ATTACHMENT (7)

Non-Proprietary -- Calculation No. CA04945, Revision No. 0,

"Pressurizer Mid and Lower Level (Nozzle) Crack Analysis"

ESP No.:	ES199800338	Supp No.	000	Rev. No.	0001	Page 1 of 1

FORM 19, CALCULATION COVER SHEET
Form Rev. 0

INITIATION (Control Doc Type - DCALC) Page 1 of 1

DCALC No.: CA04945 Revision No.: 0000

Vendor Calculation (Check one): ☒ Yes ☐ No

Responsible Group: MEU

Responsible Engineer: J. R. Sponsel

CALCULATION

ENGINEERING DISCIPLINE:

☐ Civil ☐ Instr & Controls ☐ Nuc Engrg
☐ Electrical ☒ Mechanical ☐ Diesel Gen Project
☐ Life Cycle Mngmt ☐ Reliability Engrg ☐ Nuc Fuel Mngmt
☐ Other:

Title: Pressurizer Mid and Lower Level Crack Analysis

Unit ☒ UNIT 1 ☒ UNIT 2 ☐ COMMON

Proprietary or Safeguards Calculation ☐ YES ☒ NO

Comments:

Vendor Calc No.: HABGE-02/00-0841 REVISION NO.: 0000

Vendor Name: HOPPER & ASSOCIATES

Safety Class (Check one): ☒ SR ☐ AQ ☐ NSR

There are assumptions that require Verification during walkdown: AIT #: N/A

This calculation **SUPERSEDES**:

REVIEW AND APPROVAL:

Responsible Engineer: J. R. SPONSEL [signature] Date: 4-11-00

Independent Reviewer: N/A Date:

Approval: N/A Date:

HOPPER AND ASSOCIATES
ENGINEERS

FAX: (310) 791-7308
E-MAIL: haieng@ix.netcom.com

300 Vista Del Mar
Redondo Beach, CA 90277
(310) 373-5573

February 24, 2000
HABGE-02/00-0841

Mr. J. Todd Conner
Baltimore Gas and Electric
Calvert Cliffs Nuclear Power Plant
1650 Calvert Cliffs Parkway
Lusby, MD 20657

Subject: Pressurizer Mid and Lower Level Nozzle Crack Analysis – Calculation Transmittal

Dear Mr. Conner:

We have completed and enclose the subject for your records. It has been a pleasure assisting you on this interesting project.

Pursuant to our blanket Purchase Order number 21842 Sub Order Release: 13, this letter provides our Certificate of Compliance/Conformance (C of C) on the subject calculation. This work product meets the requirements of the procurement documents.

Very truly yours,

Kelley S. Elmore
Professional Engineer

Enclosure

HOPPER AND ASSOCIATES ENGINEERS

PROFESSIONAL ENGINEERING SUPPORT TO INDUSTRY

Pressurizer Mid and Lower Level

Nozzle Crack Analysis

Calculation Transmittal

HABGE-02/00-0841

HOPPER AND ASSOCIATES
ENGINEERS

CCNPP UNIT 2 PRESSURIZER MID AND LOWER LEVEL NOZZLE CRACK ANALYSIS

Prepared for: Baltimore Gas and Electric Company
Calvert Cliffs Nuclear Power Plant
1650 Calvert Cliffs Parkway
Lusby, MD 20657

Prepared by: Hopper and Associates
300 Vista Del Mar
Redondo Beach, CA 90277

February 2000

BGE050

HOPPER AND ASSOCIATES
ENGINEERS
CALCULATION SHEET

TITLE: PRESSURIZER NOZZLE CRACK ANALYSIS **DATE:** 2 / 08 / 00 **PAGE:** i

SUBJECT: TABLE OF CONTENTS **BY:** MG **CK:** BK **SHT:** i **OF** ii

HOPPER AND ASSOCIATES
ENGINEERS

CALCULATION SHEET

TITLE: PRESSURIZER NOZZLE CRACK ANALYSIS DATE: 2 / 08 / 00 PAGE: ii

SUBJECT: TABLE OF CONTENTS BY: MG CK: BK SHT: ii OF ii

Prepared by Mark Gielow 2/18/00
MARK GIELOW

Reviewed by Brett Kurkjian 2/22/00
BRETT KURKJIAN

1.1 Problem Statement

A postulated through cladding flaw in the Unit 2 Pressurizer upper level nozzle was previously evaluated in [1, 2] in response to leakage at that nozzle. The purpose of this analysis is to perform a similar crack growth evaluation for the Pressurizer side temperature nozzle and the two bottom head level nozzles. The evaluation will assume that a flaw existed in the vessel cladding when the Pressurizer was put in service, and the flaw has grown into the base metal due to cyclic stresses. As in the previous analysis, the postulated flaw geometry will be a through clad radial corner flaw. The crack growth rate will be estimated using conservative linear elastic methods from the ASME Boiler and Pressure Vessel Code, Section XI, Appendix A [3]. Remaining vessel life will be estimated using the Section XI criteria for critical crack size. The number of cycles required to exceed Section XI Article IWB-3000 acceptable flaw sizes will also be calculated. To prevent new leaks at the instrument nozzles, Mechanical Nozzle Seal Assemblies (MNSA) are to be installed on each nozzle. The vessel modifications and loading associated with these devices are analyzed in [4]. The effects of the MNSA modifications and loads on postulated crack growth will be considered.

1.2 Investigation Approach

A flaw geometry similar to the previous Pressurizer instrument nozzle crack growth analysis [1, 2] will be assumed. Stresses in the Pressurizer wall at the side temperature nozzle and the bottom head level nozzles will be obtained from the original analysis of the Pressurizer [5]. The analysis in [1, 2] assumed that thermal stresses can be ignored because of the location of the upper nozzle in the Pressurizer steam dome. This will not be assumed for the side and bottom nozzles, so both pressure and thermal loading will be considered in this analysis. The Mechanical Nozzle Seal Assembly analysis [4] will be reviewed to determine if any additional loading of the vessel/nozzle occurs due to the MNSAs or if associated modifications to the vessel will affect the crack growth rate. The approach in the ASME Code Section XI, Appendix A will be used to conservatively estimate crack growth rates and to determine critical crack size. As stated in [2], this approach, which is based on elastic fracture mechanics, is conservative because significant yielding occurs as crack growth progresses. Because thermal loading is considered in this analysis, stresses will be higher than in the previous analysis (for the bottom nozzles), resulting in greater plasticity. Therefore the Section XI approach provides even more conservatism in this analysis.

