10 CFR 50.55a

VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

May 4, 2009

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 09-266
NL&OS/ETS R0
Docket No. 50-338
License No. NPF-4

VIRGINIA ELECTRIC AND POWER COMPANY (DOMINION)
NORTH ANNA POWER STATION UNIT 1
FOURTH INTERVAL ISI PROGRAM
RESPONSE TO REQUEST FOR INFORMATION FOR NDE-004

In a letter dated October 17, 2008 (Serial No. 08-0595), Dominion submitted the North Anna Power Station Unit 1 inservice inspection (ISI) program for the fourth inservice inspection (ISI) interval applicable to Class 1, 2, and 3 components and component supports. The ISI Plan described the programmatic aspects of ISI examinations of components and component supports. Included with the program were requests for alternatives or relief from the specific code requirements in accordance with 10 CFR 50.55a (a)(3)(i) and/or (ii) or 10 CFR 50.55a(g)(5)(iii). In an April 8, 2009 phone call, the NRC staff requested additional information to complete their review of relief request NDE-004. The attachment to this letter provides Revision 1 to NDE-004, which includes the information requested by the staff.

If you have any questions or require additional information, please contact Mr. Thomas Shaub at (804) 273-2763.

Sincerely,

J. Alan Price
Vice President – Nuclear Engineering

Enclosure

Response to Request for Additional Information for NDE-004

Commitments made in this letter:

1. None

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ENCLOSURE

FOURTH INTERVAL ISI PLAN
RESPONSE TO REQUEST FOR INFORMATION FOR NDE 004

NDE-004 - Revision 1

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION UNIT 1

Proposed Alternative in Accordance with 10 CFR 50.55a(a)(3)(ii)

-- Hardship or Unusual Difficulty without Compensating Increase in Level of Quality or Safety --

1.0 ASME CODE COMPONENTS AFFECTED

Service Water System Components shown on the following drawings:

1) Drawing 11715-CBB-040D-4, Sheet 1 - 4"-WS-G01-163-Q3 and 4"-WS-F99-163-Q3
2) Drawing 11715-CBM-078A-4, Sheet 1 - 4"-WS-F62-163-Q3, 4"-WS-F64-163-Q3, 4"-WS-G35-163-Q3, 4"-WS-F63-163-Q3, 4"-WS-F65-163-Q3, and 8"-WS-94-163-Q3
3) Drawing 11715-CBM-078A-4, Sheet 4 - 8"-WS-113-163-Q3, 8"-WS-115-163-Q3, 8"-WS-114-163-Q3, and 8"-WS-116-163-Q3
4) Drawing 11715-CBM-078C-4, Sheet 2 - 2"-WS-84-163-Q3, 2"-WS-377-163-Q3, and 2"-WS-376-163-Q3

Pressure retaining piping, fittings, and associated welds on moderate energy stainless steel piping of the Service Water System (SW). This piping system provides cooling water from the Service Water Reservoir to safety related equipment and returns the Service Water back through the return headers. Normal operating pressure is 100 psig. The design pressure is 150 psig and the design temperature is 150°F. This is an ASME, Section XI, Class 3 system.

2.0 APPLICABLE CODE EDITION AND ADDENDA

The ASME Boiler and Pressure Vessel Code (ASME Code) of record for the North Anna Power Station Unit 1 fourth inspection interval is the 2004 Edition.

3.0 APPLICABLE CODE REQUIRMENTS

Through-wall leakage is required to be located and evaluated in accordance with the requirements of IWA-5250 of the 2004 Edition for Unit 1. The specific Code requirement for which an alternative is proposed to the requirements of IWA-5250(a)(3).

"IWA-5250 Corrective Measures

(a) The source of leakage detected during the conduct of a system pressure test shall be located and evaluated by the Owner for corrective measures as follows:

  (3) Components requiring corrective action shall have repair/replacement activities performed in accordance with IWA-4000 or corrective measures performed where the relevant condition can be corrected without a repair/replacement

activity."

Articles IWA-4000 of ASME Section XI Code repair/replacements requires removal of the flaw by either subsequent weld repair or replacement.

The use of ASME Code Case N-513-2, "Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping," is authorized for use by Revision 15 of Regulatory Guide 1.147 as an acceptable Section XI Code Case. However, the Code Case requires a Code repair or replacement not exceeding the time to the next scheduled outage. Additionally, ASME Code Case N-513-2 is only applicable up to and including ASME Section XI Code, 2001 Edition and 2003 Addenda.

4.0 REASON FOR REQUEST

Leaks found in Service Water piping have most commonly been due to microbiologically influenced corrosion (MIC) and could require an attempt to make corrective measures within the 72 hour Technical Specification Limiting Condition for Operation or to shut both units down to complete repairs. The Service Water System at North Anna Power Station has a history of MIC that develops into areas of through wall pits. Evidence of these leaks is found either by discolored corrosion products on the exterior of the pipe or by observed active leakage.

Code repairs for through-wall leaks require the line to be isolated and drained. Taking a train of Service Water out of service in some instances is a major evolution and requires entering a Technical Specification action statement. The Service Water System is common to both Units. As long as one Unit is in Mode 1, 2, 3, or 4 both trains of Service Water must be operable. If both Units are in Mode 5 or 6, then one train of Service Water must be operable.

A Service Water loop may be removed from service for 7 days for system upgrades. System upgrades include modification and maintenance activities associated with the installation of new discharge headers and spray arrays, mechanical and chemical cleaning of SW System piping and valves, pipe repair and replacement, valve repair and replacement, installation of corrosion mitigation measures and inspection of and repairs to buried piping interior coatings and pump or valve house components.

If a Service Water loop must be removed from service for a repair that is not considered a system upgrade, then a 72 hour completion time is required. Draining and refilling the system takes 24 hours, leaving only 48 hours to complete the repair and perform post maintenance testing. Thus, completing a repair in 72 hours that requires a Service Water loop to be removed from service would be a hardship. System maintenance, repairs, and improvements are scheduled on a 3 refueling outage frequency. Header outages are a major planning effort. Under Code Case N-513-2, if a leak occurred during an operating cycle on a header not scheduled for upgrades or maintenance at the next refueling outage then that affected header would be required to be removed from service during the next refueling outage. This unplanned event could force scheduled work to be dropped from that refueling outage. This would extend preventative maintenance of Service Water valves and expansion which would challenge the reliability of the system.

