may be required. They did conclude that the specified faulted condition (large steam line break) would be the limiting case relative to the code acceptance criteria for faulted conditions. In our report, the specified faulted condition is evaluated, by a conservative thermal stress and fracture toughness approach, and it is shown to be well within acceptance limits and therefore less critical than the hydrotest condition discussed above.

MEB MASTER FILE

Attachment 46K-227

4. In summary, we feel that report CEB-CQS-79-1 provides adequate assurance that the flaw indication is acceptable for the full service life of the unit 1 reactor vessel and that the SwRI report basically substantiates this conclusion. We do not feel that any repair is necessary for this flaw. Finally, we do not recommend further faulted condition evaluation by SwRI.

R. G. Domer

RGD:JKR:DB
Attachment
cc (Attachment):
R. M. Pierce, 204 GB-K (2)
MEDS, E4B37 C-K

ENCLOSURE 4

UNITED STATES GOVERNMENT

Memorandum

MEB '79 0228 379

TENNESSEE VALLEY AUTHORITY

TO : G. G. Stack, Project Manager, Sequoyah Nuclear Plant, CONST (4)

FROM : R. M. Pierce, Sequoyah and Watts Bar Design Projects Manager, 204 GB-K

DATE : FEB 28 1979

SUBJECT: SEQUOYAH NUCLEAR PLANT UNITS 1 AND 2 - NONCONFORMANCE REPORT (NCR) NO. 6P

We are in agreement with the recommended disposition of attached NCR 6P and that the nonconformance is classified as significant. No drawings will be revised.

Original Signed by
R. M. Pierce

R. M. Pierce

DRP:EAM:MGR
Attachment
cc: J. M. Ballentine, Sequoyah P PROD
Roy H. Dunham, W11A9 C-K
J. P. Knight, W12B30 C-K
MEDS, E4B37 C-K, w/1
J. L. Parris, W11C126 C-K, w/1
D. R. Patterson, W10C126 C-K
H. H. Mull, E7B24 C-K

461 229

DIVISION OF CONSTRUCTION

NONCONFORMING CONDITION REPORT

1. Nuclear Project: Sequoyah — Unit 1 — NCR: 6P

ASME Code Item: [X] Yes [ ] No

2. Area: [ ] Civil [ ] Electrical [X] Mechanical [ ] Instrumentation [ ] Welding

3. Activity: [ ] Receiving [ ] Storage [ ] Fabricating [ ] Installing [ ] Other [X] Testing — Contract No. ______

4. Type: [ ] Damage [ ] Failure [X] Defect [ ] Documentation [ ] Other ______

5. Item Description:

Reactor vessel closure head seam weld W09-10

6. Nonconformance Description:
(Include Apparent Cause) See attached SwRI Customer Notification Form, Serial No. 10 dated January 31, 1979.

Recommended Disposition: [ ] Rework [ ] Reject [ ] Repair [X] Use-As-Is [ ] Other
(Check Block & Detail Below)

Use Code Case N-209 as basis to resolve acceptance. Perform stress analysis, per IWB-3600, to determine acceptability. Disposition will be reported to NRC as soon as all information is available.

Action Required to Prevent Recurrence:

This area will be re-examined each inspection interval.

NCR Initiator: E. F. Harwell EFH Date February 13, 1979

7. Referred to Design Project Organization (DPO): [X] Yes [ ] No — DPO Coordination Contact ______
Disposition: [X] As Recommended [ ] Other (Describe) — Significant Condition [X] Yes [ ] No

Approved by Power Plant Supt. [signature] Date 2/15/79

8. DPO Disposition: [X] As Recommended [ ] Other (Describe)

Edm 2/23/79 TEH 2/27/79

Approved by Design Project Organization: [signature] Date 3-2-79

9. Disposition Inspection and Release from Nonconforming Status: [ ] Yes [ ] No
Inspected by: ______ Date ______

10. Action Required to Prevent Recurrence Complete: [ ] Yes [ ] No
Verified by Construction Engineer: ______ Date ______

Distribution:
- Site QA Records File
- Construction Engineer
- Site QA Unit
- OEDC QA Manager
- Design Project Organization (Items for his action only)
- Authorized Nuclear Inspector (Code items only)
- EN DES MEB-NLS (Significant NCR's only)
- MEDS

Disposition Reviewed and Accepted By:

______ Authorized Nuclear Inspector ______ Date

461 230

POOR ORIGINAL

POTENTIAL REPORTABLE OCCURRENCE

79-7
PRO No.

TO : (1) Section Supervisor — Time/Date ____
(2) QA Staff Supervisor — Time/Date 2/13/79 5:50 pm

FROM: E. F. Harwell EFH (Initiator) Unit 1 System No. 68

Event Description: UT flaw found in closure head seam weld W09-10 during preservice examination performed by SwRI which exceeded limits of IWB-3511.1

Event Discovered Time/Date: January 12, 1979

Potential LER	☐ YES	☒ NO
Potential 10 CFR 50.55(e)	☒ YES	☐ NO
10 CFR 21 Evaluation Required?	☐ YES	☒ NO

(If YES, attach evaluation forms)

2/13/79

TO : Plant Superintendent

FROM: QA Staff Supervisor WBC

QA Staff Recommendation: Reportable occurrence?
☐ NO
☐ LER
☒ 10 CFR 50.55(e)
☐ 10 CFR 21

Reportable per ASME Section XI

Immediate Report? ____
30 day Report? ____

Description: (If not reportable, explain below.)

Refer to ~~NRC~~ NCR 6P WBC 2/13/79

Joshua Ballentine / 2/13/79
Plant Superintendent — Date

TO : QA Staff

FROM: PORC and Plant Superintendent

PORC Review Date 2/14/79

Recommendation Approved ✓ Rejected ____

Joshua Ballentine / 2/14/79
Plant Superintendent — Date

461 231

Southwest Research Institute CUSTOMER NOTIFICATION FORM	Serial Nº 10 Utility TVA Site Sequoyah Unit 1

Part I - SwRI Findings

Project Nº 17-5022	Type of Examination	NDT Method ☒UT ☐PT	SwRI Procedure/Rev
Examination Date: 12 Jan 79 / 25 Jan 79	☒PSI ☐ISI	☐MT ☐RT ☐ET ☐VT	600-15/37

Comments

This is to inform you of a flaw indication found in RPV Closure Head Weld 1009-10, which exceeds the allowable limits as outlined in Section XI, Summer 75' Addenda, Table IWB 3511-1.

