CORROSION EVALUATION

ISSUED BY
RPP-WTP PDC

LVP-SCB-00001
LAW Melter Offgas Caustic Scrubber

Contents of this document are Dangerous Waste Permit Affecting

Results

Materials Considered

Materials Considered (UNS No.)	Acceptable Materials
Type 304L (S30403)	
Type 316L (S31603)	X (temp less than 200 °F)
Al-6XN® 6% Mo (N08367)	X
Hastelloy® C-22® (N06022)	X (temp above 200 °F)
Hastelloy® C-276 (UNS N10276)	X (temp above 200 °F)

Recommended Material Types:

Top head/Upper shell – Type 316 (max 0.030% C; dual certified)

Lower shell/Bottom head -- Hastelloy® C-276 (UNS N10276) or Hastelloy® C-22® (UNS N06022)

Nozzles (high temp region) – Hastelloy® C-276 (UNS N10276) or Hastelloy® C-22® (UNS N06022)

Internal hardware – Type 316 (max 0.030% C; dual certified) above the packing; Hastelloy® C-276 or C-22® in or below the packing (temp greater than 200 °F)

Packing – Higher alloy materials are recommended for packing to increase the period between replacement (Hastelloy® C-276 or C-22®)

Mist eliminators (demisters) – The unit contains non-metallic mist eliminators. The fiber media will be selected to provide longevity, optimal operation, and maximum efficiency. The mist eliminators will be monitored during operation and are expected to require maintenance and replacement during the 40-year life of the plant.

The scrubber has a high temperature (higher than 200 °F) region in or below the packing and a lower temperature region above the packing. At a minimum either Hastelloy® C-276 or C-22® is recommended for the high temperature region. Type 316 (max 0.030% C; dual certified) is recommended for the lower temperature region.

Minimum Corrosion Allowance:

Vessel - 0.040 inch (includes 0.024 inch corrosion and 0.004 inch erosion allowance)
Internal hardware - 0.040 inch (includes 0.024 inch corrosion and 0.004 inch erosion allowance)
Packing & mist eliminator–Packing and mist eliminator are considered consumable and are designed to be replaced so no corrosion allowance is required.

Inputs and References

- Operating Temperature, gaseous (°F) (max/nom): 412/370 (24590-LAW-M4C-LOP-00001)
- Operating Temperature, aqueous (°F) (max/nom): 122 (24590-LAW-M4C-LOP-00001)
- Vessel general corrosion allowance (inch): 0.024 (24590-WTP-RPT-M-04-0008)
- Vessel general erosion allowance (inch): 0.004 (24590-WTP-M0C-50-00004)
- Consumable internals general corrosion allowance: None required (24590-WTP-GPG-M-047)
- Location: Room L-0304F; out cell (24590-LAW-P1-P01T-00005)
- Operating conditions are as stated in applicable section of the Process Corrosion Data report (24590-WTP-RPT-PR-04-0001-04)

REV	DATE	REASON FOR REVISION	ORIGINATE	CHECK	REVIEW	APPROVE
7	07/30/15.	Modifications to text throughout to amplify material selection discussion. Modified Corrosion/Erosion Detailed Discussion section to better describe component and operations. Removed "Internal Housing" CA. Removed items under "Assumptions. Added design limit table for alloys C-22 and C-276. Expand material selection information and references to address ORP and Ecology comments. No modifications to recommended material; no change to margin.	DLAdler	Checked By: A. Rangus - aprangus Org Name: Bechtel Placed: Jul 30, 2015, 12:28 pm TRangus	RBDavis	~~TErwin~~ J.S. LEAM. JSL 07.3.15

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Assumptions and Supporting Justifications (see References, Section 19)

- Operating conditions presented on the PCDS are conservative with respect to corrosion.[11]
- The PCDS states that the scrubber solution pH can be raised to 14 when high halide concentrations are measured in the scrubber bottom (Ref. 11, Section 6.6.3.1.14 included on page 13 of this document). While operating at pH 14 would not be deleterious to the scrubber materials of construction, such operations would significantly reduce the efficiency of the operations of the scrubber.[5] This statement will be removed from the PCDS at the next revision.
- The scrubber has provisions for process water addition during startup and to provide makeup water as necessary. A spray wash nozzle is also provided for wash down during maintenance periods.

Operating Restrictions

- To protect against localized corrosion in the vessel and transfer piping, develop procedure to bring the vessel aqueous contents within the limits defined for Type 316L in 24590-WTP-RPT-M-11-002, *WTP Materials Localized Corrosion Design Limits,* in the event that sampling indicates that temperature, pH, or chloride concentration exceeds those limits.
- Develop a work process to control, at a minimum, cleaning, rinsing, and flushing of vessel and internals, as applicable.
- Develop work process to control lay-up and storage; including during plant startup and during periods while the component is not in use once plant is operational.
- Procedures and work processes are to be reviewed and accepted by MET prior to use.

Concurrence KG
Operations

REVISION HISTORY

REV	DATE	REASON FOR REVISION	PREPARER	CHECKER	MET	APPROVER
6	4/28/15	Complete re-write; no rev bars shown New format Incorporate revised PCDS Update references	DLAdler	TRangus	RBDavis	TErwin
5	9/25/13	Incorporate revised design temperature/pressure Incorporate revised PCDS Editorial changes Changes do not reduce margin	DLAdler	RBDavis	NA	MWHoffmann
4	9/25/12	Incorporate revised PCDS Identify internals CA Extensive re-write; no rev bars shown Addt'l Ops Limitation AEA Notice Update references	DLAdler	RBDavis	NA	DJWilsey
3	8/31/06	Update design temperature based on revised Mechanical Data Sheet Revise to require either Hastelloy C-276, or C-22, in place of Inconel 600 with stress relief heat treatment Remove section p Update wear allowance based on 24590-WTP-RPT-04-0008	DLAdler	HMKrafft	NA	SWVail
2	6/24/04	Incorporate new PCDS Clarify material recommendations for nozzles New section p – Inadvertent Addition of Nitric Acid	DLAdler	JRDivine	NA	APRangus
1	3/22/04	Update vessel description Update design temp/pressure Include material recommendation for nozzles and interior Remove reference to open issues Add DWP note	DLAdler	JRDivine	APR	APRangus
0	3/6/02	Initial Issue	JRDivine	DLAdler	NA	SMKirk

Please note that source, special nuclear and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA), are regulated at the U.S. Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts, that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

This bound document contains a total of 15 sheets.

