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ANALYSIS OF THE EFFECTS OF CORROSION PROBE ON RISER 241-AN-102-WST-16 DURING SEISMIC EVENT

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Riser 241-AN-102-WST-16 during a seismic event.

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**ANALYSIS OF THE EFFECTS OF
THE CORROSION PROBE ON
RISER 241-AN-102-WST-16
DURING A SEISMIC EVENT**

H. H. Ziada

September 1998

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ANALYSIS OF THE EFFECTS OF THE CORROSION PROBE ON RISER 241-AN-102-WST-16 DURING A SEISMIC EVENT

1.0 INTRODUCTION AND OBJECTIVE

This analysis supports the installation activity of the corrosion probe in Tank 241-AN-102. The probe is scheduled to be installed in Riser 241-AN-102-WST-16 (formerly known as Riser 15B).

The purpose of this analysis is to evaluate the potential effect of the corrosion probe on the riser during a credible seismic event. The previous analysis (HNF 1997a) considered only pump jet impingement loading.

2.0 CONCLUSIONS

The corrosion probe will contact Riser 241-AN-102-WST-16 at the lower end of the riser during a seismic event. The resulting stresses and loads are acceptable for the riser, based on seismic loads of Performance Category 1 (PC1) and AISC (1989) design stress allowables.

The bending stress in the upper portion of the 1.0-in. SCH XXS pipe (304L SST material) of the corrosion probe will exceed the yield strength, but will remain below the ultimate strength of the 304L SST. Thus, the probe will deform plastically but will not rupture (fail by separation).

3.0 CONFIGURATION AND MATERIAL

The configuration of the corrosion probe is shown in Figure 1, as obtained from Hiline (1998). The probe is 52-ft long. The upper 18-ft 8-in. of the probe is a 1.5-in. SCH 160 pipe and the lower portion is 1.0 in. SCH XXS pipe. The top 48.5-in. is constructed of 3.75-in. diameter pipe filled with low density concrete (surrounding the 1.5-in. pipe) to serve as a shield plug for the riser. The pipes material is 304L stainless steel with a yield strength of 25,000 lbf/in² and an ultimate strength of 70,000 lbf/in².

The probe fits through a 4-in. SCH 40 pipe riser located at a radius of 28-ft from the tank center. The riser has a total length of 161-in. extended below the top flange, see reference drawings; VITRO (1977, 1978a, and 1979) and LMH (1998). Figure 2 illustrates the attachment of the riser to the tank dome (VITRO 1977). The riser material is ASTM A106 Grade A carbon steel (VITRO 1978b) with a yield strength of 30,000 lbf/in² and an ultimate strength of 48,000 lbf/in² (ASTM 1997).

The low density concrete of the shielded plug of the corrosion probe has a density of 144 lbf/ft³ and a compressive strength of 3,000 lbf/in².

The bolts for the 4-in. risers are 0.75-in. diameter and made of A307 carbon steel material or better (usually A325).

3.1 GEOMETRIC PROPERTIES AND DENSITIES

The details of the geometric properties and densities of the different pipes and materials are given in the Appendix, Sections 2.1 to 2.5.

3.2 ADDED MASS OF DISPLACED WASTE

Assume the 400-in. length of the 1.0-in SCH XXS pipe is submerged in the waste. The weight of the displaced waste is added to the weight of the pipe to account for the fluid added mass in the calculations (Blevins 1979). The added mass calculations appear in Section 2.6 of the Appendix.

4.0 LOADING AND CRITERIA

This analysis considers the seismic load only. The probe and the riser were analyzed as a Performance Category 1 (PC1) structure, which is equivalent to General Service structure, as given by the Cognizant Engineer (Glenn Edgemon). The Engineering Design and Evaluation Procedure (HNF 1997b) specifies that the earthquake load design of PC1 structures shall comply with Uniform Building Code (UBC) requirements (UBC 1997). The riser acceptability is based on AISC (1989) design stress allowable requirements.

4.1 SEISMIC LOADS

The seismic loads are calculated in accordance with the guidelines of UBC (1997) using horizontal static force procedure of nonbuilding structures.

