Case N-786-3
Alternative Requirements for Sleeve Reinforcement of Class 2 and 3 Moderate-Energy Carbon Steel Piping Section XI, Division 1

Inquiry: As an alternative to replacement or weld repair in accordance with IWA-4400, what requirements may be applied for wall reinforcement of Class 2 and 3 moderate-energy carbon steel piping systems that have experienced wall thinning from localized erosion, corrosion, and cavitation or pitting?

Reply: It is the opinion of the Committee that, in lieu of IWA-4400, Class 2 and 3 moderate-energy [i.e., less than or equal to 200°F (93°C) and less than or equal to 275 psig (1.9 MPa) maximum operating conditions] carbon steel piping experiencing wall thinning from localized erosion, corrosion, and cavitation or pitting (collectively referred to herein as corrosion) may have the wall thickness reinforced by applying full-circumferential reinforcing sleeves to the outside surface of the piping in accordance with the following requirements. Excluded from these provisions are conditions involving any form of cracking.

1 GENERAL REQUIREMENTS

(a) Installation of the reinforcing sleeve shall be in accordance with a Repair/Replacement Plan satisfying the requirements of IWA-4150.

(b) The design, materials, and installation shall meet the requirements of the Construction Code and IWA-4000, except as stated in this Case.

(c) If the minimum required thickness of reinforcing sleeve necessary to satisfy the requirements of 3 is greater than 1.4 times the nominal thickness for the size and schedule of the piping, this Case may not be used.

(d) Additional reinforcement or repair is not permitted on top of an existing reinforcing sleeve.

(e) This Case may be applied only to piping not required to be ultrasonically examined for in-service inspection.

(f) This Case may not be applied to pumps, valves, expansion joints, vessels, heat exchangers, tubing, flanged joints, socket welded or threaded joints, or branch connection welds.

2 INITIAL EVALUATION

(a) The material beneath the surface to which the reinforcing sleeve is to be applied shall be ultrasonically measured to establish the existing wall thickness and the extent and configuration of degradation to be reinforced. The adjacent area shall be examined to verify that the repair will encompass the entire unacceptable area, and that the adjacent base material, including at least \(0.75 \sqrt{R_{t,om}}\) of base metal beyond the toe of partial penetration attachment welds, is of sufficient thickness to accommodate the attachment welds at the edges of the sleeve.

(b) The cause and rate of degradation shall be determined. The extent and rate of degradation in the piping shall be evaluated to ensure that there will be no other unacceptable locations within the surrounding area that could affect the integrity of the reinforced areas for the life of the repair. Surrounding areas showing signs of degradation shall be identified and included in the Owner’s plan for thickness-monitoring inspections of full-structural reinforcing sleeves [see 8(c)]. The dimensions of the surrounding area to be evaluated shall be determined by the Owner, based on the type and rate of degradation present.

(c) The effects of the reinforcing sleeve and attachment welds on the piping and any remaining degradation shall be evaluated in accordance with IWA-4311.
3 DESIGN

3.1 TYPES OF REINFORCING SLEEVES

(a) Type A reinforcing sleeves as shown in Figure 1 may be used for structural reinforcement of thinned areas which are not expected to penetrate the wall and cause leakage. The piping longitudinal stresses shall meet the requirements of the Construction Code. Type A reinforcing sleeves shall have a maximum service life of the time until the end of the next refueling outage.2

(b) Type B reinforcing sleeves as shown in Figure 2 may be used for pressure plus full- or partial-structural reinforcement of thinned areas that penetrate, or are expected to penetrate the wall and cause leakage.

(1) Full-structural reinforcement is designed to accommodate pressure plus axial and circumferential design loadings at the location for the design life of the repair without taking credit for any portion of the degraded segment. Full-structural reinforcement sleeves shall be removed and the piping repaired or replaced in accordance with IWA-4000 no later than the end of the design life of the repair.