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Corrosion/Erosion Detailed Discussion

The LAW Melters Offgas Caustic Scrubber is the final offgas abatement equipment in the secondary offgas treatment system. At this point in the process, the offgas is relatively clean as it has been processed through several stages of chemical and radiological abatement. In the Caustic Scrubber, high temperature offgas enters the scrubber near the bottom of the vessel. Four spray lances atomize water and spray it into the path of the incoming hot offgas. The majority of this spray is evaporated as it cools the incoming offgas. The offgas then flows vertically up through the vessel, through packing and mist eliminators, to the discharge near the top of the vessel. Countercurrent to this offgas flow, a high flow of scrubber solution is introduced above the vessel packing. This solution is broken into droplets that "rain" down through the packing, to the bottom of the scrubber. The countercurrent scrubber solution flow provides additional cooling and removes additional acid gasses that may be present in the offgas stream. The aggressive constituents of concern are chlorides, fluorides, and SOx. The pH of the caustic solution will be maintained nominally at 9.5 through the addition of sodium hydroxide. The corrosion evaluation assumes all surfaces are wetted and that the scrubber solution flows through the packing, including the vessel side walls, to the bottom drain nozzle and out to the collection vessel for caustic addition prior to being pumped back into the scrubber above the packing.

Although rough estimates indicate the concentrations are well within the ability of the austenitic stainless steels, a high nickel alloy is recommended for the packing. The packing and the mist eliminator are designed to be periodically washed with water and ultimately replaced when the performance becomes degraded and cleaning is no longer effective. No corrosion allowance is required for the packing and mist eliminator (24590-WTP-GPG-M-047, *Design Guide: Preparation of Corrosion Evaluations*). The gas stream is not expected to contain solids, so sediment is not expected to accumulate on the bottom.

The evaluation of the upper portion of the scrubber is based on the temperature of the recirculated scrubber solution, 122 °F. According to the Mechanical Datasheet, 24590-LAW-MKD-LVP-00011, the temperature at Nozzle N06, the packing wash inlet, is expected to have a maximum temperature of 212 °F. It should be noted that the maximum temperature of the process service water received at N06 is 95 °F (24590-LAW-M6WX-LVP-00002002, *MS Line List for P&ID 24590-LAW-M6-LVP-00002002*).

1 General/Uniform Corrosion Analysis

a Background

General corrosion or uniform corrosion is corrosion that is distributed more-or-less uniformly over the surface of a material without appreciable localization. This leads to relatively uniform thinning on sheet and plate materials and general thinning on one side or the other (or both) for pipe and tubing. It is recognized by a roughening of the surface and usually by the presence of corrosion products. The mechanism of the attack typically is an electrochemical process that takes place at the surface of the material. Differences in composition or orientation between small areas on the metal surface create anodes and cathodes that facilitate the corrosion process.

b Component-Specific Discussion

The scrubber is exposed to one offgas stream (LVP09) and one main fluid stream (LVP17) during normal operations. In this system, the pH of 9.5 and temperature of 122 °F indicate that Type 304L, Type 316L and higher alloys (including Hastelloy® C-22® and C-276) will be acceptable for most of the component. The maximum temperature at the scrubber bottom (412 °F) is such that either Hastelloy® C-276 or C-22® is recommended as a minimum for the lower shell. For Type 316L and the higher alloys, the expected uniform corrosion rate for 40 years, based upon a conservative value of 0.6 mpy, is 0.024 inches (24590-WTP-RPT-M-04-0008, *Evaluation Of Stainless Steel and Nickel Alloy Wear Rates In WTP Waste Streams At Low Velocities*). Dillon (2000) and Sedriks (1996) both state that the 300 series stainless steels are acceptable in up to 50% NaOH at temperatures up to about 122°F or slightly above. The usual corrosion rate for Type 304L in pure NaOH will be less than about 1 mpy up to about 212°F; although Sedriks states that the data beyond about 122°F are incorrect due to the presence of oxidizer contaminants, such as those contained in the waste.

2 Pitting Corrosion Analysis

Pitting is localized corrosion of a metal surface that is confined to a point or small area and takes the form of cavities. Chloride is known to cause pitting in acid and neutral solutions. The aqueous portion of the vessel is to operate at about 122 °F at a pH of 9 to 9.5, based on receipt of caustic scrubber solution recirculated from LVP-TK-00001. Pitting is not expected over the range of temperature and with water at a pH greater than 5. Long periods of stagnant conditions and no flow shall be avoided; procedures should be developed to ensure that materials are not compromised. If the vessel walls were wetted and left stagnant and the acid gas components concentrate by evaporation, there would be a tendency to pit. An operation limitation is provided to reduce the likelihood of corrosion initiation. According to section 6.3 of 24590-WTP-3YD-PSW-00001, *System Description for the Process Service Water System (PSW)*, water provided by the process service water (PSW) system is monitored for pH, chlorine concentration, and temperature.

The expected aqueous chemistry and temperature in this vessel fall within the limits for localized corrosion established for Type 316L in Table 1-2 and the limits for Hastelloy® C-22® (or C-276) in Table 1-4 of 24590-WTP-RPT-M-11-002, *WTP Materials Localized Corrosion Design Limits* report. Type 316L is not suitable for the expected gaseous temperatures above 200 °F that could exist in the bottom of the vessel below the packing. For the region that exceeds 200 °F, Hastelloy® C-276 or C-22® is recommended.

3 Crevice Corrosion Analysis

Crevice corrosion is a form of localized corrosion of a metal or alloy surface at, or immediately adjacent to, an area that is shielded from full exposure to the environment because of close proximity of the metal or alloy to the surface of another material or an adjacent surface of the same metal or alloy. Crevice corrosion is similar to pitting in mechanism; however, it can be initiated at lower temperatures. All welding uses butt welds and crevices in this vessel are limited by design and fabrication practice. There are no designed crevices in the pressure boundary; however, the packing, support structure and demister section have numerous crevices due to the crisscross "egg crate" design of the structure packing and the use of spot welds, which tend to create numerous crevices. The caustic scrubber design allows for the replacement of the packing. With the stated operating conditions, Type 316L is acceptable for the vessel pressure boundary above the packing. The packing is recommended to be fabricated using a higher nickel alloy which has greater crevice corrosion resistance.

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The expected aqueous chemistry and temperature in this vessel fall within the limits established for Type 316L in Table 1-2 of 24590-WTP-RPT-M-11-002 and the limits for Hastelloy® C-22® (or C-276) in Table 1-4 of 24590-WTP-RPT-M-11-002. Type 316L is not suitable for the expected high temperature gaseous conditions and is only recommended for the top head and shell. For the region that exceeds 200 °F, Hastelloy® C-276 or C-22® is recommended because the nickel-based alloys will perform better than AL-6XN®, Type 304L, and Type 316L in the high temperature conditions.

