VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

May 13, 1999

United States Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 99-222
NL&OS/GDM R0
Docket Nos. 50-280, 281
50-338, 339
License Nos. DPR-32, 37
NPF-4, 7

Gentlemen:

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA AND SURRY POWER STATIONS UNITS 1 AND 2
ASME SECTION XI INSERVICE INSPECTION PROGRAM
REQUEST FOR APPROVAL - CODE CASE N-597

ASME Boiler and Pressure Vessel Code, Section XI, IWA-4000, provides the process for assessing a component for continued service after a defect has been removed. This provision stipulates that where the section thickness has been reduced below the minimum design thickness, the component shall be repaired. As an alternative, the component may be evaluated and accepted in accordance with the design rules of either the construction code or ASME Section III.

As an alternative to the requirements of IWA-4000, Virginia Electric and Power Company (Virginia Power) proposes to use the provisions of ASME Section XI Code Case N-597 for the analytical evaluation of Class 1, 2 and 3 carbon and low alloy steel piping components subjected to wall thinning as a result of flow accelerated or other corrosion phenomena. The ASME Code Committee approved Code Case N-597, "Requirements for Analytical Evaluation of Pipe Wall Thinning, Section XI, Division 1," on March 2, 1998. A copy of the Code Case is attached. Code Case N-597 has not yet been approved for use in Regulatory Guide 1.147, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1." However, provisions stated in footnote 6 to 10 CFR 50.55a provide for the use of other Code Cases upon request, if approved by the Director of the Office of Nuclear Reactor Regulation pursuant to 10 CFR 50.55a(a)(3).

Therefore, in accordance with 10 CFR 50.55a(a)(3)(i), Virginia Power requests NRC approval for the use of ASME Section XI Code Case N-597 as an alternative to the requirements of the ASME Boiler and Pressure Vessel Code, Section XI, IWA-4000 relating to the evaluation of a component where the thickness has been reduced below the minimum design thickness. The NRC has previously approved a 50.55a(a)(3) request to use Code Case N-597 for Northeast Nuclear Energy Company's Millstone Units 2 and 3 as documented in the safety evaluation report included in a letter dated February 23, 1999. The use of the analytical evaluation criteria specified in Code Case

A047

N-597 to evaluate wall thinning will provide a level of safety and quality consistent with the requirements of Section XI, IWA-4000.

If you have any questions or comments, please contact us.

Very truly yours,

L. N. Hartz
Vice President - Nuclear Engineering and Services

Commitments made in this letter: None.

Attachment

cc: U.S. Nuclear Regulatory Commission
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Mr. R.A. Musser
NRC Senior Resident Inspector
Surry Power Station

Mr. M. J. Morgan
NRC Senior Resident Inspector
North Anna Power Station

Attachment

ASME Code Case N-597, "Requirements for Analytical Evaluation of Pipe Wall Thinning, Section XI, Division 1," dated March 2, 1998

North Anna and Surry Power Stations Units 1 and 2

Virginia Electric and Power Company

Approval Date: March 2, 1998

See Numerical Index for expiration and any reaffirmation dates.

Case N-597
Requirements for Analytical Evaluation of Pipe Wall Thinning
Section XI, Division 1

Inquiry: What requirements may be used for analytical evaluation of Class 1, 2, and 3 carbon and low-alloy steel piping items subjected to internal or external wall thinning as a result of flow-accelerated or other corrosion phenomena?

Reply: It is the opinion of the Committee that the following rules may be used.

-1000 SCOPE

This Subsection provides requirements for analytical evaluation of Class 1, 2, and 3 carbon and low-alloy steel piping items (e.g., piping and fittings) with internal or external wall thinning as a result of corrosion phenomena, including flow-accelerated corrosion. These requirements are applicable to nonplanar flaws.

-3000 ACCEPTABLE STANDARDS

-3100 Preservice Examination

Piping items examined prior to commercial service are acceptable for service when the measured wall thickness meets the requirements of the Construction Code.

-3200 INSERVICE EXAMINATION

-3210 General

Upon completion of pipe wall thickness examinations, the predicted remaining wall thickness, t_p, at the time of the next scheduled examination shall be calculated for piping items under evaluation. The predicted remaining wall thickness is the spatial distribution of wall thickness remaining throughout the piping item and may have a unique value at any given location on the piping item. Alternatively, the minimum predicted value, $t_{p\text{-min}}$, may be used in determining acceptability for continued service. Methods of predicting the rate of wall thickness loss and the value of t_p shall be the responsibility of the Owner.

-3220 Acceptance

-3221 Acceptance By Examination

Piping items whose examination and evaluation results reveal that t_p meets the acceptance standards of -3500 or the Construction Code are acceptable for continued service. When these criteria are not met, the alternatives of -3222, -3223, and -3224 may be used. Fig. -3220-1 shows a flow chart of the acceptance alternatives.

-3222 Acceptance by Repair/Replacement Activity

Piping items whose thickness is less than that required by -3500, -3223, -3224 shall be corrected by a repair/replacement activity.

-3223 Acceptance by Engineering Evaluation

Piping items whose examination and evaluation results reveal that the criteria of -3221 are not satisfied may be accepted for continued service by engineering evaluation.

(a) For Class 1 piping items, this evaluation shall be conducted in accordance with evaluation methods and criteria developed by the Owner.

(b) For Class 2 and 3 piping items, an acceptable evaluation method and criteria are provided in -3600. Alternative evaluation methods and criteria may be specified by the Owner.

-3224 Acceptance by Reduction of Time to Next Examination

Piping items whose examination and evaluation results reveal that the criteria of -3221 are not satisfied, are acceptable for continued service when the time to the next examination for the affected piping items is reduced such that the acceptance criteria of -3221 or -3223 are met using the t_p for the reduced examination period.

