R10509330

CORROSION EVALUATION

FRP-VSL-00002A-D (PTF)
Waste Feed Receipt Vessels

- Design Temperature (°F)(max/min): 240/5
- Design Pressure (psig) (max/min): 15/-2.5
- Location: incell
- PJM Discharge Velocity (fps) (max): 40
- PJM Duty Cycle: 25 %

Off spring items

FRP-PJM-00001- FRP-PJM-00036,
FRP-PJM-00061- FRP-PJM-00072

ISSUED BY RPP-WTP PDC

Contents of this document are Dangerous Waste Permit affecting

Operating Conditions are as stated on attached Process Corrosion Data Sheet.

The waste for these vessels primarily comes from the DOE.

Operating Modes Considered:

- Vessel is alkaline at between 60 and 120°F operating temperature range.
- Vessel is alkaline at 240 °F design temperature.
- Vessel is subjected to acid cleaning.

Materials Considered:

Material (UNS No.)	Relative Cost	Acceptable Material	Unacceptable Material
Carbon Steel	0.23		X
304L (S30403)	1.00		X
316L (S31603)	1.18	X	
6% Mo (N08367/N08926)	7.64	X	
Alloy 22 (N06022)	11.4	X	
Ti-2 (R50400)	10.1		X

Recommended Material: 316 (max 0.030% C; dual certified)

Recommended Corrosion Allowance: 0.040 inch (includes 0.024 inch corrosion allowance and 0.016 inch general erosion allowance; additional localized erosion protection is required as discussed in section j)

Process & Operations Limitations:

- Maintain pH>12.
  Exceptions:
  - Nitric acid cleaning shall be performed only after removal of waste and an initial water rinse.
  - Untreated rinse water shall not be left in the vessel for more than 7 days to prevent microbiological attack.

Concurrence GLJ
Operations

REV	DATE	REASON FOR REVISION	PREPARER	CHECKER	MET	APPROVER
7	3/8/05	Update wear allowance based on 24590-WTP-RPT-M-04-0008	DLAdler	JRDivine	NA	APRangus

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Revision History

REV	DATE	REASON FOR REVISION	PREPARER	CHECKER	MET	APPROVER
6	7/23/04	Modify section j – Erosion Include additional references	DLAdler	APRangus	NA	SWVail
5	7/19/04	Modify section j – Erosion Modify section q – Inadvertent Addition of Nitric Acid	DLAdler	APRangus	NA	SWVail
4	5/17/04	Addition of information regarding inadvertent nitric acid addition Append updated PCDS	DLAdler	APRangus	NA	SWVail
3	5/12/04	Incorporate new PCDS Correct design pressure Correct duty cycle	DLAdler	JRDivine	NA	APRangus
2	8/20/03	Complete re-write; revision bars not shown.	DLAdler	JRDivine	HMK	APRangus
1	2/6/02	Update MSDS; Specify max C content	JRDivine	DLAdler	NA	BPosta
0	1/14/02	Initial Issue	JRDivine	DLAdler	NA	BPosta

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Corrosion Considerations:

The waste feed receipt vessels can accept tank farm waste providing its storage temperature is below 120 °F and its undissolved solids content is below 5 wt%. The waste is then transferred to either the ultrafiltration feed preparation vessels or the waste feed evaporator feed vessels.

a General Corrosion
Dillon (2000) and Sedriks (1996) reported that 300 series stainless steels have corrosion rates less than 1 mpy in 50% NaOH at 122°F. Nelson (1987) reported that 304 and 316 have a corrosion rate less than 0.1 mpy in 60 % NaOH at 200°F. Danielson and Pitman (2000) found that 316L has a corrosion rate of 0.5 mpy in simulated Hanford waste (1 to 14 % NaOH) at its boiling point of ~220°F. Sedriks states higher corrosion rates may occur above 122°F if oxidizing species are present. Hanford waste contains nitrate and nitrite, which, though oxidizing, mitigates corrosion at higher temperatures.