4 Stress Corrosion Cracking Analysis

Stress corrosion cracking (SCC) is the cracking of a material produced by the combined action of corrosion and sustained tensile stress (residual or applied). The exact amount of chloride required to cause SCC in alkaline solutions is unknown. In part, this is because the amount varies with temperature, metal sensitization, the environment, and also because chloride tends to concentrate under heat transfer conditions by evaporation, and electrochemically during a corrosion process. Generally, as seen in Sedriks (1996) and Davis (1987), stress corrosion cracking does not usually occur below about 140°F for sensitized alloys. With the proposed normal conditions, Type 304L and Type 316L are not expected to become sensitized. Therefore, SCC is not expected.

In the region of the scrubber where there is potential for high temperature, presence of acid gases, and the potential use of acid for cleaning, Hastelloy® C-276 or C-22® offer resistance to corrosion both at low pH from acid gas and high pH from the sodium hydroxide. These conditions fall within the design limits established for alloy C-22® in Table 1-4 of 24590-WTP-RPT-M-11-002. Further up the side walls when the temperature cools, the expected aqueous chemistry and temperature in this vessel fall within the limits established for Type 316L in Table 1-2 of 24590-WTP-RPT-M-11-002.

5 End Grain Corrosion Analysis

End grain corrosion is preferential aqueous corrosion that occurs along the worked direction of wrought stainless steels exposed to highly oxidizing acid conditions. End grain corrosion typically is not a major concern, it propagates along the rolling direction of the plate, not necessarily through the cross sectional thickness. In addition, end grain corrosion is exclusive to metallic product forms with exposed end grains from shearing or mechanical cutting. Conditions which lead to end grain corrosion are not present in this component; therefore, end grain corrosion is not a concern.

6 Weld Corrosion Analysis

The welds used in the fabrication will follow the WTP specifications and standards for quality workmanship. The materials selected for this fabrication are compatible with the weld filler metals and ASME/AWS practice. Using the welding practices specified for the project there should not be gross micro-segregation, precipitation of secondary phases, formation of unmixed zones, or volatilization of the alloying elements that could lead to localized corrosion of the weld. Assuming that correct weld procedures are followed, no preferential corrosion of weld beads or heat-affected zones occurs in the expected aqueous chemistry and temperature.

7 Microbiologically Influenced Corrosion Analysis

Microbiologically influenced corrosion (MIC) refers to corrosion affected by the presence or activity, or both, of microorganisms. Typically, with the exception of cooling water systems, MIC is not observed in operating systems. The proposed operating conditions are not conducive to microbial growth; the inlet temperature is too high, and the pH is generally too high. Rinsing with untreated process water may be a concern; the use of DIW is recommended. Conditions which lead to MIC are not present in this vessel.

8 Fatigue/Corrosion Fatigue Analysis

Corrosion-fatigue is the result of the combined action of cyclic stresses and a corrosive environment. The fatigue process is thought to cause rupture of the protective passive film, upon which stainless steel can actively corrode in the localized area of the film rupture. The corrosive environment may also act to reduce the stress necessary for film rupture. The result is that a metal exposed to a corrosive environment and cyclic mechanical load may initiate cracking at conditions at stress levels less than the endurance limit for the material.

The caustic scrubber is not cyclically operated; offgas flow is constant, steady and dry. Thermal cycles and therefore thermal stress is also low and associated with the start-up and shut down of the off gas system; according to the *LAW, BOF, and LAB VESSEL Cyclic Datasheet Inputs*, 24590-WTP-MVC-50-00009, the component is expected to experience 4200 thermal cycles during the design life. Based on the low mechanical and thermal cycling, corrosion fatigue will not be observed in the scrubber.

9 Vapor Phase Corrosion Analysis

Conditions in the vapor phase and at the vapor/liquid interface can be significantly different than those present in the liquid phase. The entire vessel that is exposed to the offgas vapor phase will be periodically flushed. Type 316L is the minimum alloy acceptable for this service in the low temperature region, while alloy C-22® or C-276 is suitable for the high temperature region.

In alkaline conditions, vapor-phase corrosion in Type 316L is less than 0.001 mpy and corrosion rates in C-22, C-276 and other nickel-based alloys are shown to be lower (Rozeveld and Chamberlain).

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10 Erosion Analysis

Erosion is the progressive loss of material from a solid surface resulting from fluid flow. The material loss is caused by mechanical interaction between the surface and the fluid, as the velocity increases the material loss increases. When the fluid contains a second phase, "two phase solution", erosion rates increase rapidly. The second phase material can be solid particles like sand or air/steam bubbles. WTP is more concerned with the solid particle impingement; the solid particles are generally oxides of waste.

Velocities within the vessel are not expected to be high. Erosion allowance of 0.004 inch for components with low solids content (< 2 wt %) at low velocities is based on 24590-WTP-RPT-M-04-0008. The recommended general erosion wear allowance provides sufficient protection for erosion of the vessel walls.

11 Galling of Moving Surfaces Analysis

Galling is a form of wear caused by a combination of friction and adhesion between moving surfaces. Under high compressive forces and movement, the friction temperatures cold-weld the two surfaces together at the surface asperities. As the adhesively bonded surface moves, some of the bonded material breaks away. Microscopic examination of the galled surface shows some material stuck or even friction-welded to the adjacent surface, while the softer of the two surfaces appears gouged with balled-up or torn lumps of material stuck to its surface.

Galling is commonly found in metal surfaces that are in sliding contact with each other. It is especially common where there is inadequate lubrication between the surfaces. Although the internal packing can move, the distance is minimized because the packing fill is placed in a fixed structure. The structure holds the packing together, maintaining the spacing for the maximum efficiency. The sliding distance is negligible and therefore the galling is minimal. Conditions which lead to galling are not present in this vessel; therefore galling is not a concern.

12 Fretting/Wear Analysis

Fretting corrosion refers to corrosion damage caused by a slight oscillatory slip between two surfaces. Similar to galling but at a much smaller movement, the corrosion products and metal debris break off and act as an abrasive between the surfaces, producing a classic three-body wear problem. This damage is induced under load and repeated relative surface motion, as induced for example by vibration. Pits or grooves and oxide debris characterize this damage. Conditions which lead to fretting are not present in this vessel; therefore fretting is not a concern.

