Shell Chemical Appalachia LLC
300 Frankfort Rd
Monaca, PA  15061

August 17, 2022

Mark Gorog P.E.
Regional Manager Air Quality Program
Pennsylvania Department of Environmental Protection
Southwest Regional Office
400 Waterfront Drive
Pittsburgh, PA 15222

**RE: PA-04-00740C Source ID 206 Spent Caustic Vent Header System Visible Emissions and Source ID 205 High Pressure (HP) Header System Malfunction Final Report**

Dear Mr. Gorog,

Shell Chemical Appalachia LLC ("Shell") is submitting this final (follow up) malfunction report to the Pennsylvania Department of Environmental Protection (PADEP) for visible emissions (smoking) from the spent caustic vent thermal oxidizer (SCTO) on July 4, 2022.  This report is being sent as follow up to the initial call on July 4 and associated follow up Malfunction Report on July 15.  The investigation has determined the cause of visible emissions to have originated from Source ID 205 High Pressure (HP) Header System as described in the letter below.

- **Name and location of the facility**
  Shell Polymers Monaca
  300 Frankfort Road, Monaca PA, 15061

- **Nature and cause of the incident**
  On July 4 at 8:00AM visible emissions were observed which lasted ~30 seconds from the Spent Caustic Vent Thermal Oxidizer (SCTO) stack.  Visible emissions were observed to periodically reoccur for ~15 to 30 seconds starting at this time and coincided with activation of the vent blower pulling vapor space from both flow equalization and oil removal (FEOR) tanks and the recovered oil (RO) tank[1][2].  The decision was made to shut down the blower as the immediate cause of visible emissions and with understanding that no hydrocarbon liquids or wastewater were being generated by any process unit at this time.  No further visible emissions were observed after shutdown of the blower.

  Initial investigation identified the probable cause to be the presence of methane in the FEOR and RO tank headspace generated from biological growth within the tanks

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[1] Identified as Storage Tanks (Recovered Oil, Equalization Wastewater), Source ID 401 in PA-04-00740C.
[2] Spent caustic is not currently being generated at the facility.

during the commissioning period. A similar phenomenon was witnessed in the biotreaters, and this appeared to be a repeat of that circumstance. Water samples taken from the tanks following the visible emissions did not detect significant organic content. However, a tank headspace analysis conducted on July 14 with a KKI Instruments Eagle 2 portable analyzer confirmed the presence of methane in both FEOR and RO tanks' headspace. The highest concentration was detected in the RO tank with lower concentrations in each FEOR tank. These results were consistent with naturally occurring biological growth observed in the biotreaters during commissioning. Furthermore, area monitors within the wastewater treatment plant area did not indicate the presence of hydrocarbons at any time.

Shell conducted a safety review of the abnormal operation of the SCTO and presence of hydrocarbons in the FEOR and RO tank headspace. This was done in conjunction with technical evaluation of short-term mitigations to safely oxidize the abnormal hydrocarbons. Risks of continuing to send high levels of hydrocarbons included flame out, trip, and smoking of the SCTO. Worst case risks included deflagration and damage to the SCTO or ancillary equipment. It was determined that 50wt% methane or less would be acceptable to prevent equipment damage due to the abnormal operation. Initial portable analyzer results indicated 75% (higher than 50%) methane in the RO tank. Risk was also present during this time due to possible oxygen ingress into any of the tanks through a vacuum breaker and creating a potentially hazardous environment. Additional sampling and analysis were deemed necessary to proceed with better information.

Headspace samples were collected from the RO and FEOR tanks on July 22 and analyzed via Method GPA 1945 by Saybolt Core Laboratories. Results indicated the presence of propane and ethane in addition to the previously detected methane. Propane and ethane concentrations were inconsistent with biogenic methane and biological growth was ruled out as a potential cause this time. Results of this analysis are included as Attachment 1. Method GPA 1945 analyzes the presence of C1 through C6+ hydrocarbons as well as nitrogen, carbon dioxide, hydrogen, helium, and oxygen. Nitrogen levels in the sample exceeded that for which the Method applies but it is considered accurate for the hydrocarbon content. Remaining balance of the tank headspace is estimated to consist of nitrogen due to the nitrogen supply blanketing which is applied to each tank.

Periodic activation of the vent blower for 1 to 2 minutes during July 4 pulled propane, ethane, methane, and nitrogen to the SCTO for oxidation in combination with the SCTO fuel natural gas. Partially incomplete combustion resulted in short term visible emissions during this portion of the incident which lasted a total of 4 minutes 47 seconds. This combination of abnormally high levels of hydrocarbons in the tank headspace, coupled with the large fixed-speed vent blower, is beyond the designed capabilities of the SCTO to safely oxidize and without generating visible emissions.

Further investigation identified the actual cause to be infiltration of vent gas from the HP flare knock out drum into the RO tank. The HP flare knock out drum is piped to the RO tank for liquid removal in the event of excess liquid accumulation in the drum. Under designed normal conditions the drum is filled with liquid, requires active pumping to draw down the liquid level, and effectively forms a barrier between the HP Header System vent gas and the RO tank. The HP flare knock out drum was initially filled with water on April 13 to test for leaks, and then pumped down to a normal minimum level on the same day. However, after the pump was turned off, water continued to drain from the drum to the RO tank without assistance under actual site conditions. This emptied the drum and created an open vapor pathway to the RO tank. Some of the hydrocarbon vapor in the RO tank migrated to the FEOR tanks as indicated by the lower hydrocarbon concentrations detected in the FEOR tanks. The liquid level in the RO tank remained stable at approximately 1.5 meters during this period forming a partial barrier to the vent gas but was insufficient to completely prevent infiltration of vent gas at elevated pressures beginning after propane and ethane were brought into ECU as of July 2 and July 3. The HP flare knock out drum was refilled with water on July 20 and a block valve closed restoring the barrier to any potential vent gas infiltration from the drum to the RO tank.