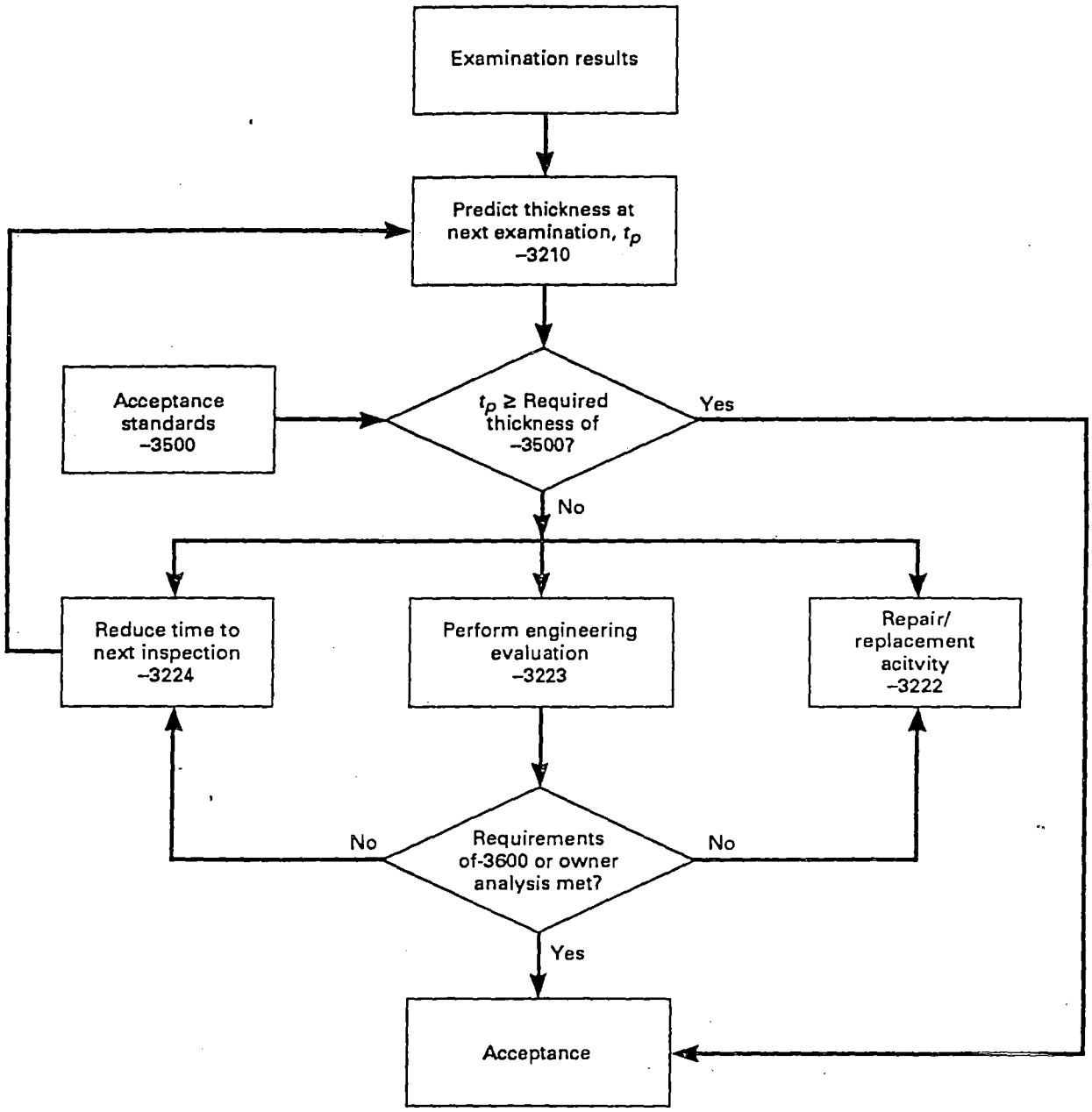
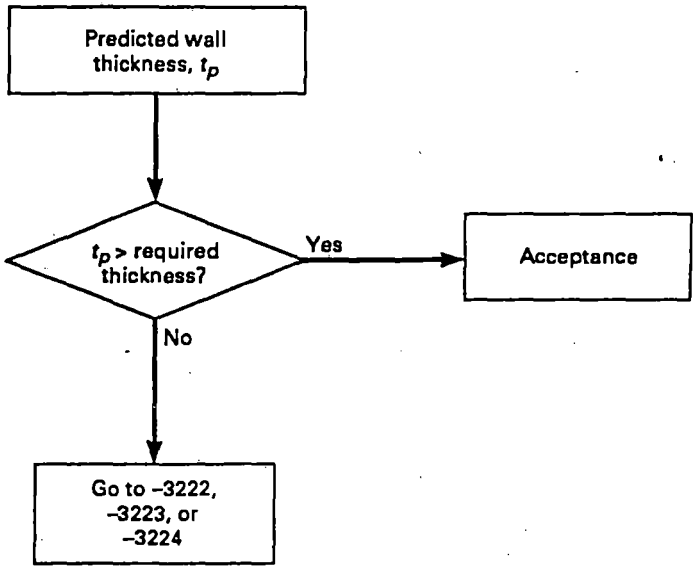


FIG. -3220-1 ACCEPTANCE FLOW CHART

Required Thickness	
Piping item	Reference
Straight pipe	-3500(a)(1)
Elbows	-3500(a)(1)
Reducers[1]	-3500(a)(2)
Tees[1]	-3500(a)(3)
Branch connections[1]	-3500(a)(3)
Designed item	-3500(a)(4)
Other items	-3500(b)

[1]Alternate of -3500(a)(5) may be used.



Thickness Limit	
Code class	Reference
1	-3500(c)
2	-3500(d)
3	-3500(e)[2]

[2]Alternate criteria may be developed in accordance with -3500(f).

FIG. -3500-1 WALL THICKNESS ACCEPTANCE STANDARD FLOW CHART

-3500 WALL THICKNESS ACCEPTANCE STANDARDS

A flow chart for the acceptance standards is shown in Fig. -3500-1.

(a) A Class 1, 2, or 3 butt welded pipe, elbow, branch connection, or reducer piping item is acceptable for continued service without further evaluation when t_p at all locations on the piping item meets the following requirements.

(1) For straight pipe and elbows purchased to a nominal pipe specification with an allowable wall thickness undertolerance of 12.5%, t_p shall be not less than 0.875 t_{nom} except that, for Class 1 short radius elbows, an evaluation shall be conducted to show that the requirements of NB-3642.2 are met.

(2) For the small end of concentric and eccentric reducers, t_p shall be not less than 0.875 t_{nom} for the pipe size at the small end. For the large end, the large end transition and the conical portion, t_p shall not be less than 0.875 t_{nom} for the pipe size at the large end. For the small end transition, the required thickness shall be gradually reduced from that required at the large end to that required at the small end (see Fig. -3622-1).

(3) For tees and branch connections, t_p shall be not less than 0.875 t_{nom} for the same size pipe for regions outside the limits of reinforcement required by the Construction Code used in the evaluation. For regions within the limits of reinforcement, t_p shall be not less than the thickness required to meet the branch reinforcement requirements of the Construction Code.

(4) For regions of piping items designed to specific wall thickness requirements, including designed weld counterbores and regions with integral reinforcement, t_p shall be not less than the minimum design thickness, including tolerances and excluding any corrosion allowances, specified in the original design analysis for the piping item.

