R11385137

CORROSION EVALUATION

ISSUED BY
RPP-WTP PDC

## HOP-SCR-00001 & HOP-SCR-00002 (HLW)
## NOx Selective Catalytic Reducer

- Design Temperature (°F): 1000
- Design Pressure (in WG) (internal/external): 84/82
- Location: outcell; Room H-A123

**Contents of this document are Dangerous Waste Permit affecting**

**Operating conditions are as stated on Process Corrosion Data Sheet**

### Operating Modes Considered:

- Normal operations up to a maximum temperature of 750 °F.
- Design to include a cool down mode that will prevent condensation of acid gasses.

### Materials Considered:

| Material (UNS No.) | Acceptable Material | Unacceptable Material |
|---|---|---|
| Carbon Steel | | X |
| Type 304L (S30403) | X[1] | |
| Type 316L (S31603) | X[2] | |
| Type 347 (S34700) | X | |
| 6% Mo (N08367/N08926) | | X |
| Hastelloy® C-22® (N06022) | | X |
| Ti-2 (R50400) | | X |

### Recommended Materials

- Enclosure/shell-side components: Type 347 stainless steel
- Catalyst support frame & instrument housings: Type 347 stainless steel
- [1]Structural support (not in contact with offgas stream): Type 304 (or Type 316L) stainless steel (max 0.030% C; dual certified)
- [2]Instrument materials: Type 316 stainless steel (max 0.030% C, dual certified)
- [2]Ammonia piping and spray nozzles: Type 316 stainless steel (max 0.030% C; dual certified)

### Recommended Corrosion Allowance: 0.010 inch (includes 0.00 inch erosion allowance)

### Process & Operations Limitations:

- Effort shall be made to prevent condensation at all times. This does not preclude use of water for cleaning with approved procedures. Procedure shall provide for drying.
- During plant start-up, effort shall be made to minimize the ammonia slip into the reducer (optimize system).
- Operating limits shall be included in the operating procedures.

**Concurrence** DR
Operations

| REV | DATE | REASON FOR REVISION | PREPARER | CHECKER | MET | APPROVER |
|---|---|---|---|---|---|---|
| | | | | | | |
| 5 | 6/30/11 | Incorporate revised PCDS<br>Addition general discussion<br>Sect d – addt'l discussion | DLAdler | RBDavis | NA | SWVail |

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## REVISION HISTORY

| REV | DATE | REASON FOR REVISION | PREPARER | CHECKER | MET | APPROVER |
|---|---|---|---|---|---|---|
| 4 | 11/6/09 | Update design temp<br>Editorial and format changes<br>Add AEA notice | DLAdler | RBDavis | NA | SWVail |
| 3 | 7/21/08 | Incorporate revised PCDS<br>Revise operating temps<br>Revise material recommendation | DLAdler | JRDivine | RBDavis | SWVail |
| 2 | 9/15/04 | Update equipment quantity<br>Update equipment description<br>Update design temp/pressure<br>Incorporate new PCDS<br>Add section p -- Inadvertent Addition of Nitric acid<br>Extensive non-technical edits | DLAdler | JRDivine | NA | APRangus |
| 1 | 9/17/02 | Correct Item Number<br>Update format<br>Remove open issues | DLAdler | JRDivine | SS | SMKirk |
| 0 | 2/4/02 | Initial Issue | DLAdler | JRDivine | NA | B. Posta |

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 8 sheets.

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## Corrosion Considerations:

The volatile organic and $NO_x$ cleanup system is a series of four components starting with the recuperative heat exchanger, electric duct heater bank, organic oxidizer catalytic bed, and the selective reduction catalytic bed. All four units are supplied on the same skid; however, because the conditions are unique to each section, individual corrosion evaluations are produced to allow the flexibility of design. This enables the supplier to tailor to the specific design conditions of each component. This evaluation is specific to the functioning of the $NO_x$ selective catalytic reducer.

The gas treatment system is designed to remove aerosols, acid gases, and radionuclides from the off-gas. The system includes coolers, scrubbers, precipitators, mist eliminators, heaters, fans, pre-heaters, catalytic beds, and exhaust blowers. The type of corrosion mechanism and its rate of attack depend on the nature of the atmosphere (temperature, chemistry, moisture, and particulates). In general, corrosion occurs when process gases contain moisture, $N_2$, $O_2$, $CO_2$, $NH_3$, NO, $N_2O$, $NO_2$, HCl, HF, $I_2$, $SO_2$, and Hg. The temperature in the component is higher than the condensation temperature of water; therefore, the component will remain dry during operation.