Sample results from July 22 indicated that hydrocarbon concentrations in the FEOR tanks were low enough to safely oxidize in the SCTO while concentrations in the RO tank remained too high to avoid the risks identified during the earlier safety review. Isolation was performed on the RO tank and the vent gas blower reactivated on July 23 to safely remove and oxidize any remaining hydrocarbons in the FEOR tanks. No visible emissions resulted from this reactivation. Safety risk also remained present at the RO tank for possible oxygen ingress creating a potentially hazardous environment. Water was added to the RO tank to raise the liquid and internal floating roof (IFR) level and then drawn down to the wastewater treatment plant while replacing the headspace with makeup nitrogen. The water level was kept at approximately 3 meters to place additional barrier between the tank and the HP flare knock out drum. A new headspace analysis conducted on August 1 with the KKI Instruments Eagle 2 portable analyzer confirmed the reduction of hydrocarbons (detected as methane) down to 9% and below the safety risk threshold. This allowed for the removal of RO tank isolation on August 2 and routing of vapors to the SCTO for oxidation. No visible emissions resulted from this isolation removal.

- **Causes and Corrective actions**

  Cause 1 (FEOR and RO Tank Blower) – The FEOR and RO tank vent blower routed too much hydrocarbon vapor to the SCTO and resulted in visible emissions and well as equipment and safety risk.

  Cause 1 Corrective Action(s) – Operations was notified of periodic visible emissions from the SCTO. Action was taken to cease any hydrocarbon unloading activities during this period and then to turn off the blower after it was discovered that visible emissions coincided with activation of the blower. Action was later taken to vent unsafe hydrocarbons from the RO tank to eliminate the safety risk and reduce concentrations to a level that could be safely moved by the blower and oxidized.

  The vent blower is a large single speed blower and temporary modifications could not be made to limit or throttle the speed without generating additional risk at the blower or in the vent piping. Attempting to throttle valves was not feasible and would result in temperature increase in the process and at the blower and not reduce flow. Long term improvements to the vent blower and SCTO continue to be evaluated to improve performance. The vent blower and SCTO have operated to safely oxidize hydrocarbons without generating visible emissions prior to and after July 4 when abnormal hydrocarbons are not present in any of the tank headspace.

  Cause 2 (HP Flare KO Drum) – The HP Flare KO Drum was empty of liquid allowing for hydrocarbon vapors to migrate to and infiltrate the RO Tank.

Cause 2 Corrective Action(s) – Action was taken to restore the liquid level in the drum with water and prevent any further infiltration of hydrocarbons to the RO and FEOR tanks. A block valve is in place and closed to prevent future drainage of the drum. Drum and RO tank liquid levels are monitored by Operations and alarms in place to warn of low liquid levels. Long term improvements to the line connecting the HP flare knock out drum to the RO tank continue to be evaluated to improve performance and minimize future risk.

- **Time when the incident was first observed, and duration of excess emissions**
  July 4, 2022, beginning at 08:00 and ending at 12:43. Visible emissions were observed for ~15 to 30 seconds each time the FEOR and RO tank blower activated. Visible emissions did not exceed 0% for greater than five (5) minutes during any consecutive 2-hour period. Excess emissions were calculated for periods of time when the blower was active and visible emissions were observed.

  July 4, 2022, beginning at 12:43 through July 20, 2022, ending at 11:19. Some hydrocarbons from the HP flare knock out drum migrated to and infiltrated the RO and FEOR tanks and then ultimately to atmosphere via the tank relief valves. Excess emissions were calculated for periods of time when the HP flare knock out drum pressure was positive and could have sent hydrocarbon vapor to the RO tank.

- **Final emissions and calculations (See Attachments 2 and 3)**

*Table 1: Emissions Summary*

| Pollutant | SCTO[a] (lbs) | HP Header[b] (lbs) | Total (lbs) | Total (tons) |
|---|---|---|---|---|
| CO2e | 1,118 | 491,282 | 492,400 | 246.2 |
| CO2 | 1,112 | 0.00 | 1,112 | 0.56 |
| Methane (CH4) | 0.19 | 19,651 | 19,651 | 9.83 |
| Ethane (C2H6) | 0.06 | 3,901 | 3,901 | 1.95 |
| CO | 0.78 | 0.00 | 0.78 | 3.9E-04 |
| NOx | 0.65 | 0.00 | 0.65 | 3.3E-04 |
| N2O | 0.00 | 0.00 | 0.00 | 0.00 |
| SO2 | 0.00 | 0.00 | 0.00 | 0.00 |
| PM (filterable) | 0.02 | 0.00 | 0.02 | 1.0E-05 |
| PM (10/2.5) | 0.07 | 0.00 | 0.07 | 3.5E-05 |
| VOC | 0.12 | 4,454 | 4,454 | 2.23 |
| HAP (Total) | 0.02 | 0.00 | 0.02 | 1.0E-05 |

[a] From minutes when VE was observed

[b] Through RO and FEOR Tanks

**Summary**

As soon as opacity was noticed in the SCTO, the PADEP Air Quality Inspector was notified. Opacity did not exceed five minutes in a two-hour period. Shell personnel took immediate action to investigate what occurred to understand the nature of the malfunction and associated opacity.

