

ATTACHMENT A

Updated Equipment List

Attachment A
Updated Equipment List
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

LNG storage tank (Application Section 2.1.4)
Propane, isopentane & ethylene storage tanks (Application Section 2.2)
Valves and flanges associated with LNG transfer to and from LNG storage tank (Application Section 2.12.3)
Gas pretreatment system (see application Section 2.1.2)
Gas liquefaction system (see application Section 2.1.3)
LNG vaporization system (see application Sections 2.1.5.1 and 2.2.1)
Boil off/flash gas recovery system (see application Section 2.1.3, 2.1.4 and 2.1.5.3)
Facility cooling water system – This is a closed system that circulates a coolant mixture of water and propylene glycol with no emissions. Heat is collected from various facility equipment, and is rejected to atmosphere via a dry (fin fan air cooled) heat exchanger. The facility will not have a wet cooling tower. It will operate year round to support the facility’s various gas compression, cooling, condensing, liquefaction, holding, and boil-off gas recovery operations. The system will have no emissions subject to permitting.
Enclosed ground flare (pilot and burners) (see application Section 2.2.2)
Heavy hydrocarbon and fuel gas collection and storage system (see application Section 2.1.2)
Control building – This building will contain instrument air compressors, a water demineralization system, computer/network servers and human machine interface systems (work stations) and staff that will operate/control the facility’s equipment. It will have no emission sources other than space heating.
Storage building –This is an existing structure at the project site. It will house materials, spare parts and supplies for facility maintenance and support. It will have no emissions sources subject to permitting.
Compressor building –This building will house compressors for natural gas liquefaction and boil off/flash gas recovery that are addressed in Application Sections 2.1.3 and 2.2.3.
Power distribution center – This will be a prefabricated building that houses electrical distribution systems, motor control centers, and other distribution panels and components. Electrical power transformers outside the building will be used to step down voltage levels for utilization within the facility. Between the power distribution center and Tacoma Power’s electrical power substation, there will be outdoor high-voltage switch gear. This area will have no emission sources subject to permitting.
Valves and flanges associated with pipeline from Tacoma LNG to TOTE terminal (see application Section 2.1.5.2)
TOTE terminal (see application Section 2.1.5.2)
Ship fueling (bunkering) arm(s) at Tote terminal (see application Section 2.1.5.2)
Truck loading racks (see application Section 2.1.5.3)
Emergency Generator (see application Sections 2.2)
Exempt emissions equipment is listed in Application Section 3, Table 5

Summary of BACT Guidance and Clearinghouse Search

Attachment B
Summary of BACT Guidance and Clearinghouse Search
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

LNG Emission Unit	Comparable BACT Process Unit	Reference	Rated Capacity	Primary Fuel	Pollutant	Control Technology Type	Emission Limits	Case-by-case Basis
Vaporizer Heater	Generic Boiler	Bay Area Air Quality Management District Guidance ^a	>50 MMBtu/hr	Natural Gas	CO	Good Combustion Practice in Conjunction with SCR or Ultra Low Nox Burners and FGR	50 ppmvd @ 3% O ₂	Guidance
					NO _x	Ultra Low NOx Burners + FGR	Not determined	Guidance
					PM ₁₀	Fuel Selection	Natural Gas	Guidance
					SO ₂	Fuel Selection	Natural gas with <100 ppmv total reduced sulfur	Guidance
	Water tube boiler	CARB BACT Clearinghouse ^b	78.6 MMBtu/hr	Natural gas	CO	SCR	400 ppmvd @ 3% O ₂ 15 minutes	BACT
					NO _x	SCR	9 ppmvd @ 3% O ₂ 15 minutes	BACT
					NH ₃	SCR	20 ppmvd @ 3% O ₂ 15 minutes	BACT
	Water tube natural boiler	CARB BACT Clearinghouse ^c	110 MMBtu/hr	Natural gas / propane	CO	Low NOx burner + FGR	100 ppmvd @ 3% O ₂ 15 minutes	BACT
					NO _x	Low NOx burner + FGR	9 ppmvd @ 3% O ₂ 15 minutes	BACT
	Petroleum Operations Boiler	TCEQ Standard Permit to Oil and Gas Handling and Production Facilities ^d	>40 MMBtu/hr	Natural gas or field gas	CO	Good combustion practices	50 ppmv	Guidance
NO _x					Good combustion practices	0.04 lb NO _x /MMBtu ^f	Guidance	
PM, PM ₁₀ , PM _{2.5}					Good combustion practices	--	Guidance	
VOCs					Good combustion practices	--	Guidance	
Enclosed Ground Flare	Enclosed ground flare	SCAQMD ^e	27 MMBtu/hr	Process gas from Oil and Gas Operations	CO	Clean Enclosed Burner	10 ppmv @ 3% O ₂ 1 hr ^g	Major / LAER
					NO _x	Clean Enclosed Burner	15 ppmv @ 3% O ₂ 1 hr ^h	Major / LAER
					VOCs	Clean Enclosed Burner	10 ppmv @ 3% O ₂ 1 hr	Major / LAER