13 Galvanic Corrosion Analysis

Galvanic corrosion is an electrochemical process in which one metal corrodes preferentially to another when both metals are in electrical contact, in the presence of an electrolyte. Dissimilar metals and alloys have different electrode potentials, and when two are in contact in an electrolyte, one metal acts as anode and the other as cathode. The electropotential difference between the dissimilar metals is the driving force for an accelerated attack. A potential difference far more than 200 mv is needed for sufficient driving force to make a difference. Galvanic compatibility is one of the attributes used to select the WTP alloys. Austenitic stainless steels in contact with other austenitic stainless steels do not have sufficient electropotential difference to significantly influence the metal loss. The potential difference for any combination of bi-metal couple between austenitic stainless steels Type 304L, Type 316L, 6% Mo alloys, and the nickel alloys is not sufficient for galvanic currents to cause corrosion. For such alloys, there is negligible potential difference in the aqueous chemistry so galvanic corrosion is not a concern for this component.

14 Cavitation Analysis

Cavitation corrosion is defined as another synergistic process, the combined influence of mechanical disruption of the metal surface and the corrosion of the active metal. Cavitation occurs when the local fluid pressure drops below the vapor pressure of the fluid resulting in a liquid vapor interface or bubbles to form. Their collapse on the metal surface has sufficient energy to rupture the oxide film and depending on alloy, may be capable of removing metal. The fluid chemistry and alloy define corrosion characteristics of the oxide film; however, localization of the cavitation produces a condition where the bubble collapse rate is greater than the ability to passivate, the normally passive alloy can experience accelerated loss. WTP design limits conditions which lead to cavitation; therefore cavitation is not a concern.

15 Creep Analysis

Creep is defined as a time-dependent deformation at elevated temperature and constant stress, creep is a thermally activated process. Creep is found in components subjected to heat for long periods and the creep rate generally increases as the temperature nears the melting point. The temperature at which creep begins depends on the alloy composition. Conditions which lead to creep are not present in this component; therefore creep is not a concern. For alloy C-276, ASME Boiler & Pressure Vessel Codes (BPVC) Section II, Part D, has design allowables at greater than 800 °F, demonstrating that the creep temperature for alloy C-276 is higher than the maximum operating temperature of this component.

16 Inadvertent Nitric Acid Addition

At this time, the design does not provide for the presence of nitric acid reagent in this system.

17 Conclusion and Justification

Type 316L and 6% Mo are expected to be sufficiently resistant to the waste solution with a probable general corrosion rate of less than 1 mpy. For components potentially exposed to high temperatures, the material of construction is Hastelloy® C-276 or C-22®. Because the operation of the internal packing and mist eliminators will be monitored and replacement is expected, no corrosion allowance is required. A corrosion allowance in all other cases is 0.04 inch. Based on the expected operating conditions at high pH, Type 316L is expected to be satisfactorily resistant to localized corrosion and is suitable for the vessel upper shell (lower temperature region). In the region of the scrubber where there is potential of for high temperature, and the presence of acid gases, Hastelloy® C-276 or C-22® offer resistance to corrosion both at low pH from acid gas and high pH from the sodium hydroxide. Further up the side walls where the temperature cools, type 316L stainless steel is appropriate. Conditions which lead to end grain corrosion, weld corrosion, MIC, and creep are not present in this system. Conditions which lead to fatigue or corrosion fatigue, vapor phase corrosion, galling, fretting, galvanic corrosion, and cavitation are not present in this component by design.

The recommended corrosion allowance provides sufficient protection for erosion of the vessel wall.

18 Margin

The system is designed with a uniform corrosion allowance of 0.04 inch based on the range of inputs, system knowledge, handbooks, literature, and engineering judgment/experience. The service conditions used for materials selection has been described above and results in a predicted uniform loss due to corrosion and erosion of 0.028 inch. The specified minimum corrosion allowance (0.040 inch) exceeds the minimum required corrosion allowance (0.028 inch) thus establishing a design margin. The uniform corrosion design margin for the operating conditions is sufficient to expect 40 year operating life of the scrubber (excludes the packing and mist eliminators which are planned to be replaced over the life of the plant) and is justified in the referenced calculations.

Localized erosion of this component is not expected. Prior to reaching the caustic scrubber, the offgas passes through a variety of equipment that will render the inlet streams particulate free. Since localized erosion effects are not present, additional localized corrosion protection is not required.

The maximum operating parameters for this vessel are defined in the PCDS. As shown in the table below, the PCDS reported pH, chemistry, and temperature are bounded by the materials localized corrosion design limits. The aqueous normal operating constituent concentrations and operating conditions are within the range allowed in the *WTP Materials Localized Corrosion Design Limits* report. The difference between the design limits and the operating maximum (PCDS values) is the localized corrosion design margin and, based on the operating conditions, is sufficient to expect a 40 year operating life. The LAW Melter Offgas Caustic Scrubber, LVP-SCB-00001, is protected from localized corrosion (pitting, crevice, and stress corrosion cracking) by operating within the acceptable range of the design limits. Operational and process restriction will be used to ensure the limits are maintained.

MATERIALS LOCALIZED CORROSION DESIGN LIMITS – Type 316L			
	Temperature (°F)	**pH**	**Chloride (ppm)**
DESIGN LIMIT	**150 max**	**5 to 10**	**300 max**
Caustic scrub solution to LVP-TK-00001 (LVP17) Note 1	122	9.5	51
Inlet Vessels to LVP-SCB-00001	**Temperature (°F)**	**pH**	**Chloride (ppm)**
Caustic scrub solution from LVP-TK-00001 (LVP17) Note 2	122	9.5	51

MATERIALS LOCALIZED CORROSION DESIGN LIMITS – Hastelloy® C-22®			
		pH	**Chloride (ppm)**
DESIGN LIMIT		**5 to 10**	**30,000 max**
Caustic scrub solution to LVP-TK-00001 (LVP17) Note 1		9.5	51
Inlet Vessels to LVP-SCB-00001		**pH**	**Chloride (ppm)**
Caustic scrub solution from LVP-TK-00001 (LVP17) Note 2		9.5	51

The comparisons in these tables covers only the aqueous portion of the vessel. Offgas conditions were not evaluated in 24590-WTP-RPT-M-11-002, the source of the design limits. For the purposes of corrosion resistance, C-22® and C-276 alloys can be considered similar, and the same material localized corrosion design limits apply.