The results of the investigation and ultimate cause of the malfunction were unexpected and not foreseen in the design of the flare system. Shell took actions to restore the HP flare knock out drum seal and to safely remove hydrocarbons from the tank to eliminate any potential hazard, while preserving the integrity of our control device, the SCTO. Shell is also committed to learning from this start up incident and implementing long term operational and design improvements for safety and the environment.

If you have any questions regarding this matter, please contact me at (724) 709-2467 or kimberly.kaal@shell.com.

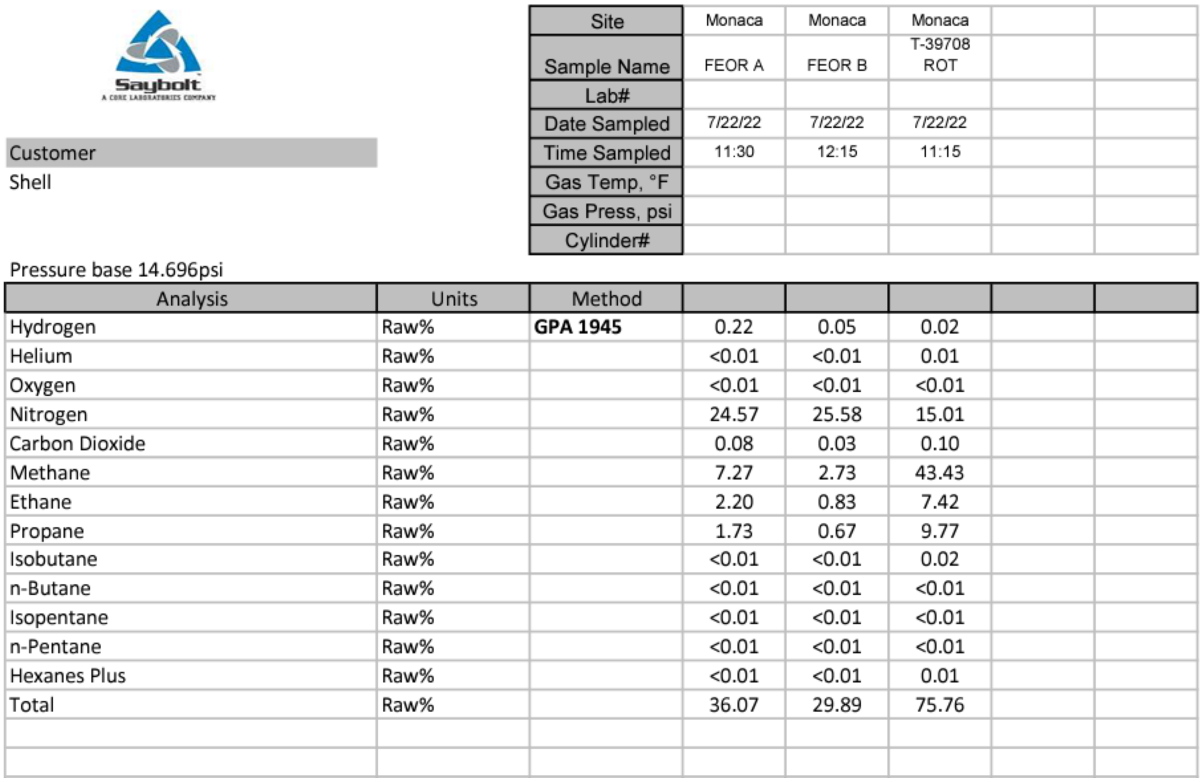
Sincerely,

Kimberly Kaal

Kimberly Kaal
Environmental Manager, Attorney-in-Fact

CC:
Scott Beaudway, Air Quality Specialist
Anna Fabrizi, District Supervisor

Attachment 1 – July 22 FEOR and RO Tank Headspace Analysis



Saybolt
A CORE LABORATORIES COMPANY

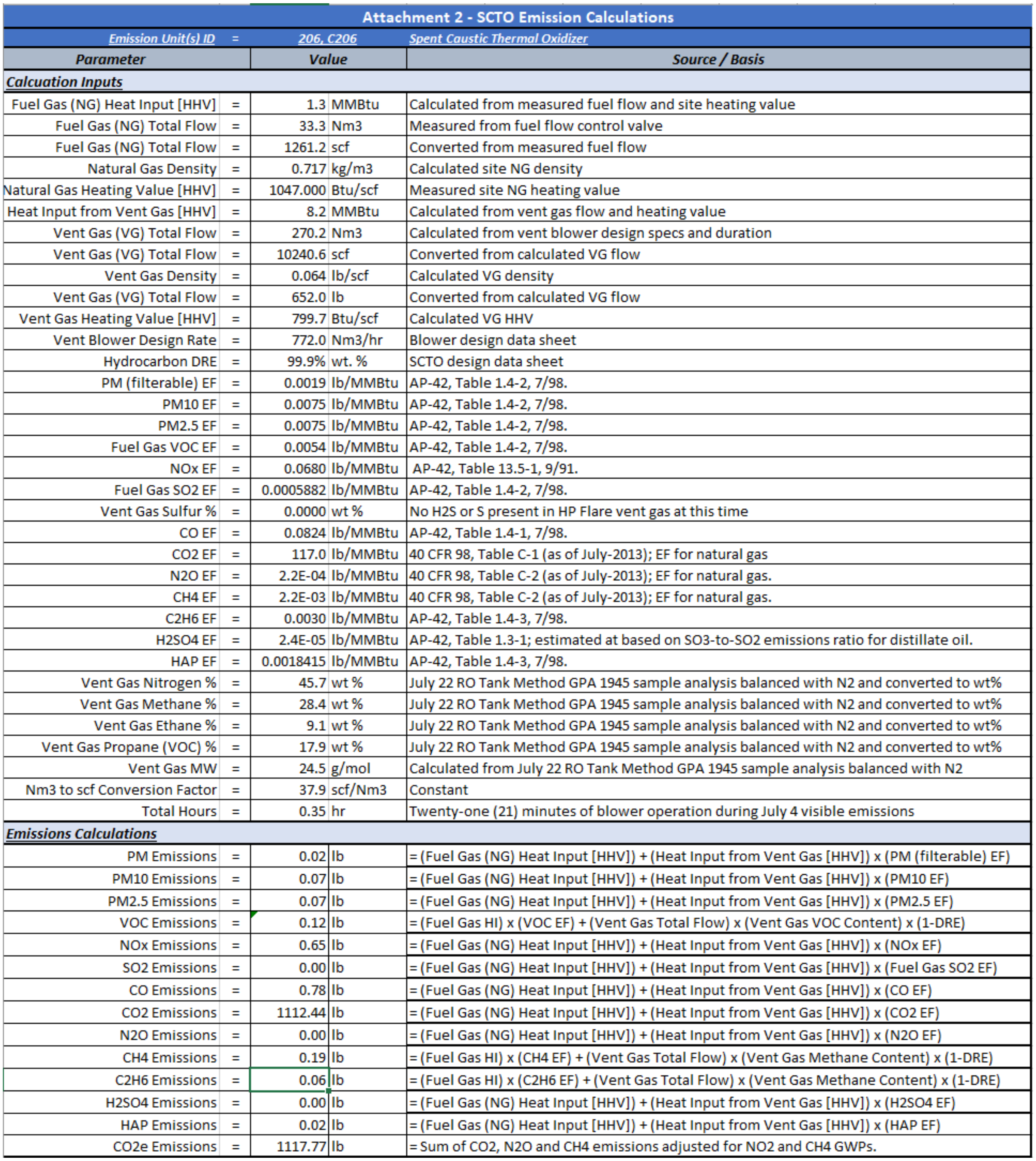
| | | | | | |
|---|---|---|---|---|---|
| Site | Monaca | Monaca | Monaca | | |
| Sample Name | FEOR A | FEOR B | T-39708<br>ROT | | |