Notes:

^a <http://www.baaqmd.gov/~media/files/engineering/bact-tbact-workshop/combustion/17-3-1.pdf?la=en>

^b <https://www.arb.ca.gov/bact/bactnew/determination.php?var=905>

^c <https://www.arb.ca.gov/bact/bactnew/determination.php?var=904>

^d http://www.tceq.texas.gov/assets/public/legal/rules/rule_lib/adoptions/OGS%20Standard%20Permit_ado.pdf

^e <http://www.aqmd.gov/docs/default-source/bact/laer-bact-determinations/aqmd-laer-bact/part-b-an538706-12-2-2016.pdf>

^f The TCEQ reported a NO_x limit of 0.04 lb/MMBtu for this emission unit. However, for project comparability purposes, the limit was converted to 9 ppmv using the equations in EPA Method 19.

^g The SCAQMD BACT database reported a CO limit of 10 ppmvd at 3 percent O₂ for this emission unit. For project comparability purposes, the proposed project emission limit converts to approximately 43 ppmvd for the high Btu gases and 106 ppmvd for the low Btu gases..

^h The SCAQMD BACT database reported a NO_x limit of 10 ppmvd at 3 percent O₂ for this emission unit. For project comparability purposes, the proposed project emission limit converts to approximately 8 ppmvd for the high Btu gases and 22 ppmvd for the low Btu gases.

BACT Cost-Effectiveness Evaluation for SO₂

Attachment C
BACT Cost-Effectiveness Evaluation for SO₂
Puget Sound Energy – Liquefied Natural Gas Project
Tacoma, Washington

1. Merox Unit:

Variables:

Sulfur Dioxide Emission Rate (<i>ER</i>) for flare:	9 T/year
Pollutant Removal Efficiency (<i>PRE</i>):	90%
Life Expectancy of Add-On (<i>n</i>):	20 years
Interest Rate (<i>i</i>):	7%
Capital Recovery Factor (<i>CRF</i>):	

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \qquad CRF = \frac{0.07(1+0.07)^{20}}{(1+0.07)^{20} - 1} = 0.09$$

Total Capital Costs (TCC): \$9,150,000
 Includes: Equipment & instrumentation

Total Cost per Year (*TCY*):

$$TCY = CRF \times TCC \qquad TCY = 0.09 \times 9,150,000 = \$823,500$$

Cost Benefit in Dollars per Ton:

$$\frac{\$}{\text{Ton}} \text{ Cost Benefit} = \frac{TCY}{(PRE \times ER)} \qquad \frac{\$}{\text{Ton}} \text{ Cost Benefit} = \frac{\$823,500}{(0.90 \times 9)} = \$100,304$$

Note: CB&I estimated the capital cost for a Merox treatment at approximately \$15,000,000. However, to be conservative, this cost-effectiveness evaluation was based on the capital cost for a less expensive Merox unit that was reporting in BACT calculations for the BP Cherry Point Refinery Coker Heater Replacement Permit Application prepared by Ramboll Environ dated June 2016.

Sulfur Inlet Concentration Calculations

Feed Gas Total Sulfur - gr/100scf

	Short-Term Max	Annual Average	Notes
Sulfur from H2S in Pipeline Gas	0.24	0.054	(1)
Other Reduced Sulfur in Pipeline Gas			
Total	0.33	0.34	(2)
<i>Dimethyl Sulfide</i>	0.016	0.017	(3)
<i>Ethyl Mercaptan</i>	0.19	0.20	(3)
<i>Isopropyl Mercaptan</i>	0.12	0.13	(3)
Odorant			
Total	0.23	0.23	(4)
<i>Methyl Ethyl Sulfide</i>	0.055	0.055	
<i>t-Butyl Mercaptan</i>	0.18	0.18	
Total Sulfur - gr/100scf	0.80	0.63	
Emission Calculation Assumption			
<i>Sulfur from H2S</i>	0.24	0.24	(5)
<i>Sulfur from other compounds</i>	0.56	0.39	(6)

Notes:

- (1) Based on Sumas data.
- (2) Based on Sumas data (reported as H2S).
- (3) Based on a weight percentage of Sumas data according to Sumner test results.
- (4) Provided by Puget Sound Energy.
- (5) Williams Northwest Pipeline tariff.
- (6) Total Sulfur minus sulfur from H2S.