(5) As an alternative to the requirements of -3500(a)(2) and -3500(a)(3), for reducers, tees, or branch connections purchased to fitting standards allowed in Table NB-3132-1 and for which baseline as-installed thickness measurements exist, t_p shall not be less than 0.875 times the as-installed thickness measurements, except that the thickness shall not be less than 0.875 t_{nom}.

(b) Acceptance criteria for Class 1, 2, and 3 pumps, valves, flanges, reducing elbows, socket weld fittings, and any other piping items not covered by -3500(a) shall be the responsibility of the Owner.

(c) For any Class 1 piping item, when t_p at any location is less than 0.3 t_{nom}, further evaluation is beyond the scope of this Case.

(d) For any Class 2 piping item, when t_p at any location is less than 0.2 t_{nom}, further evaluation is beyond the scope of this Case.

(e) Except as provided in *(f)* below, for any Class 3 piping item, when t_p at any location is less than 0.2 t_{nom} or 0.5 t_{min}, whichever is less, further evaluation is beyond the scope of this Case. The value of t_{min} shall be determined in accordance with -3600.

(f) As an alternative to -3500(e), decreased wall thickness, including local through-wall leakage in Class 3 piping items whose maximum operating temperature does not exceed 200°F and whose maximum operating pressure does not exceed 275 psi may be accepted. Evaluation methods and acceptance criteria shall be specified by the Owner.

-3600 ANALYTICAL EVALUATION FOR CLASS 2 AND CLASS 3 PIPING ITEMS

-3610 General Requirements

(a) Analytical evaluations shall be conducted in accordance with Construction Code. Later Code Editions and Addenda may be used. Use of later Code Editions and Addenda shall be reviewed for acceptability to the regulatory and enforcement authorities having jurisdiction at the plant site.

(b) Analytical evaluations shall be conducted using the predicted wall thickness, t_p, at the next examination of the piping item. The methods used to determine t_p are the responsibility of the Owner.

(c) A piping item is acceptable for continued service if the minimum pipe wall thickness, branch reinforcement requirements, and piping stress criteria of the Construction Code used in the evaluation are met for all specified loading conditions.

(d) As an alternative to -3610(c), butt welded pipe, elbow, branch connection, and reducer piping items may be evaluated in accordance with -3620.

(e) Alternative evaluation of pumps, valves, flanges, and other piping items are the responsibility of the Owner.

(f) Piping items under evaluation with t_p, exceeding the acceptance standards of -3500 and satisfying -3600 shall be monitored for continued degradation. The frequency and means of monitoring for degradation are the responsibility of the Owner.

-3620 EVALUATION OF PIPE, ELBOWS, BRANCH CONNECTIONS, AND REDUCERS

-3621 General Requirements

(a) The evaluation shall meet the requirements of -3622 and -3623.

(b) For a branch connection or tee, the region within the limits of reinforcement defined in the Construction Code shall meet the requirements of -3624.

(c) Evaluations shall be conducted using the appropriate piping equations, loadings, load combinations, allowable material properties, and other acceptance standards from the Construction Code used in the evaluation, except as specifically modified by this Case.

(d) When the ratio R/t_p is greater than 50, the potential for buckling of the thinned region shall be evaluated. Evaluation methods and acceptance criteria shall be specified by the Owner.

-3622 THICKNESS EVALUATION

-3622.1 Evaluation for Minimum Wall Thickness

(a) Except as provided in -3622.1(b), the value of t_p at any location shall not be less than 90% of the minimum wall thickness of the piping item, t_{min}, required for design pressure, defined in the Construction Code used in the evaluation, exclusive of any additional corrosion allowance.

(1) For straight pipe, bends, and elbows, t_{min} shall be determined by:

$$t_{min} = \frac{PD_o}{2(S + yP)}$$

(2) For concentric and eccentric reducers, t_{min} at each end shall be equal to t_{min} of straight pipe of the same nominal size as the reducer end. For the conical portion of the reducer and the transition at the large diameter end, t_{min} shall be that of the large diameter end. A gradual transition in t_{min} shall be assumed for the transition at the small end (see Fig. -3622-1).

(3) For branch connections and tees, except at regions providing reinforcement of the opening required by the Construction Code used in the evaluation, t_{min} shall be as required for straight pipe.

(b) When t_p is less than 0.9 t_{min} at any location, additional evaluations may be conducted to determine the allowable local thickness, t_{aloc}, subject to the limitations in (c). The thinned region and the parameters that define the depth and extent of thinning are illustrated in Fig. -3622-2. The allowable local thickness shall be determined in accordance with any one of the methods in -3622.2, -3622.3, -3622.4, -3622.5, or -3622.6.

(c) Local thinning evaluation shall not be allowed for the following:

(1) A region adjacent to any branch connection on the run piping, unless the distance between the center of the branch connection and the edge of the thinned area predicted to be less than t_{min} exceeds D_i, where D_i is the nominal inside diameter of the branch connection and L_m is the maximum dimension of the thinned region less than t_{min}.

(2) At the small end transition of a reducer.

(3) Inner portion of elbows and pipe bends (Fig. -3622-3), excluding a region within $1.5\sqrt{R_{nom}t_{nom}}$ of the butt welds, unless the t_{min} in the evaluation of -3622.2, -3622.3, or -3622.4 is replaced by t'_{min}, defined by:

$$t'_{min} = \left(0.5 + \frac{0.5}{1 + \dfrac{\cos\theta}{(R_b/R_o)}}\right) t_{min,\ pipe}$$

-3622.2 Local Thinning — Limited Transverse Extent

(a) The evaluation procedure shall consider the depth and extent of the affected area and require that the wall thickness exceed t_{min} for a distance that is the greater of $2.5\sqrt{R_{nom}t_{nom}}$ or $2L_{m,\ avg}$ between adjacent thinned regions, where R_{nom} is the mean radius of the piping item based on nominal wall thickness and $L_{m,\ avg}$ is the average of the extent of L_m below t_{min} for the adjacent areas (see Fig. -3622-4). Alternatively, the adjacent thinned regions shall be considered a single thinned region in the evaluation.

(b) Provided that the transverse extent of wall thinning predicted to be less than t_{min}, $L_{m(t)}$, is less than or equal to $\sqrt{R_{min}t_{min}}$, the allowable local thickness, t_{aloc}, shall be determined from Table -3622-1, where R_{min} is the mean radius of the piping item based on the minimum wall thickness t_{min}. For straight pipe, Table -3622-1 may be used when $L_{m(t)}$ exceeds $\sqrt{R_{min}t_{min}}$, except that an additional thickness t_b shall be added to the value determined from Table -3622-1.