Divine (1986) found that 304L corroded less than 316L in simulated Hanford complexant waste (22 to 30 % NaOH) saturated with fluorides (F^-) and 5,000 to 27,000 ppm chlorides (Cl^-) at 140°F. The corrosion rate of 304L after six months of testing was less than 0.2 mpy and for 316L, less than 1 mpy.

Sedriks (1996) using 10% nitric acid with 3,000 ppm fluoride at 158°F showed the corrosion rate of 304L and 316L was over 4 in/yr. Wilding and Paige (1976) showed that in 5% nitric acid with 1,000 ppm fluoride at 290°F the corrosion rate of 304L and 316L could be reduced to 5 mpy with the addition of trivalent aluminum (Al^{+++}). The Al^{+++} present in WTP waste is high enough to inhibit most of the fluoride activity during the nitric acid cleaning cycles.

***Conclusion*:** Either 304L or 316L is acceptable with a corrosion allowance of 0.04 inch.

b Pitting Corrosion
Chloride can cause pitting of stainless steel and nickel alloys in acid and neutral solutions. Dillon (2000) advised that in alkaline solution with pH>12, 304L is acceptable and that Cl^- might only promote attack in very tight crevices, if at all. Molybdenum containing stainless steels such as 316L and 6% Mo provide increased resistance to pitting by chlorides. Dillon and Koch (1995) concluded that fluoride would have little effect at this high pH range.

Divine and Carlos (1992) reported no pitting of 304L after six months at 140°F under 'boiling heat transfer' conditions in simulated Hanford 242-A evaporator operations. Revie (2000) showed that nitrate levels comparable to those present in WTP waste inhibit chloride induced pitting corrosion of 304L. Ohl and Carlos (1994) in their review of the Hanford 242-A evaporator, found that 304L had neither pitting nor cracking after two years of operation in waste similar to that expected in LAW, including the presence of radiation.

Conclusion: Both type 304L and 316L are acceptable, but 316L is preferred as more conservative.

c End Grain Corrosion
End grain corrosion can occur in stainless steels in hot, highly oxidizing acids. This system is alkaline except for brief periods during nitric acid cleaning and high temperatures are not expected.

***Conclusion*:** Type 316L is acceptable.

d Stress Corrosion Cracking
Sedriks (1996) and Davis (1987) concluded that chloride induced stress corrosion cracking (SCC) of 300 series stainless steel rarely occurs at the 102°F operating temperature in neutral and acidic conditions; and, not at all in high pH conditions. Emptying and rinsing the tank prior to nitric acid washes and proper flushing afterwards will minimize the effects of chlorides during cleaning. Type 316L is resistant to welding induced sensitization and SCC due to its low carbon content.

Caustic SCC of 300 series stainless steel does not occur below 140°F in 25 % NaOH according to Jones (1992).

***Conclusion*:** Type 316L is recommended.

e Crevice Corrosion
See discussion under Pitting.

***Conclusion*:** Type 316L is acceptable.

f Corrosion at Welds
Type 316L welds with a minimum delta ferrite content of 5% (5 Ferrite Number) are equally resistant to corrosion as 316L base material.

***Conclusion*:** Type 316L welds are recommended.

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g Microbiologically Induced Corrosion (MIC)
MIC does not occur in 12 pH solutions (Borenstein 1988). Untreated water left stagnant for more than 7 days may lead to conditions favorable to MIC in 304L and 316L stainless steel.

***Conclusion*:** MIC is not a concern for high pH conditions. Controls are required for hydrotest or flush water.

h Corrosion Fatigue
Corrosion fatigue is not a concern for high pH conditions.