The materials selection encompasses the enclosure, interior and exterior structural framework, ammonia spray heads, and the catalyst boxes. Any moisture in the system is vaporized prior to entering the system during normal operations. When the system is operational, conditions should preclude moisture; however, during startup and shutdown, moisture could enter the crevices and occluded areas through condensation. Preventing condensation during off normal operation is important. Proper insulation and its maintenance can sometimes solve corrosion problems during short temperature transients or cause the condensation to occur on surfaces distant from the housing. However, insulated equipment with operating gas temperatures during startup and shutdown will pass through the dew point can still have significant corrosion issues. Using corrosion resistant material will limit corrosion losses due to the condensation. Moisture may wet the surfaces resulting in conditions that could support electrochemical processes. Precaution is taken to insulate the duct and enclosure to reduce the heat loss and the cold surfaces that can support condensation. In addition, corrosion resistant stainless steel is used to minimize the consequences of corrosion.

The moisture content in the gas that reaches the catalyst skid components (pre heater, heater, SCO and SCR) is less than 30% relative humidity. Dry surfaces do not corrode. The uniform corrosion, crevice corrosion, and pitting corrosion can be managed with austenitic stainless steel alloys Type 304/304L and Type 316/316L. The corrosion with these alloys is expected to be relatively low, 0.25 mpy max. Therefore, a total corrosion allowance of 0.010 inch is adequate for the offgas treatment system.

**a General Corrosion**
Uniform corrosion is not anticipated for all normal operating conditions. The dry air eliminates the electrolyte necessary to support electrochemical processes. However, because sections of the selective catalytic reducer may experience elevated temperatures, both types 304L and 316L stainless steel are precluded from use as the primary pressure boundary or enclosure. The stabilized austenitic grade of type 347 stainless steel is recommended and is suitable for the elevated temperatures and design conditions for the enclosure.

*Conclusion*
Type 304L is satisfactory for structural components not in contact with the offgas stream. Type 347 is recommended for all components of the pressure boundary and enclosure that are in contact with the offgas. A uniform corrosion allowance is added for normal wear and corrosion during off-normal events.

**b Pitting Corrosion**
Pitting corrosion is not anticipated for all normal, dry-air operating conditions. Localized corrosion for short durations during off-normal conditions may occur.

*Conclusion*
At the stated operating conditions, pitting corrosion is not a concern. Type 316L and 347 are both resistant to pitting corrosion.

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**c End Grain Corrosion**
End grain corrosion only occurs in high acid conditions and is not a concern.

*Conclusion:*
Not a concern

**d Stress Corrosion Cracking**
The system is normally dry, free of moisture and most acid gases. Stress corrosion cracking will only be a concern if the column is allowed to have multiple cooling cycles below 225°F in the presence of moisture. Aggressive ion concentrations are small; therefore, any corrosion that could be accelerated by the aggressive ions will be low. While concentration mechanisms like evaporation are expected, their contribution would be small based upon the dry operating conditions.

*Conclusion*
At the stated operating conditions, stress corrosion cracking is not a concern.

**e Crevice Corrosion**
Crevice corrosion will only be a concern if column is allowed to cool below 225°F in the presence of moisture.

*Conclusion*
At the stated operating conditions, crevice corrosion is not a concern.

**f Corrosion at Welds**
None anticipated.

*Conclusion*
Not a concern.

**g Microbiologically Induced Corrosion (MIC)**
Conditions in this equipment are not conducive to MIC

*Conclusion*
Not a concern.

**h Fatigue/Corrosion Fatigue**
Equipment shall be designed to accommodate the expected fatigue cycles over the 40-year design life.

*Conclusion*
Not a concern.

**i Vapor Phase Corrosion**
Offgas equipment is essentially entirely vapor space. Comments under General Corrosion apply.

*Conclusion*
Not a concern.

**j Erosion**
Velocities are not expected to be sufficient to cause concern.

*Conclusion*
Not a concern.

**k Galling of Moving Surfaces**
None expected.

*Conclusion*
Not a concern.

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**l Fretting/Wear**
None anticipated.

*Conclusion*
Not a concern.

**m Galvanic Corrosion**
None anticipated.

*Conclusion*
Not a concern.

**n Cavitation**
None anticipated.

*Conclusion*
Not a concern.

**o Creep**
At the design and operating temperatures, creep is not a concern.

*Conclusion*
At the stated operating conditions, creep is not a problem.

**p Inadvertent Addition of Nitric Acid**
Introduction of nitric acid into the offgas stream is not a likely scenario.

*Conclusion*
Not applicable.

**q. Non-Routine, Start-up, Shut-down and Transient Operations**
Non-routine operations will likely not influence corrosion.

*Conclusion*
Not a concern.