The total design base shear load (V) need not exceed the following:

$$V = 2.5 \times C_a \times I \times W/R = A_{cc}(g) \times W$$

Where:

$C_a = 0.28$ Seismic coefficient (Table 16-Q) for stiff soil profile (S_D , Table 16-J) and Z of 0.2 (zone 2B, Table 16-I) of UBC (1997).

$I = 1.0$ Importance factor (Table 16-K) for standard occupancy structures.

$R = 2.9$ Numerical coefficient representative of the inherent over-strength and global ductility-capacity of distributed mass cantilever structures (Table 16-P).

$A_{cc} =$ Acceleration force (g level).

$$A_{cc} = 2.5 C_a \frac{I}{R} = 0.241 g$$

$W =$ Weight of the probe parts.

The horizontal seismic load on each part of the probe was calculated from the following equation:

$$V = 0.241 \times W \text{ lbf}$$

The evaluation of the distributed loads on the probe sections appears in the Appendix, Section 3.2.

4.2 ALLOWABLE STRESSES AND LOADS

The allowable stresses and loads are obtained from AISC (1989), allowable strength method.

The bending stress allowable (F_{bss}) of the 304L SST pipes is 0.66 of the yield strength.

$$F_{bss} = 0.66 \times 25,000 = 16,500 \text{ lbf/in}^2$$

However, the corrosion probe is acceptable as long as it is below the yield strength (i.e., within the elastic limit) as given in HNF (1997a).

The bending stress allowable (F_{bcs}) of the ASTM A106 Grade A Carbon Steel riser is:

$$F_{bcs} = 0.66 \times 30,000 = 19,800 \text{ lbf/in}^2$$

The allowable tension (F_t) load for 0.75-in. bolt made of ASTM A307 material is provided in AISC (1989).

$$F_t = 8,800 \text{ lbf}$$

5.0 ANALYSIS AND RESULTS

This section provides a summary of the analysis approach and the analysis results. The analysis was performed by hand calculations using formulas from Roark (1975) and Timoshenko (1976). The analysis details appear in Section 4.0 of the Appendix.

5.1 OPEN ITEMS

None.

5.2 ANALYSIS APPROACH

First, the probe was analyzed as a cantilever with various cross-sections, assuming no contact with the riser. The stresses and deflections of the probe were calculated.

Second, the deflections at the possible points of contacts between the probe and the riser were compared against the clearances at these locations. The

two possible locations of contact are at the end of the 3.75-in. probe pipe (at 48.5-in. from the riser flange), and at the bottom of riser with the 1.5-in. probe pipe (at 161-in. from the flange). The clearances at the two locations are 0.138-in. and 1.063-in., respectively. The results show that the probe will contact the riser at the bottom end of the riser.

Third, the stresses in the riser and the probe were calculated with the contact at the bottom of the riser. The loads and stresses were calculated by applying superposition techniques, assuming an overhang beam with a simple support at the point of contact and fixed support at the lower end of the 3.75-in. pipe. The bending stress in the riser (at the connection with the tank dome) and the maximum local bending stress in the riser wall, were calculated. The bending stress in the probe at the point of contact was also calculated.

Fourth, the tension loads on the bolts of the riser flange were calculated. The calculations were based on two conservative assumptions; (1) the bending moment at the flange without contact, and (2) only two opposite bolts react the bending moment.

To determine if a detailed seismic analysis including sloshing effects needs to be performed or not, the stress results of a detailed seismic analysis including sloshing for a Thermocouple Probe (TCP) were compared with the results of a scoping evaluation using the equivalent-static method. The TCP configuration and loading conditions are similar to the corrosion probe. The TCP stress results of the detailed seismic sloshing analysis are presented in Appendix A of WHC, 1994. A scoping evaluation for the TCP using equivalent static method (without sloshing effect) was performed by the Author. The comparison of the resulting stresses shows that the equivalent-static method is conservative and envelopes the combined effects of seismic and sloshing of the detailed analysis. Therefore, it was concluded that the equivalent-static method is sufficiently conservative (particularly for these components because they have low natural frequencies, less than one HZ) to envelope the combined seismic and sloshing effects for the corrosion probe, and there is no need to perform a sloshing evaluation.

5.3 ANALYSIS RESULTS

The analysis results for each component are summarized below.