| Lab# | | | | | |
| Date Sampled | 7/22/22 | 7/22/22 | 7/22/22 | | |
| Time Sampled | 11:30 | 12:15 | 11:15 | | |
| Gas Temp, °F | | | | | |
| Gas Press, psi | | | | | |
| Cylinder# | | | | | |

**Customer**
Shell

Pressure base 14.696psi

| Analysis | Units | Method | | | | | |
|---|---|---|---|---|---|---|---|
| Hydrogen | Raw% | **GPA 1945** | 0.22 | 0.05 | 0.02 | | |
| Helium | Raw% | | <0.01 | <0.01 | 0.01 | | |
| Oxygen | Raw% | | <0.01 | <0.01 | <0.01 | | |
| Nitrogen | Raw% | | 24.57 | 25.58 | 15.01 | | |
| Carbon Dioxide | Raw% | | 0.08 | 0.03 | 0.10 | | |
| Methane | Raw% | | 7.27 | 2.73 | 43.43 | | |
| Ethane | Raw% | | 2.20 | 0.83 | 7.42 | | |
| Propane | Raw% | | 1.73 | 0.67 | 9.77 | | |
| Isobutane | Raw% | | <0.01 | <0.01 | 0.02 | | |
| n-Butane | Raw% | | <0.01 | <0.01 | <0.01 | | |
| Isopentane | Raw% | | <0.01 | <0.01 | <0.01 | | |
| n-Pentane | Raw% | | <0.01 | <0.01 | <0.01 | | |
| Hexanes Plus | Raw% | | <0.01 | <0.01 | 0.01 | | |
| Total | Raw% | | 36.07 | 29.89 | 75.76 | | |
| | | | | | | | |
| | | | | | | | |