Notes:
1) LVP-SCB-00001 (aqueous) process stream LVP17 – 24590-WTP-RPT-PR-04-0001-04, Figure C-36
2) LVP-TK-00001 process stream LVP17 – 24590-WTP-RPT-PR-04-0001-04, Figure C-38

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19 References

1. 24590-LAW-M4C-LOP-00001, *LAW Melter Offgas System Design Basis Flowsheets.*
2. 24590-LAW-M6WX-LVP-00002002, *MS Line List For P&ID 24590-LAW-M6-LVP-00002002.*
3. 24590-LAW-MKD-LVP-00011, *24590-LAW-MK-LVP-SCB-00001 - LAW Melter Offgas Caustic Scrubber.*
4. 24590-LAW-P1-P01T-00005, *LAW Vitrification Building General Arrangement Plan at El. 48 Feet - 0 Inches.*
5. 24590-QL-POA-MKAS-00003-06-00001, *Calculation - LAW Melter Offgas Caustic Scrubber Process.*
6. 24590-WTP-GPG-M-047, *Preparation of Corrosion Evaluations.*
7. 24590-WTP-M0C-50-00004, *Wear Allowance for WTP Waste Slurry Systems.*
8. 24590-WTP-MVC-50-00009, *LAW, BOF, and LAB Vessel Cyclic Datasheet Inputs.*
9. 24590-WTP-RPT-M-04-0008, *Evaluation Of Stainless Steel and Nickel Alloy Wear Rates In WTP Waste Streams At Low Velocities.*
10. 24590-WTP-RPT-M-11-002, *WTP Vessel Localized Corrosion Limit Analysis Report.*
11. 24590-WTP-RPT-PR-04-0001-04, *WTP Process Corrosion Data – Volume 4.*
12. 24590-WTP-3YD-PSW-00001, *System Description for the Process Service Water System (PSW).*
13. ASME. *ASME Boiler and Pressure Vessel Code*, Section II, Part D – Properties. American Society of Mechanical Engineers, New York, NY.
14. Davis, JR (Ed), 1987, *Corrosion, Vol 13*, In "Metals Handbook", ASM International, Metals Park, OH 44073
15. Rozeveld, A and Chamberlain DB. 1997. *Mobile Evaporator Corrosion Test Results*, ANL-97/2. Argonne National Laboratory, Argonne, IL.
16. Sedriks, AJ, 1996, *Corrosion of Stainless Steels*, John Wiley & Sons, Inc., New York, NY 10158

Additional Reading

- 24590-LAW-M6-LVP-00002002, *P&ID-LAW - LAW Secondary Offgas/Vessel Vent Process System Caustic Scrubber LVP-SCB-00001.*
- 24590-QL-POA-MKAS-00003-07-00002, *LAW Offgas Scrubber FMEA and Reliability Report.*
- CCN 088587, Meeting Minutes from 6/1/2004 meeting with the following purpose: LAW Caustic Scrubber pH Requirements to Address ICD-6 and Material Selection, by Scott Colby
- CCN 130170, Blackburn, LD to PG Johnson, Internal Memo, Westinghouse Hanford Co, *Evaluation of 240-AR Chloride Limit*, August 15, 1991.
- CCN 130173, Dillon, CP (Nickel Development Institute), Personal Communication to J R Divine (ChemMet, Ltd., PC), 3 Feb 2000.
- Agarwal, DC, *Nickel and Nickel Alloys*, In: Revie, WW, 2000. *Uhlig's Corrosion Handbook*, 2nd Edition, Wiley-Interscience, New York, NY 10158
- Berhardsson, S, R Mellstrom, and J Oredsson, 1981, *Properties of Two Highly Corrosion Resistant Duplex Stainless Steels*, Paper 124, presented at Corrosion 81, NACE International, Houston, TX 77218
- Chambers, G and NS Meck, 2002, *Caustic Dealloying Corrosion of High Performance Nickel Alloys*, Presented at Stainless Steel World Conference and Expo, Houston TX 77218
- Davis, JR (Ed), 1994, *Stainless Steels*, In ASM Metals Handbook, ASM International, Metals Park, OH 44073
- Hamner, NE, 1981, *Corrosion Data Survey*, Metals Section, 5th Ed, NACE International, Houston, TX 77218
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PROCESS CORROSION DATA SHEET (extract)

Component(s) (Name/ID #) LAW Melter Offgas Caustic Scrubber (LVP-SCB-00001)

Facility: LAW

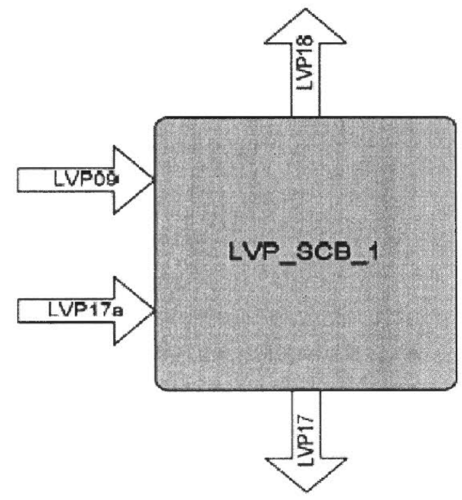
In Black Cell?: No

Chemicals	Unit	Stream ID LVP17 AQUEOUS	DESIGN LIMIT*
Cations (ppm)			
Al^{+3} (Aluminum)	ppm	0	NA
Fe^{+3} (Iron)	ppm	0	NA
Hg^{+2} (Mercury)	ppm	0	NA
Pb^{+2} (Lead)	ppm	0	NA
Anions (ppm)			
Cl^- (Chloride)	ppm	51	300 max
CO_3^{-2} (Carbonate)	ppm	5518	NA
F^- (Fluoride)	ppm	15	NA
NO_2^- (Nitrite)	ppm	0	NA
NO_3^- (Nitrate)	ppm	1	NA
PO_4^{-3} (Phosphate)	ppm	0	NA
SO_4^{-2} (Sulfate)	ppm	31	NA
		LVP09	
Chemicals		**GASEOUS**	
CO2	ppmV	22,330	NA
HCl	ppmV	7	NA
HF	ppmV	4	NA
NH3	ppmV	237	NA
NO	ppmV	35	NA
SO2	ppmV	7	NA
SO3(s)	mg/m3	3	NA
$OH(aq)^-$	ppm	76	NA
$OH(s)^-$	ppm	0	NA
pH		9.50	5 to 10
Suspended Solids	wt%	0	NA
Temperature	°F	122.00	150 max

* Design limits from 24590-WTP-RPT-M-11-002.

