

CORROSION EVALUATION

ISSUED BY
APP-WTP PDC



HLP-VSL-00028 (PTF)

HLW Feed Blending Vessel

- Design Temperature (°F)(max/min): 237/40
- Design Pressure (psig) (max/min): 15/-8
- Location: incell
- PJM Discharge Velocity (fps): 40
- Drive Cycle: 14 % (at 40 fps)

Offspring Items

HLP-PJM-00076 – HLP-PJM-00083

Contents of this document are Dangerous Waste Permit affecting

Operating conditions are as stated on attached Process Corrosion Data Sheet

Options Considered:

- Normal operating conditions
- 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 protection is required as discussed in section j)

Process & Operations Limitations:

- Develop rinsing/flushing procedure for acid and water

Concurrence KW
Operations

REV	DATE	REASON FOR REVISION	PREPARER	CHECKER	MET	APPROVER
6	1/5/06	Update PJM and erosion info based on 24590-WTP-M0C-50-00004 Update wear allowance based on 24590-WTP-RPT-M-04-0008			NA	

CORROSION EVALUATION**REVISION HISTORY**

5	5/17/04	Addition of information regarding inadvertent nitric acid addition Append updated PCDS	DLAdler	APRangus	NA	SWVail
4	5/11/04	Revised to incorporate new PCDS	DLAdler	JRDivine	NA	APRangus
3	12/24/03	Update design temp Add PJM info	DLAdler	JRDivine	NA	APRangus
2	9/25/03	Update assoc. items DCA#24590-PTF-DCA-M-02-006 REV. 0 Expand erosion comments Modify reference page Editorial changes	DLAdler	JRDivine	NA	A.P. Rangus
1	11/21/02	Update design temp/pressure Update format Append updated MSDS Add DWP note Remove reference to open issues Minor editorial changes	DLAdler	JRDivine	NA	SWVail
0	3/19/02	Initial Issue	DLAdler	JRDivine	SS	BPosta
REV	DATE	REASON FOR REVISION	PREPARER	CHECKER	MET	APPROVER

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Corrosion Considerations:

In this vessel, treated solids may be blended with various HLW wastes; including Sr/TRU precipitate slurries and Cs concentrates recovered from the LAW treatment process and possibly treated Cs/Sr slurry from the Hanford Cs/Sr capsules.

a General Corrosion

Hamner (1981) lists a corrosion rate for 304 (and 304L) in NaOH of less than 20 mpy (500 $\mu\text{m}/\text{y}$) at 77°F and over 20 mpy at 122°F. He states 316 (and 316L) has a rate of less than 2 mpy in 50% NaOH at temperatures up to 122°F. Dillon (2000) and Sedriks (1996) both state that the 300 series are acceptable in up to 50% NaOH at temperatures of about 122°F. Davis (1987) states the corrosion rate for 304L in pure NaOH will be less than about 1 mpy up to about 212°F though Sedriks states the data beyond about 122°F are incorrect. Danielson & Pitman (2000), based on short term studies, suggest a corrosion rate of about 0.5 mpy for 316L in simulated waste at boiling, >212°F. Divine (1986) showed that in simulated waste at 140°F, 304L, with a corrosion rate < 1 mpy, performed slightly better than 316L – possibly due to the presence of nitrate. In this system, the hydroxide concentrations and temperatures are such that 304L stainless steel will be acceptable. If the alkaline waste reaches boiling, Zapp's work (1998) suggests 304L would be acceptable, probably due to the presence of nitrate.