Attached Sheets: 390012 390011 Original Exam. Ind #5
390024 Recheck Data *
Additional Resolution Data: ~~390024~~ 390025, 390023, 450012, 450013, 450014 370062, 360034
* Indication sized to data on sht #390024

Examination Reference: See Above & Draft Field Letter of Jan. 31 1979 RT Review

Signature of SwRI Representative W. C. McGaughey	Date 26 Jan. 79

Part II - Customer Notification

Notification Acknowledged by	Date

Part III - Indication Disposition by Customer

Comments

Signature of Customer Representative	Date

Part IV Reexamination

Comments

Reexamination Reference

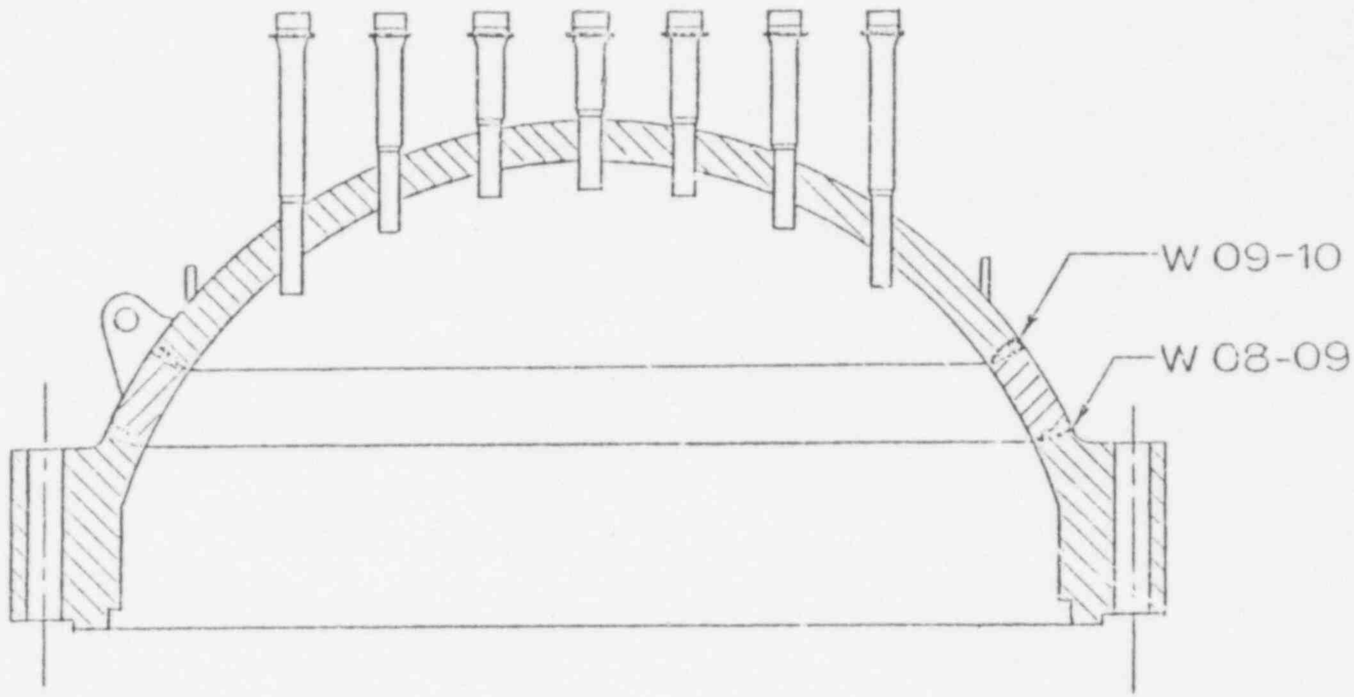
Signature	Date

CNF Closed (Customer Representative Signature)	Date

POOR ORIGINAL

461 232

TVA 6690-A (PP-2-76)



TENNESSEE VALLEY AUTHORITY

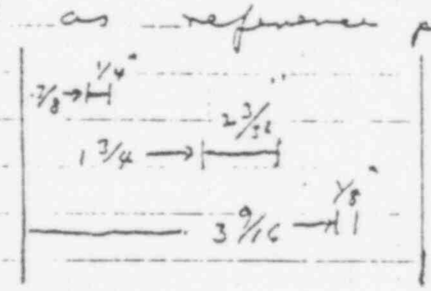
SEQUOYAH
REACTOR VESSEL
CLOSURE HEAD

SCALE NTS	SUBMITTED	APPROVED	DATE 4-11-75
DRAWN			SHEET 1 OF 1 SHEET
TRACED RGS			CH-M-235R-A
CHECKED			

461 233

Draft Field Notes

On Jan 31, 1979 the undersigned reviewed the construction radiographs of the area of the ring-to-dollar plate weld of the Sequoyah #1 RPV closure head which contains a reportable UT indication. On film 27-28, there are two ball point pen marks which would appear to indicate a previous review of that area. Close examination revealed a very faint interrupted linear indication having the appearance of tight rolled-in slag. The location and size of the indications are shown below using the film ID as reference pts.



27 30616 C1RW09 LEG10 28

The approximate width of all three indications is 1/32" and they do not appear to be slag. The lengths and grouping are acceptable in accordance with N624.3 of Section

1968 Edition of the ASME Boiler and Pressure Vessel Code. It is recom d that the provisions of Code Case N209 be applied to the resolution of this indication.