(c) This approach shall not be used to evaluate a reducer.

-3622.3 Local Thinning — Limited Axial and Transverse Extent

(a) When the maximum extent of wall thinning, L_m, for which thickness is predicted to be less than t_{min} is less than or equal to $2.65\sqrt{R_{min}t_{min}}$, and t_{nom} is greater than 1.13 t_{min}, t_{aloc} shall be determined by satisfying (b) below and (c) or (d) below. This approach requires that adequate reinforcement be available surrounding the thinned area in accordance with (c) or (d) below. This evaluation approach is not applicable for the following conditions:

(1) Thinned areas adjacent to branch connections, when the reinforcement zone for the thinned area would overlap the required reinforcement of the branch connection.

(2) Thinned areas for which any portion of the reinforcement zone would lie on the conical or small diameter transition zone of a reducer.

(3) Adjacent thinned areas qualified by this approach when the reinforcement zones associated with each area would overlap.

(b) The thickness of the remaining pipe wall at the thinned section is adequate if the following equation is satisfied.

$$\frac{t_{aloc}}{t_{min}} \geq \frac{0.353L_m}{\sqrt{R_{min}t_{min}}}$$

(c) If there is a surrounding reinforcement zone with predicted thickness of at least t_{nom} for a minimum

dimension of $L/2$ in all directions, reinforcement for the thinned area shall satisfy the following equation.

$$\frac{t_{aloc}}{t_{min}} \geq 1 - \left(\frac{1.5\sqrt{R_{min}t_{min}}}{L}\right)\left(\frac{t_{nom}}{t_{min}} - 1\right)$$

(d) As an alternative to (c) above, the reinforcement adjacent to the thinned area shall justify the following equation.

$$\frac{t_{aloc}}{t_{min}} \geq 1 - \left(\frac{0.935A_{rein}}{L_m t_{min}}\right)$$

-3622.4 Local Thinning — Unlimited Transverse Extent

(a) The evaluation shall include consideration of the depth and extent of the affected area less than t_{min}. The wall thickness shall exceed t_{min} for an axial distance the greater of $2.5\sqrt{R_{nom}t_{nom}}$ or 2 $L_{ma,max}$ between adjacent thinned regions at each circumferential location on the piping item (see Fig. -3622-5). Alternatively, the adjacent thinned regions shall be considered a single thinned region in the evaluation.

(b) Thickness t_{aloc} shall be determined from Table -3622-1.

(c) This approach shall not be used to evaluate a reducer.

-3622.5 Local Thinning — Elbows and Bent Pipe

(a) For locations farther than $\sqrt{R_{min}t_{min}}$ from welds to adjacent piping items, the predicted thickness on the outer portion of an elbow or bend may be less than t_{min} for straight pipe. The local allowable thickness at each location shall be determined by:

$$\frac{t_{aloc}}{t_{min,\,pipe}} \geq 0.5 + \frac{0.5}{1 + \dfrac{\cos\theta}{\left(\dfrac{R_b}{R_{min}}\right)}}$$

where

R_b/R_{min} = ratio of elbow bend radius to mean pipe radius, based on t_{min} for the same size pipe

-3622.6 Local Thinning — Central Portions of Concentric Reducers

(a) For the conical portion of concentric reducers, the local allowable thickness less than t_{min} shall satisfy the following equation:

$$\frac{t_{aloc}}{t_{min,\,1}} \geq \frac{d_o/D_1}{\cos\alpha}$$

(b) For the flared transition at the small end of a concentric reducer, the local allowable thickness shall be gradually reduced from the value determined at the conical end of the flare to t_{min} for the small end of the reducer.

(c) This approach shall not be used to evaluate eccentric reducers.

-3623 PIPING STRESS EVALUATION

-3623.1 Evaluation Requirements

(a) The effects of piping stresses shall be evaluated in accordance with the equations of the Construction Code used in the evaluation. If the piping analysis is based on nominal piping thickness, allowable stresses may be multiplied by 1.143. Consideration shall be given to changes in the pipe metal area, pipe inside area, section modulus, and stress indices or stress intensification factors, as described in -3623.2, -3623.3 and -3623.4. The effects of cyclic operating conditions shall be addressed in accordance with -3625.

(b) The piping stress evaluation, shall be based on the predicted thickness at each cross section of the piping item that exhibits significant thinning or is affected by a change in stress index or stress intensification factor. Alternatively, the evaluation may be based on the limiting cross section.

-3623.2 Nominal Longitudinal Pressure Stresses

(a) The pipe metal area and the pipe inside area, for the thinned cross section might result in stresses different from those of the piping stress analysis of record.

(b) For simplified analysis, the piping item may be assumed to be uniformly thinned with a thickness of $t_{p,\,min}$. For this approach, the nominal longitudinal pressure stress shall be determined by:

$$S_p = \frac{PD_o}{4t_{p,\,min}}$$

When evaluating reducers, the large and small ends shall be evaluated separately. For the large end, $t_{p.min}$ shall be determined from all locations for the large end and conical section. For the small end, $t_{p.min}$ for the entire reducer shall be used.

(c) Detailed stress analysis may be conducted based on the complete set of measurements around the thinned cross-section of the piping item. The nominal longitudinal pressure stress, S_p, shall be determined by:

$$S_p = \frac{PA_i}{A_p}$$

(1) To evaluate piping at a branch connection beyond the limits of reinforcement, it shall be assumed that the entire region within limits of reinforcement is at thickness t_{min} for the unreinforced pipe section, with the outside surface at the pipe nominal outside radius. If excess reinforcement is available within the limits of reinforcement, the excess metal area may be included in A_p.

(2) When evaluating the longitudinal pressure stress in the central cone of a reducer, the stress shall be determined based on the local radius at the cross section and the local t_p at and adjacent to the cross section of interest, except that the resulting stress shall be multiplied by a factor of $1/\cos\alpha$.

(d) When using Code Editions and Addenda that require use of stress indices, the nominal longitudinal stress determined in accordance with (b) and (c) above shall be doubled.

-3623.3 Nominal Longitudinal Bending Stresses

(a) Thinning of the piping item cross-sectional area might result in bending stresses different from those of the piping stress analysis of record. The nominal longitudinal bending stress, S_b, for the various loading conditions and load combinations shall be determined by:

$$S_b = \frac{M_b + PA_c\delta}{Z_{min}}$$

(b) For simplified analysis, the piping item section modulus may be based on a uniformly thinned section with thickness $t_{p.min}$. When evaluating reducers, the large and small ends shall be evaluated separately. For the large end, $t_{p,\,min}$ shall be determined from all locations for the large end and conical section. For the small end, $t_{p,\,min}$ for the entire reducer shall be used.