Figure C-36 LVP-SCB-00001 Aqueous PCDS

Vessel : LVP_SCB_1



	Stream ID			
	LVP09	LVP17a	LVP18	LVP17
Properties				
Suspended Solids [wt %]	n/a	0	0	0
Total Salts [wt %]	n/a	0.62	0.00	0.63
Sodium Molarity [M]	n/a	0.11	n/a	0.11
Relative Humidity [%]	1.25	n/a	100.00	n/a
pH	n/a	11.43	n/a	9.50
Anti-Foam Agent [ppm]	0	0	0	0
TOC [kg/h]	1.46E-04	5.68E-03	2.40E-11	4.87E-02
Pressure [bar]	0.90	0.90	0.87	0.90
Temperature [C]	211.11	50.00	50.00	50.00
Temperature [F]	412.00	122.00	122.00	122.00
Water Flow Rate [kg/hr]	319.15	45,169.00	539.18	44,948.97
Total Aqueous Flow Rate [kg/hr]	319.15	45449.33	539.18	45229.30
Total Flow Rate [kg/hr]	6.20E+03	4.54E+04	6.42E+03	4.52E+04
UserNote	VIT VAPOR Caustic Scrubber Inlet	VIT LIQUID LAW Liquid to LVP-SCB-00001	VIT VAPOR Caustic Scrubber Offgas Discharge	VIT LIQUID Caustic Scrubber Scrubbing Solution Recirc.
AQUEOUS				
Cations (ppm)				
Ag+	0	0	0	0
Al+3	0	0	0	0
Am+3	0	0	0	0
As+5	0	0	0	0
B+3	0	0	0	0
Ba+2	0	0	0	0
Be+2	0	0	0	0
Bi+3	0	0	0	0
Ca+2	0	0	0	0
Cd+2	0	0	0	0
Ce+4	0	0	0	0
Co+2	0	0	0	0
Cr+3	0	0	0	0
Cr+6	0	0	0	0
Cs+	0	0	0	0
Cu+2	0	0	0	0
Eu+3	0	0	0	0
Fe+2	0	0	0	0
Fe+3	0	0	0	0
H+	0	0	0	4
Hg+2	0	0	0	0
K+	0	0	0	0
La+3	0	0	0	0
Li+	0	0	0	0
Mg+2	0	0	0	0
Mn+4	0	0	0	0
Mo+6	0	0	0	0
Na+	0	2435	0	3994
Nd+3	0	0	0	0
Ni+2	0	0	0	0
Pb+2	0	0	0	0
Pd+2	0	0	0	0
Pr+4	0	0	0	0
Pu+4	0	0	0	0
Ra+2	0	0	0	0
Rb+	0	0	0	0
Rh+3	0	0	0	0
Ru+4	0	0	0	0
Sb+3	0	0	0	0
Se+4	0	0	0	0
Si+4	0	0	0	0
Sr+2	0	0	0	0
Ta+5	0	0	0	0
Tc+4	0	0	0	0
Te+4	0	0	0	0
Th+4	0	0	0	0
Ti+4	0	0	0	0
Tl+5	0	0	0	0
U+4	0	0	0	0
V+3	0	0	0	0
W+6	0	0	0	0
Y+3	0	0	0	0
Zn+2	0	0	0	0
Zr+4	0	0	0	0
Anions (ppm)				
B(OH)4-	0	0	0	0
C2O4-2	0	0	0	0
Cl-	0	49	0	51
CN-	0	0	0	0
CO3-2	0	3400	0	5518
F-	0	15	0	15
H2PO4-	0	0	0	0
H2SiO4-2	0	0	0	0
H3SiO4-	0	0	0	0
HCO3-	0	0	0	0
HPO4-2	0	0	0	0
HSO3-	0	0	0	0
HSO4-	0	0	0	0
I-	0	0	0	0
IO3-	0	0	0	0
NH4+	0	222	0	236
NO2-	0	0	0	0
NO3-	0	1	0	1
O-2	0	0	0	0
O2-2	0	0	0	0
OH(aq)-	0	46	0	76
OH(s)-	0	0	0	0
PO4-3	0	0	0	0
SO3-2	0	0	0	101
SO4-2	0	1	0	31
Organics (ppm)				
AFA_DCMP	0	0	0	0
AFA_NVOC	0	0	0	0
NVOC	0	0	0	0
Sucrose	0	0	0	0
SVOC	0	0	0	0
VOC	0	0	0	1

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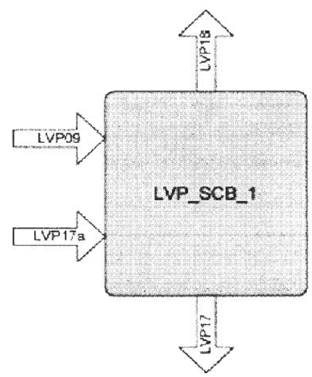
Figure C- 37 LVP-SCB-00001 Gaseous PCDS

Vessel : LVP_SCB_1

	Stream ID			
	LVP09	**LVP17a**	**LVP18**	**LVP17**
Properties				
Suspended Solids [wt %]	n/a	0	0	0
Total Salts [wt %]	n/a	0.62	0.00	0.63
Sodium Molarity [M]	n/a	0.11	n/a	0.11
Relative Humidity [%]	1.25	n/a	100.00	n/a
pH	n/a	11.43	n/a	9.60
Anti-Foam Agent [ppm]	0	0	0	0
TOC [kg/h]	1.46E-04	5.68E-03	2.40E-11	4.87E-02
Pressure [bar]	0.90	0.90	0.87	0.90
Temperature [C]	211.11	50.00	50.00	50.00
Temperature [F]	412.00	122.00	122.00	122.00
Water Flow Rate [kg/hr]	319.15	45,169.00	539.18	44,948.97
Total Aqueous Flow Rate [kg/hr]	319.15	45449.33	539.18	45229.30
Total Flow Rate [kg/hr]	6.20E+03	4.54E+04	6.42E+03	4.52E+04
UserNote	VIT VAPOR Caustic Scrubber Inlet	VIT LIQUID LAW Liquid to LVP-SCB-00001	VIT VAPOR Caustic Scrubber Offgas Discharge	VIT LIQUID Caustic Scrubber Scrubbing Solution Recirc.
GASEOUS				
(ppmV or mg/m^3)				
Ar	8401	0	6199	0
CH3I	0	0	0	0
Cl2	0	0	0	0
CO	18	0	8	0
CO2	22330	0	9761	0
F2	0	0	0	0
H2	0	0	0	0
HCl	7	0	0	0
HCN	0	0	0	0
HF	4	0	0	0
I2	0	0	0	0
N2	711873	0	526157	0
NaCl(s)	0	0	0	0
NaCN(s)	0	0	0	0
NaF(s)	0	0	0	0
NaI(s)	0	0	0	0
NH3	237	0	122	0
NO	35	0	25	0
NO2	0	0	0	0
O2	190801	0	141350	0
P2O5(s)	0	0	0	0
PO2	0	0	0	0
SO2	7	0	0	0
SO3(s)	3	0	0	0