H.A. Wenk
SwRI Level III-RT

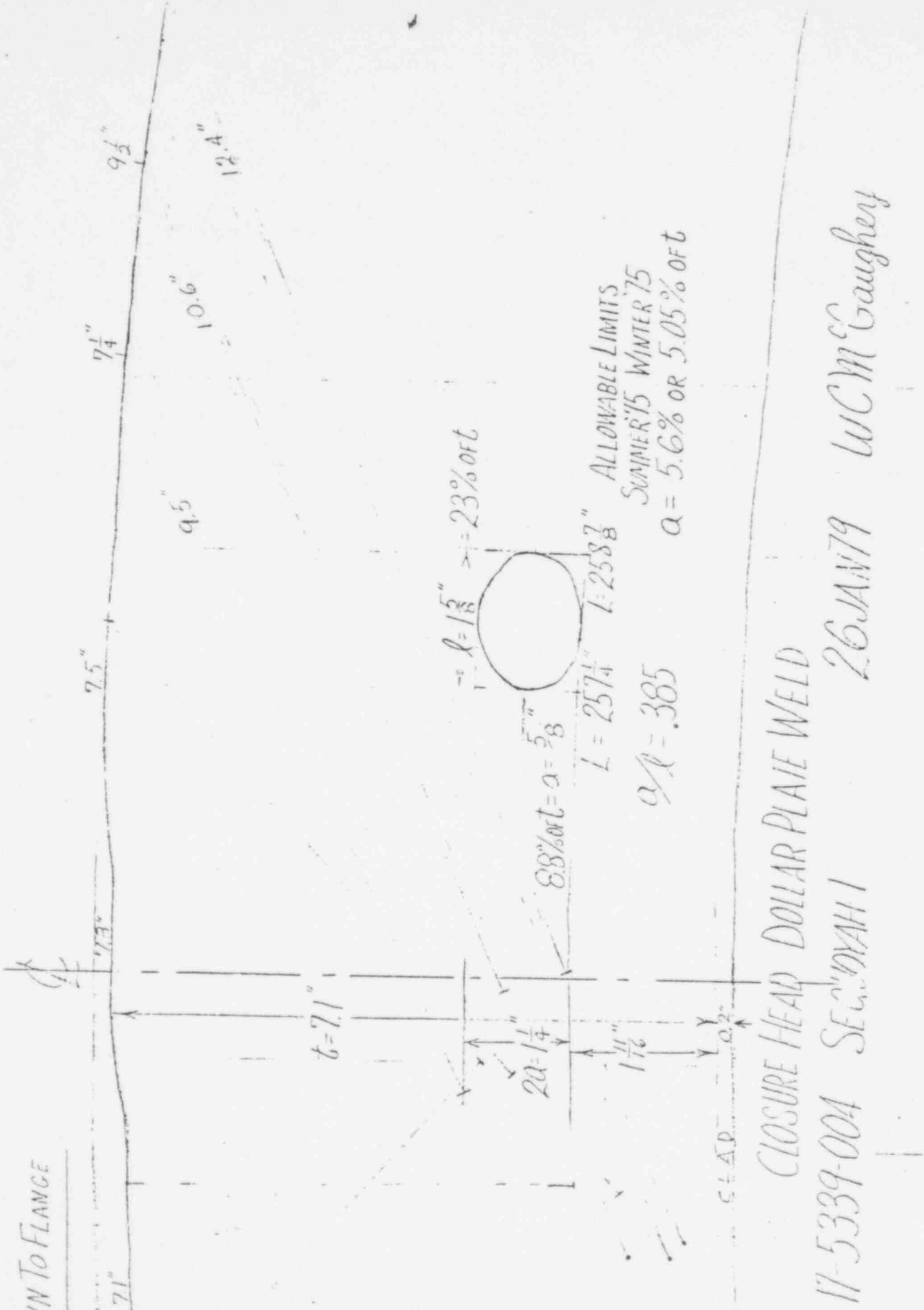
W.C. McGaughey
SwRI Level III UT

SwRI will need stress values for the closure head dollar plate weld in order to perform stress analysis to determine acceptability of the ultrasonic indication to the criteria of IWB-3600. Please obtain these values from Westinghouse Electric Co.

W.C. McGaughey
31 JAN 79

461 235

POOR ORIGINAL



DOWN TO FLANGE
7.1"
7.3"
7.5"
7 1/4"
9 1/2"
9.5"
10.6"
12.4"
t = 7.1"
2a = 1 1/4"
1 11/16"
0.2"
CLAD
88% of t = a = 5/8"
ℓ = 1 5/8"
23% of t
L = 257 1/4
L = 258 7/8"
a/ℓ = .385
ALLOWABLE LIMITS
SUMMER '75 WINTER '75
a = 5.6% OR 5.05% OF t
CLOSURE HEAD DOLLAR PLATE WELD
SwRI 17-5339-004 SEQUOYAH I
26 JAN 79
WC McGaughey

Sw. R. I. PRESSURE VESSEL ULTRASONIC EXAMINATION RECORD

PROJECT NO.: 17-[illegible]	SITE: Sequoyah Power Station, Unit 1	DATE: (DAY-MON.-YR.) [illegible]	TIME (24 HR. CLOCK) SHEET STARTED: [illegible] SHEET ENDED: [illegible]	SHEET NO.: [illegible]
EXAMINATION AREA (SYSTEM/COMPONENT) RPV	(LINE / SUBASSEMBLY) [illegible]	(IDENTIFICATION) [illegible]	L_o LOCATION: [illegible]	W_o LOCATION: [illegible]

EXAMINER: [illegible]	SNT LEVEL: [illegible]	PROCEDURE NO. [illegible] REV. 37	CALIBRATION SHEET(S) 450[illegible]	ANGLE USED	0°	45°	45°T	60°	OTHER °	°		WELD TYPE: [illegible] WELD LENGTH: [illegible]
EXAMINER: [illegible]	SNT LEVEL: [illegible]			SCANNING dB	N/A	N/A	N/A	[illegible]	N/A	N/A		EXAMINATION SURFACE INSIDE ☐ OUTSIDE ☐