Service Water loops can be removed from service outside of a refueling outage. This scheduling is sometimes preferred to provide better management of the Service Water header outage than during refueling outages and can be performed within 18 months of the discovery of a leak.

Under current station processes, any flaws found in the Service Water system would be evaluated under the normal operability determination processes to determine whether the flaw requires immediate repair or should be repaired at the next scheduled header outage in accordance with this relief (based on ASME Code Case N-513-2 evaluation guidelines).

5.0 PROPOSED ALTERNATIVES AND BASIS FOR USE

Code repairs in accordance with IWA-5250(a)(3) will be performed to the above identified welds and piping in the Service Water System in accordance with the Corrective Action Program and Operability Determination process. Upon identification of a leak or evidence of a thru-wall leak (discolored corrosion products on the exterior of the pipe), a Condition Report is submitted, a Work Order is initiated to repair, Engineering performs walkdowns, the Operability Determination is completed, and additional walkdowns are performed as required. Unless immediate repair is required, an evaluation will be performed per the requirements of Attachment 1 to this request for relief. If supported by the evaluation, flaws will be replaced within 18 months from the time of discovery coinciding with the affected Service Water header outage. Because North Anna Power Station, Unit 1, is also on an 18-month refueling cycle, this allowed duration of operation is considered to comparable to industry expectations for repair of such leaks.

Although required repairs may not be performed at the next scheduled refueling outage, they will be performed at the next scheduled corresponding Service Water header outage or planned header outage not to exceed 18 months.

Attachment 1 provides the methodology that will be employed by North Anna in determining the acceptance of an identified flaw for continued service. The methodology is based on the requirements of ASME Code Case N-513-2, "Evaluation Criteria for Temporary Acceptance of Flaws in Class 3 Piping."

NRC Letter dated April 27, 2000, (TAC No. MA8567), states "This relief request is only applicable to SWS piping that is accessible to flaw characterization...." This limitation on the use of the relief granted by the April 27, 2000 letter will also govern the use of this request for relief. Additionally, the request will only address leakage determined to be caused by microbiologically influenced corrosion (MIC), based upon our preliminary assessment.

Virginia Electric and Power Company (Dominion) has determined that performance of an immediate Code repair after each newly discovered flaw caused by microbiologically influenced corrosion (MIC) would constitute an undue burden (create undue hardship) without a compensating increase in the level of quality or safety if structural integrity of the line can be established, since the repair may exceed the time limits imposed by the governing Technical Specification. This would necessitate the isolation of portions of the Service Water System that are otherwise structurally sound and capable of performing their intended safety function. Isolating portions of the Service Water system to perform a Code repair is not in the best interest of plant safety. Immediate repair would reduce the system reliability with a header out of service and possibly cause a plant transient if the repair cannot be affected within the limits of the Technical Specification completion time for an inoperable header. Therefore, Dominion requests approval of this alternative pursuant to the provisions of 10 CFR 50.55a(a)(3)(ii).

6.0 DURATION OF PROPOSED ALTERNATIVE

The proposed alternative to the ASME Code is applicable for the duration of the fourth 10-year inservice inspection (ISI) interval at NAPS Unit 1.

7.0 PRECEDENTS

This request for alternative evaluation and repair of Service Water piping subject to microbiological influenced corrosion has been approved previously by the NRC for NDE-32 (2nd interval corresponding relief request) in letter dated December 22, 1998 (TAC NOS. MA1222 and MA1223) and NDE-15 (3rd interval corresponding relief request) in a letter dated April 27, 2000 (TAC No. MA8567).

It should be noted that the ASME recently approved Code Case N-513-3 which will allow up to 26 months of operation if supported by the evaluation, and the time period is not linked to outage frequency.

8.0 REFERENCES

1. ASME Code Case N-513-2, "Evaluation Criteria for Temporary Acceptance of Flaws in Class 3 Piping."

9.0 ATTACHMENTS

1. Service Water Piping Flaw Assessment and Evaluation Procedure

Attachment 1

Service Water Piping Flaw Assessment and Evaluation Procedure

1 SCOPE

a) Use of the flaw evaluation criteria within this attachment is permitted for pipe and tube associated with the Service Water System only. The flaw evaluation criteria are permitted for adjoining fittings and flanges to a distance of $(R_0t)^{1/2}$ from the weld centerline.

b) The provisions of this attachment do not apply to the following: 1) pumps, valves, expansion joints, and heat exchangers, 2) socket welds, 3) leakage through a flange joint; and 4) threaded connections employing nonstructural seal welds for leakage protection.

2 PROCEDURE

(a) The flaw geometry shall be characterized by volumetric inspection methods or by physical measurement. The full pipe circumference at the flaw location shall be inspected to characterize the length and depth of all flaws in the pipe section.

(b) Flaw shall be classified as planar or nonplanar.

(c) When multiple flaws, including irregular (compound) shape flaws, are detected, the interaction and combined area loss of flaws in a given pipe section shall be accounted for in the flaw evaluation.

(d) A flaw evaluation shall be performed to determine the conditions for flaw acceptance. Section 3.0 provides accepted methods for conducting the required analysis.

(e) Frequent periodic inspections of no more than 30 day intervals shall be used to determine if flaws are growing and to establish the time at which the detected flaw will reach the allowable size. Alternatively, a flaw growth evaluation may be performed to predict the time at which the detected flaw will grow to the allowable size. The flaw growth analysis shall consider the relevant growth mechanisms such as general corrosion or wastage, fatigue, or stress corrosion cracking. When a flaw growth analysis is used to establish the allowable time for temporary operation, periodic examinations of no more than 90 day intervals shall be conducted to verify the flaw growth analysis predictions.

(f) For through-wall leaking flaws, leakage shall be observed by daily walkdowns to confirm the analysis conditions used in the evaluation remain valid.

(g) If examinations reveal flaw growth rate to be unacceptable, a repair or replacement shall be performed.