(2) Partial-structural reinforcement is designed to accommodate design loadings at the segment being reinforced, taking partial credit for the degraded segment after factoring in predicted degradation over the life of the repair. Partial credit is considered taken if the design relies on any portion of the segment of piping beneath the sleeve, other than the base metal beneath the attachment welds, to provide structural or pressure integrity. Partial-structural reinforcing sleeves shall have a maximum service life of the time until the end of the next refueling outage.

3.2 GENERAL DESIGN REQUIREMENTS — TYPE A AND B SLEEVES

(a) The design of reinforcing sleeves shall be in accordance with the requirements of NC-3100 and ND-3600, or NC-3100 and ND-3600, and Section III Appendices, Mandatory Appendix II.

(b) Material for reinforcing sleeves shall be ferritic, with welds of compatible weld filler metal.

(c) The minimum width of reinforcing sleeves shall be 4 in. (100 mm).

(d) The thickness of the reinforcing sleeve shall be sufficient to maintain required thickness for the predicted life of the repair.

(e) The following factors shall be considered, as applicable, in the design and application of the sleeves:

(1) all loading the sleeve is expected to encounter

(2) shrinkage effects, if any, on the piping

(3) stress concentrations caused by installation of the reinforcing sleeve or resulting from existing and predicted piping surface configuration

(4) effects of welding on any interior coating

(5) differential thermal expansion between reinforcing sleeve, the attachment welds, and the pipe

(6) potential for loose debris in the system from continued degradation of the reinforced area of the piping

(f) Longitudinal seam welds shall be full penetration. Backing may be applied to prevent burn-through of the pipe. If full contact between sleeve and pipe is required, any backing shall be recessed into the underside of the sleeve, or hardenable fill shall be used to fill the void, as indicated in Figure 3.

(g) Longitudinal seam joint efficiency of 0.8 shall be used, except that 100% joint efficiency is permitted if the longitudinal seam is volumetrically examined.

(h) Fatigue evaluation shall be performed if required for the original pipe, or if thermal gradients exceed 100°F (56°C), or if lesser thermal gradients will occur during more than 200 heatup and cool-down cycles over the life of the repair.

(i) If flexibility analysis was required by the original Construction Code, the effect of the reinforcement shall be reconciled with the original analysis.

(j) Final configuration of the attachment welds shall permit the examinations and evaluations required herein, including any required preservice or inservice examinations of attachment or adjacent welds.

(k) The predicted maximum degradation of the carrier base metal and reinforcing sleeve over the design life of the reinforcement shall be based on in-situ inspection and established data for similar base metals.

The initial degradation rate selected for design of the sleeve shall be at least 2 times the maximum rate observed at that location; or if unknown, 4 times the estimated maximum degradation rate for that system or a similar system at the same plant site for the same degradation mechanism. If the degradation rate for that location and the cause of the degradation are not conclusively determined, 4 times the maximum degradation rate observed for all degradation mechanisms for that system or a similar system at the same plant site shall be applied.

(l) Weld seams encompassed by the sleeve shall be ground flush. Alternatively, bulges may be rolled or formed in the sleeves to accommodate such obstructions. Refer to Figure 4.

(m) Sleeves shall closely match the outside surface of the carrier piping. If required by design, gaps shall be filled with hardenable fill.

(n) Where sleeves are applied on the outside of piping to mitigate externally corroded areas with potential for bulging, the corrosion cavity shall be restored to the original contour of the pipe with hardenable fill to minimize the gap beneath the sleeve.

2 If a Type A or partial-structural Type B reinforcing sleeve is installed during a refueling outage, the maximum permitted service life is one fuel cycle, until the end of the next refueling outage.
Hardenable fill shall be suitable for the system operating conditions, and shall be compatible with the sleeve, weld metal, piping, and any exterior coating that is not removed from the piping.

Branch connections may be installed on reinforcing sleeves only for the purpose of filling or venting during installation, or for leak testing of the sleeve, and shall be limited to NPS 1 (DN 25) or smaller.