IND. NO.	% OF DAC MAX	50 % DAC W_1	50 % DAC MP	W MAX W	W MAX MP	50 % DAC W_2	50 % DAC MP	L_1 50 % DAC	L POSITION	L_2 50 % DAC	SEARCH UNIT LOCATION	SEARCH UNIT ANGLE	THRU WALL DEPTH % OF T *	DEPTH BELOW SURFACE % OF T **	REMARKS:	INI.
															[illegible]	[illegible]
(1)	57	[illegible]	[illegible]	[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	up	60	N/A	N/A	No Damp	[illegible]
(2)	[illegible]			[illegible]	[illegible]			—	[illegible]	—	up	60	N/A	N/A	No Damp	[illegible]
3	90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	up	60	N/A	N/A	No Damp	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N/A	N/A	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	up	[illegible]	N/A	N/A	No Damp	[illegible]
7	[illegible]	—	—	[illegible]	[illegible]	—	—	—	[illegible]	—	up	60	N/A	N/A	No Damp	[illegible]
8	[illegible]	—	—	[illegible]	[illegible]	—	—	—	[illegible]	—	up	60	N/A	N/A	No Damp	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	up	60	N/A	N/A	No Damp	[illegible]
11	[illegible]	—	—	[illegible]	[illegible]		—		[illegible]	—	up	60	N/A	N/A	No Damp	[illegible]
12	[illegible]	—		[illegible]	[illegible]				[illegible]		up	60	N/A	N/A	No Damp	[illegible]

* SEE NOTE 1 - BACK OF PAGE

** SEE NOTE 2 - BACK OF PAGE

EXAMINATION AREA LIMITATION (IF NONE, SO STATE) [illegible]

REVIEWED BY: [illegible]	SNT LEVEL: [illegible]	DATE: [illegible]	PAGE [illegible] OF [illegible]

FORM NO. SWRI NPTR 17-39 (REV 10-11-76)

Page 8 of 18

461 237

POOR ORIGINAL

Sw. R. I. PRESSURE VESSEL ULTRASONIC EXAMINATION RECORD

PROJECT NO.: 17[illegible]	SITE: [illegible] Station, [illegible]	DATE: (DAY-MON.-YR.) [illegible]	TIME (24 HR. CLOCK) SHEET STARTED: [illegible] SHEET ENDED: [illegible]	SHEET NO.: [illegible]
EXAMINATION AREA (SYSTEM/COMPONENT) [illegible]	(LINE / SUBASSEMBLY) [illegible]	(IDENTIFICATION) [illegible]	L_o LOCATION: [illegible] of Vessel	W_o LOCATION: [illegible]

EXAMINER: [illegible]	SNT LEVEL: II	PROCEDURE NO. [illegible] REV. [illegible]	CALIBRATION SHEET(S) [illegible]	ANGLE USED	0°	45°	45°T	60°	OTHER °	OTHER °	WELD TYPE: [illegible]
EXAMINER: [illegible]	SNT LEVEL: I			SCANNING dB	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	WELD LENGTH: [illegible] EXAMINATION SURFACE INSIDE ☐ OUTSIDE ☐

IND. NO.	% OF DAC MAX	50 % DAC W_1	50 % DAC MP	W MAX W	W MAX MP	50 % DAC W_2	50 % DAC MP	L_1 50 % DAC	L POSITION	L_2 50% DAC	SEARCH UNIT LOCATION	SEARCH UNIT ANGLE	THRU WALL DEPTH % OF T *	DEPTH BELOW SURFACE % OF T **	REMARKS: [illegible]	[illegible] INI.
[illegible]	[illegible]	[illegible]									[illegible]	[illegible]				[illegible]
[illegible]	[illegible]	[illegible]									[illegible]	[illegible]				[illegible]
[illegible]	[illegible]	[illegible]									[illegible]	[illegible]				[illegible]
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 330°	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* SEE NOTE 1 - BACK OF PAGE

** SEE NOTE 2 - BACK OF PAGE

EXAMINATION AREA LIMITATION (IF NONE, SO STATE) [illegible]

REVIEWED BY: [illegible]	SNT LEVEL: [illegible]	DATE: [illegible]	PAGE 2 OF 2

FORM NO. S.W.R.I. NDTR 17-39 (REV 10-11-76)

Page 9 of 18

POOR ORIGINAL

238

SwRI SONIC INSTRUMENT VESSEL CALIBRATION RECORD

PROJECT NO: 17-5339	SITE: Sequoyah Power Station, Unit 1	DATE (DAY-MON.-YR.): [illegible]	TIME (24 HR. CLOCK): 1940	SHEET NO. 150014

1.) EXAMINER: [illegible]	SNT LEVEL: II	PROCEDURE NO. 600-15	INSTRUMENT: SONIC MARK: I ☐ II ☐ III ☐	SERIAL NO: [illegible]
2.) EXAMINER: (OPERATOR) [illegible]	SNT LEVEL: III	REV. 37	COUPLANT: GLYCERINE ☐ WATER ☐ OTHER (SPECIFY) ______	

CALIBRATION VERIFICATION

TIME:	2001	[illegible]	[illegible]	[illegible]	
INITIALS:	[illegible]	[illegible]	[illegible]	[illegible]	

SEARCH UNITS		
NOMINAL ANGLE	0°	N/A
MEASURED ANGLE	0°	
BRAND	SERIAL NUMBER	
SwRT	[illegible]	
SIZE:	1" Rd	
NOMINAL FREQUENCY (MHZ):	2.25	

REFERENCE BLK: [illegible]

CAL. BLK. TEMPERATURE [illegible] °F

MEASURED ANGLE:	0°	N/A
SIGNAL AMPLITUDE (SCREEN DIVISIONS):	8	
SIGNAL DISTANCE (IN):	4	
SCREEN DIVISIONS:	4	
COARSE RANGE:	5	
FINE dB:	7	
COARSE dB:	30	

CABLE TYPE

RG62 ☐ RG174 ☐

OTHER ______

LENGTH 72 IN.

JACK USED

R ☐ T ☐

MODE OF TRANS.

