Exelon Generation
4300 Winfield Road
Warrenville, IL 60555

www.exeloncorp.com

Exelon Nuclear

RS-02-039

February 22, 2002

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Quad Cities Nuclear Power Station, Unit 2
Facility Operating License No. DPR-30
NRC Docket No. 50-265

Subject: Request for Approval of Pipe Flaw Evaluation

In accordance with Generic Letter (GL) 88-01, "NRC Position on IGSCC in BWR Austenitic Stainless Steel Piping," Exelon Generation Company (EGC), LLC, requests NRC approval of a pipe flaw evaluation for a weld in the Reactor Recirculation (RR) system piping at Quad Cities Nuclear Power Station (QCNPS), Unit 2 that we propose to leave as-is without repair. The flaw did not meet the acceptance standards of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code Section XI, 1989 edition, for continued operation without evaluation.

On February 17, 2002, during the current QCNPS, Unit 2 refueling outage (i.e., Q2R16) while conducting inspections in accordance with GL 88-01/ Boiling Water Reactor Vessel and Internals Project (BWRVIP) Report 75,"Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules," (as modified by associated NRC Safety Evaluation dated September 15, 2000), EGC discovered, using automated ultrasonic testing (UT), a 0.56 inch deep throughwall circumferential flaw 10 inches long in an RR weld. The UT examination used Performance Demonstration Initiative (PDI) qualified personnel, equipment, and procedures. The weld, identified as 02BD-F9, is located in the 28 inch diameter "B" RR loop discharge pipe which has a nominal wall thickness of 1.40 inches where the pipe connects to the discharge isolation valve on the RR pump side. The flaw is located in the heat affected zone on the pipe side of the weld. Weld 02BD-F9 is a category "C" weld which received induction heating stress improvement (IHSI) in 1983. The IHSI was confirmed to be effective in 1999. The weld had been examined five times since 1983 using manual UT, with the flaw previously being identified as inside pipe diameter and/or weld root geometry. Each of these examinations was done using qualified UT techniques.

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An evaluation of the flaw assuming conservative crack growth rates has been performed by General Electric (GE) and is included as an Attachment. The evaluation was performed using the methodology and acceptance criteria specified in ASME B&PV Code, Section XI, 1989 edition, subarticle IWB-3640, "Evaluation Procedures and Acceptance Criteria for Austenitic Piping," and the guidance of NUREG-0313, Revision 2, "Technical Report on Material Selection and Process Guidelines for BWR Coolant Pressure Boundary Piping." This flaw evaluation considered the initial flaw size, expected growth rates, and plant chemistry parameters, and demonstrates that substantial structural margin exists for more than one operating cycle since the acceptance criteria of IWB-3640 are met.

In addition to the structural margin, QCNPS has implemented significant intergranular stress corrosion cracking (IGSCC) mitigation strategies. Hydrogen water chemistry has been implemented since 1990, and system average availability has been greater than 90% over the past three years, with electro-chemical potential (ECP) values consistently less than negative 230 millivolts – Standard Hydrogen Electrode (SHE). Noble metal chemical application was performed in 2000. Weld 02BD-F9 was effectively treated with IHSI that met or exceeded the minimum requirements for throughwall temperature differential and other essential parameters in accordance with the industry guidelines in BWRVIP Report 61, "BWR Vessel and Internals Project Heating Stress Improvement Effectiveness on Crack Growth in Operating Plants." These IGSCC mitigation measures reduce the likelihood of a service induced crack.

Therefore, based on the above it is concluded that the flaw is acceptable as-is for continued operation through the next operating cycle. However, based on the Q2R16 inspection results and the weld classifications contained in GL 88-01, weld 02BD-F9 will be reclassified from category "C" to "F" (i.e., cracked weld with inadequate or no repair) and will require inspection each refueling outage.

The original scope of UT examinations of IGSCC susceptible welds for Q2R16 was in accordance with our commitments to GL 88-01 and included seven category "C" welds. Following the discovery of the flaw in weld 02BD-F9, the inspection scope was expanded in accordance with GL 88-01/ BWRVIP Report 75, (as modified by associated NRC Safety Evaluation dated September 15, 2000), by adding eight other category "C" welds that had similar characteristics as weld 02BD-F9 (i.e., effective IHSI welds in RR piping with an inconsistent UT history). No other flaws were identified within the expanded weld inspection population.