(h) Repair or replacement shall be performed no later than when the predicted flaw size from either periodic inspection or by flaw growth analysis exceeds the acceptance criteria
of 4.0, or the next scheduled outage allows for removal of the components from service, whichever occurs first. Repair or replacement shall be in accordance with IWA-4000.

(i) Evaluations and examination shall be documented in accordance with IWA-6300. Use of this request for relief shall be documented on the applicable data report form.

3 FLAW EVALUATION

(Note: Reference in the following paragraphs to "Appendix C" is a reference to Nonmandatory Appendix C of the 2004 Edition of ASME Section XI)

(a) For planar flaws, the flaw shall be bounded by a rectangular or circumferential planar area in accordance with the methods described in Appendix C. IWA-3300 shall be used to determine when multiple proximate flaws are to be evaluated as a single flaw. The geometry of a through-wall planar flaw is shown in Fig. 1 of Code case N-513-2.

(b) For planar flaws in austenitic piping, the evaluation procedure in Appendix C shall be used. Flaw depths up to 100% of wall thickness may be evaluated. When through-wall circumferential flaws are evaluated, the formulas for evaluation given in C-5320 of Appendix C may be used, with the flaw penetration *(a/t)* equal to unity.

When through-wall axial flaws are evaluated, the allowable flaw length is:

$$\ell_{all} = 1.58\sqrt{Rt}\left[\left(\frac{\sigma_f}{(SF_m)\sigma_h}\right)^2 - 1\right]^{1/2} \qquad (1)$$

$$\sigma_h = pD_o/2t \qquad (2)$$

$$\sigma_f = (S_y + S_u)/2 \qquad (3)$$

where

p = pressure for the loading condition
D_o = pipe outside diameter
σ_f = flow stress
S_y = Code specified yield strength
S_u = Code specified ultimate tensile strength and
SF_m = structural factor on primary membrane stress as specified in C-2622

Material properties at the temperature of interest shall be used.

(c) For planar flaws in ferritic piping, the evaluation procedure of Appendix C shall be used. Flaw depths up to 100% of wall thickness may be evaluated. When through-wall circumferential flaws are evaluated in accordance with C-5300 or C-6300, the flaw penetration (a/t) shall be set to unity. When through-wall axial flaws are evaluated in accordance with C-5400, the allowable length is defined by Eqs. (1) through (3), with the appropriate structural factors from Appendix C, C-2622. When through-wall flaws are evaluated in accordance with C-7300 or C-7400, the formulas for evaluation given in C-4300 may be used, but with values for F_m, F_b, and F applicable to through-wall flaws. Relations for F_m, F_b, and F that take into account flaw shape and pipe geometry $(R/t$ ratio) shall be used. The appendix to this Attachment provides equations for F_m F_b, and F for a selected range of R/t. Geometry of a through-wall crack is shown in Fig. 1.

d) For nonplanar flaws, the pipe is acceptable when the remaining pipe thickness (t_p) is greater than or equal to the minimum wall thickness t_{min}:

$$t_{min} = \frac{pD_o}{2(S + 0.4p)} \qquad (4)$$

where

p = maximum operating pressure at flaw location
S = allowable stress at operating temperature and the longitudinal stress limits for the

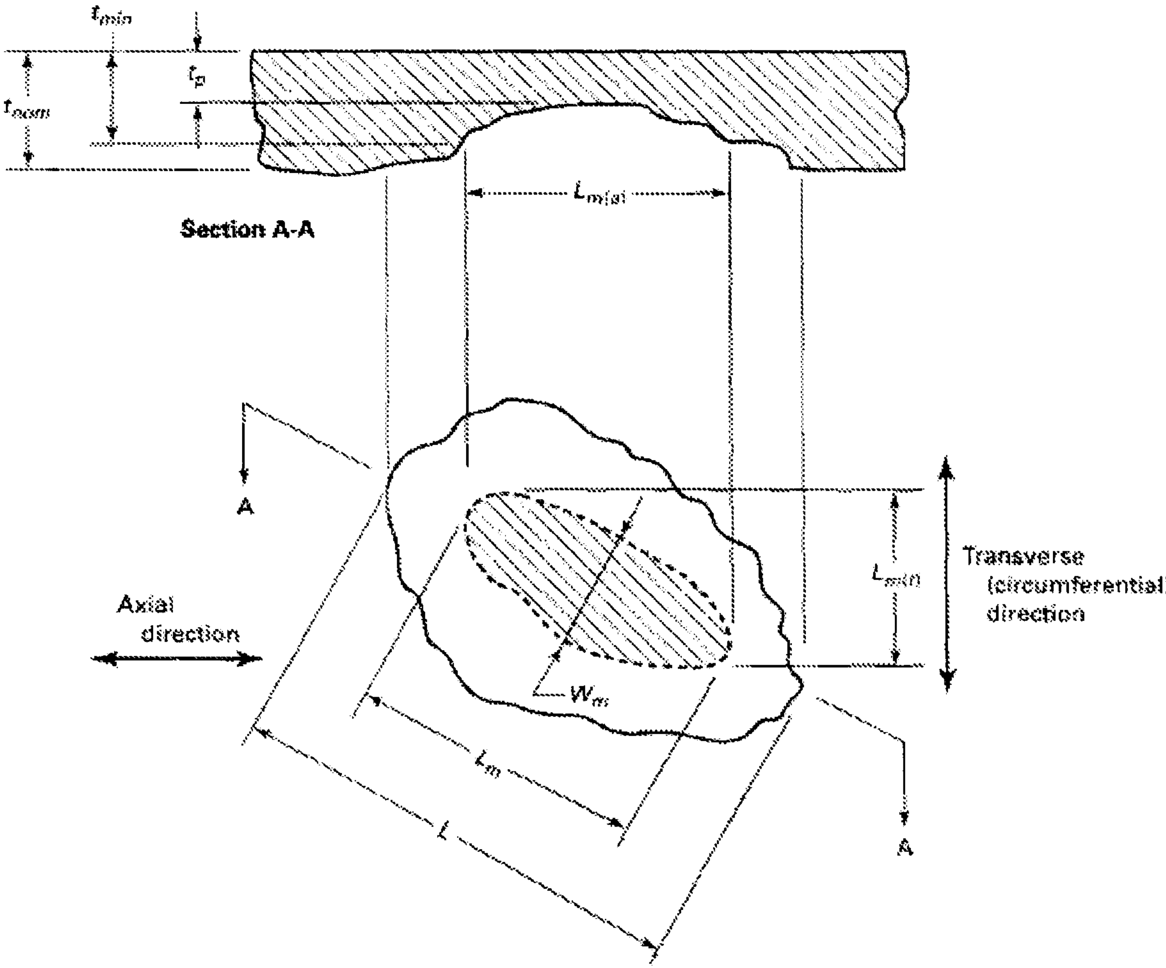
Construction Code are satisfied for a uniform wall thickness equal to t_p.

