24590-PTF-N1D-UFP-00009
Rev. 2

CORROSION EVALUATION

UFP-HX-00001A/B (PTF)
UFP Slurry Cooler

- Design Temperature (max/min) (°F): Hot side: 230/32; Cold side: 230/32
- Design Pressure (max/min) (psig): Hot side: 312/0; Cold side: 388/0
- Location: Room P-0123; hot cell

Contents of this document are Dangerous Waste Permit affecting

Operating conditions are as stated on attached Process Corrosion Data Sheet

Operating Modes Considered:

- Normal operations under the stated conditions
- Operating temperature will remain below 140 °F
- Solids will be flushed after each use
- Constant water flow shall be maintained when not in use to prevent dry-out

Materials Considered:

Material (UNS No.)	Acceptable Material	Unacceptable Material
Type 304L (S30403)	X	
Type 316L (S31603)	X	
6% Mo (N08367/N08926)	X	
Hastelloy® C-22® (N06022)	X	

Recommended Material: Type 304 (max 0.030% C; dual certified)

Recommended Corrosion Allowance: Hot side (slurry): 0.040 inch (includes 0.024 corrosion allowance and 0.016 erosion allowance);

Cold side (water): 0.040 inch (includes 0.024 corrosion allowance and 0.004 erosion allowance)

Heat transfer surface: 0.040 inch erosion allowance (total)

Process & Operations Limitations:

- None

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Concurrence NA
Operations

REV	DATE	REASON FOR REVISION	PREPARER	CHECKER	MET	APPROVER
2	10/18/10	Modify heat trans. surface CA Modify text sect c Modify text sect f Modify text sect j	DLAdler	RBDavis	NA	SWVail
1	7/13/10	Incorporate revised PCDS Flushing info and weld req'ts Add AEA notice Update design temp/pressure Expand sec j – Erosion Minor edit and format changes	DLAdler	RBDavis	NA	SWVail
0	3/14/05	Initial Issue	DLAdler	APRangus	APR	SWVail

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Corrosion Considerations:

This heat exchanger performs a dual function of cooling the contents of vessel UFP-VSL-00002A/B from 113 °F to 77 °F and maintaining the temperature of vessel contents at 77 °F by removing the heat input from pump UFP-PMP-00042A/B, UFP-PMP-000043A/B and the Pulse Jet Mixers using a recirculating loop. Maximum operating temperature is expected to be 113 °F. The corrosion evaluation assumes that waste will not be allowed to dry out and that waste is flushed from the channels after each batch or recirculation cycle, if the heat exchangers are used intermittently. The corrosion evaluation is also based on the use of reagent grade chemicals in the process.

a General Corrosion
Hamner (1981) lists a corrosion rate for Type 304 (and Type 304L) in NaOH of less than 20 mpy (500 µm/y) at 77°F and over 20 mpy at 122 °F. He shows Type 316 (and Type 316L) has a rate of less than 2 mpy up to 122°F and 50 % NaOH. Dillon (2000) and Sedriks (1996) both state that the 300 series are acceptable in up to 50 % NaOH at temperatures up to about 122 °F or slightly above. Davis (1994) states the corrosion rate for Type 304L in pure NaOH will be less than about 0.1 mpy up to about 212 °F though Sedriks states the data beyond about 122 °F are incorrect.

In this system, the normal pH and temperature are such that either Type 304L or Type 316L stainless steel will be acceptable for both the water side and the process side.

Conclusion:
At the stated concentrations of halides, either Type 304L or Type 316L stainless steel will be satisfactory.

b Pitting Corrosion
Chloride is known to cause pitting in acid and neutral solutions. Dillon (2000) is of the opinion that in alkaline solutions, pH>12, chlorides are likely to promote pitting only in tight crevices. Dillon and Koch (1995) are both of the opinion that fluoride will have little effect in an alkaline media. If the chloride concentrations are low at the low pH and high at the high pH, then even the low pH conditions are expected to be benign towards Type 304L. Revie (2000) and Uhlig (1948) note nitrate inhibits chloride pitting.

Normally the cooler is to operate between 77 and 113°F. At the normal temperature, based on the work of Zapp (2001) and others, Type 304L stainless steel would be acceptable in the proposed alkaline conditions.

If the exchanger were filled with process water and left stagnant, there would be a tendency to pit. The time to initiate would depend on the amount of residual chlorides.

Conclusion:
Based on the normal operating conditions, and because the system is maintainable, Type 304 is acceptable. Water flow should be maintained on the cold side.

c End Grain Corrosion
End grain corrosion only occurs in metal with exposed end grains and in highly oxidizing acid conditions.