Based on the information provided in the Attachment, we request NRC review and approval of the evaluation of the flaw in weld 02BD-F9. NRC approval is requested by March 1, 2002, in support of unit startup, which is expected on that day.

Should you have any questions related to this letter, please contact Mr. Patrick R. Simpson at (630) 657-2823.

Respectfully,

Keith R. Jury
Director – Licensing
Mid-West Regional Operating Group

Attachment: GE Nuclear Energy Report No. GE-NE-0000-0002-5067-02, "Fracture Mechanics Evaluation of the Indication in the Recirculation Pipe to Valve Weld 02BD-F9 at the Quad Cities Unit 2," dated February 2002

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Quad Cities Nuclear Power Station

Attachment

GE Nuclear Energy Report No. GE-NE-0000-0002-5067-02, “Fracture Mechanics Evaluation of the Indication in the Recirculation Pipe to Valve Weld 02BD-F9 at the Quad Cities Unit 2,” dated February 2002

GE Nuclear Energy

ENGINEERING AND TECHNOLOGY
GE Nuclear Energy
175 Curtner Avenue, San Jose, CA, 95125

GE-NE-0000-0002-5067-02
DRF 0000-0002-5067-01
Class II
February 2002

FRACTURE MECHANICS EVALUATION OF THE INDICATION IN THE RECIRCULATION PIPE TO VALVE WELD 02BD-F9 AT THE QUAD CITIES UNIT 2

Prepared By:

H. S. Mehta, Engineering Fellow,
Structural Mechanics & Materials

Verified By:

Ron Horn, Manager,
Structural Mechanics & Materials

IMPORTANT NOTICE REGARDING

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ABSTRACT

During the February 2002 in-service inspection of the Quad Cities Unit 2 Recirculation Piping, an indication was found in the material adjacent to the pipe-to-valve 02BD-F9 weld that exceeded the ASME acceptance standards. The inspection program was performed in accordance with the requirements of Generic Letter 88-01 and BWRVIP-75. The examination was performed using automated UT procedures qualified in accordance with ASME Appendix VIII requirements. The results of the examination of weld 02BD-F9 showed a circumferential indication, 10 inches long (approximately 10.5% in circumference) with maximum depth of 39.4% of wall (approximately 0.56 inch). Figure 1 shows a schematic of the observed indication. The flaw was evaluated for continued operation using the criteria of Appendix C, Section XI, ASME Code. The results of the evaluation confirm that the required ASME Code structural factors are maintained well beyond the next cycle and that continued operation can be justified for the next cycle.

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1. INTRODUCTION

During the February 2002 in-service inspection of the Quad Cities Unit 2 Recirculation Piping, an indication was found in the material adjacent to the pipe-to-valve 02BD-F9 weld that exceeded the ASME acceptance standards. The inspection program was performed in accordance with the requirements of Generic Letter 88-01 and BWRVIP-75. The examination was performed using automated UT procedures qualified in accordance with ASME Appendix VIII requirements. The results of the examination of weld 02BD-F9 showed a circumferential indication, 10 inches long (approximately 10.5% in circumference) with maximum depth of 39.4% of wall (approximately 0.56 inch). The flaw was evaluated for continued operation using the criteria of Appendix C, Section XI, ASME Code 1989 Edition [1]. The results of the evaluation confirm that the required ASME Code structural factors are maintained well beyond the next cycle and that continued operation can be justified for the next cycle.

2. FLAW DESCRIPTION

Reference 2 provides details of the UT examination of the 02BD-F9 weld. The flaw is approximately 10 inches in length with a through wall dimension of 0.56", and is connected to the inside surface of the pipe in the area of the root. Low amplitude reflectors were observed along the length of the circumferential flaw when scanning parallel to the weld with the search unit skewed toward the flaw. The circumferential flaw starts at 6.07" counter clockwise from top dead center and ends at 3.93 clockwise from top dead center. The indication exceeds the acceptance standards of IWB 3514-2 and must be evaluated using the procedures outlined in IWB-3600, Section XI, ASME Code. This report describes the results of the evaluation.