Wilding and Paige (1976) have shown that in 5% nitric acid with 1000 ppm fluoride at 290°F, the corrosion rate of 304L can be kept as low as 5 mpy by the use of Al^{+++} . Additionally, Sedriks (1996) has noted with 10% ($\approx 2\text{N}$) nitric acid and 3,000 ppm fluoride at 158°F, the corrosion rate of 304L is over 4,000 mpy. There is substantial Al^{+++} present. Therefore, there is little concern about excessive corrosion rates unless acid cleaning is planned. In that case, the vessel must be thoroughly flushed prior to the addition of acid to assure the fluoride is well diluted. Keeping the vessel at or below 122°F during acid cleaning would reduce the extent of attack by chloride (pitting and crevice corrosion). 304L will be marginally suitable if the stated temperature is maintained and if properly protected by fluoride complexants such as Al^{+++} . If acid conditions cannot be fully controlled, 316L is the minimum alloy suitable.

Conclusion:

Based on Zapp's work (1998), 304L is expected to be sufficiently resistant to the waste solution with a probable general corrosion rate of less than 1 mpy even to the design temperature. Because of the possibility of acid cleaning, in the presence of halides, 316L is the minimum alloy recommended.

b Pitting Corrosion

Chloride is known to cause pitting of stainless steel and related alloys in acid and neutral solutions. Dillon (2000) is of the opinion that in alkaline solutions, $\text{pH} > 12$, 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. Jenkins (2000) has stated that localized corrosion can occur under the waste deposits on heat transfer surfaces, probably due to the chlorides. Further, Revie (2000) and Uhlig (1948) note nitrate inhibits chloride pitting.

Normally the vessel is to operate between 50 and 122°F. At the normal temperature, based on the work of Zapp (1998) and others, 304L stainless steel would be acceptable in the proposed alkaline conditions at the upper pH values. The presence of solids and deposits mean that 316L is the lowest alloy recommended. If the duration of exposure to acidic conditions and lowered pH can be controlled, by proper flushing procedures, it will be feasible to use 316L stainless steel.

If the vessel were filled with process water and left stagnant, there would be a tendency to pit. The time to initiate would depend on the source of the water, being shorter for filtered river water, which tends to be dirtier, and longer for DIW. Pitting has been observed in both cases, and is likely because residual chlorides are likely to remain and to concentrate.

Conclusion:

Based on the expected operating conditions, 316L is expected to be satisfactory.

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, but also because chloride tends to concentrate under heat transfer conditions, by evaporation, and electrochemically during a corrosion process. Hence, even as little as 10 ppm can lead to cracking under some conditions. Generally, as seen in Sedriks (1996) and Davis (1987), stress corrosion cracking does not usually occur below about 140°F. With the stated low operating temperature and alkaline conditions, 304L is expected to be satisfactory. However, because acid cleaning could be used, and because the operating temperature is at the upper end of the acceptable range, 316L will be the minimum acceptable alloy.

Conclusion:

The minimum alloy recommended is a 316L stainless steel.

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e Crevice Corrosion

See Pitting.

Conclusion:

See Pitting

f Corrosion at Welds

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

Conclusion:

Weld corrosion is not considered a problem for this system.

g Microbiologically Induced Corrosion (MIC)

The proposed operating conditions are not conducive to microbial growth – the temperature is approximately correct but the pH is generally too alkaline. The use of process water may be a concern and untreated process water should not be used.

Conclusion:

MIC is not considered a problem.

h Fatigue/Corrosion Fatigue

Corrosion fatigue is a not expected to be a problem.

Conclusions

Not a concern.

i Vapor Phase Corrosion

The vapor phase portion of the vessel is expected to be contacted with particles of waste from splashing. Since solids will possibly be present and acid wash is likely, 316L is recommended.

Conclusion:

Vapor phase corrosion is not a concern.

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%. 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 26.46 wt% for a usage of 100 % operation as documented in 24590-WTP-MOC-50-00004. HLP-VSL-00028 requires at least 0.434-inch additional protection. The 26.46 wt% is considered to be conservative and is based on the WTP Prime Contract maximum. During normal operation, the solids content of HLP-VSL-00028 is expected to be well below the anticipated maximum.

The wear of the PJM nozzles can occur from flow for both the discharge and reflood cycles of operation. At least 0.290-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 26.46 wt% for usage of 100 % operation as documented in 24590-WTP-MOC-50-00004.