Conclusion:
Not believed likely in this system.

d Stress Corrosion Cracking
The exact amount of chloride required to cause stress corrosion cracking is unknown. In part, this is because the amount varies with temperature, metal sensitization, and the environment. It is also unknown because chloride tends to concentrate under heat transfer conditions, by evaporation, and electrochemically during a corrosion process. Hence, even as little as a few ppm can lead to cracking under some conditions. Generally, as seen in Sedriks (1996) and Davis (1987), chloride stress corrosion cracking does not usually occur below about 140 °F. The use of "L" grade stainless steel reduces the opportunity for sensitization.

Neither Type 304L nor Type 316L are susceptible to stress corrosion cracking at the proposed conditions.

Conclusion:
With the given conditions, Type 304L is acceptable.

e Crevice Corrosion
Crevice corrosion is not anticipated on the alkaline process side. Because of the built-in crevices and operating temperatures, crevice corrosion is a potential concern on the water side.

Conclusion:
To minimize crevice corrosion, water flow should be maintained on the cold side.

f Corrosion at Welds
Corrosion at welds is not considered a problem in the proposed environment.

Conclusion:
Efforts should be made to minimize spacer welds. Otherwise, weld corrosion is not considered a problem for this system.

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g Microbiologically Induced Corrosion (MIC)
The proposed operating conditions are not conducive to microbial growth on the process side. The chilled water is treated to prevent MIC.

Conclusion:
MIC is not considered a problem.

h Fatigue/Corrosion Fatigue
Not expected to be a concern.

Conclusions:
Not a concern.

i Vapor Phase Corrosion
Not expected in this system.

Conclusion:
Not considered to be a concern.

j Erosion
Velocities within the coolers are expected to be low. Further, the particles are soft. Based on 24590-WTP-RPT-M-04-0008, a general erosion allowance of 0.016 inch is adequate for the slurry side with solids content less than 27.3 wt% and 0.004 inch is adequate for the water side with solids content less than 2 wt%. Therefore, a combined corrosion/erosion allowance of 0.040 inch on all wetted surfaces is adequate.

Conclusion:
Heat exchangers are designed to minimize expected erosion. Additionally, the heat exchangers are replaceable.

k Galling of Moving Surfaces
Not applicable.

Conclusion:
Not applicable.

l Fretting/Wear
No contacting surfaces expected.

Conclusion:
Not applicable.

m Galvanic Corrosion
No dissimilar metals are present.

Conclusion:
Not applicable.

n Cavitation
None expected.

Conclusion:
Not believed to be of concern.

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

Conclusion:
Not applicable.

p Inadvertent Addition of Nitric Acid
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 stream by inadvertent addition of 2 M nitric acid. Lowering of pH may make a chloride-containing solution more likely to cause pitting of stainless alloys. Increasing the nitric acid content of the process fluid adds more of the pitting-inhibiting nitrate ion to the process fluid. In addition, adding the nitric acid solution to the stream will dilute the chloride content of the process fluid.

Conclusion:
The recommended materials will be able to withstand a plausible inadvertent addition of 2 M nitric acid for a limited period.

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References:

1. 24590-WTP-RPT-ENG-07-007, Rev. 00A, *Process Stream Properties*
2. 24590-WTP-RPT-M-04-0008, Rev. 3, *Evaluation Of Stainless Steel Wear Rates In WTP Waste Streams At Low Velocities*
3. 24590-WTP-RPT-PR-04-0001, Rev. 0CC, *WTP Process Corrosion Data*
4. Davis, JR (Ed), 1987, *Corrosion, Vol 13*, In "Metals Handbook", ASM International, Metals Park, OH 44073
5. Davis, JR (Ed), 1994, *Stainless Steels*, In ASM Metals Handbook, ASM International, Metals Park, OH 44073
6. Dillon, CP (Nickel Development Institute), Personal Communication to J R Divine (ChemMet, Ltd., PC), 3 Feb 2000.
7. Hamner, NE, 1981, *Corrosion Data Survey*, Metals Section, 5th Ed, NACE International, Houston, TX 77218
8. Koch, GH, 1995, *Localized Corrosion in Halides Other Than Chlorides*, MTI Pub No. 41, Materials Technology Institute of the Chemical Process Industries, Inc, St Louis, MO 63141
9. Revie, WW, 2000. *Uhlig's Corrosion Handbook*, 2nd Edition, Wiley-Interscience, New York, NY 10158
10. Sedriks, AJ, 1996, *Corrosion of Stainless Steels*, John Wiley & Sons, Inc., New York, NY 10158
11. Uhlig, HH, 1948, *Corrosion Handbook*, John Wiley & Sons, New York, NY 10158
12. Zapp, PE, 2001, *Material Corrosion and Plate-Out Test of Types 304L and 316L Stainless Steel*, WSRC-TR-2000-00434, Savannah River Site, Aiken, SC