Alternatively, an evaluation may be performed as given below. The evaluation procedure is a function of the depth and the extent of the affected area as illustrated in, Fig. 2.

(1) When the width of wall thinning W_m , that exceeds t_{min}, is less than or equal to 0.5 $(R_o t)^{1/2}$ where R_o is the outside radius and W_m , is defined in Fig. 2, the flaw can be classified as a planar flaw and evaluated in accordance with 3(a) through 3(c), above. When the above requirement is not satisfied, (2) shall be met.

(2) When the transverse extent of wall thinning that exceeds t_{min}, $L_{m(t)}$, is not greater than $(R_0 t_{min})^{1/2}$, t_{aloc} is determined from Curve 1 of Fig. 3, where $L_{m(t)}$ is defined in Fig. 2. When the above requirement is not satisfied, (3) shall be met.

FIG. 2 ILLUSTRATION OF NONPLANAR FLAW DUE TO WALL THINNING



(3) When the maximum extent of wall thinning that exceeds t_{min} , L_m , is less than or equal to 2.65 $(R_o\ t_{mln})^{1/2}$ and t_{nom} is greater than $1.13t_{min}$, t_{aloc} is determined by satisfying both of the following equations:

$$\frac{t_{aloc}}{t_{min}} \geq \frac{1.5\sqrt{R_o t_{min}}}{L}\left[1 - \frac{t_{nom}}{t_{min}}\right] + 1.0 \qquad (5)$$

$$\frac{t_{aloc}}{t_{min}} \geq \frac{0.353L_m}{\sqrt{R_o t_{min}}} \qquad (6)$$

When the above requirements are not satisfied, (4) shall be met.

(4) When the requirements of (1), (2), and (3) above are not satisfied, t_{aloc} is determined from Curve 2 of Fig. 3. In addition, t_{aloc} shall satisfy the following equation:

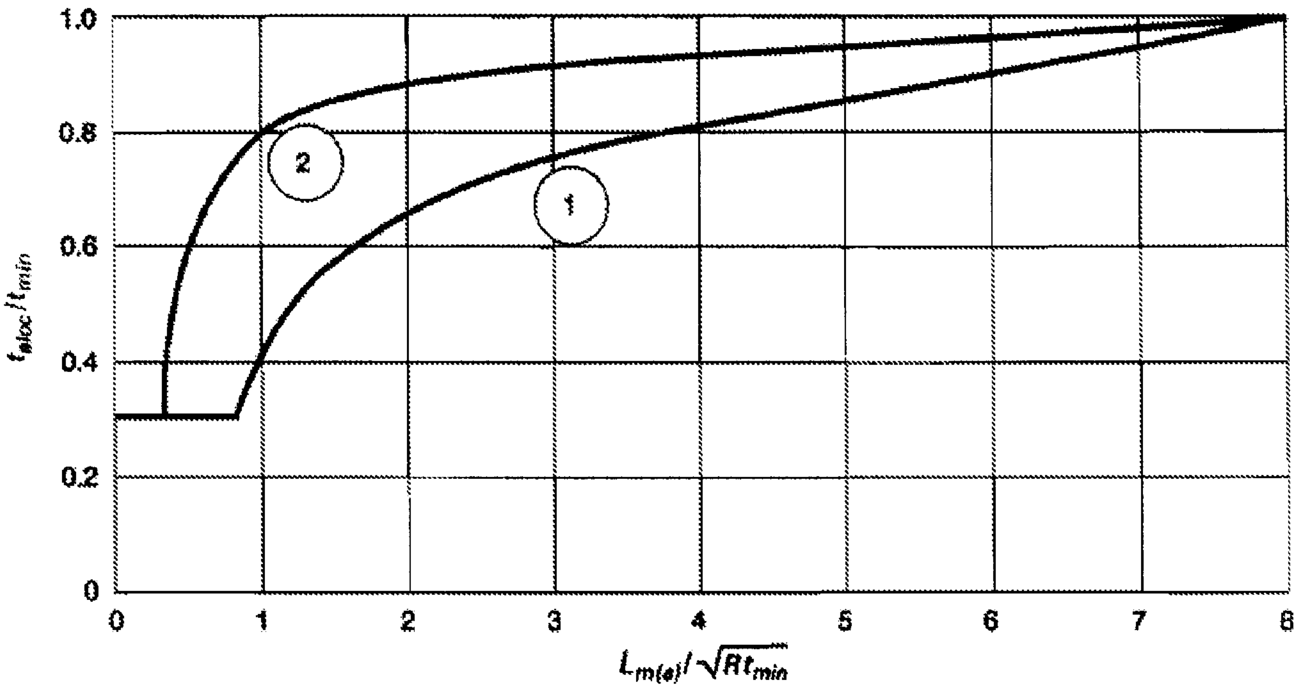
$$\frac{t_{aloc}}{t_{min}} \geq \frac{\left[0.5 + \left(\frac{t_{nom}}{t_{min}}\right)\left(\frac{\sigma_b}{S}\right)\right]}{1.8} \qquad (7)$$

where σ_b is the nominal pipe longitudinal bending stress resulting from all primary pipe loadings.

(e) When there is through-wall penetration along a portion of the thinned wall, as illustrated in Fig. 4, the flaw may be evaluated by the branch reinforcement method. The thinned area including the through-wall penetration shall be represented by a circular opening at the flaw location. Only the portion of the flaw lying within t_{adj} need be considered as illustrated in Fig. 5. When evaluating multiple flaws in accordance with IWA-3330, only the portions of the flaws contained within t_{adj} need be considered.