1.3 Result Summary

The postulated flaws at the side and bottom nozzles do not limit the expected life of the Pressurizer vessel. The critical crack size for the side temperature nozzle crack is greater than the vessel wall thickness according to ASME Section XI Appendix A criteria. Therefore the postulated through clad flaw at that location cannot grow to a critical size within the lifetime of the plant. The flaw is also not expected to grow through wall during the plant lifetime. The postulated flaw at the bottom head level nozzles reaches critical size at a depth of 1.23". The flaw is predicted to grow to this depth after 6100 cycles. The most significant Pressurizer stress cycling is caused by heat-up/cool-down cycles, with a total of 500 cycles specified for the Pressurizer operating life. Therefore the bottom nozzle flaw is not expected to reach a critical size during the plant lifetime. Intensified stresses at the bottom nozzle exceed the yield stress, so these results, which are based on an elastic analysis, are conservative. The Section XI Article IWB-3000 flaw acceptance criteria was also considered. Both the side and bottom nozzle flaws are not predicted to reach the maximum acceptable flaw depth within the plant lifetime. Therefore, based on this analysis, other than routine inspections at these locations are not required. The Mechanical Nozzle Seal Assemblies to be installed on the Pressurizer nozzles will not affect the crack growth rates of the postulated flaws.

The general configuration of the Pressurizer vessel indicating the locations of the nozzles under consideration is shown in Figure 2.1. The vessel shell and head material is SA-533 Gr. B Cl. 1. The shell wall thickness is 4.875" and the bottom and top head wall thickness is 3.875". The minimum cladding thickness is specified as 0.125". The Pressurizer design and operating conditions are:

Design pressure:	2500 psia
Design temperature:	700 °F
Operating pressure:	2250 psia
Operating temperature:	653 °F

All preceding data is obtained from [5].

Details of the side temperature nozzle and the two identical bottom head level nozzles are shown in Figure 2.2.

The Mechanical Nozzle Seal Assemblies for the side and bottom nozzles are shown in Figures 2.3 and 2.4.

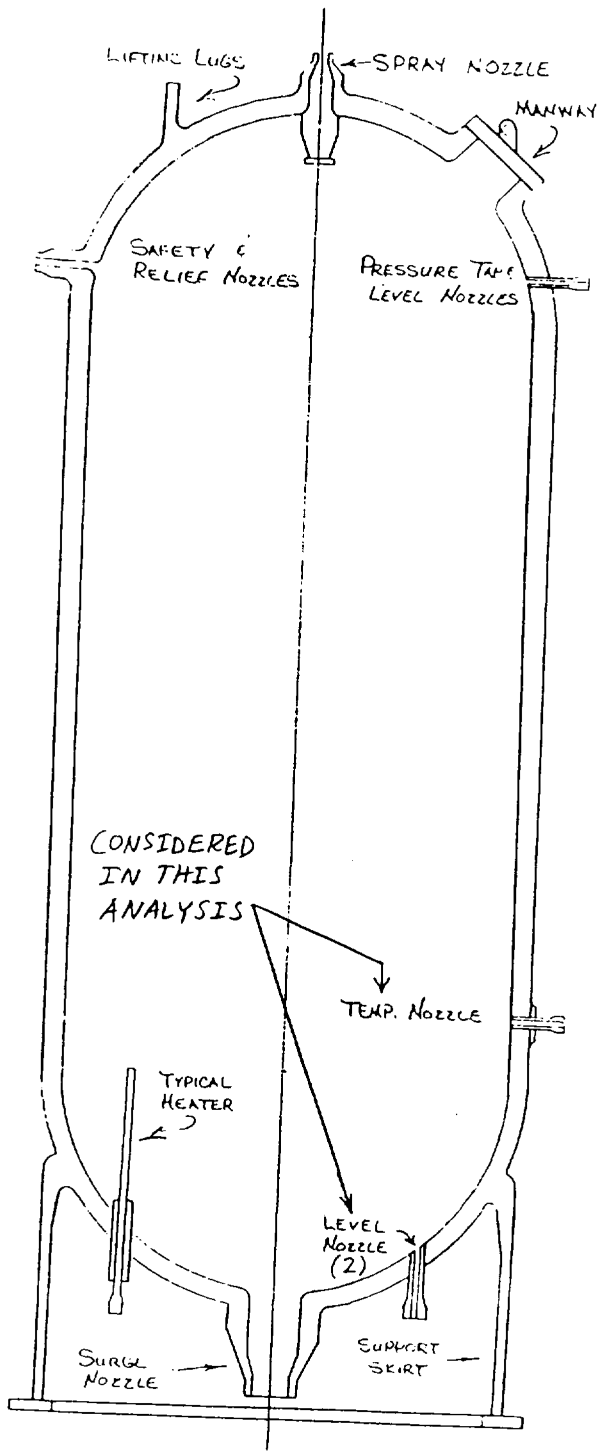
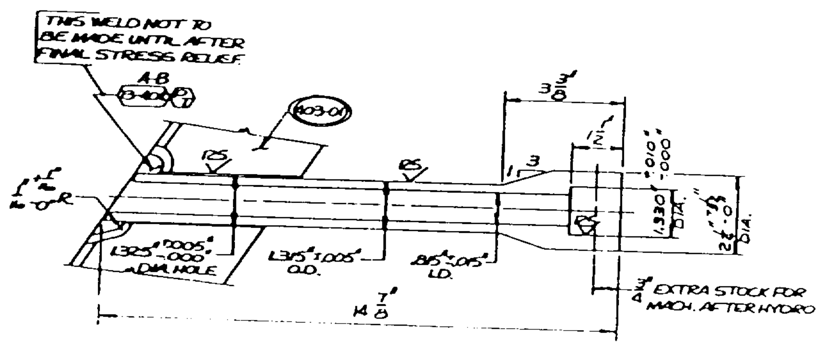
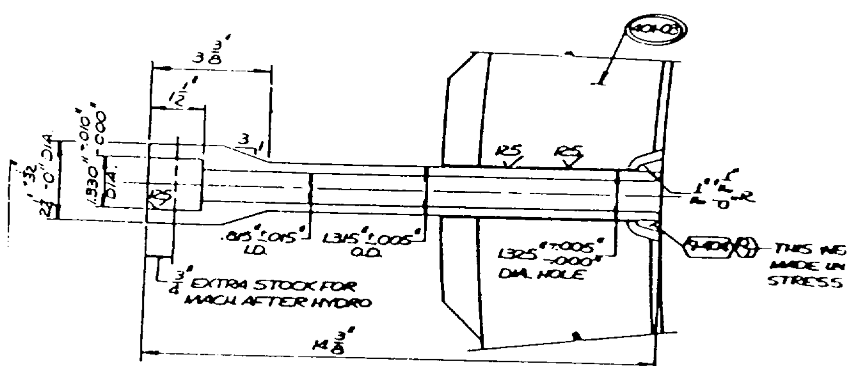