5.3.1 Corrosion Probe

The results show that the corrosion probe will contact the riser at the lower end of the riser. The effect of the contact on the probe is beneficial, because it reduces the bending moment on the probe above the point of contact. This in turn, reduces the bending stresses in the 1.5-in. pipe, and brings it below the yield strength. The maximum bending stress in the 1.5-in. pipe occurs at the point of contact.

Bending stress in 1.5-in. pipe = $19,071 \text{ lbf/in}^2$

This is less than the 304L SST yield strength of $25,000 \text{ lbf/in}^2$ (acceptable).

The maximum bending stress in the 1.0-in. pipe occurs at the junction with the 1.5-in. pipe.

The maximum bending stress in 1.0-in. pipe = $33,781 \text{ lbf/in}^2$.

This stress exceeds the yield strength of ($25,000 \text{ lbf/in}^2$), but is less than the ultimate strength ($70,000 \text{ lbf/in}^2$).

Thus, the 1.0-in. pipe of the probe will deform plastically but will not rupture (fail by separation).

5.3.2 Riser

The bending stresses in the riser were checked for two cases; (1) at the junction with the tank dome, and (2) in the wall of the riser.

The bending stress at the junction with the tank dome = 207 lbf/in^2 .

The maximum local stress in the riser wall = $2,688 \text{ lbf/in}^2$.

This occurs at a distance of 0.446 in. from the bottom of the riser, which is less than the 0.50-in. distance from the riser bottom to the tank dome.

Both stresses are well below the allowable bending stress of $19,800 \text{ lbf/in}^2$. Thus, the riser is acceptable for seismic loads.

5.3.3 Riser Flange Bolts

The loads on the bolts of the riser flange were checked to make sure that the flange connection will not separate and cause radiation release. For conservatism, only two opposite bolts were assumed to carry the moment for the case without contact.

The tensile load on the 0.75-in. bolt = $2,785 \text{ lbf}$.

This is less than the allowable load of $8,800 \text{ lbf}$ for the .075-in. bolt (made of ASTM A307 material). Thus, the bolts are acceptable and the flanges will remain in tight contact during the seismic event.

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Figure 1. Configuration of The Corrosion Probe.

Figure 2. Attachment of Riser to Tank Dome.

APPENDIX

**ANALYSIS OF THE EFFECTS OF THE CORROSION PROBE
ON RISER 241-AN-102-WST-16 DURING A SEISMIC EVENT**

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CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Analysis of the Effects of the Corrosion Probe on Riser
241-AN-102-WST-16 During a Seismic Event.

Document No. HNF-3162 REVO

Author H. H. Ziada

Yes No N/A

☒	☐	☐	Problem completely defined.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors.
☐	☐	☒	Code run streams correct and consistent with analysis documentation.
☐	☐	☒	Code output consistent with input and with results reported in analysis documentation.
☒	☐	☐	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒	☐	☐	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.

Reviewer L. J. Julyk

8/11/92
Date

Client: Lockheed Martin Hanford, Corp.WQ/Job No. E57230Subject: Analysis of the Effects of the Corrosion Probe on RiserDate: 7/30/98241-AN-102-WST-16 During Seismic EventChecked: 8/11/98By: H. H. Zloda *H.H. Zloda*Location: 241-AN-102 Tank, 200E Area Hanford, Washington

Revised:

By: L. J. Julek *L.J. Julek*

ANALYSIS OF THE EFFECTS OF THE CORROSION PROBE ON RISER 241-AN-102-WST-16 DURING A SEISMIC EVENT

1.0 INTRODUCTION AND OBJECTIVE

This analysis supports the installation activity of the corrosion probe in tank 241-AN-102. The probe is scheduled to be installed in riser 241-AN-102-WST-16 (formerly known as riser 15B).

The purpose of this analysis is to evaluate the potential effect of the corrosion probe on the riser during a credible seismic event. The previous analysis (HNF 1997a) considered only pump jet impingement loading. The probe and the riser were analyzed as General Service structure (Glenn Edgemon), which is equivalent to Performance Category 1 (PC1) structures as defined in HNF (1997b). The riser acceptability is based on the design stress allowables set in AISC (1989).