3.3 SPECIFIC REQUIREMENTS — TYPE A SLEEVES

Type A sleeves in moist environments shall have edges sealed, but not seal welded, to prevent moisture intrusion and corrosion.

3.4 SPECIFIC REQUIREMENTS — TYPE B SLEEVES

(a) If permitted by the design, suitable gasket material may be applied inside the sleeve to prevent moisture during welding (see Figure 2).

(b) Hardenable fill and gasket material shall be compatible with the system fluid.

(c) Partial-structural sleeves shall be designed to withstand the design pressure.

(d) Partial-structural sleeves may be attached by fillet welds in accordance with the requirements of 3.2(a).

(e) Full-structural sleeves shall be attached by partial-penetration welds in accordance with Figure 5, or complete joint penetration (CJP) welds in accordance with Figure 6, unless otherwise established by analysis in accordance with the requirements of 3.2(a), and except for attachment welds at weld neck flanges as shown in Figure 6, extend for a distance of at least $s$ in each axial direction beyond the area predicted, over the design life of the repair, to infringe upon the required thickness, where

$$s \geq 0.75 \sqrt{R t_{\text{nom}}}$$

and $s \geq 1$ in. (25 mm)

where

$$R = D/2 = \text{outer radius of the piping}$$
$$t_{\text{nom}} = \text{nominal wall thickness of the piping}$$

The thickness of the partial-penetration attachment welds shall equal the thickness of the sleeve, and the outer edges of the welds shall be tapered to the piping surface at a maximum angle ("$\alpha$" in Figure 5) of 45 deg.

(f) If flexibility analysis was required by the original Construction Code, and unless a lower stress intensification factor (SIF or $i$) is established, an SIF ($i$) of 2.1 shall be applied for attachment fillet welds and tapered edges of partial-penetration attachment welds on straight pipe and at adjacent welds. Also, a stress multiplier of 1.7 shall be applied to the SIF ($i$) for sleeves enclosing standard elbows, and an SIF ($i$) of 2.1 shall be applied for sleeve attachments on tees and branch connections provided the toe of the fillet or tapered edge is not less than $2.5 \sqrt{R t_{\text{nom}}}$ from any branch reinforcement. (See Figure 5.)

3 Design thickness as prescribed by the Construction Code.
4 WATER-BACKED APPLICATIONS

(a) Manual welding of reinforcing sleeves on water-backed piping shall use the SMAW process and low-hydrogen electrodes. 4

(b) When welding a reinforcing sleeve to a leaking area, precautions, such as installation of a gasket or sealant beneath the sleeve, shall be taken to prevent welding on wet surfaces. Any residual moisture shall then be removed by heating prior to welding.

(c) For piping materials other than P-No. 1 Group 1, the surface examination of welds required in 6 shall be performed no sooner than 48 hr after completion of welding.

5 INSTALLATION

(a) The circumference of the base material in the area to be welded or to provide backing for welding shall be cleaned to bare metal. The entire area shall be cleaned, if required for application of hardenable fill.

(b) The sleeve shall be fitted tightly around the pipe. Preheating the sleeve to achieve a shrink fit, or use of mechanical or hydraulic clamping, draw bolts, or other devices may be used to ensure fit.

(c) If hardenable fill is used, it may be applied prior to sleeve installation or pumped into the annulus between the sleeve and base metal after the sleeve is in place. If pumped into the annulus, provisions shall be made to prevent over-pressurization and intrusion of the hardenable fill into the system.

(d) Means shall be provided to isolate or divert leakage to eliminate moisture during welding. If welding is performed on a wet surface, the maximum permitted life of the reinforcing sleeve shall be the time until the next refueling outage.

(e) Weld metal shall be deposited using a groove-welding procedure qualified in accordance with Section IX and the Construction Code.

(f) Fillet weld leg length shall be increased by the amount of fit-up gap. Care shall be exercised to avoid sharp discontinuities that could cause stress risers at the toes of fillet welds or tapered edges of partial-penetration attachment welds.