The minimum wall thickness, t_{min} , shall be determined by eq. (4). For evaluation purposes, the adjusted wall thickness, t_{adj}., is the postulated thickness as shown in Fig. 5. The pipe wall thickness is defined as the thickness of the pipe in the non-degraded region as shown in Fig. 5(a). The diameter of the opening is equal to d_{adj} as defined by t_{adj} as shown in Fig. 5(a). The postulated value for t_{adj} shall be greater than t_{min} and shall not exceed the pipe wall thickness. The t_{adj} value may be varied between t_{min} and the pipe wall thickness to determine whether there is a combination of t_{adj} and d_{adj} that satisfies the branch reinforcement requirements.

FIG. 3 ALLOWABLE WALL THICKNESS AND LENGTH OF LOCALLY THINNED AREA



The required area reinforcement for the postulated circular opening, d_{adj} and t_{adj}, as illustrated in Fig. 5(b), shall be calculated in accordance with NC-3643.3 or ND-3643.3, as appropriate. If a flaw growth analysis is performed, the growth in flaw dimensions shall consider the degradation mechanism(s) as relevant to the application. The flaw is acceptable when there is sufficient thickness in the degraded area to provide the required area reinforcement. Compliance with the primary stress limits of the Construction Code shall be verified. The flow area of the flaw, or the total of the flow areas of multiple flaws that are combined into a single flaw for the purpose of evaluation, shall not exceed the lesser of the flow area of the pipe or 20 in^2 (130 cm^2).

(f) Alternatively, when there is through-wall penetration along a portion of the thinned wall as illustrated in Fig. 4 the flaw may be evaluated as two independent planar through-wall flaw-one oriented in the axial direction and the other oriented in the circumferential direction. The minimum wall thickness t_{min}, shall be determined by eq. (4). The through-wall lengths for each flaw are the lengths L_{axial} and L_{circ} , where the local wall thickness is equal to t_{min} as projected along the axial and circumferential planes as shown in Fig. 4. The two planar flaws so constructed shall be evaluated to 3(a) and 3(b) or 3(c), as appropriate. If a flaw growth analysis is performed, the growth in flaw dimensions shall consider both corrosion and crack-growth mechanisms as relevant to the application. The flow area of the flaw, or the total of the flow areas of multiple flaws that are combined into a single flaw for the purpose of evaluation, shall not exceed the lesser of the flow area of the pipe or 20 in.^{2} (130 cm^2).

(g) In performing a flaw growth analysis, the procedures in C-3000 may be used as guidance. Relevant growth rate mechanisms shall be considered. When stress corrosion cracking (SCC) is active, the following growth rate equation shall be used:

$$da/dt = S_T C K_{max}^n \tag{8}$$

where da/dt is flaw growth rate in inches/hour, K_{max} is the maximum stress intensity factor under long-term steady state conditions in ksi in.$^{0.5}$, S_T is a temperature correction factor, and C and n are material constants.

For intergranular SCC in austenitic steels, where $T \leq$ 200°F (93°C).

$C = 1.79 \text{ X } 10^{-8}$
$S_T = 1$
$n = 2.161$

For transgranular SCC in austenitic steels, where $T \leq$ 200°F (93°C).

$C = 1.79 \text{ X } 10^{-7}$
$S_T = 3.71 \text{ X } 10^{8}\ [10^{(0.01842\,T - 12.25)}]$
$n = 2.161$

The temperature T is the metal temperature in degrees Fahrenheit. The flaw growth rate curves for the above SCC growth mechanisms are shown in Figs. 6 and 7. Other growth rate parameters in eq. (8) may be used, provided they are supported by appropriate data.