(c) Detailed stress analysis may be conducted based on a complete set of measurements around the thinned cross section of the piping item.

(d) When evaluating thinning at the cross section of a branch connection, the requirements of -3623.2(c)(1) shall be met.

-3623.4 Stress Intensification Factors and Stress Indices

The local piping item wall thickness could affect the stress indices or stress intensification factors used in determination of the effective piping stress at a branch connection. When reduced wall thickness could increase these factors, the effect shall be considered by using a reduced piping item thickness determined in accordance with (a), (b), or (c) below.

(a) Except as allowed in (b) or (c) below, stress intensification factors or stress indices for a piping item shall be based on the assumption of uniform wall thickness, using a value of $t_{p,\,min}$ and an associated mean pipe radius in the formula for these factors.

(b) As an alternative (a) above, the factors may be based on the average t_p of the piping item excluding branch reinforcement zones, except that predicted thickness at locations within a distance of twice the pipe nominal wall thickness from butt welds to adjacent components need not be considered. For reducers, the average t_p of the small end shall be used with the small end diameter to determine the factor.

(c) As an alternative to (a) or (b) above, stress analysis of thinned piping items may be conducted to show the effects of wall thinning and the distribution of stresses on an affected piping item.

-3624 Evaluation of Branch Connections

-3624.1 The region of branch connections and tees within limits of reinforcement of the Construction Code used in the evaluation shall be evaluated in accordance with -3624.2 or -3624.3.

-3624.2 Branch Connections Not Requiring Reinforcement

(a) The region on the piping run shall be evaluated in accordance with the requirements of -3622 and -3623, without consideration of the branch connection, except that t_p within a region of radius of D_i of the branch pipe from the center of the branch connection shall not be less than t_{min} for the pipe run.

(b) The branch piping shall be evaluated in accordance with the requirements of -3622 and -3623.

-3624.3 Branch Connections Requiring Reinforcement

(a) Branch reinforcement requirements shall be determined in accordance with the Construction Code used in the evaluation.

(b) For the region of the piping run that provides branch reinforcement, the value of t_p at any location shall not be less than t_{min} for the nominal pipe run plus any required reinforcement at that location.

(c) For the region of the branch pipe that provides branch reinforcement, t_p shall not be less than t_{min} for the branch pipe plus any required reinforcement.

-3625 Evaluation for Cyclic Operation

(a) For piping items with $t_{p,\ min}$ not less than 0.75 t_{nom} and subject to no more than 150 equivalent full temperature cycles at the time of the next examination, in accordance with the Construction Code used in the evaluation, piping stress equations that include thermal expansion and anchor movement stresses need not be evaluated.

(b) For piping items not meeting the requirements of -3625(a), when the design includes consideration of thermal expansion stresses, the allowable stress range for expansion stress shall be determined in accordance with the Construction Code used in the evaluation, except that the stress intensification factor, i, shall be revised to take into account the geometry of the thinned region. As an alternative to establishing a revised stress intensification factor, the stress range reduction factors of Table -3625-1, which are based on an increase in the stress intensification factor by a factor of 2 over the life of the component, may be used.

(c) The potential for local overstrain in the thinned region for the combination of maximum sustained plus thermal expansion stresses shall be considered. Sustained loads include pressure, weight, and other sustained mechanical loads. Local overstrain is defined in NC-3672.6(b). Evaluation methods and acceptance criteria shall be specified by the Owner.

-3626 Nomenclature/Definitions

A_o = total cross-sectional area of pipe based on nominal outside diameter, $\frac{\pi D_o^2}{4}$, in.^{2}

A_i = predicted inside cross-sectional area for a pipe that has experienced wall thinning, in.^{2}

A_m = predicted metal cross-sectional area for a pipe that has experienced wall thinning, in.^{2}

A_p = predicted metal cross-sectional area of pipe, in.^{2}

A_{rein} = the reinforcement area available in the pipe wall based on the predicted thickness distribution in excess of t_{min} and within the limits of reinforcement of the Construction Code for an opening with diameter L_m at the region of local thinning, in.^{2}

D_o = nominal outside diameter of piping item (e.g., 10.75 for NPS 10 pipe), in.

d_o = maximum outside diameter of a reducer at the thinned location, in.

D_1 = outside diameter at the large end of the reducer, in.

D_i = nominal inside diameter of a branch connection, in.

f = stress range reduction factor

i = stress intensification factor of the Construction Code (not less than 1.0)

I_{min} = predicted minimum moment of inertia of the thinned pipe about the neutral axis of the pipe section, considering all orientations of the section neutral axis, in.^{4}

L = maximum extent of a local thinned area with wall thickness less than t_{nom}, in.

L_m = maximum extent of a local thinned area with wall thickness less than t_{min}, in.

$L_{m(a)}$ = maximum axial extent of a local thinned area with wall thickness less than t_{min}, in.

$L_{ma,\ max}$ = maximum of the axial extents of two adjacent local thinned areas with wall thickness less than t_{min}, in.

$L_{m(t)}$ = maximum transverse extent of a local thinned area with wall thickness less than t_{min}, in.

$L_{m,\ avg}$ = average of the extents of thickness less than t_{min} for two adjacent thinned areas, in.

M_b = resulting bending moment from the design analysis of record for each loading condition under consideration, in-lb