## Attachment 2 – SCTO Emission Calculations



**Attachment 2 - SCTO Emission Calculations**

| *Emission Unit(s) ID* | = | *206, C206* | | *Spent Caustic Thermal Oxidizer* |
|---|---|---|---|---|
| ***Parameter*** | | ***Value*** | | ***Source / Basis*** |
| ***Calcuation Inputs*** | | | | |
| Fuel Gas (NG) Heat Input [HHV] | = | 1.3 | MMBtu | Calculated from measured fuel flow and site heating value |
| Fuel Gas (NG) Total Flow | = | 33.3 | Nm3 | Measured from fuel flow control valve |
| Fuel Gas (NG) Total Flow | = | 1261.2 | scf | Converted from measured fuel flow |
| Natural Gas Density | = | 0.717 | kg/m3 | Calculated site NG density |
| Natural Gas Heating Value [HHV] | = | 1047.000 | Btu/scf | Measured site NG heating value |
| Heat Input from Vent Gas [HHV] | = | 8.2 | MMBtu | Calculated from vent gas flow and heating value |
| Vent Gas (VG) Total Flow | = | 270.2 | Nm3 | Calculated from vent blower design specs and duration |
| Vent Gas (VG) Total Flow | = | 10240.6 | scf | Converted from calculated VG flow |
| Vent Gas Density | = | 0.064 | lb/scf | Calculated VG density |
| Vent Gas (VG) Total Flow | = | 652.0 | lb | Converted from calculated VG flow |
| Vent Gas Heating Value [HHV] | = | 799.7 | Btu/scf | Calculated VG HHV |
| Vent Blower Design Rate | = | 772.0 | Nm3/hr | Blower design data sheet |
| Hydrocarbon DRE | = | 99.9% | wt. % | SCTO design data sheet |
| PM (filterable) EF | = | 0.0019 | lb/MMBtu | AP-42, Table 1.4-2, 7/98. |
| PM10 EF | = | 0.0075 | lb/MMBtu | AP-42, Table 1.4-2, 7/98. |
| PM2.5 EF | = | 0.0075 | lb/MMBtu | AP-42, Table 1.4-2, 7/98. |
| Fuel Gas VOC EF | = | 0.0054 | lb/MMBtu | AP-42, Table 1.4-2, 7/98. |
| NOx EF | = | 0.0680 | lb/MMBtu | AP-42, Table 13.5-1, 9/91. |
| Fuel Gas SO2 EF | = | 0.0005882 | lb/MMBtu | AP-42, Table 1.4-2, 7/98. |
| Vent Gas Sulfur % | = | 0.0000 | wt % | No H2S or S present in HP Flare vent gas at this time |
| CO EF | = | 0.0824 | lb/MMBtu | AP-42, Table 1.4-1, 7/98. |
| CO2 EF | = | 117.0 | lb/MMBtu | 40 CFR 98, Table C-1 (as of July-2013); EF for natural gas |
| N2O EF | = | 2.2E-04 | lb/MMBtu | 40 CFR 98, Table C-2 (as of July-2013); EF for natural gas. |
| CH4 EF | = | 2.2E-03 | lb/MMBtu | 40 CFR 98, Table C-2 (as of July-2013); EF for natural gas. |
| C2H6 EF | = | 0.0030 | lb/MMBtu | AP-42, Table 1.4-3, 7/98. |
| H2SO4 EF | = | 2.4E-05 | lb/MMBtu | AP-42, Table 1.3-1; estimated at based on SO3-to-SO2 emissions ratio for distillate oil. |
| HAP EF | = | 0.0018415 | lb/MMBtu | AP-42, Table 1.4-3, 7/98. |
| Vent Gas Nitrogen % | = | 45.7 | wt % | July 22 RO Tank Method GPA 1945 sample analysis balanced with N2 and converted to wt% |
| Vent Gas Methane % | = | 28.4 | wt % | July 22 RO Tank Method GPA 1945 sample analysis balanced with N2 and converted to wt% |
| Vent Gas Ethane % | = | 9.1 | wt % | July 22 RO Tank Method GPA 1945 sample analysis balanced with N2 and converted to wt% |
| Vent Gas Propane (VOC) % | = | 17.9 | wt % | July 22 RO Tank Method GPA 1945 sample analysis balanced with N2 and converted to wt% |
| Vent Gas MW | = | 24.5 | g/mol | Calculated from July 22 RO Tank Method GPA 1945 sample analysis balanced with N2 |
| Nm3 to scf Conversion Factor | = | 37.9 | scf/Nm3 | Constant |
| Total Hours | = | 0.35 | hr | Twenty-one (21) minutes of blower operation during July 4 visible emissions |
| ***Emissions Calculations*** | | | | |
| PM Emissions | = | 0.02 | lb | = (Fuel Gas (NG) Heat Input [HHV]) + (Heat Input from Vent Gas [HHV]) x (PM (filterable) EF) |
| PM10 Emissions | = | 0.07 | lb | = (Fuel Gas (NG) Heat Input [HHV]) + (Heat Input from Vent Gas [HHV]) x (PM10 EF) |
| PM2.5 Emissions | = | 0.07 | lb | = (Fuel Gas (NG) Heat Input [HHV]) + (Heat Input from Vent Gas [HHV]) x (PM2.5 EF) |
| VOC Emissions | = | 0.12 | lb | = (Fuel Gas HI) x (VOC EF) + (Vent Gas Total Flow) x (Vent Gas VOC Content) x (1-DRE) |
| NOx Emissions | = | 0.65 | lb | = (Fuel Gas (NG) Heat Input [HHV]) + (Heat Input from Vent Gas [HHV]) x (NOx EF) |
| SO2 Emissions | = | 0.00 | lb | = (Fuel Gas (NG) Heat Input [HHV]) + (Heat Input from Vent Gas [HHV]) x (Fuel Gas SO2 EF) |
| CO Emissions | = | 0.78 | lb | = (Fuel Gas (NG) Heat Input [HHV]) + (Heat Input from Vent Gas [HHV]) x (CO EF) |
| CO2 Emissions | = | 1112.44 | lb | = (Fuel Gas (NG) Heat Input [HHV]) + (Heat Input from Vent Gas [HHV]) x (CO2 EF) |
| N2O Emissions | = | 0.00 | lb | = (Fuel Gas (NG) Heat Input [HHV]) + (Heat Input from Vent Gas [HHV]) x (N2O EF) |
| CH4 Emissions | = | 0.19 | lb | = (Fuel Gas HI) x (CH4 EF) + (Vent Gas Total Flow) x (Vent Gas Methane Content) x (1-DRE) |
| C2H6 Emissions | = | 0.06 | lb | = (Fuel Gas HI) x (C2H6 EF) + (Vent Gas Total Flow) x (Vent Gas Methane Content) x (1-DRE) |
| H2SO4 Emissions | = | 0.00 | lb | = (Fuel Gas (NG) Heat Input [HHV]) + (Heat Input from Vent Gas [HHV]) x (H2SO4 EF) |
| HAP Emissions | = | 0.02 | lb | = (Fuel Gas (NG) Heat Input [HHV]) + (Heat Input from Vent Gas [HHV]) x (HAP EF) |
| CO2e Emissions | = | 1117.77 | lb | = Sum of CO2, N2O and CH4 emissions adjusted for NO2 and CH4 GWPs. |