NORM ☐

THRU TRANS. ☐

AMPLITUDE DETERMINATION FOR 5/8 NODE

3/8 ECHO N/A dB N/A LINES OF AMPLITUDE

5/8 ECHO N/A dB N/A LINES OF AMPLITUDE

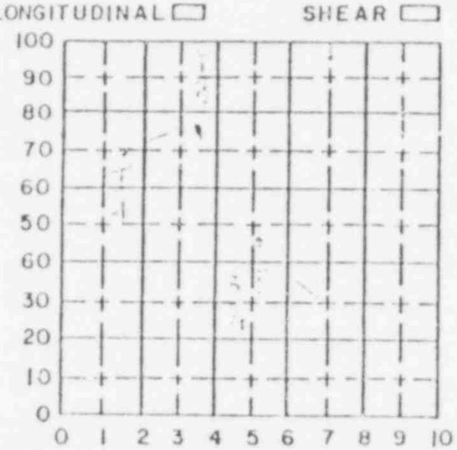
Δ dB N/A (3/8 - 5/8 ECHO)

REMARKS: Re-look W09-10 60° Tubes. [illegible]

INSTRUMENT SETTINGS		
REJECT:	0	
DEC:	off	
FINE dB:	0	
COARSE dB:	76	
FREQUENCY:	2	
DELAY:	353-1	
MAT'L CAL:	399	
RANGE:	5	
DAMPING:	min	
REP RATE:	1K	
FILTER:	Hi	
VIDEO:	[illegible]	

10 SCREEN DIVISIONS: 10 INCHES OF METAL

LONGITUDINAL ☐ SHEAR ☐



BASIC CALIBRATION BLOCK NO. 05

EXAMINATION AREA(S)

[illegible]

Weld W09-10 [illegible]

[illegible]

REVIEWED BY: [illegible]	SNT LEVEL: II	DATE: 26 [illegible] 79

FORM NO. SwRI NDTR 17-45 (REV 4-6-77)

POOR ORIGINAL

461 239

SwRI SONIC INSTRUMENT VESSEL CALIBRATION RECORD

PROJECT NO:	17-5339
SITE:	Sequoyah Power Station, Unit 1
DATE: (DAY-MON.-YR.)	25 Jan 79
TIME: (24 HR. CLOCK)	1102
SHEET NO.	[illegible]
1.) EXAMINER:	[illegible]
SNT LEVEL	[illegible]
2.) EXAMINER: (OPERATOR)	[illegible]
SNT LEVEL	III
PROCEDURE NO.	600-15
REV.	37
INSTRUMENT: SONIC MARK: I ☐ II ☐ III ☐	
SERIAL NO:	[illegible]
COUPLANT: GLYCERINE ☐ WATER ☐ OTHER (SPECIFY)	

CALIBRATION VERIFICATION

TIME:	1836	—		/	
INITIALS:	[illegible]	[illegible]			

SEARCH UNITS

NOMINAL ANGLE	60°	
MEASURED ANGLE	60°	
BRAND	SERIAL NUMBER	
SwRI	[illegible]	
SIZE:	1.0"	
NOMINAL FREQUENCY (MHz):	2.25	

REFERENCE BLK: [illegible]	CAL. BL. TEMPERATURE 75 °F
MEASURED ANGLE:	60°
SIGNAL AMPLITUDE (SCREEN DIVISIONS):	8
SIGNAL DISTANCE (IN):	4
SCREEN DIVISIONS:	2
COARSE RANGE:	5
FINE dB:	11
COARSE dB:	70

CABLE TYPE	
RG62 ☐ RG174 ☒	
OTHER	
LENGTH	72 IN.
JACK USED	R ☒ T ☐
MODE OF TRANS.	NORM ☒
	THRU TRANS. ☐

AMPLITUDE DETERMINATION FOR 5/8 NODE

3/8 ECHO [illegible] dB 2 LINES OF AMPLITUDE

5/8 ECHO [illegible] dB 5 LINES OF AMPLITUDE

Δ dB 1 (3/8 - 5/8 ECHO)

REMARKS: [illegible]

[illegible] 98°F [illegible]

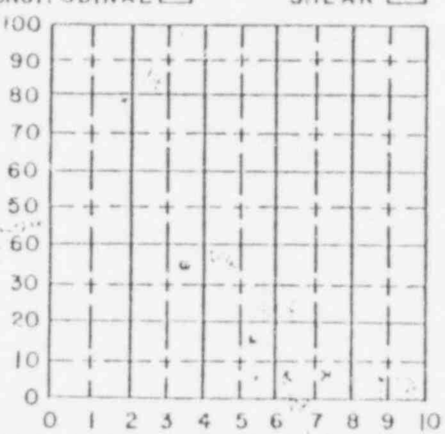
[illegible]

INSTRUMENT SETTINGS

REJECT:	0	
DEC:	off	
FINE dB:	9	
COARSE dB:	80	
FREQUENCY:	2	
DELAY:	3.84	
MAT'L CAL:	661	
RANGE:	10	
DAMPING:	Min	
REP RATE:	HI	
FILTER:	H.	
VIDEO:	Full	

10 SCREEN DIVISIONS: 20 INCHES OF METAL

LONGITUDINAL ☐ SHEAR ☐



BASIC CALIBRATION BLOCK NO. 05

EXAMINATION AREA(S)

[illegible]

[illegible] 253" [illegible]

REVIEWED BY: [illegible]	SNT LEVEL:	DATE: [illegible]

FORM NO. SwRI NDTR. 17-45 (REV 4-6-77)

Page 11 of 13

461 240

POOR ORIGINAL

Sw. R. I. PRESSURE VESSEL ULTRASONIC EXAMINATION RECORD

PROJECT NO.: 175339	SITE: Sequoyah Power Station, Unit 1	DATE: (DAY-MON.-YR.) [illegible]	TIME (24 HR. CLOCK) SHEET STARTED: [illegible] SHEET ENDED: [illegible]	SHEET NO.: 390024
EXAMINATION AREA (SYSTEM/COMPONENT): RPV	(LINE / SUBASSEMBLY): Closure head	(IDENTIFICATION): [illegible]	L_o LOCATION: [illegible] of Vessel	W_o LOCATION: [illegible]