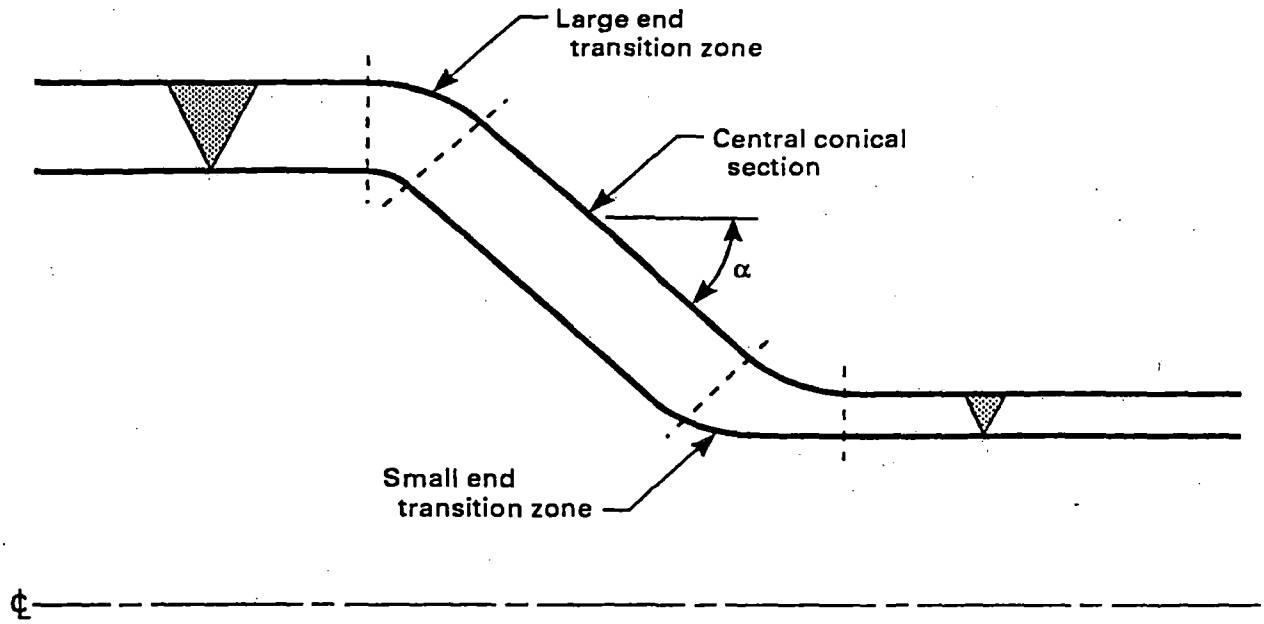
P = design pressure, psi

R_b = bend radius of an elbow to the elbow center line, in.

R_o = nominal outside radius (e.g., 2.25 for NPS 4 pipe), in.

R_{max} = radius to the nominal outside surface of the pipe plus the nominal distance between the center of the pipe and the neutral axis, in.

R_{min} = mean radius of piping item based on the nominal outside radius and the minimum



GENERAL NOTE:
Transition zones extend from the point on the ends where the diameter begins to change to the point on the central cone where the cone angle is constant.

FIG. -3622-1 ZONES OF REDUCER

wall thickness (e.g., 7.85 for NPS 16 pipe with t_{min} = 0.30 in.), in.

R_{nom} = mean radius of piping item based on the nominal radius and thickness (e.g., 6.75 for NPS 14 XS pipe with t_{nom} = 0.5 in.), in.

S = allowable stress for piping item, including joint efficiency factor, E, if applicable, psi.

S_b = maximum nominal bending stress at the thinned section, psi.

S_p = nominal longitudinal pressure stress, psi.

t_{aloc} = allowable local thickness, in.

t_b = uniform thickness, of piping item, required by the Construction Code, to withstand sustained and occasional bending loadings in the absence of pressure, thermal expansion, and anchor movement loadings, in.

t_{min} = minimum wall thickness required by the Construction Code to sustain pressure, exclusive of tolerances and any allowances for corrosion, in.

$t_{min,\ 1}$ = t_{min} for large end of a reducer, in.

$t_{min,\ pipe}$ = t_{min} for straight pipe, in.

t'_{min} = adjusted minimum thickness for inner portion of an elbow, in.

t_{nom} = nominal thickness of pipe or fitting specified in the applicable industry standard for the piping item. For items designed to specified minimum thickness, the nominal thickness is the design thickness, including corrosion allowance and excluding tolerances, in.

t_p = distribution of predicted local thickness of a piping item at the next scheduled examination, in.

$t_{p,\ min}$ = minimum predicted local thickness of a piping item at the next scheduled examination, in.

y = factor required by the Construction Code used in the evaluation

Z_{min} = predicted minimum section modulus for the thinned section, including consideration of the shift of the neutral axis of the thinned pipe section, I_{min}/R_{max}, in.^{3}