* Excess emissions are calculated based upon the RO Tank headspace sample composition as the worst case for all three tanks, vent blower design flow rate, and measured fuel flow rate and characteristics. Duration of the calculation is for all times when the blower was active.

## Attachment 3 – HP Flare KO Drum, through RO and FEOR Tanks, Vent Loss Calculations

Vent gas losses were conservatively calculated from the HP flare knock out drum based upon the pressure differential (ΔP) between the drum and atmosphere accounting for all periods when ΔP was positive allowing for flow. The total calculation considers the drum pressure, pressure drop (resistance) from piping to the RO tank, backpressure from the RO tank liquid level relative to piping inlet, and backpressure from the relief valve. Additional factors include the specific gravity and vent gas composition as measured by the gas chromatograph downstream of the HP flare knock out drum. See Figure 1 below for the flow pathway visual.

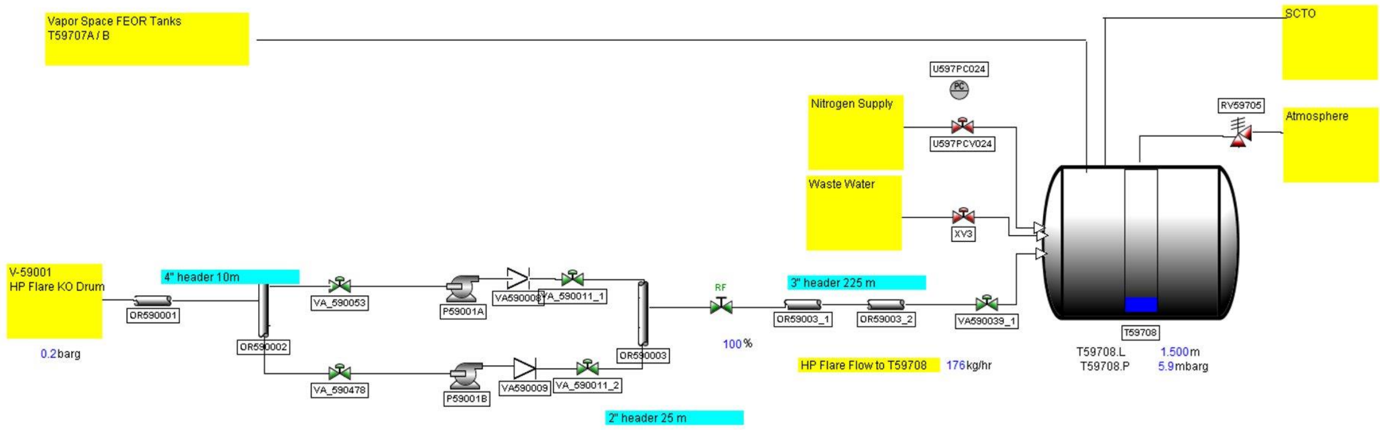
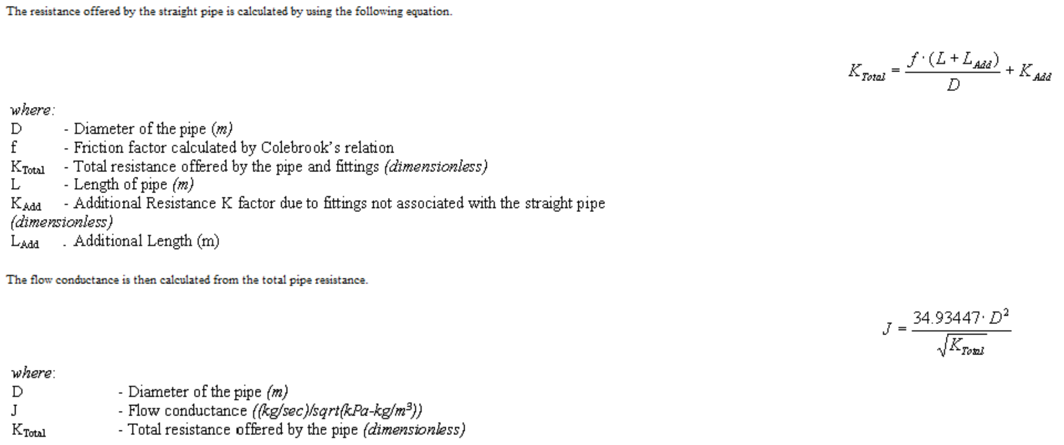


*Figure 1: Vent Gas Flow Pathway from HP Flare KO Drum to Atmosphere. Note: this is a model and does not show normal flow path from RO Tank to SCTO.*

Resistance is included from the total length, diameter, and friction factor of piping between the drum and RO tank. The calculation is conservative because there are additional valve and pump features in the line between the drum and tank which would contribute to resistance but have not been included for simplicity. Resistance, and ultimately flow conductance, from the pipe was calculated using the following Darcy's equation