3. CRACK GROWTH ASSESSMENT

Quad Cities Unit 2 has been operating under Hydrogen Water Chemistry (HWC) since 1990. NobleChem was implemented during the last outage in April 1999. Hydrogen availability during the last year was in excess of 90%. It is expected that the hydrogen availability will be at least 95% during the coming cycle. Thus, Quad Cities Unit 2 is judged to have effective HWC using the criteria of BWRVIP-75 [3]. For the purposes of this evaluation, a conservative factor of improvement (FOI) of 2 will be used for HWC conditions.

Crack growth evaluation will be performed using three different approaches and the structural margin assessment for these cases will be provided next.

1. *Bounding crack growth rates for normal water chemistry (NWC) based on the recommendations in NUREG-0313 Rev. 2 [4]*

   Figure 2 from [4] shows the typical stress intensity factors for different pipe sizes and typical weld residual stress patterns. This weld has been subjected to IHSI and has the benefit of stress improvement. The residual stress profile after stress improvement is expected to reduce the axial tensile stress acting on the flaw when compared to the as-welded residual stresses, making the use of the use of the as-welded residual stress profile conservative when predicting crack growth. Nevertheless, a high constant value of K is used in the crack growth evaluation to conservatively account for any changes in the weld residual stress pattern. For a 28 inch diameter pipe the maximum K value over the relevant range of crack depths (up to 1 inch depth) is 21 ksi-$\sqrt{}$in. The associated crack growth rate (CGR) corresponding to NUREG-0313 Rev.2 is:

   CGR $= 3.59 \times 10^{-8} K^{2.161}$ in/ hour where K is the applied stress intensity factor in ksi-$\sqrt{}$in.

   Using a K value of 21 ksi-$\sqrt{}$in, the corresponding CGR is 2.58×10^{-05} in/hour. This takes no credit for HWC/NobleChem operation during the next cycle and is therefore extremely conservative. Assuming 17500 hours of hot operation for the next cycle, the incremental crack depth is 0.45 in. This results in a maximum depth of 0.56 + 0.45 = 1.01 in. at the end of the next cycle.

2. *Plateau crack growth rates based on NRC SER for BWRVIP-14[5]*

   In the SER on BWRVIP-14, the NRC approved a plateau CGR of 2.2×10^{-5} in/hour for NWC conditions. Although this was primarily intended for BWR internals, it is conservative to use this for the recirculation piping since the environment in the piping is less oxidizing than that for the internals. Again, this takes no credit for HWC. Using this CGR and Assuming 17500 hours of hot operation for the next cycle, the incremental crack depth is 0.39 in. This results in a maximum depth of 0.56 + 0.39 = 0.95 in. at the end of the next cycle.

3. *Plateau crack growth rates taking credit for HWC*

This approach takes credit for the HWC operation during the next cycle.

As discussed earlier, assuming a conservative FOI of 2, and the BWRVIP-14 plateau CGR of 2.2 x10-5 in/hour for NWC, the CGR for HWC is 1.1 x10-5 in/hour. Assuming a conservative value of 90% for HWC availability, the effective CGR for the next cycle is given by:

Effective CGR = (0.1 x 2.2 + 0.9 x 1.1) x10-5 in/hour or 1.21 x10-5 in/hour.

Using this CGR and assuming 17500 hours of hot operation for the next cycle, the incremental crack depth is 0.21 in. This results in a maximum depth of 0.56 + 0.21 = 0.77 in.

For all the crack growth evaluations described above, the length at the end of the next cycle will be based on the recommended process described in [4]. Essentially, it assumes that the aspect ratio will be increased by the same ratio as the depth is increased. Essentially this means that the length increases in proportion to the square of the depth ratio. This is extremely conservative. For example, if the depth is doubled, the new length is four times higher.