EXAMINER: WC McGaughey	SNT LEVEL: III	PROCEDURE NO. [illegible]	CALIBRATION SHEET(S)	ANGLE USED	0°	45°	45°T	60°	OTHER °	OTHER °	WELD TYPE: [illegible]
EXAMINER: [illegible]	SNT LEVEL: I	REV. 57	45393	SCANNING dB	N/A	—	N/A	90% +	N/A	N/A	WELD LENGTH: [illegible]; EXAMINATION SURFACE INSIDE ☐ OUTSIDE ☐

IND. NO.	% OF DAC MAX	50% DAC W_1	50% DAC MP	W MAX W	W MAX MP	50% DAC W_2	50% DAC MP	L_1 50% DAC	L POSITION	L_2 50% DAC	SEARCH UNIT LOCATION	SEARCH UNIT ANGLE	THRU WALL DEPTH % OF T *	DEPTH BELOW SURFACE % T **	REMARKS: + 6dB Scan [illegible]	INI.
(5)	141	7 1/4"	9.5	9 1/2"	10.[illegible]	11 [illegible]"	13.4	5 1/4	5 [illegible]	5 [illegible]	UP	60°	N/A	N/A	(relook) [illegible]	[illegible]
5A	14	[illegible]	13.0	10 [illegible]	14.3	11 [illegible]"	14.6	[illegible]	[illegible]	[illegible]	UP	60°	N/A	N/A	[illegible]	[illegible]

* SEE NOTE 1 - BACK OF PAGE N/A
** SEE NOTE 2 - BACK OF PAGE N/A

EXAMINATION AREA LIMITATION (IF NONE, SO STATE) relook of indication (5) [illegible] and (5A) [illegible]

REVIEWED BY: [signature]	SNT LEVEL: [illegible]	DATE: [illegible] 79	PAGE 1 OF 1

FORM NO. SWRI NDTP 17-39 (REV 10-11-76)

POOR ORIGINAL

461 241

Sw. R. I. PRESSURE VESSEL ULTRASONIC EXAMINATION RECORD

PROJECT NO.: 17-5339	SITE: Sequoyah Power Station, Unit 1	DATE: (DAY-MON.-YR.) 25 JAN '79	TIME (24 HR. CLOCK) SHEET STARTED: [illegible] SHEET ENDED: [illegible]	SHEET NO.: 390025
EXAMINATION AREA (SYSTEM/COMPONENT) RPV	(LINE / SUBASSEMBLY) Closure Head	(IDENTIFICATION) W04-15	L_o LOCATION: [illegible]	W_o LOCATION: [illegible]

EXAMINER: WC McGonagle	SNT LEVEL: III	PROCEDURE NO. 450-15 REV. 37	CALIBRATION SHEET(S) 450014	ANGLE USED / SCANNING dB	0°: [illegible]	45°: NA	45°T: NA	60°: NA	OTHER: N A	WELD TYPE: [illegible]
EXAMINER: WT Weinmann	SNT LEVEL: II									WELD LENGTH: [illegible] EXAMINATION SURFACE INSIDE ☐ OUTSIDE ☐

IND. NO.	% OF DAC MAX	50 % DAC W_1	50 % DAC MP	W MAX W	W MAX MP	50 % DAC W_2	50 % DAC MP	L_1 50 % DAC	L POSITION	L_2 50% DAC	SEARCH UNIT LOCATION	SEARCH UNIT ANGLE	THRU WALL DEPTH % OF T *	DEPTH BELOW SURFACE % OF T **	REMARKS:	INI.
1	9	—	—	3½"	52"	—	—	—	45"	—	4u	0°	NA	NA	× 14 Back to Down	WCM

* SEE NOTE 1 - BACK OF PAGE
** SEE NOTE 2 - BACK OF PAGE

EXAMINATION AREA LIMITATION (IF NONE, SO STATE) Rear of L 23.5" to 46" WCMcGonagle

REVIEWED BY: [illegible] | SNT LEVEL: [illegible] | DATE: [illegible] | PAGE 1 OF 1

Page 13 of 18

POOR ORIGINAL

461 242

Sw. R. I. PRESSURE VESSEL ULTRASONIC EXAMINATION RECORD

PROJECT NO.: 17-5339	SITE: Sequoyah Power Station, Unit 1	DATE: (DAY-MON.-YR.) [illegible]	TIME (24 HR. CLOCK) SHEET STARTED: [illegible] SHEET ENDED: [illegible]	SHEET NO.: 380023
EXAMINATION AREA (SYSTEM/COMPONENT): RPV	(LINE / SUBASSEMBLY): Closure head	(IDENTIFICATION): [illegible]	L_o LOCATION: [illegible] of vessel	W_o LOCATION: [illegible]

EXAMINER: W. J. Heinemann	SNT LEVEL: II	PROCEDURE NO. 600-5	CALIBRATION SHEET(S)	ANGLE USED	0°	45°	45°T	60°	OTHER °	OTHER °	WELD TYPE: [illegible]
EXAMINER: N/A	SNT LEVEL: N/A	REV. 37	450012	SCANNING dB	N/A	60/8	N/A	N/A	N/A	N/A	WELD LENGTH: [illegible] EXAMINATION SURFACE INSIDE ☐ OUTSIDE ☐

IND. NO.	% OF DAC MAX	50 % DAC W_1	50 % DAC MP	W MAX W	W MAX MP	50 % DAC W_2	50 % DAC MP	L_1 50 % DAC	L POSITION	L_2 50% DAC	SEARCH UNIT LOCATION	SEARCH UNIT ANGLE	THRU WALL DEPTH % OF T *	DEPTH BELOW SURFACE % OF T **	REMARKS:	INI.
															+ [illegible] switch down	[illegible]
13-8-1	141	5½	8.8	[illegible]	9.2	[illegible]	9.6	[illegible]	[illegible]	[illegible]	[illegible]	45°	N/A	N/A	(relook) No change	[illegible]
															"L" measurement made to	[illegible]
															point xducer aiming to	[illegible]
															on weld centerline	[illegible]