The resistance offered by the straight pipe is calculated by using the following equation.

$$K_{Total} = \frac{f \cdot (L + L_{Add})}{D} + K_{Add}$$

*where:*

D - Diameter of the pipe *(m)*

f - Friction factor calculated by Colebrook's relation

$K_{Total}$ - Total resistance offered by the pipe and fittings *(dimensionless)*

L - Length of pipe *(m)*

$K_{Add}$ - Additional Resistance K factor due to fittings not associated with the straight pipe *(dimensionless)*

$L_{Add}$ . Additional Length (m)

The flow conductance is then calculated from the total pipe resistance.

$$J = \frac{34.93447 \cdot D^2}{\sqrt{K_{Total}}}$$

*where:*

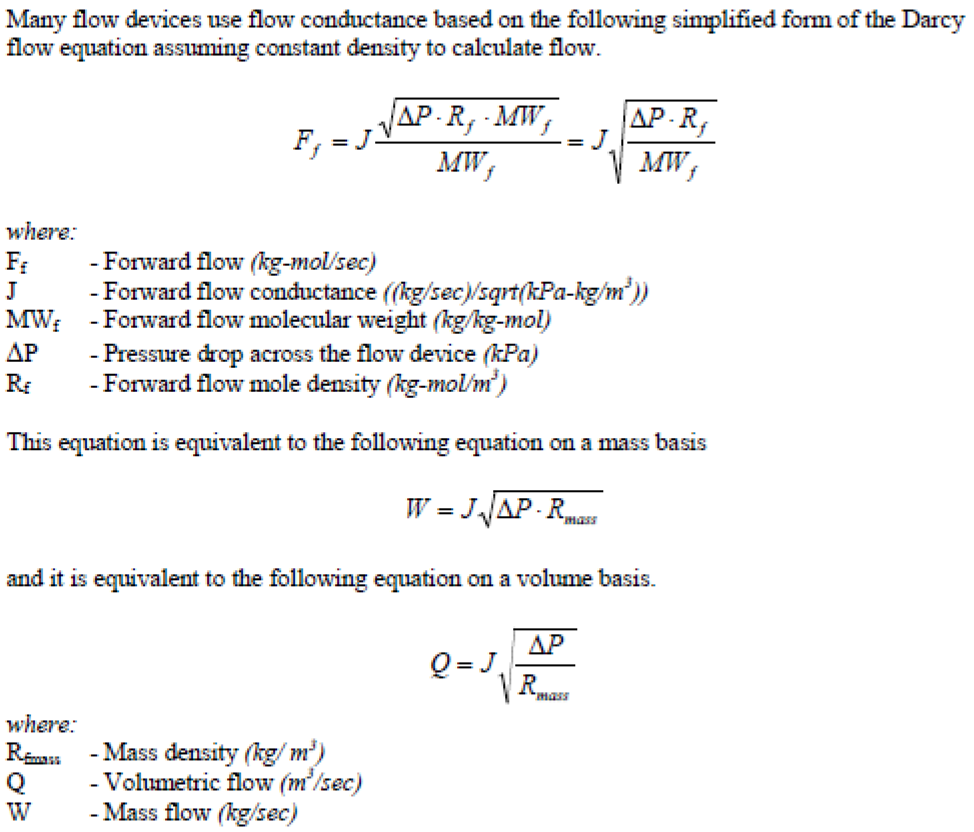
D - Diameter of the pipe *(m)*

J - Flow conductance *((kg/sec)/sqrt(kPa-kg/m³))*

$K_{Total}$ - Total resistance offered by the pipe *(dimensionless)*

*Figure 2: Pipe Resistance and Flow Conductance Equations*

Mass flowrate was calculated using the calculated flow conductance, ΔP, and density (specific gravity) in the system.



Many flow devices use flow conductance based on the following simplified form of the Darcy flow equation assuming constant density to calculate flow.

$$F_f = J\frac{\sqrt{\Delta P \cdot R_f \cdot MW_f}}{MW_f} = J\sqrt{\frac{\Delta P \cdot R_f}{MW_f}}$$

*where:*

$F_f$ - Forward flow *(kg-mol/sec)*

J - Forward flow conductance *((kg/sec)/sqrt(kPa-kg/m³))*

$MW_f$ - Forward flow molecular weight *(kg/kg-mol)*

ΔP - Pressure drop across the flow device *(kPa)*

$R_f$ - Forward flow mole density *(kg-mol/m³)*

This equation is equivalent to the following equation on a mass basis

$$W = J\sqrt{\Delta P \cdot R_{mass}}$$

and it is equivalent to the following equation on a volume basis.

$$Q = J\sqrt{\frac{\Delta P}{R_{mass}}}$$

*where:*

$R_{fmass}$ - Mass density *(kg/ m³)*

Q - Volumetric flow *(m³/sec)*

W - Mass flow *(kg/sec)*

*Figure 3: Mass Flow Equation*

Inputs to all calculations include a combination of site measured data, design data, and material physical properties. A summary of all inputs and outputs (and total emissions) are included in Emission Calculations tables below. The calculation was performed for all times when the HP flare knock out drum pressure was greater than the backpressure from the RO tank.