Attachment 1

FIG. 4 ILLUSTRATION OF THROUGH-WALL NONPLANAR FLAW DUE TO WALL THINNIN

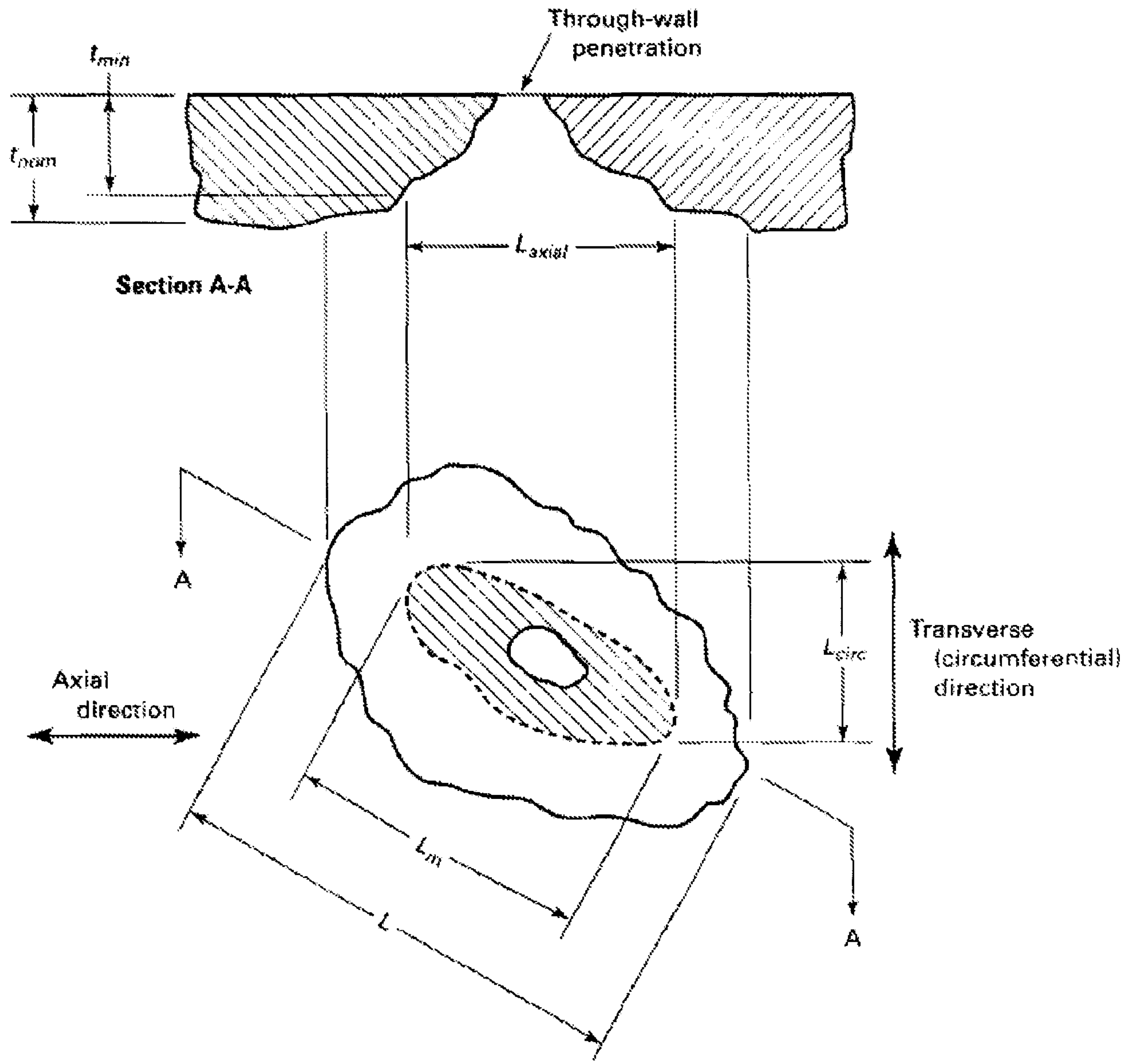
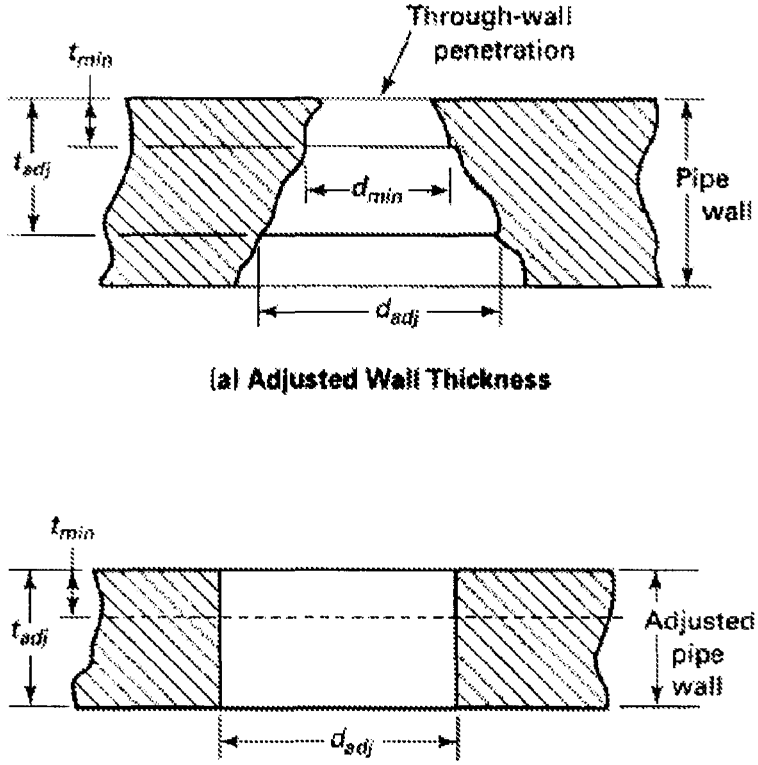


FIG. 5 ILLUSTRATION OF ADJUSTED WALL THICKNESS AND EQUIVALENT HOLE DIAMETER



(b) Equivalent Hole Representation

(h) For nonferrous materials, nonplanar and planar flaws may be evaluated following the general approach of 3(a) through 3(g) above. For planar flaws in ductile materials, the approach given in 3(b) and 3(g) may be used; otherwise, the approach given in 3(c) and 3(g) should be applied. Structural factors provided in 4 shall be used. It is the responsibility of the evaluator to establish conservative estimates of strength and fracture toughness for the piping material.

4 ACCEPTANCE CRITERIA

Piping containing a circumferential planar flaw is acceptable for temporary service when flaw evaluation provides a margin using the structural factors in Appendix C, C-2621. For axial planar flaws, the structural factors for temporary acceptance are as specified in Appendix C, C-2622. Piping containing a nonplanar part through-wall flaw is acceptable for temporary service if $t_p \geq t_{aloc}$ where t_{aloc} is determined from 3(d). Piping containing a nonplanar through-wall flaw is acceptable for temporary service when the flaw conditions of 3(e) or 3(f) are satisfied.

5 AUGMENTED EXAMINATION

An augmented volumetric examination or physical measurement to assess degradation of the affected system shall be performed as follows:

(a) From the engineering evaluation, the most susceptible locations shall be identified. A sample size of at least five of the most susceptible and accessible locations, or, if fewer than five, all susceptible and accessible locations shall be examined within 30 days of detecting the flaw.

(b) When a flaw is detected, an additional sample of the same size as defined in 5(a) shall be examined.

(c) This process shall be repeated within 15 days for each successive sample, until no significant flaw is detected or until 100% of susceptible and accessible locations have been examined.