(g) Provision for venting during the final closure weld or pressure testing shall be made if necessary.

(h) The surfaces of all welds shall be prepared, if necessary, by machining or grinding to permit performance of surface and volumetric examinations required by 6. For ultrasonic examination, a surface finish of 250 RMS or better is required.

6 EXAMINATION

(a) All welds shall be examined using the liquid penetrant or magnetic particle method and shall satisfy the surface examination acceptance criteria for welds of the Construction Code or Section III (NC-5300 or ND-5300).

(b) Except for tapered edges, attachment welds, including the piping base metal upon which they are applied, shall be measured ultrasonically to verify and record baseline wall thickness.

(c) Longitudinal seam welds in the sleeve shall be ultrasonically or radiographically examined in accordance with the Construction Code or Section III if longitudinal seam welds in the piping require volumetric examination. If the design does not permit a joint efficiency of 0.8, Class 3 longitudinal seam welds may be examined in accordance with (d), in lieu of volumetric examination.

4 Testing has shown that piping with areas of wall thickness less than the diameter of the electrode may burn through during welding on water-backed piping.
Type B reinforcing sleeves attached to piping that has not been breached shall be equipped with pressure taps for performance of pressure testing.

**8 INSERVICE EXAMINATION**

(a) Preservice and inservice examination of Type B full-structural reinforcing sleeve welds shall be performed in accordance with IWC-2000 or IWD-2000, if required. [See 1(e).]

(b) The Owner shall perform a base-line inspection of full-structural reinforcing sleeves, their attachment welds, adjacent base metal to the extent it can be examined for a length of at least $0.75 \sqrt{R_{\text{nom}}}$ and the surrounding areas showing signs of degradation [see 2(b)], using ultrasonic or direct thickness measurement.

(c) The Owner shall prepare a plan to repeat the thickness monitoring inspections at least every refueling outage, to verify that minimum design thicknesses as required by the Construction Code or Section III are not violated in the sleeve or at the attachment welds, including the underlying base metal.

(1) More frequent thickness monitoring inspections shall be scheduled when warranted by the degradation rates calculated using reductions in thicknesses observed during these inspections, such that the required design thicknesses will be maintained at least until the subsequently scheduled thickness monitoring inspection.

(2) Provisions shall be made for access to full-structural reinforcing sleeves on buried piping in order to accomplish these inspections.

(d) Type A and partial-structural Type B reinforcing sleeves shall be visually monitored for evidence of leakage at least monthly. If the areas containing these sleeves are not accessible for direct observation, monitoring shall be accomplished by visual assessment of surrounding areas or adjacent ground surface areas above reinforcing sleeves on buried piping, or by monitoring of leakage collection systems, if available.

(e) For Type A and partial-structural Type B reinforcing sleeves, regardless of when during a cycle or inspection interval they are installed, the repair shall be considered to have a maximum service life of the time until the end of the next refueling outage.

(f) If the cause of the degradation is not determined, the maximum permitted service life of any reinforcing sleeve shall be the time until the end of the next refueling outage.
Figure 4
Bulge to Accommodate Girth Weld

Constant root gap
Figure 5
Design Details — Type B Full-Structural Sleeves

Minimum plate length = predicted maximum degradation

\[ \chi = 2.5 \sqrt{R_{\text{nom}}} \]
Figure 6
Sleeve Reinforcement Connection to Weld Neck Flange

Width of weld, w, to be greater than or equal to that shown

Predicted degradation

CJP

L_{max} = maximum length of corroded area with t < t_{design\ min}

= the greater of

(a) \sqrt{R_o t}
where
\( R_o \) = outside radius of the pipe
\( t \) = average pipe wall thickness adjacent to degraded area

or

(b) Y - t_f - (X - A_h)/2
where
\( A_h \) = diameter at beginning of chamfer
\( t_f \) = minimum thickness of flange
\( X \) = diameter of hub
\( Y \) = welding neck length through hub
all as defined in ASME B16.5