2.0 CONFIGURATION AND MATERIAL

The configuration of the corrosion probe is shown on the following page from Heline (1998). The probe is 52-ft long. It fits through a 4-in. riser located at a radius of 28-ft from the tank center. The upper 18-ft 8-in. of the probe is a 1.5-in. SCH 160 pipe and the lower portion is 1.0-in. SCH XXS pipe. The top 48.5-in. is constructed of 3.75-in. diameter pipe filled with low density concrete (surrounding the 1.5-in. pipe) to serve as a shield plug for the riser. The pipes material is 304L stainless steel with a yield strength of 25,000 lbf/in² and an ultimate strength of 70,000 lbf/in².

The riser is a 4-in. SCH 40 pipe with a total length of 161-in. extended below the top flange, see reference drawings; VITRO (1977, 1978a, and 1979) and LMH (1998). The riser material is ASTM A106 Grade A carbon steel (VITRO 1978b) with a yield strength of 30,000 lbf/in² (ASTM 1997).

The low density concrete has a density of 144 lbf/ft³ and a compressive strength of 3,000 lbf/in².

The bolts for 4-in. risers are 0.75-in. diameter and made of A307 carbon steel material or better (usually A325).

2.1 Geometric Properties of 1.0-in. Pipe

The lower 400-in. is made of 1-in. SCH XXS pipe with the following properties.

$D_{10} := 1.315\text{-in}$ Outside diameter.

$D_{11} := 0.599\text{-in}$ Inside diameter.

$A_1 := \frac{\pi}{4} (D_{10}^2 - D_{11}^2)$ Cross-sectional area.

$A_1 = 1.076\text{-in}^2$

Client: Lockheed Martin Hanford, Corp.

WO/Job No. E57230

Subject: Analysis of the Effects of the Corrosion Probe on Riser

Date: 7/30/88

By: H. H. Zaida

Location: 241-AN-102 Tank, 200E Area Hanford, Washington

Checked: 8/11/98

By: L. J. Juhk

Revised:

By:

$$I_1 := \frac{\pi}{64} (D_{1o}^4 - D_{1i}^4) \quad \text{Moment of inertia.}$$

$$I_1 = 0.14 \cdot \text{in}^4$$

$$S_1 := \frac{\pi}{32} \frac{D_{1o}^4 - D_{1i}^4}{D_{1o}} \quad \text{Modulus of section.}$$

$$S_1 = 0.214 \cdot \text{in}^3$$

$$W_{1p} := 0.305 \frac{\text{lb}}{\text{in}} \quad \text{Weight per inch length.}$$

$$L_1 := 400 \cdot \text{in} \quad \text{Length.}$$

2.2 Geometric Properties of 1.5-in. Pipe

Above the 1.0-in. pipe there is 175.5-in. length pipe of 1.5-in. SCH 160 with the following properties.

$$D_{2o} := 1.9 \cdot \text{in}$$

$$D_{2i} := 1.338 \cdot \text{in}$$

$$A_2 := \frac{\pi}{4} (D_{2o}^2 - D_{2i}^2)$$

$$A_2 = 1.429 \cdot \text{in}^2$$

$$I_2 := \frac{\pi}{64} (D_{2o}^4 - D_{2i}^4)$$

$$I_2 = 0.482 \cdot \text{in}^4$$

$$S_2 := \frac{\pi}{32} \frac{D_{2o}^4 - D_{2i}^4}{D_{2o}}$$

$$S_2 = 0.508 \cdot \text{in}^3$$

$$W_2 := 0.405 \frac{\text{lb}}{\text{in}} \quad \text{Weight per inch length.}$$

$$L_2 := 175.5 \cdot \text{in}$$

Client: Lockheed Martin Hanford, Corp.WO/Job No. E57230Subject: Analysis of the Effects of the Corrosion Probe on RiserDate: 7/30/88By: H. H. Zia

241-AN-102-WST-18 During Seismic Event

Checked: K/A/88By: L. J. JulekLocation: 241-AN-102 Tank, 200E Area Hanford, Washington

Revised:

By:

2.3 Geometric Properties of 3.75-in Pipe

The upper 48.5-in. is surrounded by 3.75-in. pipe with the following properties.