α = maximum cone angle at the center of a reducer, degree

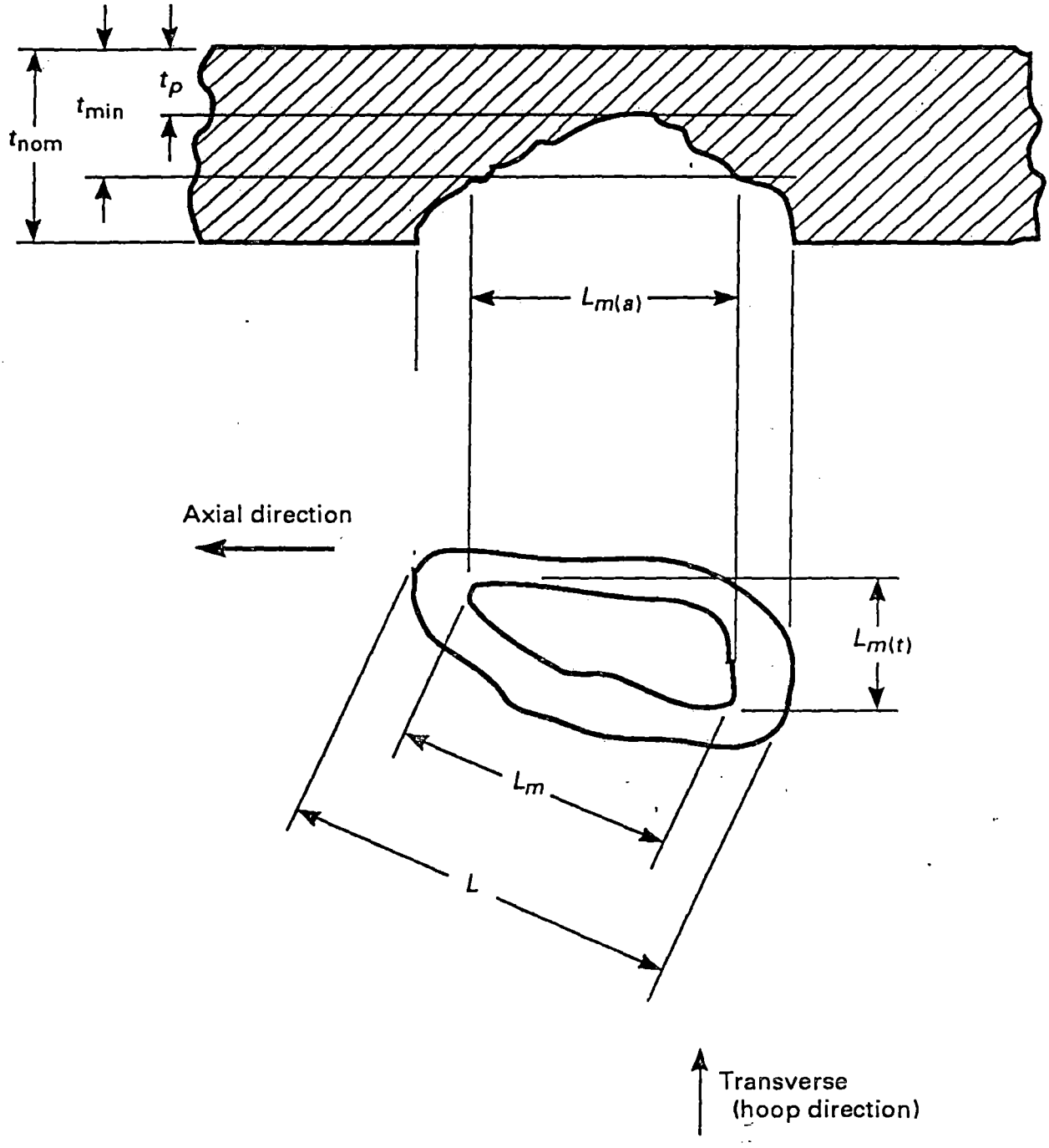


FIG. -3622-2 ILLUSTRATION OF FLOW-ACCELERATED-CORROSION WALL THINNING

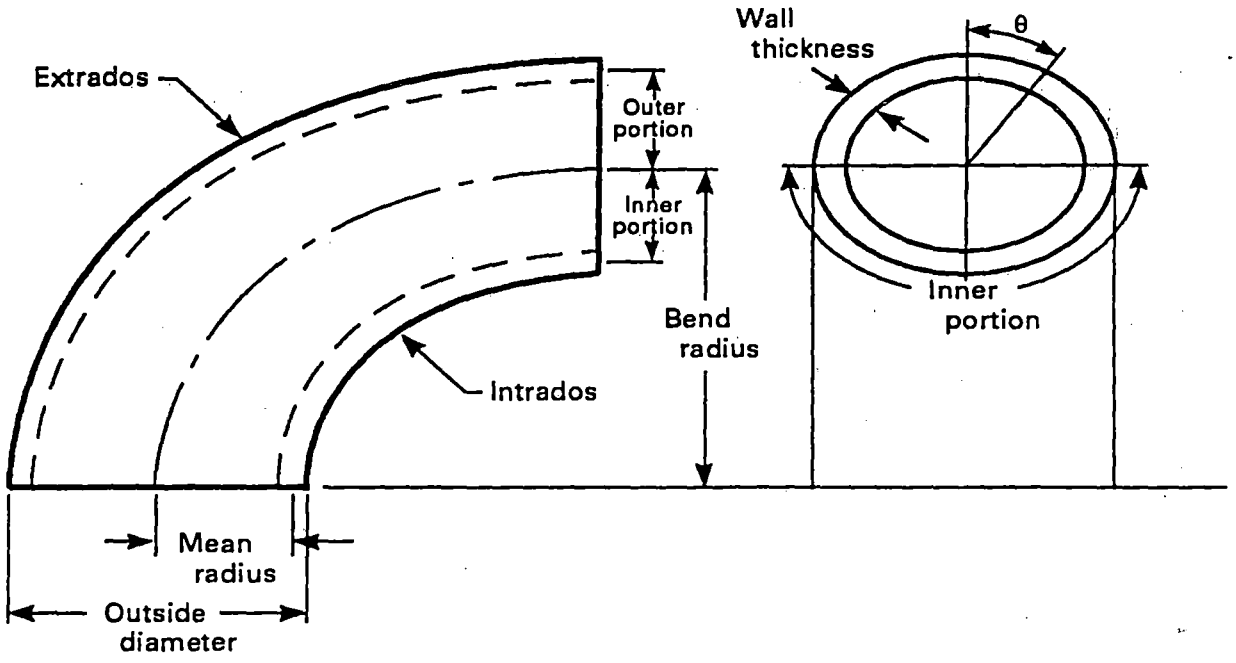
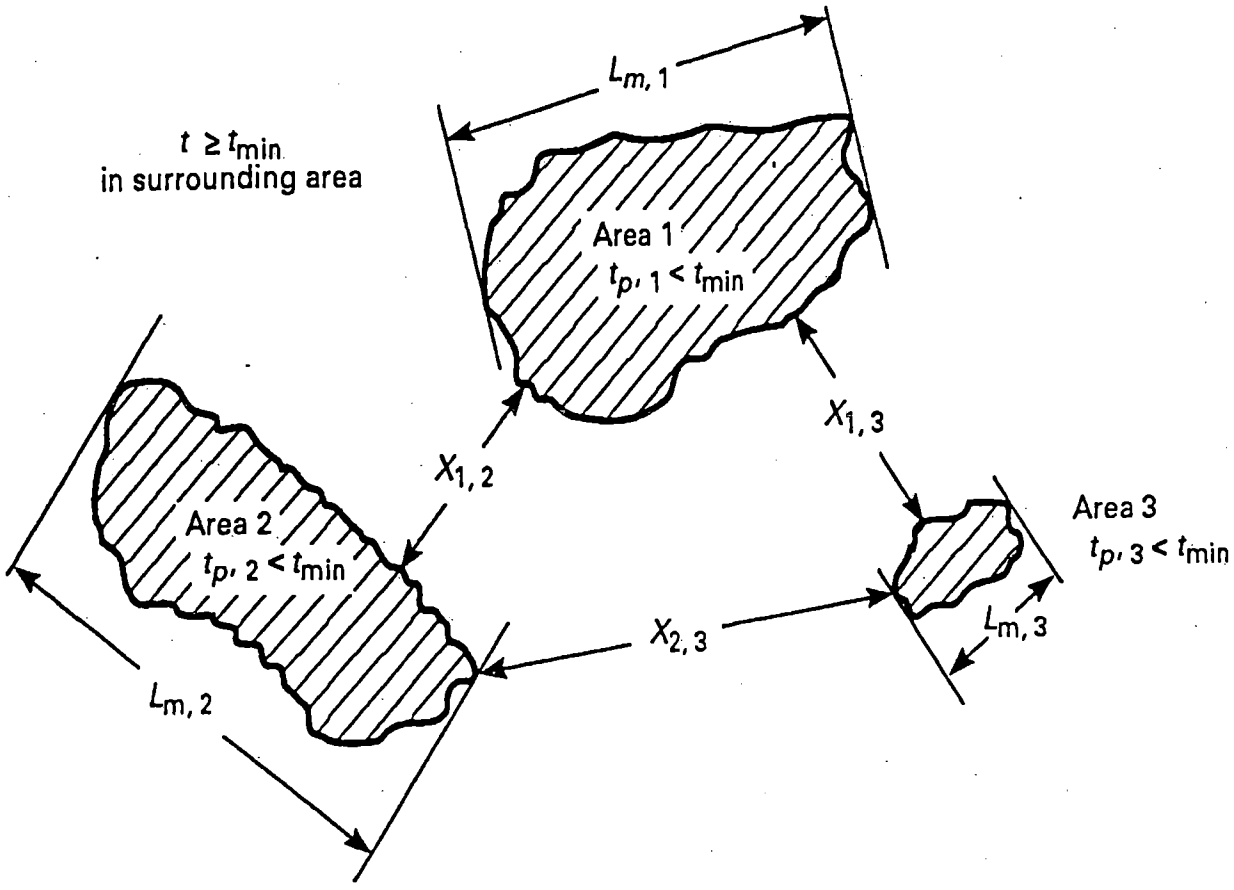