4. STRUCTURAL MARGIN ASSESSMENT

Based on the predicted final flaw depth, the structural margin assessment can be performed using the procedures of Appendix C of the ASME Code. Figure 3 is an excerpt from Appendix C that describes the methodology used in the evaluation. The Appendix C approach is dependent on the type of the weld, i.e. whether it is GTAW or SMAW or SAW weldment. The subject weld is a field weld generally made using a shielded metal arc weld (SMAW) process and the associated Z factor is 1.51. Essentially the Z factor accounts for the reduced toughness of the flux welds and also requires consideration of thermal expansion stresses. Appendix A describes the stresses used for the different load cases in the analysis. This includes cases for deadweight, seismic, thermal expansion. Stresses for normal, upset and emergency conditions are described.

The safety factors for a given end of evaluation period flaw size can be derived using the equations from Appendix C of Section XI. For the case of flux welds, the structural factor is given by:

SF = (Pb' + Pm - Z1*Pe)/{Z1*(Pm + Pb)}

Where Pb' is the failure bending stress as defined in Appendix C-3320 and Pm and Pb are the primary membrane and bending stresses, Pe is the thermal expansion stress and Z1 is the weld factor equal to 1.51 for the 28 inch SMAW weld. The required structural factors per Section XI are 2.77 for normal and upset conditions and 1.39 for emergency and faulted conditions. The actual structural factor for the different final crack sizes (depending upon the different CGR assumptions) were calculated for both normal and emergency/faulted conditions. Table 1 summarizes the results of the evaluation. It is seen that the available structural margin exceeds the required margin for all the cases. Even for the extremely conservative assumptions based on NUREG-0313 Rev. 2, e.g. bounding K value, no HWC credit, no IHSI credit and the very conservative crack lengthening assumptions, the available structural margin is well in excess of the required margins.

5. CONCLUSIONS

The evaluation presented is based on several conservative assumptions concerning crack growth and follows the procedures of the ASME Code and NUREG-0313 Rev. 2 criteria. In all cases, it is shown that adequate structural margins are maintained considering one additional cycle of operation. Therefore continued operation 'as is' for the two year cycle is justified and all required structural margins are maintained.

6. REFERENCES

1. Section XI, ASME Code 1989 Edition, American Society of Mechanical Engineers
2. 029BD-F9 Ultrasonic Examination Report, INR-Q2R16-ISI-01, General Electric Company, February 21, 2002.
3. BWRVIP-75 Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules, Electric Power Research Institute
4. "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping," NUREG-0313, Rev.2, Nuclear Regulatory Commission, January, 1988.
5. EPRI Report No. TR-105873, BWR Vessel and Internals Project, "Evaluation of Crack Growth in BWR Stainless Steel Reactor Internals (BWRVIP-14)," March 1996.

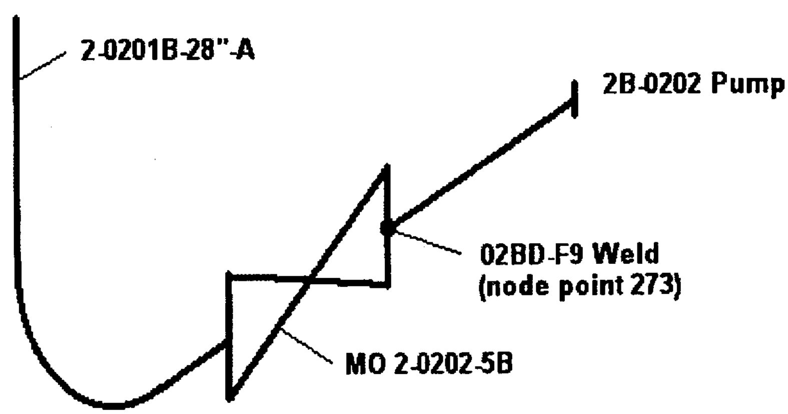
Table 1 Comparison of available and required structural margins for different crack growth assumptions

CGR Assumption	Final Flaw Size after one Cycle (inches)		Structural Margin for Normal Conditions		Structural Margin for Emergency/Faulted conditions	
	Depth	Length	Required	Available	Required	Available
CGR Based on NUREG-0313 Rev. 2 CGR= 2.58×10^{-5} in/hr	1.01	32.6	2.77	3.38	1.39	3.05
CGR Based on NRC SER for BWRVIP-14 CGR= 2.2×10^{-5} in/hr	0.95	28.5	2.77	3.93	1.39	3.54
CGR taking credit for HWC operation CGR= 1.21×10^{-5} in/hr	0.77	19.0	2.77	5.09	1.39	4.59