$$D_{30} := 3.75\text{-in}$$

$$D_{3i} := 3.25\text{-in}$$

$$A_3 := \frac{\pi}{4} (D_{30}^2 - D_{3i}^2)$$

$$A_3 = 2.749 \cdot \text{in}^2$$

$$I_{3p} := \frac{\pi}{32} (D_{30}^4 - D_{3i}^4)$$

$$I_{3p} = 8.461 \cdot \text{in}^4$$

$$S_{3p} := \frac{\pi}{32} \frac{D_{30}^4 - D_{3i}^4}{D_{30}}$$

$$S_{3p} = 2.256 \cdot \text{in}^3$$

$$W_{3p} := 0.78 \frac{\text{lb}}{\text{in}}$$

$$L_3 := 48.5\text{-in}$$

2.4 Geometric Properties of Concrete

The concrete inside the 3.75-in. pipe has the following properties.

$$D_{co} := 3.25\text{-in}$$

$$D_{ci} := 1.9\text{-in}$$

$$A_c := \frac{\pi}{4} (D_{co}^2 - D_{ci}^2)$$

$$A_c = 5.46 \cdot \text{in}^2$$

$$I_c := \frac{\pi}{64} (D_{co}^4 - D_{ci}^4)$$

$$I_c = 4.837 \cdot \text{in}^4$$

$$S_c := 2 \cdot \frac{I_c}{D_{co}}$$

$$S_c = 2.976 \cdot \text{in}^3$$

EVALUATION ANALYSIS

Doc No. HNF-3162Revision: 0Page No. 4 of 12Client: Lockheed Martin Hanford, Corp.WO/Job No. E57230Subject: Analysis of the Effects of the Corrosion Probe on RiserDate: 7/30/98241-AN-102-WST-18 During Seismic EventChecked: 8/11/98By: H. H. ZulaLocation: 241-AN-102 Tank, 200E Area Hanford, Washington

Revised:

By: L. J. Juby

By:

$$\rho_c := 0.0833 \frac{\text{lb}_f}{\text{in}^3} \quad \rho_c \text{ is } 144 \text{ lb}_f/\text{ft}^3 \text{ (HNF, 1997a)}$$

$$W_c := \rho_c \cdot A_c$$

$$W_c = 0.455 \frac{\text{lb}_f}{\text{in}}$$

$$L_c := L_3 \quad L_c = 48.5 \cdot \text{in}$$

2.5 Geometric Properties of 4-in. SCH 40 Riser

$$D_{ro} := 4.5 \cdot \text{in} \quad t_r := 0.237 \cdot \text{in}$$

$$D_{ri} := 4.026 \cdot \text{in}$$

$$A_r := \frac{\pi}{4} (D_{ro}^2 - D_{ri}^2)$$

$$A_r = 3.174 \cdot \text{in}^2$$

$$I_r := \frac{\pi}{64} (D_{ro}^4 - D_{ri}^4)$$

$$I_r = 7.233 \cdot \text{in}^4$$

$$S_r := \frac{2 \cdot I_r}{D_{ro}}$$

$$S_r = 3.214 \cdot \text{in}^3$$

$$W_r := 0.9 \frac{\text{lb}_f}{\text{in}}$$

$$L_r := 161 \cdot \text{in} \quad 10\text{-ft} - 11\text{-in. plus } 2\text{-ft} - 2\text{-in. per VITRO (1977, 1978 and 1979).}$$

2.6 Added Mass of Displaced Waste

The weight of the displaced waste is added to the mass of the 1.0-in. pipe to account for fluid added mass in the calculations. Assume the whole 400-in. length if the pipe is submerged in the waste.

$$\rho_w := 0.0506 \frac{\text{lb}_f}{\text{in}^3} \quad \rho_w \text{ is } 87.4 \text{ lb}_f/\text{ft}^3 \text{ (HNF 1997a).}$$

$$A_w := \frac{\pi}{4} D_{10}^2$$

$$A_w = 1.358 \cdot \text{in}^2$$

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$$W_w := \rho_w A_w$$

$$W_w = 0.069 \frac{\text{lbf}}{\text{in}}$$

2.7 Mass Densities of the different Probe Lengths

$$W_1 := W_{1p} + W_w$$

$$W_1 = 0.374 \frac{\text{lbf}}{\text{in}}$$

Mass density for the lower 400-in.

$$W_2 = 0.405 \frac{\text{lbf}}{\text{in}}$$

Mass density for the 175.5-in. length.

$$W_3 := W_2 + W_{3p} + W_c$$

$$W_3 = 1.64 \frac{\text{lbf}}{\text{in}}$$

Mass density of the upper 48.5-in.

$$W_r = 0.9 \frac{\text{lbf}}{\text{in}}$$

Mass density of riser.