Note: Concentrations for constituents representing particulates (as denoted by suffix "(s)" in their name) are reported in units of mg/m^3; all others are reported in units of ppmV

GENERAL NOTE FOR USE OF PCDS:

- *The data in the non-shaded columns of the PCDSs has NOT been adjusted to comply with the highest expected, vessel-specific operational conditions. It is provided in the initial-pass through the PCDSs for completeness.*
- *The information provided by the PCDS report is intended solely for use in support of the vessel material selection process and Corrosion Evaluations. The inputs, assumptions, and computational/engineering models used in generating the results presented herein are specific to this effort. Use of the information presented herein for any other purpose will require separate consideration and analysis to support justification of its use for the desired, alternative purpose.*
- *The process descriptions in this report cover routine process operations and non-routine (infrequent) process operations, when such exist, that could impact corrosion or erosion of process equipment.*
- *The process descriptions provided in this report are for general information and reflective of the corrosion engineer's analysis for transparency, the information is current only at the time this document is issued. These process descriptions should not be referenced for design.*

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6.6.1 Description of Vessel/Equipment

The LAW Secondary Offgas/Vessel Vent Process (LVP) System is designed to treat the offgas from the LAW Primary Offgas Process (LOP) System and the LAW Facility vessel vents. The purpose of the LVP System is to remove almost all remaining particulates, miscellaneous acid gases, nitrogen oxides, VOCs, and mercury from the LAW Facility offgas that have not been removed by the LOP system.

Figure 10 is a sketch of the input and output arrangement of streams for all equipment within the LVP System. Streams that are not primary routes (infrequent transfers) are represented with dashed lines.

Figure 10a - LVP System Sketch

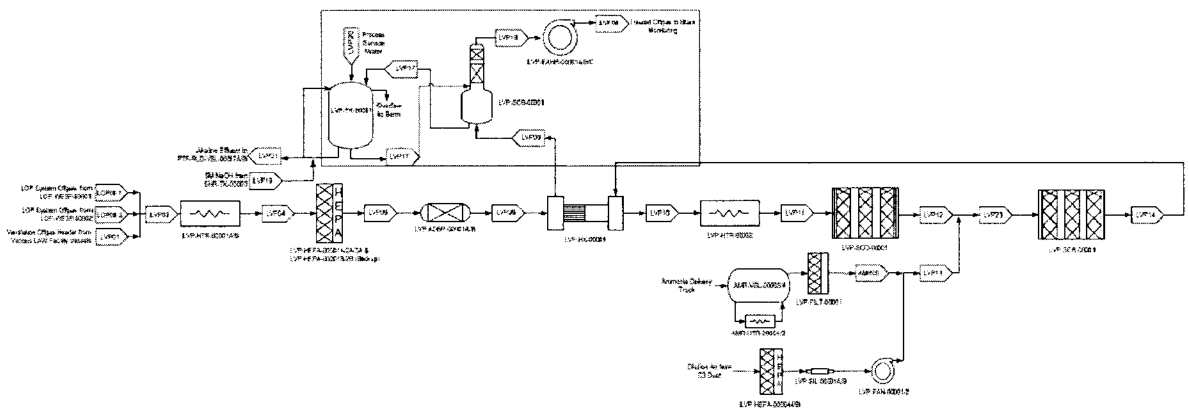
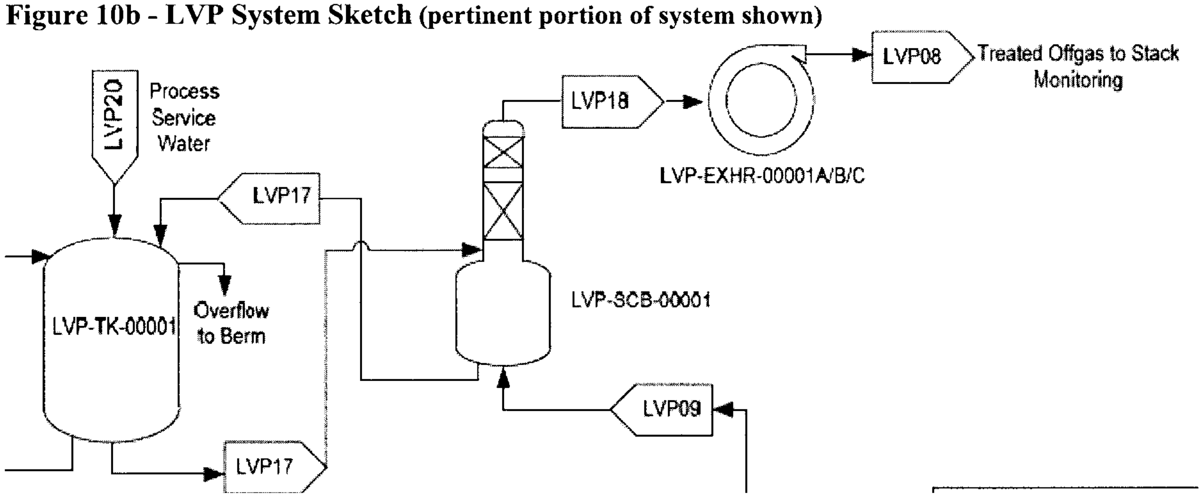


Figure 10b - LVP System Sketch (pertinent portion of system shown)



6.6.2 System Functions

The process functions of this system are as follows:

- Receive LAW Offgas from LOP System and LAW Facility Vessel Ventilation Streams
- Receive Reagents Streams Such as Ammonia or Dilution Air to Ensure Offgas Component Destruction
- Treat Offgas to Ensure Requirements are Met Before Emitting to Atmosphere
- Transfer Offgas to Stack
- Transfer Liquid Effluents to RLD-VSL-00017A/B

These vessels perform additional system functions beyond the process functions, but these are outside the scope of this document. The non-process functions are not discussed any further in this document. However, they are listed below for completeness:

- Confine Hazardous Materials
- Flush System Components
- Report System Data

6.6.3 Description of Process Functions

All process streams have been taken from Process Flow Diagrams 24590-LAW-M5-V17T-00010 and 24590-LAW-M5-V17T-00011 and associated drawing change notices (DCNs) 24590-LAW-M5N-V17T-00012/15/17/29 and 24590-LAW-M5N-V17T-00012/19/23/29, respectively. The P&IDs have also been looked at to obtain the most accurate flow diagram. These are as follows: 24590-LAW-M6-LVP-00001001 / 1002 / 1003 / 1004 / 1005 / 1006 / 2001 / 2002 / 2003 / 2004 / 2005 / 2006 / 3001 / 4001 / 4002 / 4003 / 5001 / 5002 and 24590-BOF-M6-AMR-00002001 / 2002 / 3001 / 3002 / 5001. See Section 7.1.3 for corresponding references in this section. A description of the process function of each piece of equipment is listed as follows:

Equipment	Process Function
LVP-SCB-00001	The caustic scrubber serves as a final offgas treatment process by further removing acid gases and providing cooling. SO_2 in the offgas stream is absorbed in the scrub solution.