FIG. -3622-3 ELBOW AND NOMENCLATURE



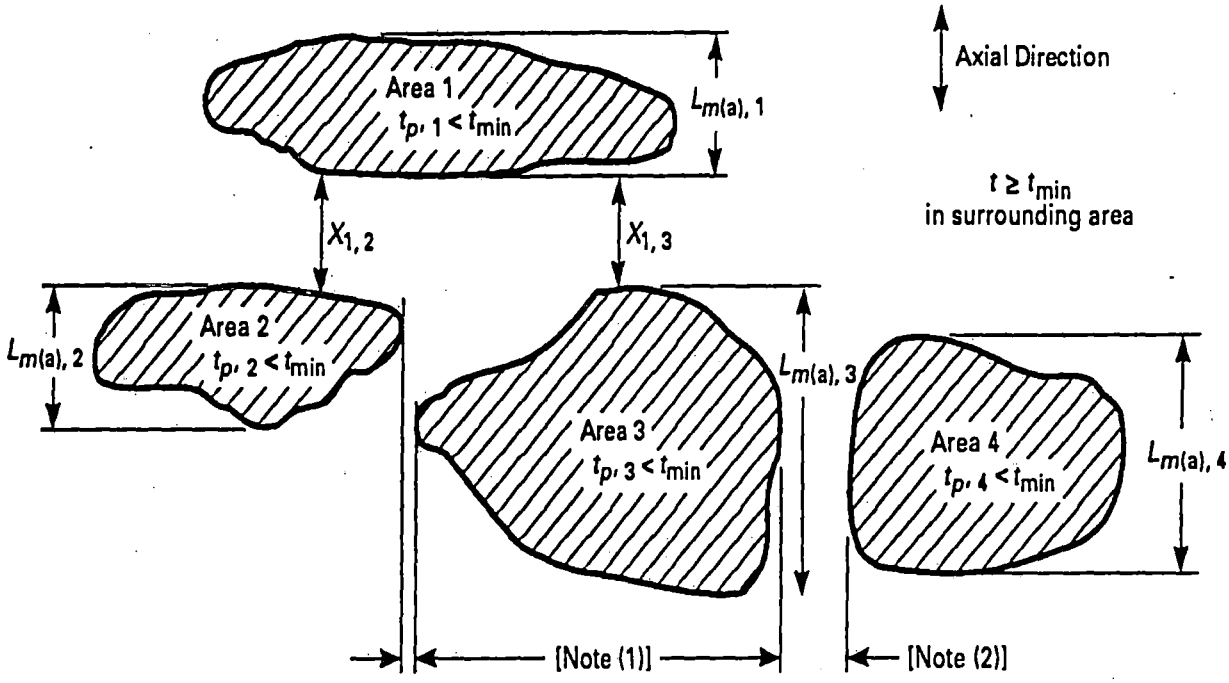
X_{ij} = minimum distance between areas i and j

$L_{m,i}$ = maximum extent of thinned area i

$L_{m,avg}$ = 0.5 $L_{m,i}$ + $L_{m,j}$

GENERAL NOTE:
Combination of adjacent areas into an equivalent single area shall be based on dimensions and extents prior to combination.

FIG. -3622-4 SEPARATION REQUIREMENTS FOR ADJACENT THINNED AREAS



X_{ij} = minimum distance between areas i and j at any circumferential location on pipe

$L_{m(a),i}$ = maximum extent of thinned area i in axial direction

L_{max} = maximum of the extents $L_{m(a),i}$ and $L_{m(a),j}$ of two adjacent areas

NOTES:

(1) Areas need not be combined into single areas based on separation in the transverse direction, provided that transverse extents of individual adjacent thinned areas do not overlap.

(2) Combination of adjacent areas into an equivalent single area shall be based on dimensions and extents prior to any combination of adjacent areas.

FIG. -3622-5 SEPARATION REQUIREMENTS FOR ADJACENT THINNED AREAS

TABLE -3622-1

$\frac{L_{m(a)}}{\sqrt{R_{min}t_{min}}}$	Allowable Local Thickness $t_{aloc}t_{min}$	
	-3622.2	-3622.4
0	0.100	0.100
0.20	0.100	0.261
0.23	0.100	0.300
0.26	0.100	0.375
0.32	0.100	0.477
0.38	0.100	0.551
0.45	0.100	0.616
0.50	0.100	0.651
0.60	0.100	0.703
0.70	0.182	0.742
0.83	0.300	0.778
0.85	0.315	0.782
0.90	0.349	0.794
1.00	0.410	0.813
1.20	0.505	0.841
1.40	0.572	0.860
1.60	0.622	0.873
1.80	0.659	0.883
2.00	0.687	0.891
2.25	0.714	0.897
2.50	0.734	0.900
2.75	0.750	0.900
3.00	0.763	0.900
3.50	0.787	0.900
4.00	0.811	0.900
4.50	0.834	0.900
5.00	0.858	0.900
5.50	0.882	0.900
6.00	0.900	0.900
>6.00	0.900	0.900

GENERAL NOTE:
Interpolation may be used for intermediate values.

θ = maximum angle from the center of the outer one-half of the elbow to the location of the thinned area being evaluated, as measured in the pipe cross section, degree

δ = nominal distance between the center of the pipe and the neutral axis of the thinned piping section, in.

TABLE -3625-1
MODIFIED STRESS RANGE REDUCTION FACTORS

Number of Equivalent Full Temperature Cycles[1], N	Stress Range Reduction Factor[2], f
650 or less	1.0
>650 to 1100	0.9
>1100 to 2000	0.8
>2000 to 3900	0.7
>3900 to 8500	0.6
>8500 to 21,000	0.5
over 21,000	0.4

NOTES:
(1) Cycles to next scheduled inspection or repair/replacement activity.
(2) The modified stress range reduction factors are based on an increase in the stress intensification factor, i, by a factor of 2 over the life of the component.