3.0 LOADING AND CRITERIA

This analysis considers the seismic load only. The structures were analyzed for Performance Category 1 (equivalent to General Service) as given by the Cognizant Engineer (Glenn Edgemon). The Engineering Design and Evaluation Procedure (HNF 1997b) specifies that the earthquake load design of PC1 structures shall comply with UBC, Seismic Zone 2B, for standard occupancy facilities. The structural components are evaluated in accordance with the AISC (1989) allowable stresses and loads.

3.1 Seismic Loads

The seismic loads are calculated in accordance with the guidelines of UBC (1997) using horizontal static force procedure of nonbuilding structures.

The total design base shear need not exceed the following:

$$V = 2.5 \times C_a \times I \times W/R = A_{cc} (g) \times W$$

Where:

$$C_a := 0.28$$

Seismic coefficient (Table 16-Q) for stiff soil profile (S_D , Table 16-J) and Z of 0.2 (zone 2B, Table 16-I) of UBC (1997).

$$I := 1.0$$

Importance factor (Table, 16-K) for standard occupancy structures.

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$$R := 2.9$$

Numerical coefficient representative of the inherent over-strength and global ductility-capacity of distributed mass cantilever structures (Table 16-P).

$$A_{cc} := 2.5 \cdot C_a \cdot \frac{I}{R}$$

$$A_{cc} = 0.241$$

Acceleration force (g level).

3.2 Distributed load on Probe Sections

$$V_1 := A_{cc} \cdot W_1$$

$$V_1 = 0.09 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}}$$

Distributed load on lower 1.0-in. pipe 400-in. long.

$$P_1 := V_1 \cdot L_1$$

$$P_1 = 36.083 \cdot \text{lb} \cdot \text{f}$$

Total weight of lower 400-in.

$$V_2 := A_{cc} \cdot W_2$$

$$V_2 = 0.098 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}}$$

Distributed load on 175.5-in. length of 1.5-in. pipe'

$$P_2 := V_2 \cdot L_2$$

$$P_2 = 17.157 \cdot \text{lb} \cdot \text{f}$$

Total weight of the 175.5-in. length.

$$V_3 := A_{cc} \cdot W_3$$

$$V_3 = 0.396 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}}$$

Distributed load on 48.5-in. upper portion.

$$P_3 := V_3 \cdot L_3$$

$$P_3 = 19.198 \cdot \text{lb} \cdot \text{f}$$

Total weight of the upper 48.5-in. portion

3.3 Allowable Stresses and Loads

The allowable stresses and loads are obtained from AISC (1989), allowable strength method.

304L SST bending stress allowable (F_{bss}) is:

$$F_{y304L} := 25000 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

Yield strength of 304 SST.

$$F_{bss} := 0.66 \cdot F_{y304L}$$

$$F_{bss} = 16500 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

Allowable bending stress of 304L SST.

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ASTM A106 Grade A carbon steel stress allowable (F_{bcs}) is:

$$F_{y bcs} := 30000 \frac{\text{lbf}}{\text{in}^2}$$

Yield strength of riser carbon steel.

$$F_{b2} := 0.66 F_{y bcs}$$

$$F_{b2} = 19800 \frac{\text{lbf}}{\text{in}^2}$$

Allowable bending stress for riser carbon steel.

A307 allowable tension (F_t) load for .75-in. bolt is:

$$F_t = 8800 \text{ lbf}$$

Allowable bolt tension load.

4.0 ANALYSIS

The probe was analyzed as a cantilever with various cross-sections as shown below.