## Attachment 3 - HP Flare System (Through FEOR and RO Tanks) Emissions

| ***Emission Unit(s) ID*** | = | ***205, 401*** | | ***HP Flare System (Through FEOR and RO Tanks)*** |
|---|---|---|---|---|
| ***Parameter*** | | ***Value*** | | ***Source / Basis*** |
| ***Model and Calculation Inputs*** | | | | |
| Vent Gas Flow Rate | = | Variable | kg/hr | Output from modified Darcy Formula (0 to 261.4 kg/hr) |
| Total Vent Gas Flow | = | 15,891.40 | kg | Calculated as Sum of Flow Rate When ΔP > 0 |
| Vent Gas Nitrogen % | = | Variable | wt % | HP Header Gas Chromatograph Measurement Converted to wt% (2.76 to 85.00%) |
| Vent Gas Methane % | = | Variable | wt % | HP Header Gas Chromatograph Measurement Converted to wt% (7.48 to 86.17%) |
| Vent Gas Ethane % | = | Variable | wt % | HP Header Gas Chromatograph Measurement Converted to wt% (0 to 75.93%) |
| Vent Gas Propane (VOC) % | = | Variable | wt % | HP Header Gas Chromatograph Measurement Converted to wt% (0.18 to 88.66%) |
| Vent Gas Specific Gravity | = | Variable | - | HP Header Gas Chromatograph Measurement (0.58 to 1.34) |
| RO Tank Liquid Inlet Height | = | 0.3969 | m | RO Tank Data Sheet Nozzle Height + Diameter |
| RO Tank Liquid Level | = | Variable | m | RO Tank Liquid Level Data (~1.54 m avg) |
| RO Tank Liquid Head Level | = | Variable | m | Calculated Delta Between Liquid Level and Inlet Height (~1.1 m avg) |
| Water Head Pressure / Meter | = | 0.0981 | barg/m | Constant |
| RO Tank Liquid Backpressure | = | Variable | barg | Calculated (~0.108 barg avg) |
| RO Tank Backpressure | = | Variable | barg | RO Tank RV Pressure Transmitter Data (~0.0047 barg avg) |
| Total RO Tank Backpressure | = | Variable | barg | Sum of RO Tank Liquid Level and RV Setting Backpressure |
| HP Flare KO Drum Avg Pressure | = | Variable | barg | Pressure Transmitter Representative of HP Flare KO Drum |
| 4" Pipe Length to RO Tank | = | 10.0000 | m | 3D Model Data |
| 3" Pipe Length to RO Tank | = | 225.0000 | m | 3D Model Data |
| 2" Pipe Length to RO Tank | = | 25.0000 | m | 3D Model Data |
| 4" Pipe Friction Factor | = | 0.0164 | - | Dimensionless Standard Friction Factor |
| 3" Pipe Friction Factor | = | 0.0175 | - | Dimensionless Standard Friction Factor |
| 2" Pipe Friction Factor | = | 0.0207 | - | Dimensionless Standard Friction Factor |
| 4" Pipe Resistance | = | 1.6093 | - | Calculated Dimensionless Standard Friction Factor |
| 3" Pipe Resistance | = | 50.8386 | - | Calculated Dimensionless Standard Friction Factor |
| 2" Pipe Resistance | = | 10.1763 | - | Calculated Dimensionless Standard Friction Factor |
| 4" Pipe Flow Conductance | = | 0.2843 | ((kg/sec)/sqrt(kPa-kg/m3)) | Calculated from Darcy Equation |
| 3" Pipe Flow Conductance | = | 0.0283 | ((kg/sec)/sqrt(kPa-kg/m3)) | Calculated from Darcy Equation |
| 2" Pipe Flow Conductance | = | 0.0285 | ((kg/sec)/sqrt(kPa-kg/m3)) | Calculated from Darcy Equation |
| Total Flow Conductance | = | 0.0200 | ((kg/sec)/sqrt(kPa-kg/m3)) | Calculated as Inverse Square Root of Sum of Flow Conductance |
| kg to lb Conversion | = | 2.2046 | lb/kg | Constant |
| Vent Blower Stop Time | = | 7/4/2022 12:43 | date/time | Vent blower run status data |
| HP Flare KO Drum Refill Time | = | 7/20/2022 11:19 | date/time | HP Flare KO Drum liquid level data |
| Total Hours | = | 133.60 | hr | ~8,016 Minutes Where ΔP > 0 (Note: less than total time delta) |
| ***Emissions Calculations*** | | | | |
| CH4 Emissions | = | 8,913.76 | kg | Calculation Output Flow x CH4 Wt% (sum each point when differential pressure > 0) |
| C2H6 Emissions | = | 1,769.30 | kg | Calculation Output Flow x C2H6 Wt% |
| VOC (C3H8) Emissions | = | 2,020.28 | kg | Calculation Output Flow x C3H8 Wt% |
| CO2e Emissions | = | 222,844.00 | kg | CH4 Emissions Adjusted for CH4 GWP |
| CH4 Emissions | = | 19,651.28 | lb | Converted Calculation Output |
| C2H6 Emissions | = | 3,900.60 | lb | Converted Calculation Output |
| VOC (C3H8) Emissions | = | 4,453.91 | lb | Converted Calculation Output |
| CO2e Emissions | = | 491,281.88 | lb | CH4 Emissions Adjusted for CH4 GWP |
| CH4 Emissions | = | 9.83 | tons | Converted Calculation Output |
| C2H6 Emissions | = | 1.95 | tons | Converted Calculation Output |
| VOC (C3H8) Emissions | = | 2.23 | tons | Converted Calculation Output |
| CO2e Emissions | = | 245.64 | tons | CH4 Emissions Adjusted for CH4 GWP |