Conclusion: Type 316L is acceptable.

i Vapor Phase Corrosion
Because of the highly alkaline conditions, no free HF or HCl gas is expected in the vapor phase and no general corrosion is expected during normal operation. Both HCl and HF gas could be generated during nitric acid cleaning and cause minor pitting during the relatively short cleaning cycle. This can be minimized with a thorough water rinse prior to nitric acid cleaning

***Conclusion*:** Type 316L is acceptable.

j Erosion
Based on past experiments by Smith & Elmore (1992), the solids are soft and erosion is not expected to be a concern for the vessel wall. Based on 24590-WTP-RPT-M-04-0008, a general erosion allowance of 0.016 inch is adequate for components with maximum solids content up to 27.3 wt%. At least 0.044 inch of additional 316L stainless steel should be provided as localized protection for the applicable portions of the bottom head to accommodate PJM discharge velocities of up to 12 m/s with solids concentrations of 3.8 wt% for 25 % operation as documented in 24590-WTP-M0E-50-00001. The 3.8 wt% is considered to be conservative and is based on the WTP Prime Contract maximum. During normal operation, the solids content of the FRP-VSL-00002 vessels is expected to be well below the contract maximum. The Process Corrosion Data Sheet states that the FRP vessels will only accept feed from the Tank Farms that is below 5 wt% solids, and notes that the maximum undissolved solids can be as high as 3.92 wt% to 4.60 wt%. These latter numbers were determined by the concentration of waste received at 3.8 wt% due to evaporation before it is processed. The 25 % operation is expected to bound normal as documented in Mitchell (2004). The wear due to solids contents up to 5 wt% and 100 % operation has been determined as documented in 24590-WTP-M0E-50-00001.

The wear of the PJM nozzles can occur from flow for both the discharge and reflood cycles of operation. At least 0.041 inch of additional 316L stainless steel should be provided on the inner surface of the PJM nozzle to accommodate wear due to PJM discharge and suction velocities with solids concentrations of 3.8 wt% for 25 % operation as documented in 24590-WTP-M0E-50-00001.

Conclusion: The recommended corrosion allowance provides sufficient protection for erosion of the vessel wall. Additional localized protection for the bottom head will accommodate PJM discharge velocities and for the PJM nozzles will accommodate PJM discharge and reflood velocities.

k Galling of Moving Surfaces
There are no moving surfaces within the vessels.

Conclusion: Galling is of no concern in these vessels.

l Fretting/Wear
There are no contacting surfaces that are part of the vessel.

Conclusion: Fretting and wear are not of concern.

m Galvanic Corrosion
The vessel contains no dissimilar metals.

Conclusion: Galvanic corrosion is not a concern.

n Cavitation
None expected.

Conclusion: Cavitation is not a concern.

o Creep
The temperatures are too low to be a concern.

Conclusion: Not applicable.

p Cold Work
Testing performed by Atteridge (2002) of type 304L and 316L pipe with three diameter bends and ~ 17 % cold work in simulated WTP cleaning conditions showed no SCC. Smaller diameter cold bends are not used for WTP piping. Neither accelerated corrosion, nor SCC, is expected in operation due to high pH conditions.

Conclusion: Type 316L is acceptable.

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q Inadvertent Nitric Acid Addition

Higher chloride contents and higher temperatures usually require higher alloy materials. Nitrate ions inhibit the pitting and crevice corrosion of stainless alloys. Furthermore, nitric acid passivates these alloys; therefore, lower pH values brought about by increases in the nitric acid content of process fluid will not cause higher corrosion rates for these alloys. The upset condition that was most likely to occur is lowering of the pH of the vessel content by inadvertent addition of 0.5 M nitric acid. Assuming that a heel is remaining in the vessel when a quantity of 0.5 M nitric acid is added and assuming that the quantity added is sufficient to drive the pH to neutral or up to the volume of nitric acid available, the composition of the waste would be sufficiently diluted as to make the drop in pH not a concern.

Conclusion: The recommended materials will be able to withstand a plausible inadvertent addition of 0.5 M nitric acid.