Bibliography:

1. 24590-PTF-MED-UFP-00005, *Mechanical Data Sheet - Spiral Plate Heat Exchanger*
2. Agarwal, DC, *Nickel and Nickel Alloys*, In: Revie, WW, 2000. *Uhlig's Corrosion Handbook*, 2nd Edition, Wiley-Interscience, New York, NY 10158
3. Jones, RH (Ed.), 1992, *Stress-Corrosion Cracking*, ASM International, Metals Park, OH 44073
4. Ohl, PC to PG Johnson, Internal Memo, Westinghouse Hanford Co, *Technical Bases for Cl- and pH Limits for Liquid Waste Tank Cars*, MA: PCO:90/01, January 16, 1990.
5. Van Delinder, LS (Ed), 1984, *Corrosion Basics*, NACE International, Houston, TX 77084
6. Wilding, MW and BE Paige, 1976, *Survey on Corrosion of Metals and Alloys in Solutions Containing Nitric Acid*, ICP-1107, Idaho National Engineering Laboratory, Idaho Falls, ID

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24590-WTP-RPT-PR-04-0001, Rev. CC
WTP Process Corrosion Data

PROCESS CORROSION DATA SHEET

Component(s) (Name/ID #) Ultrafiltration feed vessels (UFP-VSL-00002 A/B)
Ultrafilter (UFP-FILT-00001,2,3,4,5 A/B), Ultrafiltration pulse pot (UFP-PP-00001,2,3,A/B
Ultrafiltration Heat Exchanger (UFP-HX-00001A/B)

Facility PTF

In Black Cell? Yes (UFP-VSL-00002A/B only)

Chemicals	Unit	Contract Max[1]		Non-Routine		Notes
		Leach	No leach	Leach	No Leach	
Aluminum	g/L	3.61E+01	4.79E+01			
Chloride	g/L	1.20E+01	1.44E+01			
Fluoride	g/L	1.43E+01	1.72E+01			
Iron	g/L	1.69E+02	1.15E+02			
Nitrate	g/L	2.29E+02	2.63E+02			
Nitrite	g/L	6.66E+01	7.97E+01			
Phosphate	g/L	4.81E+01	5.63E+01			
Sulfate	g/L	2.56E+01	3.06E+01			
Mercury	g/L	1.18E+00	1.67E+00			
Carbonate	g/L	1.05E+02	1.06E+02			
Undissolved solids	wt%	25%	25%			
NaMnO4	g/L	1.00E+01				Note 3, Assumption 1
Other	g/L					Note 5, Note 6
pH	N/A					Note 2, Assumption 2
Temperature	°F					Note 4

List of Organic Species:

References
System Description: 24590-PTF-3YD-UFP-00001
Mass Balance Document: 24590-WTP-M4C-V11T-00005, Rev A
Normally Associated Streams: UFP04, UFP17, UFP39, UFP07
Off Normal Streams (e.g., overflow from other vessels): N/A
P&ID: N/A
PFD: 24590-PTF-M5-V17T-00032001, and -00032002
Technical Reports: N/A

Notes:
1. Data developed from a mass balance model which has constituents in the plant feed which are important to corrosion, adjusted to contract maximum values, except as noted.
2. pH of alkaline streams range from approximately 12 to 14.
3. $NaMnO_4$ is added for oxidative leaching, which is performed at a maximum temperature of 113 °F.
4. Direct injection of steam, below the surface of the vessel contents, is a normal operation.
* Maximum operating temperature is 194 °F (Basis of Design, page 6-6, 24590-WTP-DB-ENG-01-001, rev 1O), based on recommendation per page 25 of 24590-WTP-RPT-ENG-08-016, Rev 1.
5. 2 M nitric acid can be added as a part of normal operations for filter cleaning.
6. Antifoam reagent can be added as a part of normal operations for foam control.

Assumptions:
1. Maximum $NaMnO_4$ concentration is based on an estimated maximum Cr concentration in the solids and $NaMnO_4$ addition at 1.1 mole NaMnO4 per mole of Cr.
2. Maximum OH^- concentration of 170 g/L (10 molar OH), prior to heating, with a maximum temperature of 113 °F.
Maximum OH^- concentration of 120 g/L (7 molar OH) for the fully heated state, at the maximum vessel temperature (see Assumption 3).

* According to 24590-WTP-RPT-ENG-07-007, Process Stream Properties, the nominal operating temperature range for UFP-HX-00001A/B is 77 to 113 °F.