FIGURE 2.1 - PRESSURIZER VESSEL [5]



STEP II MACHINING
LOWER LEVEL NOZZLE ASSEMBLY



STEP II MACHINING
LOWER TEMPERATURE NOZZLE ASSEMBLY

FIGURE 2.2 - NOZZLE DETAILS [5]

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CALCULATION SHEET

TITLE: PRESSURIZER NOZZLE CRACK ANALYSIS DATE: 2/8/00 PAGE: 7

SUBJECT: 2.0 SYSTEM DESCRIPTION BY: MG CK: BK SHT: 4 OF 5

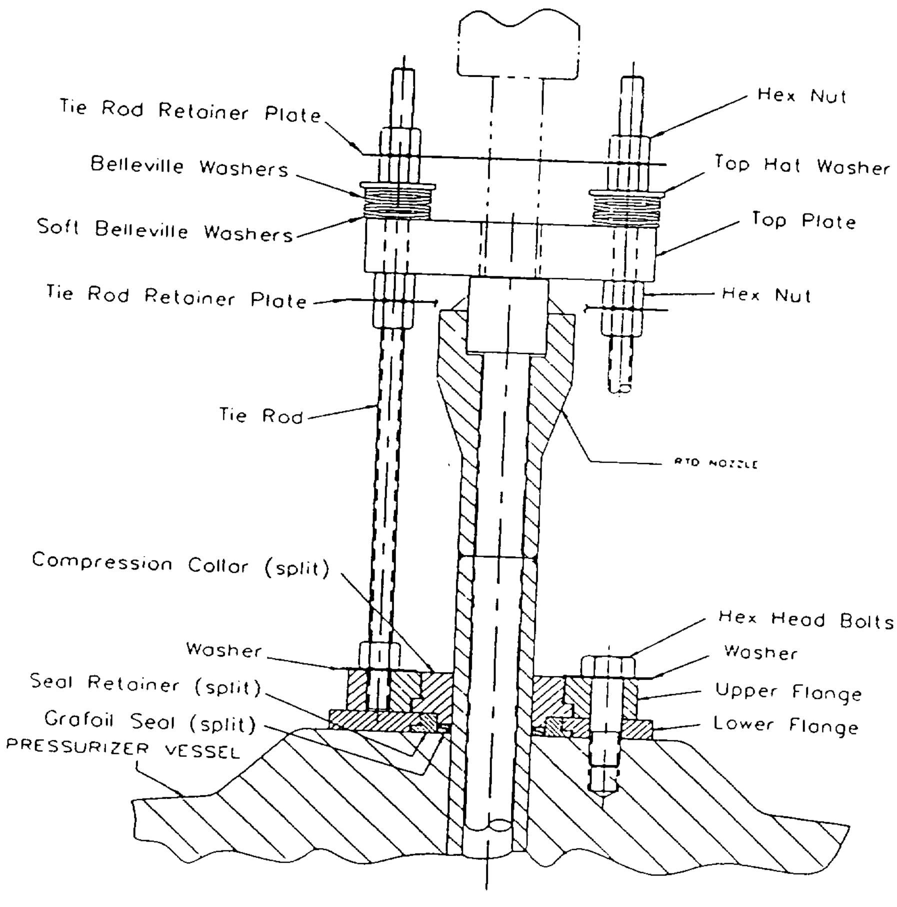


FIGURE 2.3 - SIDE NOZZLE MNSA [4]