APPENDIX A

LOAD INPUTS USED IN THE STRUCTURAL MARGIN EVALUATIONS

Load Case	FA (lbs)	FB (lbs)	FC (lbs)	MA (ft-lbs)	MB (ft-lbs)	MC (ft-lbs)
GRAV	337.49	7375.13	-251.20	-24680.62	3924.92	-18744.27
THER-1	5589.40	-686.75	-317.14	5403.98	41594.09	-12613.88
THER-2	3376.96	915.73	-755.51	-1336.68	34699.37	-8514.77
THER-3	5279.03	-1102.73	-432.90	9767.34	43869.02	-7282.44
OBE	4690.48	2947.51	3581.41	36824.23	17414.07	16262.02
DBE	9380.96	5895.01	7162.83	73648.46	34828.14	32524.04



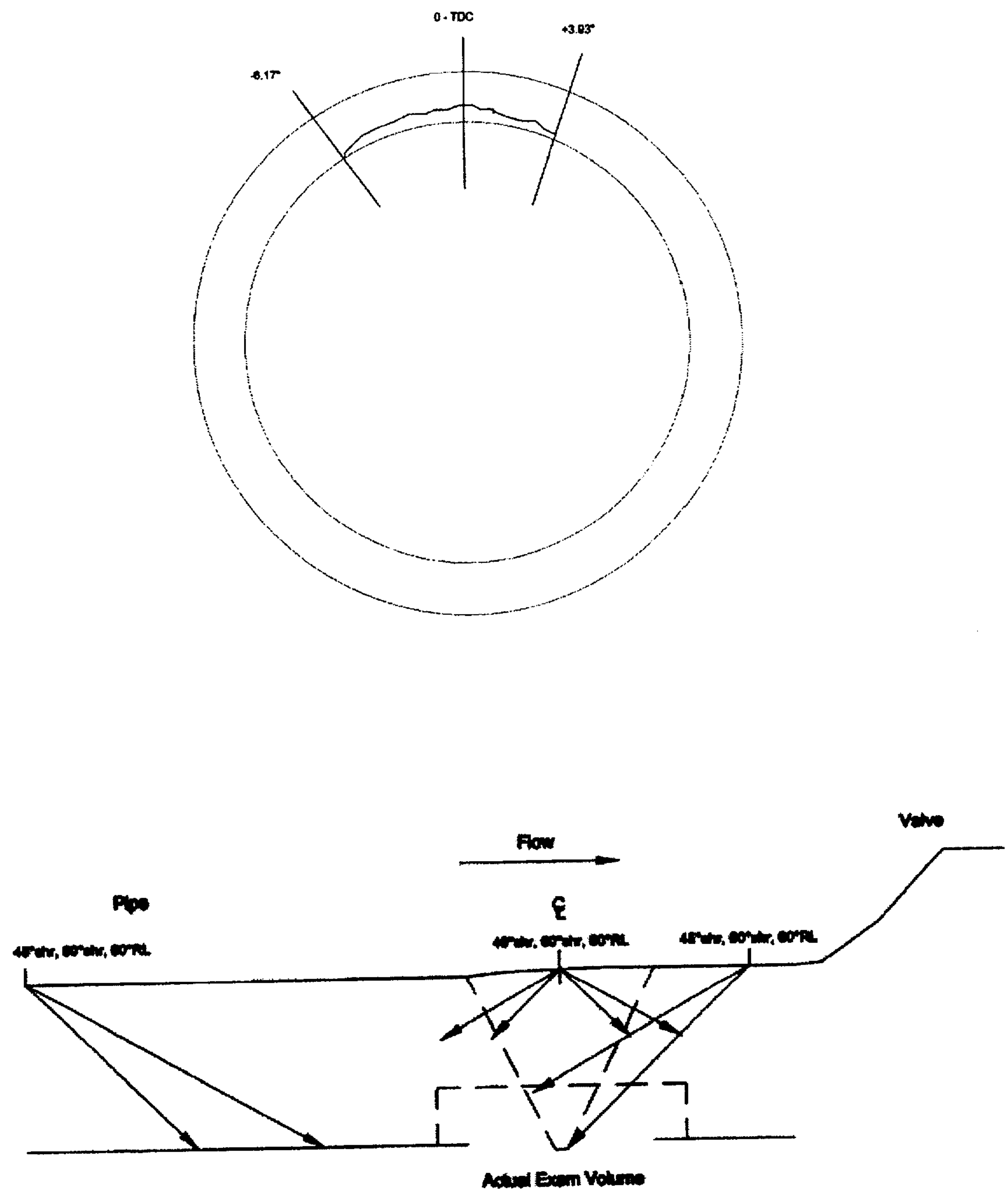


Figure 1 Schematic of the Indication in Weld 02BD-F9

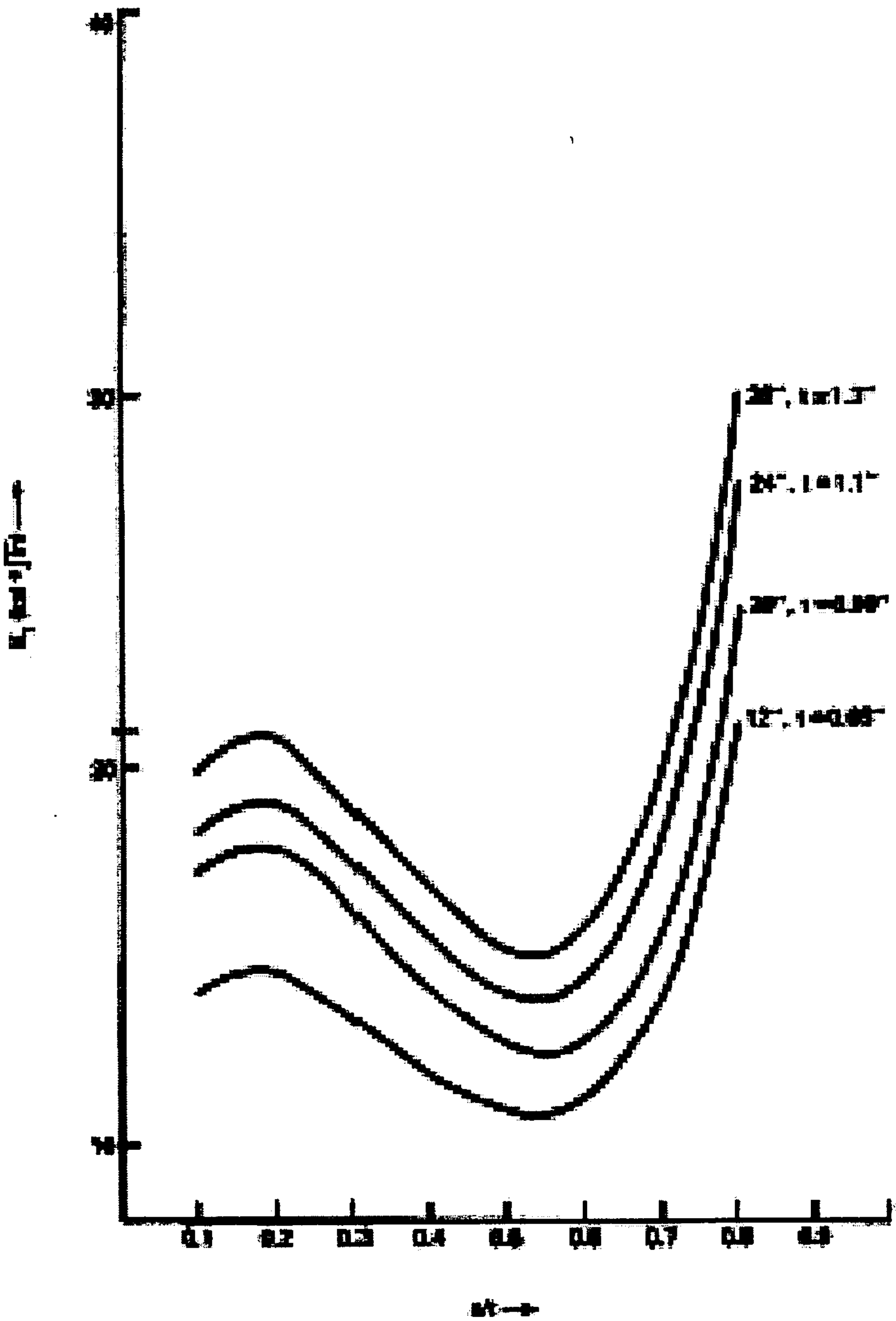


Figure 2 Stress Intensity Factors for different pipe sizes (From NUREG-0313)
(Includes a membrane stress of 7500 psi and typical weld residual stress)

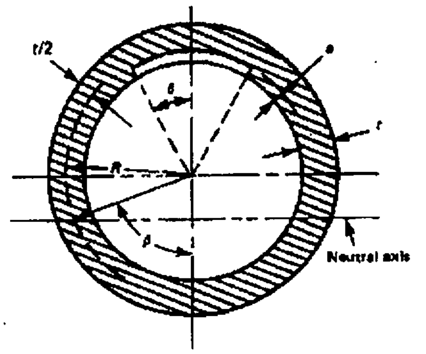


FIG. C-3320-1 CROSS SECTION OF FLAWED PIPE

(c) For shielded metal-arc welds (SMAW) and submerged arc welds (SAW), the results in Tables IWB-3641-5 and IWB-3641-6 can be closely approximated by taking