* SEE NOTE 1 - BACK OF PAGE ** SEE NOTE 2 - BACK OF PAGE	EXAMINATION AREA LIMITATION (IF NONE, SO STATE): [illegible] from original exam WJH

REVIEWED BY: [illegible]	SNT LEVEL: II	DATE: 3-1-79	PAGE 1 OF 1

Page 14 of 18

POOR ORIGINAL

461 243

SwRI SONIC INSTRUMENT VESSEL CALIBRATION RECORD

PROJECT NO: 17-5339	SITE: Sequoyah Power Station, Unit 1	DATE: (DAY-MON.-YR.) [illegible]	TIME: (24 HR. CLOCK) 1553	SHEET NO. [illegible]

1.) EXAMINER: [illegible]	SNT LEVEL II	PROCEDURE NO. [illegible] REV. 37	INSTRUMENT: SONIC MARK: I ☐ II ☐ III ☐	SERIAL NO: [illegible]	CALIBRATION VERIFICATION
2.) EXAMINER: (OPERATOR) N/A	SNT LEVEL N/A		COUPLANT GLYCERINE ☐ WATER ☐ OTHER (SPECIFY) ____		TIME: [illegible] / INITIALS: [illegible]

SEARCH UNITS		
NOMINAL ANGLE	45°	
MEASURED ANGLE	46°	
BRAND	SERIAL NUMBER	
Aerotech	[illegible]	N/A
SIZE:	1.0" rd	
NOMINAL FREQUENCY (MHZ):	2.25	

REFERENCE BLK: [illegible]		
MEASURED ANGLE:	[illegible]	N/A
SIGNAL AMPLITUDE (SCREEN DIVISIONS):	8	
SIGNAL DISTANCE (IN):	4	
SCREEN DIVISIONS:	2	
COARSE RANGE:	10	
FINE dB:	6	
COARSE dB:	50	

CAL. BLK. TEMPERATURE 75 °F

CABLE TYPE
RG62 ☐ RG174 ☒
OTHER ____
LENGTH 72 IN.

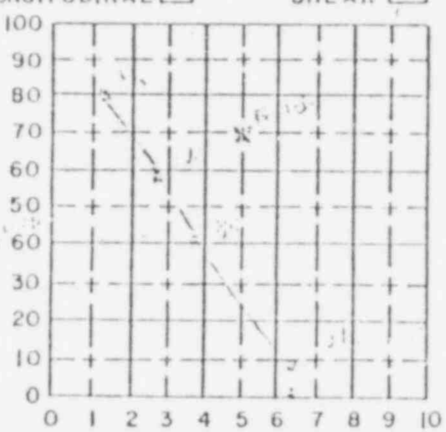
JACK USED
R ☐ T ☐
MODE OF TRANS.
NORM ☐
THRU TRANS. ☐

AMPLITUDE DETERMINATION FOR 5/8 NODE
3/8 ECHO 15 dB [illegible] LINES OF AMPLITUDE
5/8 ECHO 29 dB [illegible] LINES OF AMPLITUDE
Δ dB 14 (3/8 - 5/8 ECHO)

REMARKS: [illegible]
[illegible]
Surface 94° [illegible] (1509)

INSTRUMENT SETTINGS		
REJECT:	0	N/A
DEC:	off	
FINE dB:	8	
COARSE dB:	60	
FREQUENCY:	2	
DELAY:	3334	
MAT'L CAL:	657	
RANGE:	10	
DAMPING:	Min	
REP RATE:	1K	
FILTER:	[illegible]	
VIDEO:	[illegible]	

1 SCREEN DIVISIONS: 2 INCHES OF METAL
LONGITUDINAL ☐ SHEAR ☒



BASIC CALIBRATION BLOCK NO. 05

EXAMINATION AREA(S) 45°
Recheck [illegible] #3 [illegible]
[illegible]
[illegible] Sheet# [illegible]

REVIEWED BY: [illegible]	SNT LEVEL: [illegible]	DATE: 26 [illegible] 79

FORM NO. SwRI NDTR 17-45 (REV 4-6-77)

POOR ORIGINAL

244

SWRI INSTRUMENT LINEARITY VERIFICATION

PROJECT NO. 14-5339	SITE: Sequoyah U-II	DATE: (DAY-MON-YR) [illegible]	TIME COMPLETED (24 HR. CLOCK) [illegible]	SHEET NO. 37062
INSTRUMENT USED: USED: BRANSON 301 [ ] 600 [ ] SONIC MK I [ ] MK II [ ] MK III [ ]		SERIAL NO. [illegible]	BASIC CALIBRATION BLOCK NO. [illegible]	
EXAMINER: [illegible]	SNT LEVEL: II	REMARKS:		
EXAMINER: [illegible]	SNT LEVEL: III			

AMPLITUDE LINEARITY

INSTRUMENT WITH FINE dB CONTROL: FIRST SIGNAL IN %	INSTRUMENT WITH FINE dB CONTROL: SECOND SIGNAL IN % *	INSTRUMENT WITHOUT FINE dB CONTROL: FIRST SIGNAL IN %	DECIBEL CHANGE	SECOND SIGNAL IN % *
100	49	100		n/a
90	~~45~~ 45	n/a	-2dB	
80	40		-2dB	
70	35		-2dB	
60	30		-2dB	
50	24		-2dB	
40	20		-2dB	
30	16		-2dB	
20	11		-2dB IF REQUIRED	

AMPLITUDE CONTROL LINEARITY

INDICATION SET AT % OF FULL SCREEN	dB CONTROL CHANGE	INDICATION LIMITS % OF FULL SCREEN	ACTUAL % OF FULL SCREEN
80	-6dB	32 TO 48	40
80	-12dB	16 TO 24	21
40	+6dB	64 TO 96	73
20	+12dB	64 TO 96	73

REVIEWED BY: [illegible] SNT LEVEL: [illegible] DATE: [illegible]

FORM NO SWRI IT-37 (REV. 6-9-77)

* READING MUST BE 50% ± 5% OF FIRST SIGNAL AMPLITUDE.