Off-Normal Operating Modes

Any loss of power is assumed to be < 72 hours and the time to heat up is slow. Therefore, the durations of off-normal operations are assumed to be short (< 36 hours). Therefore, more rapid corrosion at temperatures up to 240°F is minimized.

Vessel cleaning with nitric acid is permitted only after an initial water rinse.

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References:

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2. 24590-WTP-RPT-M-04-0008, Rev. 2, *Evaluation Of Stainless Steel Wear Rates In WTP Waste Streams At Low Velocities*
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20. WTP Prime Contract No. DE-AC27-01RV14136, Section C, *Statement of Work,* Modification No. M033, Specification 7.2.2.1.

Bibliography:

1. Blackburn, LD to PG Johnson, Internal Memo, Westinghouse Hanford Co, Evaluation of 240-AR Chloride Limit, August 15, 1991.
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CORROSION EVALUATION

PROCESS CORROSION DATA SHEET

Component(s) (Name/ID #) Waste feed receipt vessel (FRP-VSL-00002A/B/C/D)

Facility PTF

In Black Cell? Yes

Chemicals	Unit[1]	Contract Max		Non-Routine		Notes
		Leach	No leach	Leach	No Leach	
Aluminum	g/l	9.79E+01	7.25E+01			
Chloride	g/l	4.24E+01	3.14E+01			
Fluoride	g/l	5.08E+01	3.76E+01			
Iron	g/l	2.34E+01	1.74E+01			
Nitrate	g/l	6.83E+02	5.06E+02			
Nitrite	g/l	2.34E+02	1.73E+02			
Phosphate	g/l	1.67E+02	1.23E+02			
Sulfate	g/l	9.00E+01	6.66E+01			
Mercury	g/l	9.26E-02	6.86E-02			
Carbonate	g/l	2.57E+02	1.91E+02			
Undissolved solids	wt%	4.60%	3.92%			Note 4
Other (NaMnO4, Pb,...)	g/l					
Other	g/l					
pH	N/A					Note 2
Temperature	°F					Note 3

List of Organic Species:

References

System Description: 24590-PTF-3YD-FRP-00001, Rev 0
Mass Balance Document: 24590-WTP-M4C-V11T-00005, Rev A
Normal Input Stream #: FRP01, FRP02
Off Normal Input Stream # (e.g., overflow from other vessels): N/A
P&ID: N/A
PFD: 24590-PTF-M5-V17T-00003, Rev 1
Technical Reports: N/A

Notes:

1. Concentrations less than 1x 10^{-4} g/l do not need to be reported; list values to two significant digits max.
2. Feed will be basic with pH of 13.8 expected to be the nominal received from tank farms.
3. T operation 60 °F to 120 °F (24590-PTF-MVC-FRP-00001, Rev 0; 24590-PTF-MVD-FRP-00006; 24590-PTF-MVD-FRP-00007, Rev 5; 24590-PTF-MVD-FRP-00008, Rev 5)
4. FRP vessels will only accept feed from Tank Farms that is below 5 % solids.

Assumptions:

4.5.1 Waste Feed Receipt Vessel (FRP-VSL-00002A/B/C/D)

Routine Operations

The four waste feed receipt vessels are primarily used to receive waste feed from the Tank Farms and transfer the waste to either the ultrafiltration feed preparation vessels (UFP-VSL-00001A/B) or the waste feed evaporator feed vessels (FEP-VSL-00017A/B). The waste feed receipt vessels (FRP-VSL-00002A/B/C/D) can accept Tank Farm waste at a temperature range of 55 °F to 120 °F with a solids content below 5 wt %. These parameters will be confirmed before the transfer. Tank Farm waste that has a temperature or solids content above these criteria will be sent to the HLW feed receipt vessel (HLP-VSL-00022) because it has a cooling jacket.

Non-Routine Operations that Could Affect Corrosion/Erosion

None identified.