6 NOMENCLATURE

C = coefficient in the crack growth relationship

D_o = outside pipe diameter

F = nondimensional stress intensity factor for through-wall axial flaw under hoop stress

F_b = nondimensional stress intensity factor for through-wall circumferential flaw under pipe bending stress

F_m = nondimensional stress intensity factor for through-wall circumferential flaw under membrane stress

L = maximum extent of a local thinned area with $t < t_{nom}$

L_{axial} = length of through-wall crack for the hole penetration in the axial direction of the pipe

L_{circ} = length of through-wall crack for the hole diameter penetration in the circumferential direction of the pipe

L_m = maximum extent of a local thinned area with $t < t_{min}$

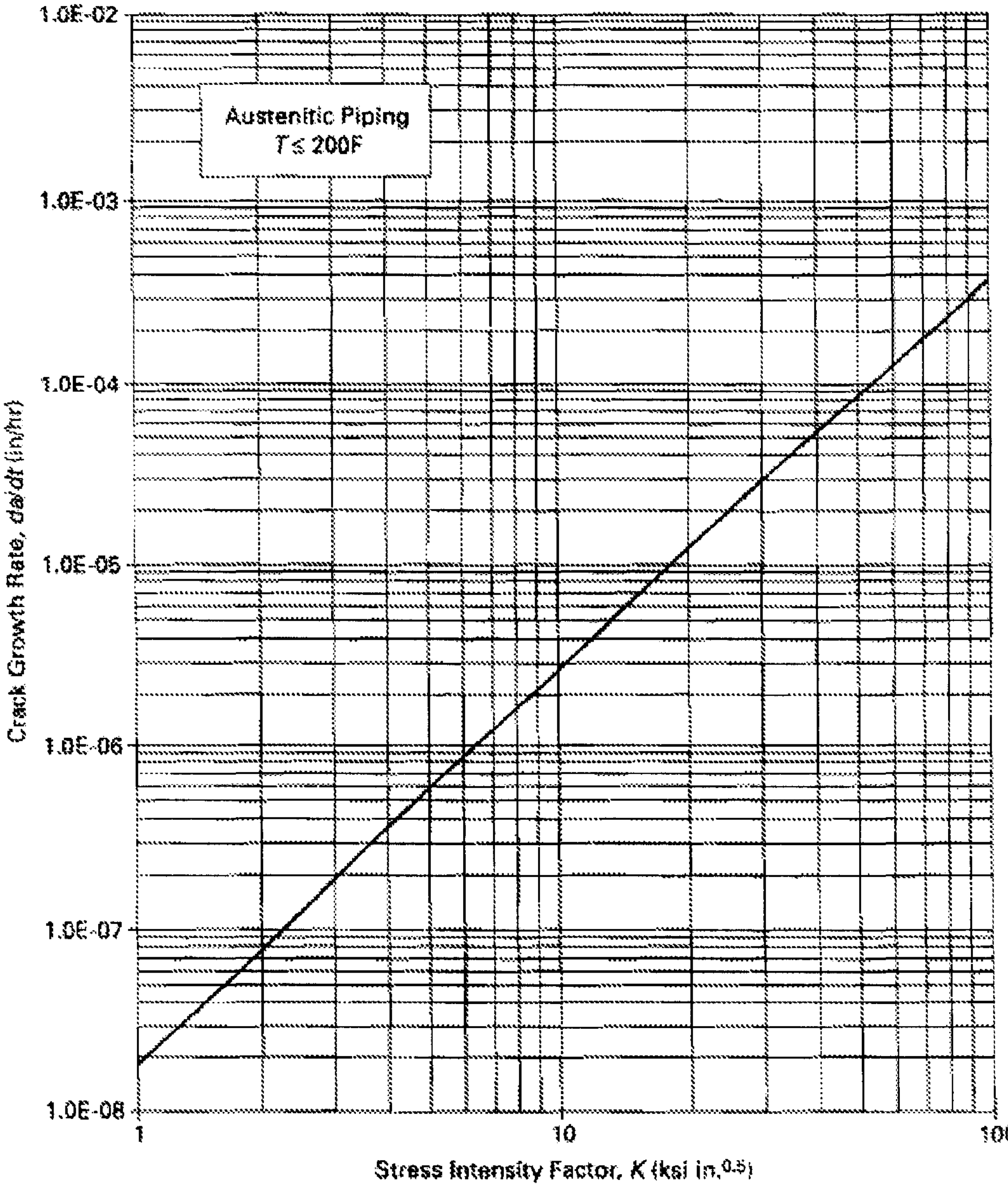
$L_{m(a)}$ = axial extent of wall thinning below t_{min}

$L_{m(t)}$ = circumferential extent of wall thinning below t_{min}

R = pipe radius
R_o = outside pipe radius
S = allowable stress at operating temperature
SF_m = structural factor on primary membrane stress
S_T = coefficient for temperature dependence in the crack growth relationship
S_u = Code-specified ultimate tensile strength
S_y = Code-specified yield strength
W_m = maximum extent of a local thinned area perpendicular to L_m with $t < t_{min}$
c = half crack length
da/dt = flaw growth rate for stress corrosion cracking
d_{adj} = diameter equivalent circular hole at t_{adj}
d_{min} = diameter of equivalent circular hole at t_{min}
ℓ = total crack length = $2c$
ℓ_{all} = allowable axial through-wall flaw length
n = exponent in the crack growth relationship
p = maximum operating pressure at flaw location
t = wall thickness
t_{adj} = adjusted wall thickness which is varied for evaluation purposes in the evaluation of a through-wall nonplanar flaw
t_{aloc} = allowable local thickness for a nonplanar flaw
t_{min} = minimum wall thickness required for pressure loading
t_{nom} = nominal wall thickness
t_p = minimum remaining wall thickness
λ = nondimensional half crack length for through-wall axial flaw
σ_f = material flow stress
σ_h = pipe hoop stress due to pressure
σ_b = nominal longitudinal bending stress for primary loading without stress intensification factor
θ = half crack angle for through-wall circumferential flaw