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**References:**

1. 24590-HLW-M4C-HOP-00011, Rev. 1, *HLW Melter Offgas System Design Basis Flowsheets*
2. 24590-WTP-RPT-PR-04-0001, Rev. 0CC, *WTP Process Corrosion Data*
3. CCN 174990, e-mail from J Wood to R Davis, 25 March, 2008, "Design Temperatures For HOP TCOs"

**Bibliography:**

1. 24590-CM-POA-MBT0-00002-03-00001, *Data Sheet – HLW Thermal Catalytic Oxidizers/Reducers – Mechanical Data Sheet*
2. Allegheny Ludlum, 2003, Stainless Steels, Types 321, 347, and 348, Technical Data Blue Sheet, Allegheny Technologies, Inc.
3. Maziasz, PJ, RW Swindeman, JP Shingledecker, KL More, BA Pint, E Lara-Curzio, and ND Evans, 2003, *Improving High-Temperature Performance of Austenitic Stainless Steels for Advanced Microturbine Recuperators,* The Institute for Materials, Minerals and Mining, Maney Publishing, London, UK
4. Sedriks, AJ, 1996, *Corrosion of Stainless Steels*, John Wiley & Sons, Inc., New York, NY 10158

## PROCESS CORROSION DATA SHEET

**Component(s) (Name/ID #)** NOx selective catalytic reducer (HOP-SCR-00001, HOP-SCR-00002)

**Facility** HLW

**In Black Cell?** No

| Chemicals | Unit[1] | Contract Maximum[2] | | Non-Routine | | Notes |
|---|---|---|---|---|---|---|
| | | Leach | No leach | Leach | No Leach | |
| Aluminum | $g/m^3$ | | | | | |
| HCl | $g/m^3$ | | | | | |
| HF | $g/m^3$ | | | | | |
| Iron | $g/m^3$ | | | | | |
| NO | $g/m^3$ | 2.86E-01 | 2.97E-01 | | | |
| $NO_2$ | $g/m^3$ | 1.05E-01 | 1.14E-01 | | | |
| Phosphate | $g/m^3$ | | | | | |
| $SO_2$ | $g/m^3$ | 9.0E-04 | 9.0E-04 | | | Note 5 |
| Mercury | $g/m^3$ | | | | | |
| Carbonate | $g/m^3$ | | | | | |
| Particulate | $g/m^3$ | | | | | |
| $HNO_3$ | $g/m^3$ | 2.6E-03 | 2.6E-03 | | | Assumption 1 |
| $HNO_2$ | $g/m^3$ | 3.4E-03 | 3.4E-03 | | | Assumption 1 |
| Ammonia | $g/m^3$ | 1.83E-01 | 1.8E-01 | | | Note 3 |
| Humidity | % | 0.1% | 0.1% | | | Note 5 |
| Temperature | °F | | | | | Note 4 |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**List of Organic Species:**

**References**

System Description: 24590-HLW-3YD-HOP-00001
Mass Balance Document: 24590-WTP-M4C-V11T-00005, Rev A
Normally Associated Streams: HOP32, HOP30
Off Normal Streams (e.g., overflow from other vessels): N/A
P&ID: N/A
PFD: 24590-HLW-M5-V17T-00004; 24590-HLW-M5-V17T-20004
Technical Reports: N/A

**Notes:**

1. Concentrations less than $1x 10^{-4}$ $g/m^3$ do not need to be reported; list concentration values to three significant digits max.
2. 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.
3. Anhydrous ammonia is injected into the SCR to aid in the conversion of $NO_X$.
4. The normal operating temperature is 750 °F at the inlet, and 678 °F at the outlet (page A-6, 24590-HLW-M4C-HOP-00011, Rev 1)
   The maximum operating temperature is 750 °F at the inlet, and 689 °F at the outlet (page A-10, 24590-HLW-M4C-HOP-00011, Rev 1)
5. Source: 24590-HLW-M4C-HOP-00011, Rev 1, pages A-10 through A-13

**Assumptions**

1. Based on empirical data from testing per Attachment 28 of 24590-HLW-M4E-HOP-00005, page 4.

#### 5.3.8.4 $NO_x$ Selective Catalytic Oxidizer Reducer (HOP-SCR-00001, HOP-SCR-00002)

**Routine Operations**

The $NO_x$ SCR reduces (destroy) nitrogen oxides ($NO_x$) in the process offgas. Gas from the TCO flows into a chamber where the gas is mixed, due to the turbulent flow, with anhydrous ammonia gas injected into the gas stream. The ammonia is added at a stoichiometric ratio of slightly more than 1 to ensure efficient reaction of about 95 %. The ammonia addition rate is controlled based on an in-stream analysis of the concentration and flow rate of the $NO_x$ into the $NO_x$ SCR. The ammonia slip needs to be controlled because ammonia is also an air pollutant. The offgas from the mixing chamber flows into the $NO_x$ SCR catalyst bed at a temperature of about 750 °F where the reaction takes place. The inlet temperature is well above the temperature for ammonium nitrate formation ($NH_4NO_3$ decomposes above 410 °F). In the SCR, $NO_x$ is reduced to nitrogen and water.

**Non-Routine Operations that Could Affect** Corrosion or Erosion

Any extended facility shutdown mode that results in cessation of airflow thorough offgas system, resulting in condensation of effluent inside equipment, is not desirable.