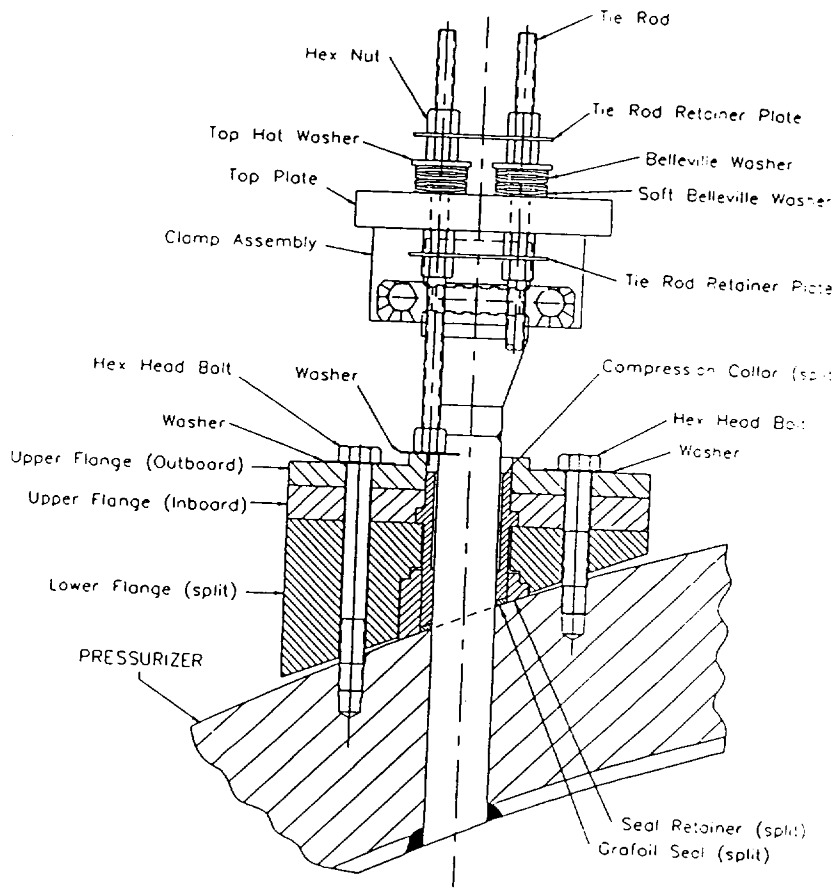


FIGURE 2.4 – BOTTOM NOZZLE MNSA [4]

1. Pressurizer wall stresses at the nozzle locations are obtained from [5]. These stresses are caused by operational pressure and thermal loading of the vessel and are assumed to be the only significant loading of the vessel at the nozzle locations.

2. Loads due to piping attached to the nozzles are neglected.

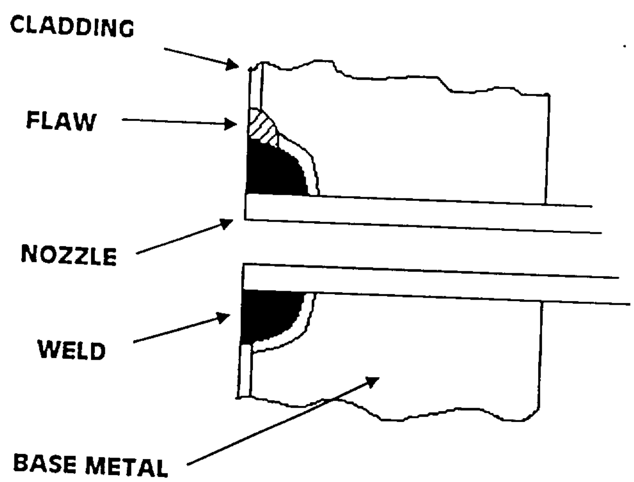
3. Weld residual stresses are neglected. The formation of the postulated cladding flaw will relieve residual stresses at the flaw location.

4. The postulated flaw is assumed to have a quarter-circular shape and is appropriately modeled using the stress intensity factor expression from the previous Pressurizer nozzle flaw evaluations [1,2].

5. The integration of the crack growth rate expression in Section 4.0 assumes a constant stress (σ) each cycle. There will be additional cycles at other stress levels. However, as explained in Section 4.0, a maximum stress level is selected for the cyclic stress. Additional lower stress cycles will not significantly contribute to crack growth

4.1 Postulated Nozzle Flaw Geometry

The postulated flaw for the side temperature nozzle and the two bottom head level nozzles is a through clad flaw as shown in the figure below. The minimum cladding thickness specified for the Pressurizer is 0.125" [5]; as in the previous nozzle flaw evaluation [2], a somewhat deeper initial flaw of 0.15" will be assumed.



4.2 Effects of Mechanical Nozzle Seal Assemblies on Crack Growth

The Mechanical Nozzle Seal Assemblies (MNSA) are shown in Figures 2.3 and 2.4 above. The MNSAs are analyzed in [4]. The following observations are made pertaining to the potential effects of the MNSAs on crack growth of the postulated flaw.

1. Review of the MNSA design and analysis indicates that a compression collar and Grafoil seal are loaded in compression against the outer vessel surface. The collar and seal are compressed by four threaded fasteners that screw into tapped holes on the vessel surface. Therefore the MNSA will induce some additional compressive loading of the vessel outer wall. This loading will not affect crack growth at the postulated flaw location on the inner surface of the Pressurizer.

2. Seismic loading due to the overhung weight of the MNSA is considered in the analysis in [4]. The weight is accelerated during a seismic event, causing a bending moment load in the vessel wall. Seismic events are rare and do not contribute significantly to crack growth because of the low number of cycles. Therefore the seismic load caused by the MNSAs will not be considered in this analysis.

3. Differential thermal expansion of the MNSA components, nozzle and Pressurizer wall will cause additional loading of the MNSA components. According to [4] this loading is minimized by Belleville springs in the MNSA assembly that deflect and absorb the differential expansion. Therefore there will be no significant loading of the vessel wall due to differential thermal expansion.

4. Installation of the MNSAs requires tapped holes to be drilled in the vessel outer wall. The analysis in [4] considers stress intensification due to the drilled holes. The maximum depth of the holes are specified as 1.12" [4]. Therefore the holes are located far from the postulated flaw location on the inner surface of the Pressurizer. Consequently the bolt hole stress intensification will not affect the growth of the postulated flaw.

In summary, the loads and design modifications associated with the MNSAs will not affect the growth rate of the postulated flaw.