461 245

SWRI BEAM SPREAD RECORD

PROJECT NO.	SITE:	DATE (DAY - MON. - YR.)	TIME COMPLETED (24HR CLOCK)	SHEET
17-3984-539 [illegible]	Seqouyah [illegible]	25 Jan 79	[illegible]	3/003 [illegible]

CALIBRATION SHEETS:	dB AT 50%:	TRANSDUCER BRAND:	TRANSDUCER SERIAL NUMBER:	
450612	39 [illegible]	SwRI	43 [illegible]	
	EXAMINER:	SNT LEVEL:	EXAMINER:	SNT LEVEL:
	W.C. McGowan	[illegible]	W.T. [illegible]	II

MEASUREMENTS TAKEN FROM INCIDENCE ANGLE TO SCRIBE LINE	W_1 50% DAC	W MAX	W_2 50% DAC
$\frac{1}{4}$T HOLE	$2\frac{1}{4}$"	$2\frac{15}{16}$"	$3\frac{1}{4}$"
$\frac{1}{2}$T HOLE	$5\frac{9}{16}$"	$6\frac{1}{4}$"	$7\frac{1}{4}$"
$\frac{3}{4}$T HOLE	$8\frac{1}{2}$"	$9\frac{1}{4}$"	$10\frac{3}{8}$"

MEASURED ANGLE OF BEAM SPREAD:

6°	3°
1-2	2-3

ACTUAL REFRACTED ANGLE:

62°	59°	61°
1-2	2-3	1-3

REMARKS: WC McG [illegible]

$1\frac{3}{4}$"

1C

$3\frac{1}{2}$"

7.25"

2C

5"

3C

$\frac{5}{32}$ Clad

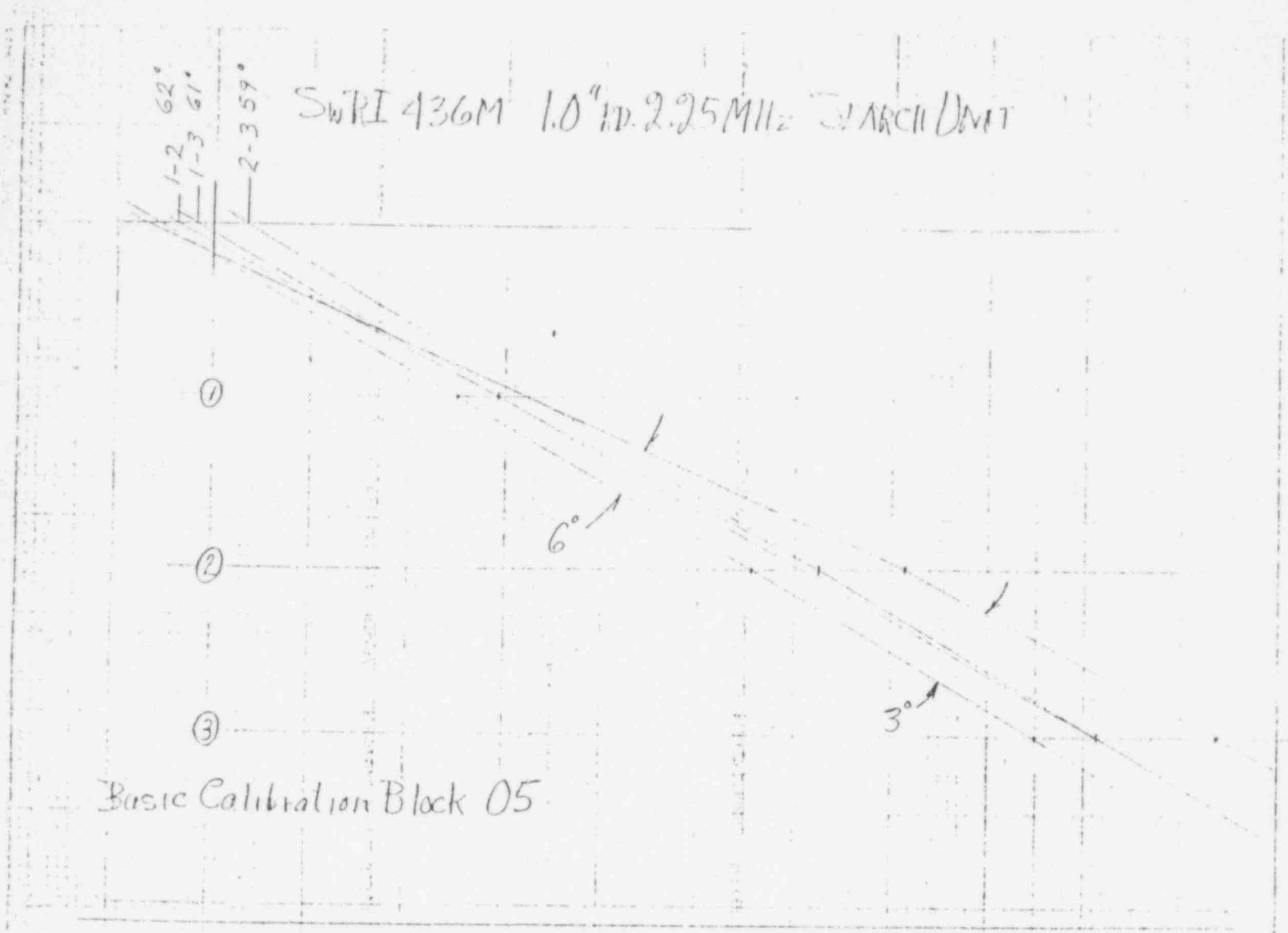
REVIEWED BY:	SNT LEVEL:	DATE:
[illegible signature]	II	26 Jan 79

FORM NO. SWRI 17-36 (REV. 9-22-76)

POOR ORIGINAL

Page 17 of 17

461 246



BEAM SPREAD SHEET 360034

SwRI 17-5339-004 SEQUOYAH 26JAN79 WC McGaughey

461 247