Moment at the top of the 400-in. length (point A) is:

$$M_a := \frac{V_1 \cdot L_1^2}{2}$$

$$M_a = 7216.689 \text{ in.lbf}$$

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Moment at the top of the 175.5-in. (point B) is:

$$M_b := M_a + V_2 \frac{L_2^2}{2} + P_1 \cdot L_2$$

$$M_b = 15054.828 \text{ in-lbf}$$

Moment at the top of the probe (point C) is:

$$M_c := M_b + \frac{V_3 \cdot L_3^2}{2} + P_1 \cdot L_3 + P_2 \cdot L_3$$

$$M_c = 18102.515 \text{ in-lbf}$$

4.1 Stresses in the Probe

Bending stress (f_{b1}) at the top of the 400-in. length in the 1.0-in. pipe (point A) is:

$$f_{b1} := \frac{M_a}{S_1}$$

$$f_{b1} = 33781.037 \frac{\text{lbf}}{\text{in}^2} \quad \text{Exceeds yield strength (25,000 lbf/in}^2\text{), but less than ultimate strength (plastically deformed).}$$

Bending stress (f_{b2}) at the top of the 175.5-in. length in the 1.5-in. pipe (point B) is:

$$f_{b2} := \frac{M_b}{S_2}$$

$$f_{b2} = 29648.517 \frac{\text{lbf}}{\text{in}^2} \quad \text{Exceeds yield strength (25,000 lbf/in}^2\text{), but less than ultimate strength (plastically deformed).}$$

Bending stress (f_{b3}) at the top of the probe in the 3.75-in. (point C), ignoring concrete and inner 1.5-in. pipe (conservative).

$$f_{b3} := \frac{M_c}{S_{3p}}$$

$$f_{b3} = 8022.801 \frac{\text{lbf}}{\text{in}^2} \quad \text{Less than allowable stress (16,500 lbf/in}^2\text{).}$$

4.2 Deflections of the Probe

It is required to determine whether the probe will contact the riser at locations B and R. The area-moment method (Timoshenko 1976) was used to calculate the deflection of the probe. For approximation in estimating the possibility of contact, assume the moment areas (to the left of point R) as a rectangular shape with average moment over the length.

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Deflection at location B:

$$E := 29000000 \frac{\text{lb}}{\text{in}^2} \quad \text{Modulus of elasticity.}$$

$$\delta_B := \frac{M_b + M_c}{2} \cdot L_3 \cdot \frac{1}{2 E I_{3p}}$$

$$\delta_B = 0.079 \cdot \text{in} \quad \text{Less than the 0.138-in clearance.}$$

There is no contact at location B.

Deflection at location R:

$$L_R := L_T - L_3$$

$$L_R = 112.5 \cdot \text{in} \quad \text{Length of 1.5-in. pipe inside the riser.}$$

$$L_X := (L_2 + L_3) - L_T$$

$$L_X = 63 \cdot \text{in} \quad \text{Distance between points A and R.}$$

$$M_R := M_a + P_1 \cdot L_X + \frac{V_2 \cdot L_X^2}{2}$$

$$M_R = 9683.948 \cdot \text{in} \cdot \text{lb} \quad \text{Over hanging moment at point R.}$$

$$\delta_R := \left[\left[\frac{M_b + M_c}{2} \cdot L_3 \cdot \left(\frac{L_3}{2} + L_R \right) \right] \cdot \frac{I_2}{I_{3p}} + \frac{M_b + M_R}{2} \cdot L_R \cdot \frac{L_R}{2} \right] \cdot \frac{1}{E I_2}$$

$$\delta_R = 6.043 \cdot \text{in} \quad \text{More than the 1.063-in. clearance.}$$

The probe will contact the riser at location R.

Bending stress at location R:

After contact, the Probe will bend around point R. The stresses will reduce at point B in the probe. This may prevent the 1.5-in. pipe from deforming plastically. The effect on the riser is shown in Section 4.3.

Bending stress (f_{bR}) in the 1.2-in. pipe at point R is:

$$f_{bR} := \frac{M_R}{S_2}$$

$$f_{bR} = 19071.269 \frac{\text{lb}}{\text{in}^2}$$

The stress at point R is less than yield strength.

4.3 Stresses in the Riser

When the probe contacts the riser (point R), it will act as an over hang beam with a simple support at point R and fixed support at point B. To get the reaction on the riser at point R, a superposition solution was used by applying formulas from Roark (1975). The sketches below show the steps of the applied superposition technique. Assume the riser is rigid.