4.3 SIDE TEMPERATURE NOZZLE CRACK GROWTH EVALUATION

THE STRESS INTENSITY FACTOR FOR THE POSTULATED QUARTER CIRCULAR FLAW IS OBTAINED FROM:

$$K_I = \sqrt{\pi a}\,(0.706)\,\sigma \quad [1], \text{ ALSO USED IN } [2]$$

a = CRACK DEPTH

σ = STRESS IN VESSEL WALL AT THE CRACK LOCATION

FROM [5] PAGE A343, THE MAXIMUM INNER WALL STRESS RANGE AT THE SIDE TEMPERATURE NOZZLE LOCATION THAT HAS A SIGNIFICANT NUMBER OF OCCURRENCES IS THE LEAK TEST — $\sigma = (1.63 - (-13.52)) = 15.15$ KSI (320 CYCLES). OTHER CONDITIONS (LOSS OF SECONDARY PRESSURE, HYDRO TEST) HAVE HIGHER STRESSES BUT ONLY 5 AND 10 OCCURRENCES EACH. THEREFORE THESE CONDITIONS WILL NOT BE CONSIDERED.*

THE INTENSIFIED STRESS AT THE FLAW LOCATION IS

$$\sigma = SCF_{HOLE} \cdot \sigma_{NOM}$$

SCF_{HOLE} = STRESS INTENSIFICATION FACTOR DUE TO NOZZLE HOLE

FROM [6] FOR BIAXIAL STRESS, $SCF_{HOLE} = 2$ AT THE EDGE OF THE HOLE. HOWEVER, THE SCF DROPS OFF SHARPLY AWAY FROM THE HOLE. THE MINIMUM DISTANCE FROM THE HOLE EDGE TO THE POSTULATED FLAW IS THE NOZZLE WALL THICKNESS, WHICH IS 0.25" [5]. FROM [7], AN EXPRESSION FOR

*OTHER CONDITIONS HAVE A GREATER NUMBER OF CYCLES BUT MUCH LOWER STRESS— THEIR CONTRIBUTION TO CRACK GROWTH WILL BE MINIMAL.

SCF_{HOLE} AS A FUNCTION OF DISTANCE FROM THE HOLE EDGE FOR UNIAXIAL STRESS IS:

$$SCF_{HOLE} = \frac{1}{2}\left(2 + \frac{r^2}{X^2} + \frac{3r^4}{X^4}\right)$$

r = HOLE RADIUS

X = DISTANCE FROM HOLE CENTER

FOR $X = r$, $SCF = 3$

FOR BIAXIAL STRESS, $SCF = 2$ WHEN $X = r$

THEREFORE FOR BIAXIAL STRESS THE ABOVE EQUATION BECOMES:

$$SCF_{HOLE} = \frac{1}{2}\left[2 + \frac{1}{2}\left(\frac{r^2}{X^2}\right) + \frac{3}{2}\left(\frac{r^4}{X^4}\right)\right]$$

$r = 0.4075''$ [5]

$X = 0.4075 + 0.25 = 0.6575''$

$$SCF_{HOLE} = \frac{1}{2}\left[2 + \frac{1}{2}\left(\frac{.4075}{.6575}\right)^2 + 3/2\left(\frac{.4075}{.6575}\right)^4\right]$$

$= 1.21$

THEREFORE

$$\sigma = (1.21)(15.15) = 18.33 \text{ Ksi}$$

REF. [3] PART IWB-3612 REQUIRES

$$K_I < \frac{K_{Ia}}{\sqrt{10}}$$

TO MAINTAIN STABLE CRACK GROWTH

K_{Ia} = FRACTURE TOUGHNESS AT METAL TEMPERATURE

= 225 ksi $\sqrt{in}$ [2], BASED ON [8]
(SA-533 GrB Cl 1)

$$\sqrt{\pi a_c}\,(.706)\sigma = K_{Ia}/\sqrt{10}$$

$$a_c = \frac{1}{\pi}\left(\frac{K_{Ia}}{\sqrt{10}\,(.706)\,\sigma}\right)^2$$

$$= \frac{1}{10\pi}\left(\frac{225}{(.706)(18.33)}\right)^2$$

$$= 9.6''$$

THIS IS GREATER THAN THE PRESSURIZER SHELL THICKNESS (4.875"). THEREFORE THE POSTULATED FLAW AT THE SIDE NOZZLE WILL NEVER GROW TO A CRITICAL SIZE AND WILL NOT LIMIT THE REMAINING LIFE OF THE PRESSURIZER.

FIND NUMBER OF CYCLES TO GROW THROUGH-WALL:

$$\frac{da}{dN} = C_o\left(\Delta K_I\right)^n = C_o\left(\sqrt{\pi a}\,(0.706)\sigma\right)^n$$

THE EXPRESSION IS INTEGRATED (SEE SECTION 4.4 BELOW) WHICH GIVES:

$$N = \left(\frac{1}{C_o\left(\sqrt{\pi}\,(.706)\,\sigma\right)^n}\right)\left(\frac{1}{1-n/2}\right)\left(a_f^{\,1-n/2} - a_0^{\,1-n/2}\right)$$

$$\Delta K_I = \sqrt{\pi(0.15)}\,(.706)(18.33) = 8.9 \text{ Ksi}\sqrt{in} < 19 \text{ Ksi}\sqrt{in}$$

THEREFORE USE LOWER PART OF CURVE FROM [3], APPENDIX A, FIG. A-4300-1:

$C_0 = 1.02 \times 10^{-12}$ inch/cycle

$n = 5.95$

$$N = \left(\frac{1}{1.02\times10^{-12}\left(\sqrt{\pi}\,(.706)(18.33)\right)^{5.95}}\right)\left(\frac{1}{1-\frac{5.95}{2}}\right)\left(4.875^{\left(1-\frac{5.95}{2}\right)} - 0.15^{\left(1-\frac{5.95}{2}\right)}\right)$$

N = 169,000 CYCLES TO GROW THROUGH WALL

N IS MUCH LARGER THAN THE NUMBER OF OCCURRENCES OF ALL OF THE HIGH STRESS PRESSURIZER LOAD CONDITIONS [5]. THEREFORE THE POSTULATED FLAW WILL NOT GROW THROUGH-WALL DURING THE LIFE OF THE PLANT.

A PLOT OF CRACK DEPTH VERSUS STRESS CYCLES IS SHOWN IN FIGURE 4.3.1.