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

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.

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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 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. 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 0.5 M nitric acid for a limited period.

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References:

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Bibliography:

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3. CCN 130174, Divine, J. R. and W. C. Carlos, 1992, *Assessment of Known Degradation and Existing Corrosion Studies on Steel*, Presented at the High-Level Waste Tank Systems Structural Integrity Workshop, February 19-20, 1992, Richland, Washington
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CORROSION EVALUATION

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

PROCESS CORROSION DATA

Component(s) (Name/ID #) HLW lag storage vessel (HLP-VSL-00027A/B,-00028)Facility PTFIn Black Cell? Yes

Chemicals	Unit ¹	Contract Max		Non-Routine		Notes
		Leach	No leach	Leach	No Leach	
Aluminum	g/l	1.71E+01	5.30E+01			
Chloride	g/l	4.51E+00	5.02E+00			
Fluoride	g/l	5.36E+00	5.98E+00			
Iron	g/l	1.88E+02	1.27E+02			
Nitrate	g/l	4.93E+02	4.84E+02			
Nitrite	g/l	2.48E+01	2.77E+01			
Phosphate	g/l	1.80E+01	1.96E+01			
Sulfate	g/l	9.58E+00	1.06E+01			
Mercury	g/l	1.31E+00	1.83E+00			
Carbonate	g/l	3.36E+01	3.43E+01			
Undissolved solids	wt%	26.7%	26.3%			
Other (NaMnO ₄ , Pb,...)	g/l					
Other	g/l					
pH	N/A					Note 3
Temperature	°F					Note 2
List of Organic Species:						
References						
System Description: 24590-PTF-3YD-HLP-00001, Rev 0						
Mass Balance Document: 24590-WTP-M4C-V11T-00005, Rev A						
Normal Input Stream #: CNP12, UFP07, HLP09						
Off Normal Input Stream # (e.g., overflow from other vessels): N/A						
P&ID: N/A						
PFD: 24590-PTF-M5-V17T-00006, 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. T operation HLP-VSL-00027A/B: 50 °F to 113 °F (24590-PTF-MVC-HLP-00002, Rev 0); T operation HLP-VSL-00028: 50 °F to 122 °F (24590-PTF-MVC-HLP-00009, Rev 0)						
3. pH can range from approximately 12 to 14						
Assumptions:						

CORROSION EVALUATION24590-WTP-RPT-PR-04-0001, Rev B
WTP Process Corrosion Data**4.6.4 HLW Feed Blend Vessel (HLP-VSL-00028)****Routine Operations**

Prior to immobilization in the HLW vitrification facility, the treated solids may be blended with a diversity of HLW wastes. These HLW wastes include Sr/TRU precipitate slurries and Cs concentrates recovered from the LAW treatment process. There will also be the option to blend treated Cs/Sr slurry from the Hanford Cs/Sr capsules. HLW feed blending will occur primarily in vessel HLP-VSL-00028. HLW feed blending depends on feed delivery scheduling and the stage of processing at the time of blending. Contractual limitations of heat duty on vessel HLP-VSL-00028 may restrict the additions of some intermediary products such as Cs concentrate and Sr/TRU precipitate slurries. This will be quantified through sampling prior to transfer to the HLW vitrification facility. The HLW feed blend vessel is fitted with two HLW meter feed pumps, HLP-PMP-00019A/B. One pump is used as a back-up pump during repair and maintenance.

Non-Routine Operations that Could Affect Corrosion/Erosion

Limitations of heat duty on the HLW blended feed may restrict the addition of some intermediate products. Cs concentrate contains considerable amounts of radiolytic cesium isotopes. These isotopes generate high heat duties from radiolytic decay. Contractual limitations for heat duties of 1500 W per canister of IHLW restrict the amount of Cs concentrate that may be blended. Moreover, to minimize the production of IHLW glass, limitations on the addition of Sr/TRU precipitate is required.