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The first condition of superposition is a simply-supported beam with a uniform load. This is case 2e in Table 3 of Roark (1975) for $a=0$. The angle of rotation θ_b at point B is:

$$\theta_b := \frac{V_2 L_R^3}{24 E I_2}$$

The second condition of superposition is a combination of moments M_B and M_R acting at the ends of a simply-supported beam. This condition is in Roark (1975) Table 3, case 3e for moments at the ends. The angle of rotation θ_{b1} at point B resulted from the combination of the two moments is:

$$M_B := 1 \cdot \text{in} \cdot \text{lbf} \quad (\text{For units purpose only})$$

$$\theta_{b1} := \frac{M_R L_R}{6 E I_2} + \frac{M_B L_R}{3 E I_2}$$

Angle θ_b must equal θ_{b1} to have zero angular deflection at the fixed support. Solving the θ_b and θ_{b1} equations gives;

$$M_B := \frac{V_2 L_R^2}{8} - \frac{M_R}{2}$$

$$M_B = -4687.317 \cdot \text{in} \cdot \text{lbf}$$

Take moment about point B to obtain the reaction on the riser (P_R).

$$P_R := \frac{M_R - M_B + \frac{V_2 L_R^2}{2}}{L_R}$$

$$P_R = 133.243 \cdot \text{lbf}$$

Force on the riser.

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By: L. J. Juhk

By:

The riser bottom is about 5.0-in. from the attachment to the tank dome. this dimension is obtained by scaling from VITRO (1977). Assume the riser is a cantilever with a 5.0-in. length.

Moment at tank dome is:

$$L_{R1} := 5 \text{ in}$$

Distance from the bottom of the riser to tank dome.

$$M := P_R \cdot L_{R1}$$

$$M = 666.217 \cdot \text{in} \cdot \text{lbf}$$

Bending stress in riser at tank dome (f_{br}):

$$f_{br} := \frac{M}{S_r}$$

$$f_{br} = 207.255 \cdot \frac{\text{lbf}}{\text{in}^2}$$

The local bending stress on the riser shell can be obtained from Case 8, Table 8 of Roark (1975); and from Timoshenko and Woinowsky-Krieger (1959). The pipe is considered as a beam on elastic foundation and the parameter β is replaced by λ .

$$\nu := 0.3$$

Poisson's ratio.

$$\lambda := \left[\frac{3 \cdot (1 - \nu^2)}{\left(\left(\frac{D_{ro}}{2} \right)^2 \cdot (t_r)^2 \right)} \right]^{.25}$$

$$\lambda = 1.76 \cdot \frac{1}{\text{in}}$$

From lower end of riser.

Maximum local bending moment in the riser shell is:

$$C := 0.3325 \cdot \frac{1}{\text{in}}$$

Coefficient

$$M_{\max} := \frac{C \cdot P_R}{\lambda}$$

$$\text{at } X := \frac{\pi}{4 \cdot \lambda}$$

$$X = 0.446 \cdot \text{in}$$

$$M_{\max} = 25.169 \cdot \text{in} \cdot \frac{\text{lbf}}{\text{in}}$$

$$f_{b\max} := \frac{6 \cdot M_{\max}}{(t_r)^2}$$

$$f_{b\max} = 2688.543 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Much less than allowable bending stress (F_{b2}) of 19,800 lbf/in².

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4.4 Stress in Bolts of Riser Flange

Assume the 0.75-in., A307 bolts are at a base circle of 6.5-in., and only two opposite bolts are assumed to carry the bending moment at point C of the probe before contact with the riser.

$$M_c = 18102.515 \cdot \text{in} \cdot \text{lbf}$$

$$D_c := 6.5 \cdot \text{in}$$

$$F := \frac{M_c}{D_c} \quad \text{Force in bolt.}$$

$$F = 2785.002 \cdot \text{lbf} \quad \text{Less than allowable load of 8,800 lbf.}$$

5.0 CONCLUSIONS

The corrosion probe will contact Riser 241-AN-102-WST-16 at the lower end of the riser during a seismic event. The resulted stresses and loads are acceptable for the riser, based on seismic loads of Performance Category 1 (PC 1) and AISC (1989) design stress allowables.

The corrosion probe will exceed the yield strength in the 1.0-in. pipe upper portion, but will remain below the ultimate strength of the 304L SST. Thus, the probe will deform plastically but will not rupture (fail by separation).

6.0 REFERENCES

See references in main text.

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