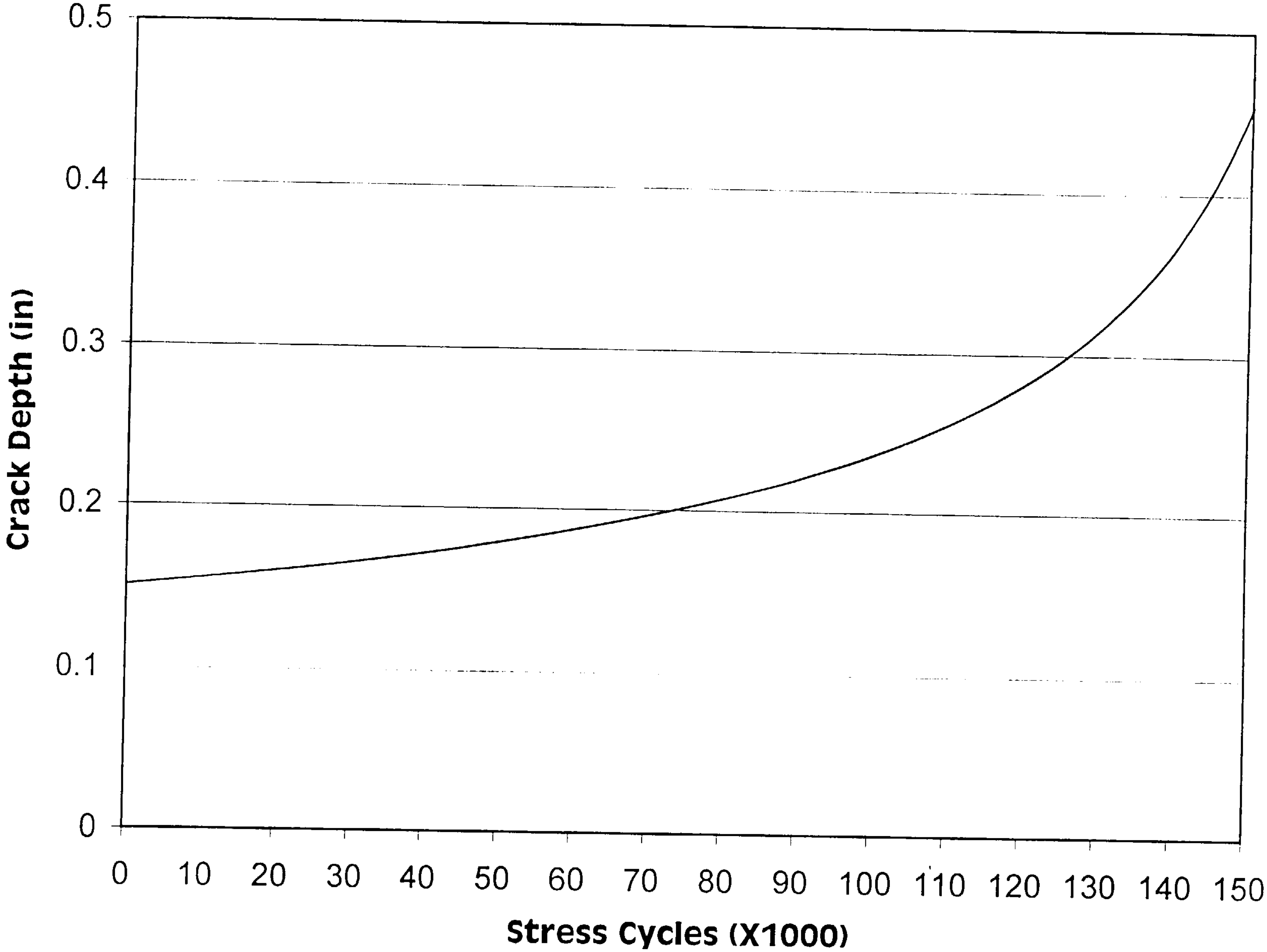


Figure 4.3.1- Side Temperature Nozzle Crack Growth

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4.4 BOTTOM HEAD LEVEL NOZZLES CRACK GROWTH EVALUATION

THE TWO BOTTOM HEAD LEVEL NOZZLES ARE LOCATED ONLY 8" APART FROM EACH OTHER AND THEY HAVE THE SAME GEOMETRY. THEREFORE THE FOLLOWING EVALUATION IS APPLICABLE TO BOTH NOZZLES.

FROM [5] PAGE A407, USE MAXIMUM INSIDE WALL STRESS RANGE FOR COOL-DOWN CONDITION — $\sigma = (3.24-(-32.07)) = 35.31$ KSI (500 cycles) (LOSS OF SECONDARY PRESSURE CONDITION HAS HIGHER STRESS BUT ONLY 5 CYCLES.)

$$\sigma = SCF_{HOLE} \cdot SCF_{HILLSIDE} \cdot \sigma_{nom}$$

FROM SECT. 4.3, $SCF_{HOLE} = 1.21$ (NOZZLE RADIUS / WALL THICKNESS SAME AS SIDE NOZZLE)

$SCF_{HILLSIDE}$ IS AN ADDITIONAL SIF DUE TO THE EFFECT OF AN OBLIQUE OR HILLSIDE NOZZLE PENETRATION.

$SCF_{HILLSIDE} = 1.2$ [1], ALSO USED IN [2]

$$\sigma = (1.21)(1.2)(35.31) = 51.27 \text{ KSI}$$

THIS STRESS EXCEEDS THE YIELD STRESS (43.5 KSI @ 650°F [9]) SO ELASTIC-PLASTIC FRACTURE MECHANICS APPLIES. ELASTIC APPROACH WILL BE USED FOR CONSERVATISM AND TO REDUCE COMPLEXITY OF CALCULATION.