$$P_b' = Z_1 (SF)(P_m + P_b + P_e/SF) - P_m \qquad (6)$$

where

$$Z_1 = 1.449$$

and for normal operating conditions

$$P_m = 0.5S_m$$

$$(P_m + P_b + P_e/SF) = \text{table ordinate value} \times S_m$$

$$SF = 2.77$$

or for emergency and faulted conditions

$$P_m = 1.0S_m$$

$$(P_m + P_b + P_e/SF) = \text{table ordinate value} \times S_m$$

$$SF = 1.39$$

When using the actual piping stresses to determine an allowable flaw size, the values in Eq. (6) are given by

P_m = piping membrane stress
P_b = piping bending stress
P_e = piping expansion stress
SF = 2.77 for normal operating conditions
= 1.39 for emergency and faulted conditions
Z_1 = 1.15 [1 + 0.013 (OD-4)] for SMAW
= 1.30 [1 + 0.010 (OD-4)] for SAW

OD is the nominal pipe size, NPS, and for NPS ≤ 24 in., use O.D. = 24. Weld material is defined in Fig. IWB-3641-1.

(a) The formulas for obtaining the allowable flaw depths a_c and a_e listed in Tables IWB-3641-1, IWB-3641-2, IWB-3641-5 and IWB-3641-6 are given here.

For circumferential flaws not penetrating the compressive side of the pipe such that $(\theta + \beta) \leq \pi$ (see Fig. C-3320-1), the relation between the applied loads and flaw depth at incipient plastic collapse is given by

$$P_b' = \frac{6S_m}{\pi}\left(2 \sin \beta - \frac{a}{t} \sin \theta\right) \qquad (3)$$

where

$$\beta = \frac{1}{2}\left(\pi - \frac{a}{t}\theta - \pi\frac{P_m}{3S_m}\right)$$

$$\theta = \text{half flaw angle}$$

P_b' is the failure bending stress as defined in paragraphs (b) and (c) below.

For longer flaws penetrating the compressive bending region where $(\theta + \beta) > \pi$ (see Fig. C-3320-1), the relation between the applied loads and the flaw depth at incipient plastic collapse is given by

$$P_b' = \frac{6S_m}{\pi}\left(2 - \frac{a}{t}\right) \sin \beta \qquad (4)$$

where

$$\beta = \frac{\pi}{2 - \frac{a}{t}}\left(1 - \frac{a}{t} - \frac{P_m}{3S_m}\right)$$

θ = half flaw angle

Figure 3 Appendix C Equations used in the Structural Margin Assessment