Attachment 1

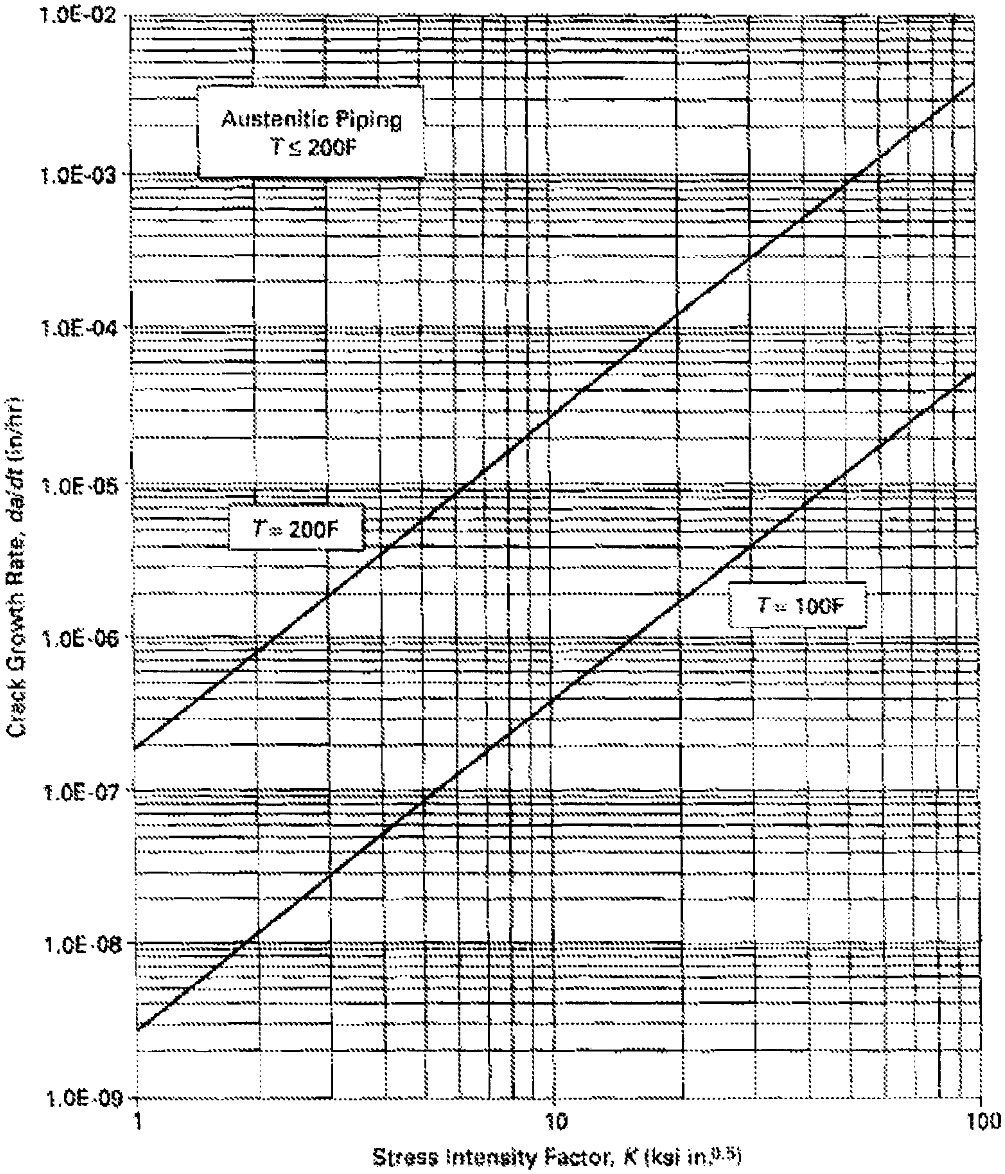
FIG. 6 FLAW GROWTH RATE FOR IGSCC IN AUSTENITIC PIPING



GENERAL NOTE: (SI conversion: 1.0 in/hr = 7.06 x 10^{3} mm/sec; 1.0 Ksi in.$^{0.5}$ = 1.099 MPa m$^{0.5}$; °C = (°F - 32)/1.8).

Attachment 1

FIG. 7 FLAW GROWTH RATE FOR TGSCC IN AUSTENITIC PIPING



GENERAL NOTE: (SI conversion: 1.0 in/hr = 7.06 x 10^{-3} mm/sec; 1.0 Ksi in.$^{0.5}$ = 1.099 MPa m$^{0.5}$; °C = (°F - 32)/1.8).

MANDATORY APPENDIX I

RELATIONS FOR F_m, F_b, AND F FOR THROUGH-WALL FLAWS

I-1 DEFINITIONS

For through-wall flaws, the crack depth *(a)* will be replaced with half crack length *(c)* in the stress intensity factor equations in C-7300 and C-7400 of Section XI, Appendix C. Also, Q will be set equal to unity in C-7400.

I-2 CIRCUMFERENTIAL FLAWS

For a range of R/t between 5 and 20, the following equations for F_m and F_b may be used:

$$F_m = 1 + A_m\,(\Theta/\pi)^{1.5} + B_m\,(\Theta/\pi)^{2.5} + C_m\,(\Theta/\pi)^{3.5}$$

$$F_b = 1 + A_b\,(\Theta/\pi)^{1.5} + B_b\,(\Theta/\pi)^{2.5} + C_b\,(\Theta/\pi)^{3.5}$$

where

Θ = Half crack angle = c/R

R = Mean pipe radius

t = Pipe wall thickness

and

$A_m = -2.02917 + 1.67763\,(R/t) - 0.07987\,(R/t)^2 + 0.00176\,(R/t)^3$

$B_m = 7.09987 - 4.42394\,(R/t) + 0.21036\,(R/t)^2 - 0.00463\,(R/t)^3$

$C_m = 7.79661 + 5.16676\,(R/t) - 0.24577\,(R/t)^2 + 0.00541\,(R/t)^3$

$A_b = -3.26543 + 1.52784\,(R/t) - 0.072698\,(R/t)^2 + 0.0016011\,(R/t)^3$

$B_b = 11.36322 - 3.91412\,(R/t) + 0.18619\,(R/t)^2 - 0.004099\,(R/t)^3$

$C_b = -3.18609 + 3.84763\,(R/t) - 0.18304\,(R/t)^2 + 0.00403\,(R/t)^3$

Equations for F_m and F_b are accurate for R/t between 5 and 20 and become increasingly conservative for R/t greater than 20. Alternative solutions for F_m and F_b may be used when R/t is greater than 20.

1.3 AXIAL FLAWS

For internal pressure loading, the following equation for F may be used:

$$F = 1 + 0.072449\lambda + 0.64856\lambda^{2} - 0.2327\lambda^{3} + 0.038154\lambda^{4} - 0.0023487\lambda^{5}$$

where

c = half crack length
$A = c/(Rt)^{1/2}$

The equation for F is accurate for λ between 0 and 5. Alternative solutions for F may be used when λ is greater than 5.