CRITICAL CRACK DEPTH $a_c = \frac{1}{\pi}\left(\frac{K_{Ia}}{\sqrt{10}\,(.706)\sigma}\right)^2$

$$a_c = \frac{1}{10\pi}\left(\frac{225}{(.706)(51.27)}\right)^2$$

$$= 1.23''$$

CALCULATE NUMBER OF CYCLES TO GROW INITIAL 0.15" FLAW TO THE CRITICAL DEPTH OF 1.23":

$$\frac{da}{dN} = C_o (\Delta K_I)^n \quad \text{CYCLIC CRACK GROWTH}$$

FROM [3] APPENDIX A, FOR WATER ENVIRONMENT, FIG. A-4300-1:

$C_o = 1.01 \times 10^{-1}$ micro-inches/cycle $= 1.01 \times 10^{-7}$ inch/cycle

$n = 1.95$

THESE COEFFICIENTS ARE APPLICABLE FOR $\Delta K_I > 19 \text{ ksi}\sqrt{in}$ AND $R = K_{min}/K_{max} \leq 0.25$.

CHECK $\Delta K_I = \sqrt{\pi a}\,(0.706)\sigma$

$$= \sqrt{\pi(.15)}\,(0.706)(51.27)$$

$$= 24.8 > 19$$

$$\frac{da}{dN} = C_o\left(\sqrt{\pi a}\,(.706)\,\sigma\right)^n$$

$$\int_0^N dN = \int_{a_0}^{a_f} \frac{da}{C_o\left(\sqrt{\pi a}\,(.706)\,\sigma\right)^n}$$

$$N = \left(\frac{1}{C_0\left(\sqrt{\pi}(.706)\sigma\right)^n}\right)\int_{a_0}^{a_f}\frac{da}{(\sqrt{a})^n}$$

$$= \left(\quad '' \quad\right)\int_{a_0}^{a_f} a^{-n/2}\,da$$

$$= \left(\quad '' \quad\right)\left.\frac{a^{1-n/2}}{1-n/2}\right|_{a_0}^{a_f}$$

$$= \left(\frac{1}{C_0\left(\sqrt{\pi}(.706)\sigma\right)^n}\right)\left(\frac{1}{1-n/2}\right)\left(a_f^{1-n/2} - a_0^{1-n/2}\right)$$

$$N = \left(\frac{1}{1.01\times10^{-7}\left(\sqrt{\pi}(.706)(51.27)\right)^{1.95}}\right)\left(\frac{1}{1-\frac{1.95}{2}}\right)\left(1.23^{\left(1-\frac{1.95}{2}\right)} - 0.15^{\left(1-\frac{1.95}{2}\right)}\right)$$

$$N = 118472\left(1.23^{.025} - 0.15^{.025}\right)$$

$N = 6100$ cycles >> 500 COOL-DOWN CYCLES

THEREFORE THE POSTULATED FLAW IS NOT EXPECTED TO GROW TO CRITICAL SIZE DURING THE LIFE OF THE PLANT. A PLOT OF CRACK DEPTH VERSUS STRESS CYCLES IS SHOWN IN FIGURE 4.4.1.