6.6.3.1 Receipt Streams

The LVP system primarily receives LAW offgas from the LOP system and LAW Facility vessel ventilation streams. Other LVP system equipment receives various streams to help process the offgas. The receipt streams for each piece of equipment are listed as follows, by vessel, in order of process flow:

<u>LVP-SCB-00001</u>

- LVP09 - Offgas from LVP-SCR-00001 via LVP-HX-00001
- LVP17 - Caustic Scrub Solution from LVP-TK-00001 to LVP-SCB-00001

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6.6.3.1.13 LVP09 - Offgas from LVP-SCR-00001 via LVP-HX-00001 to LVP-SCB-00001

This stream is the offgas from the selective catalytic reducer via the heat exchanger to the scrubber.

Molarity
N/A

Temperature
The temperature will normally be 370°F (24590-LAW-M4E-LOP-00009, pg. 11, Cell Q45, Ref. 7.1.4(13)). The maximum temperature is 412°F (24590-LAW-M4E-LOP-00009, pg. 15, Cell Q45, Ref. 7.1.4(13)).

Solids Concentration
The solids concentration will normally be near zero or trace solids.

Vapor Density
The vapor density will normally be 3.27E-2 lb/ft^3 to 2.84E-2 lb/ft^3 (24590-LAW-M4E-LOP-00009, pg. 11, Cell AI44; pg. 15, Cell AI44, Ref. 7.1.4(13)).

Liquid pH
N/A

6.6.3.1.14 LVP17 - Caustic Scrub Solution from LVP-TK-00001 to LVP-SCB-00001

Stream LVP17 is the caustic scrubber solution recirculating from LVP-TK-00001 to LVP-SCB-00001.

Molarity
The normal sodium molarity range of the caustic scrubber solution from LVP-TK-00001 is 1.78-1.89 molar Na (24590-WTP-M4C-V11T-00024, Ref. 7.1.4(30)). Note that 5M NaOH is added to the scrubbing solution to neutralize the acid gases collected in the caustic collection tank LVP-TK-00001 and maintain the pH value of the scrubbing solution. The resulting sodium molarity for this stream will be provided in the corrosion data sheet.

Temperature
The minimum temperature of the caustic scrubber solution from LVP-TK-00001 is 59°F based on the minimum temperature of the C3 area (24590-WTP-DB-ENG-01-001, Ref. 7.1.1(2), Table 12-1). The normal and maximum temperature of the caustic scrubber solution from LVP-TK-00001 is 122°F based on the scrubber solution temperature in equilibrium with the scrubber exit offgas temperature (24590-LAW-MEC-LVP-00003, Ref. 7.1.4(14), Section 6.14).

Solids Concentration
The solids concentration for the caustic scrubber solution from LVP-TK-00001 is negligible (24590-WTP-DB-PET-09-001, Ref. 7.1.1(3), Appendix B, Table B-23).

Liquid Density
Process service water is added to the caustic scrubber solution to maintain the scrubber solution below 10wt% dissolved solids (24590-LAW-MEC-LVP-00003, Ref. 7.1.4(14), Section 2.4). The maximum density of the caustic scrubber solution is 68.6 lb/ft^3 (24590-LAW-MEC-LVP-00003, Ref. 7.1.4(14), Section 2.30)

Liquid pH
The pH of the scrubber solution is continuously monitored and normally maintained in the range of 9.0 to 9.5 (24590-LAW-MTC-LVP-00002, Ref. 7.1.4(19), Section 8). The scrubber solution pH can be raised to 14 when high halide concentrations are measured in the scrubber bottom to control 316L stainless steel corrosion rates (24590-LAW-MKD-LVP-00011, Ref. 7.1.5(4), pg.10, Note 2).

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6.6.3.2 Outlet Streams

The outlet streams for each piece of equipment are listed as follows, by vessel, in order of process flow:

LVP-SCB-00001

- LVP17 - Scrub Solution to LVP-TK-00001
- LVP18 - Offgas from LVP-SCB-00001 to LVP-EXHR-00001A/B/C

6.6.3.1.15 LVP18 - Offgas from LVP-SCB-00001

This stream is the offgas from the scrubber that is sent to the exhausters and subsequently to the stack.

Molarity
N/A

Temperature
The normal and maximum temperature of stream LVP18 will be 122°F (24590-LAW-M4E-LOP-00009, Ref. 7.1.4(13)).

Solids Concentration
The solids concentration will normally be near zero or trace solids because water is added to LVP-TK-00001 for precipitation control.

Vapor Density
The vapor density will normally be 4.84E-2 lb/ft^3 to 3.71E-2 lb/ft^3 (24590-LAW-M4C-LOP-00001, pg. 37, Cell AI48; pg. 41, Cell AI48, Ref. 7.1.4(12)).

Liquid pH
N/A

6.6.4 Process Modes

6.6.4.1 Normal Operations

Based on the assessment of streams frequently transferred in and out of the LVP System equipment, the following normal processing modes are considered:

LVP-SCB-00001

- LVP09 - Offgas from LVP-SCR-00001 via LVP-HX-00001
- LVP17 - Caustic Scrub Solution from LVP-TK-00001
- Scrub Solution to LVP-TK-00001
- LVP18 - Offgas from LVP-SCB-00001 to LVP-EXHR-00001A/B/C

6.6.4.2 Infrequent Operations

None identified.

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6.6.5 Summary of Processing Conditions for LVP System

6.6.5.1 Normal Operations

The following table summarizes the normal processing modes for LVP System equipment.

Stream Number	**Weight % UDS**		**Na Molarity**		**Temperature (°F)**	
	normal	upper	normal	upper	normal	upper
LVP-SCB-00001						
LVP09 (in)	0	trace	n/a	n/a	370	412
LVP17 (in)	0	trace	1.79-1.89	Note 1	122	122
Scrub Solution to LVP-TK-00001 (out)	0	trace	1.79-1.89	Note 1	122	122
LVP18 (out)	0	trace	n/a	n/a	122	122