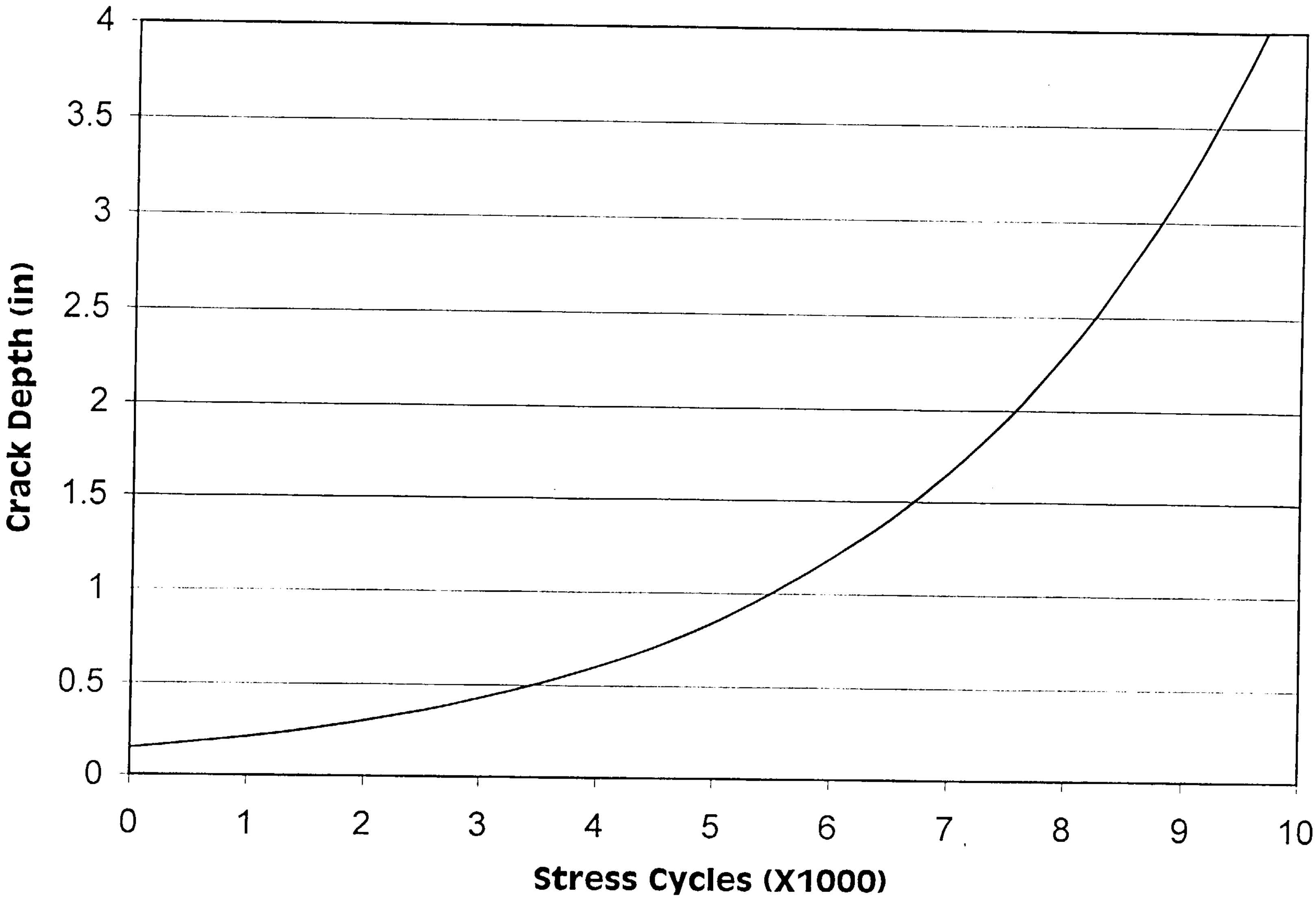

Figure 4.4.1- Bottom Head Level Nozzles Crack Growth

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4.5 Section XI Allowable Flaw Size and Recommended Inspection Interval

Allowable Flaw Size

The ASME B&PV Code Section XI [3], Article IWB-3000, provides acceptance standards for flaw indications detected during inservice inspections. Examination category B-B, Pressure Retaining Welds in Vessels, (Standard IWB-3511) is applicable to flaws at the instrument nozzles. Examination category B-D (Standard IWB-3512) pertains to pressure vessel nozzles with full penetration welds; the instrument nozzle welds are not full penetration but this category will also be considered.

The postulated flaw under consideration is a planar flaw as defined by Section XI. Allowable planar indications are specified as a function of the flaw aspect ratio a/l (depth/length). For the assumed circular flaw geometry, a/l=0.5. For examination category B-B, Table IWB-3511-1, the allowable planar indication depth for a/l=0.5 is 3.7% of the wall thickness. For examination category B-D, Table IWB-3512-1, the allowable planar indication depth for a/l=0.5 is 3.5% of the wall thickness. The lower value of 3.5% will be used as the acceptance standard for the instrumentation nozzle flaw.

For the side temperature nozzle, the allowable flaw depth = (0.035)(4.875) = 0.17".

For the bottom head level nozzles, the allowable flaw depth = (0.035)(3.875) = 0.14".

The allowable crack depths are depths into the base metal. The initial through cladding flaw depth does not have to be considered as part of the total flaw depth.

Recommended Inspection Interval

Side temperature nozzle: Figure 4.3.1 shows crack growth as a function of cycles at this location. The number of cycles required to grow an additional 0.17" into the base metal is over 100,000 cycles. Therefore the Section XI acceptance criteria will never be exceeded during the life of the plant and other than routine inspections at the side nozzle are not required.

Bottom head level nozzles: Figure 4.4.1 shows crack growth as a function of cycles at this location. Approximately 1900 cycles are required to grow an additional 0.14" into the base metal. Therefore the heat-up/cool-down cycles are not expected to cause enough crack growth to exceed the Section XI acceptance criteria during the life of the plant. Based on this result, other than routine inspections at the bottom nozzles are not required.

Postulated through clad flaws were evaluated at the side temperature and bottom head level nozzles on the Pressurizer vessel. Crack growth rates were estimated using a conservative ASME Section XI, Appendix A elastic fracture mechanics approach.

The critical crack size according to Section XI Appendix A criteria was found to be greater than the shell thickness at the side nozzle. Therefore the postulated flaw at that location will never grow to critical size. The side nozzle flaw will require 169,000 cycles to grow through-wall, which is much greater than the expected number of significant stress cycles in the life of the Pressurizer. More than 100,000 cycles are required to reach the maximum acceptable flaw depth of 0.17" per Section XI Article IWB-3000.

Stress levels in the bottom head are larger than in the shell so crack growth is more rapid at the bottom nozzles than at the side nozzle. The critical Appendix A crack depth at the bottom nozzles is 1.23". The postulated flaw is estimated to reach this depth after 6100 cycles. The number of expected significant lifetime stress cycles due to heat-up/cool-down is 500. Therefore the postulated bottom nozzle flaw is not expected to grow to critical size during the life of the plant. Approximately 1900 cycles are required to reach the maximum acceptable flaw size of 0.14" per Section XI Article IWB-3000. Intensified stresses at this location exceed the yield stress, so these results, which are based on an elastic analysis, are conservative.

Mechanical Nozzle Seal Assemblies are to be installed on the Pressurizer nozzles. Additional loading and vessel modifications resulting from the MNSAs will not affect crack growth rates of the postulated flaws.

In summary, the postulated flaws at the side and bottom nozzles do not limit the expected life of the Pressurizer vessel. Furthermore, the flaws are not expected to reach the maximum acceptable flaw size per Article IWB-3000 so other than routine inspections of the side and bottom nozzles are not required based on this analysis.

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CALCULATION SHEET

TITLE: PRESSURIZER NOZZLE CRACK ANALYSIS **DATE:** 2 / 08 / 00 **PAGE:** 23

SUBJECT: 6.0 REFERENCES **BY:** MG **CK:** BK **SHT:** 1 **OF** 1

1. Framatome Technologies Calculation No. 32-5002086-00, Allowable Corner Flaws for PRZ Upper Head Instru. Nozzle, Rev. 0, 8/4/98.
2. Hopper and Associates Calculation HABGE-09/98-0667, Postulated Flaw Fatigue Growth Evaluation For CCNPP Unit 2 Pressurizer Upper Level Tap Leak, Rev. 0, 9/9/98.
3. ASME Boiler and Pressure Vessel Code, Section XI, Rules For Inservice Inspection of Nuclear Power Plant Components, 1983.
4. ABB-CE Design Report No. B-PENG-DR-006, Addendum to CENC-1187 Analytical Report for Baltimore Gas and Electric Calvert Cliffs Station Units No. I and II Pressurizers, Rev. 00, 1/5/00.
5. Combustion Engineering Report No. CENC-1187, Analytical Report for Baltimore Gas and Electric Calvert Cliffs Station Units No. I and II Pressurizers, July 1972.
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