Report Name: Gas Quality Total Sulfur Chromatograph
 TSP Name: Northwest Pipeline LLC
 TSP: 67977322
 Location Name: Sumas
 Begin Date: 1/1/2015
 End Date: 7/19/2017
 Statment Date/Time: 7/19/2017 - 9:47:30

http://www.northwest.williams.com/NWP_Portal/gasQualityValues.action

Total S Grains/100SCF

	last 12 months
Avg	0.421
Max	0.603

H2S Grains/100SCF

	last 12 months*
Avg	0.057
Max	0.238

{Use tariff value of 0.25 gr/100scf to be conservative}

*Excluding 13 days of spurious and missing H2S data that are highlighted yellow.

GasDay	H2S		% H2S	Notes
	Grains/100 SCF	Total S (as H2S) Grains/100 SCF		
8/18/2015	0.049	0.557	9%	
8/19/2015	0.046	0.605	8%	
8/20/2015	0.042	0.603	7%	
8/21/2015	0.039	0.624	6%	
8/22/2015	0.07	0.698	10%	
8/23/2015	0.053	0.699	8%	
8/24/2015	0	0.731	0%	
8/25/2015	-0.184	0.663	-28%	
8/26/2015	-0.068	0.653	-10%	
8/27/2015	0.037	0.692	5%	
8/28/2015	0.05	0.625	8%	
8/29/2015	0.045	0.607	7%	
8/30/2015	0.045	0.557	8%	
8/31/2015	0.042	0.649	6%	
9/1/2015	0.045	0.593	8%	
9/2/2015	0.041	0.625	7%	
9/3/2015	0.042	0.661	6%	
9/4/2015	0.041	0.813	5%	
9/5/2015	0.043	0.853	5%	
9/6/2015	0.048	0.779	6%	
9/7/2015	0.047	0.878	5%	
9/8/2015	0.049	0.782	6%	
9/9/2015	0.054	0.662	8%	
9/10/2015	0.046	0.691	7%	
9/11/2015	0.048	0.639	8%	
9/12/2015	0.044	0.664	7%	
9/13/2015	0.038	0.546	7%	
9/14/2015	0.043	1.019	4%	
9/15/2015	0.042	0.917	5%	
9/16/2015	0.049	0.674	7%	
9/17/2015	0.041	0.777	5%	
9/18/2015	0.062	0.81	8%	
9/19/2015	0.046	0.693	7%	
9/20/2015	0.044	0.629	7%	
9/21/2015	0.04	0.813	5%	
9/22/2015	0.046	0.956	5%	
9/23/2015	0.051	0.764	7%	
9/24/2015	0.038	0.718	5%	
9/25/2015	0.038	0.646	6%	
9/26/2015	0.039	0.687	6%	
9/27/2015	0.043	0.642	7%	
9/28/2015	0.034	0.51	7%	
9/29/2015	0.039	0.518	8%	
9/30/2015	0.026	0.46	6%	

10/1/2015	0.038	0.504	8%
10/2/2015	0.041	0.521	8%
10/3/2015	0.041	0.714	6%
10/4/2015	0.041	0.7	6%
10/5/2015	0.043	0.595	7%
10/6/2015	0.043	0.704	6%
10/7/2015	0.042	0.64	7%
10/8/2015	0.043	0.621	7%
10/9/2015	0.056	0.585	10%
10/10/2015	0.042	0.594	7%
10/11/2015	0.041	0.577	7%
10/12/2015	0.041	0.717	6%
10/13/2015	0.04	0.613	7%
10/14/2015	0.046	0.643	7%
10/15/2015	0.056	0.645	9%
10/16/2015	0.046	0.682	7%
10/17/2015	0.043	0.724	6%
10/18/2015	0.045	0.604	7%
10/19/2015	0.044	0.628	7%
10/20/2015	0.042	0.583	7%
10/21/2015	0.051	0.675	8%
10/22/2015	0.046	0.581	8%
10/23/2015	0.084	0.493	17%
10/24/2015	0.069	0.623	11%
10/25/2015	0.044	0.577	8%
10/26/2015	0.042	0.603	7%
10/27/2015	0.051	0.594	9%
10/28/2015	0.059	0.588	10%
10/29/2015	0.044	0.531	8%
10/30/2015	0.038	0.526	7%
10/31/2015	0.037	0.473	8%
11/1/2015	0.042	0.538	8%
11/2/2015	0.043	0.59	7%
11/3/2015	0.053	0.497	11%
11/4/2015	0.092	0.453	20%
11/5/2015	0.094	0.521	18%
11/6/2015	0.058	0.581	10%
11/7/2015	0.046	0.574	8%
11/9/2015	0.039	0.492	8%
11/10/2015	0.054	0.575	9%
11/11/2015	0.047	0.525	9%
11/12/2015	0.093	0.534	17%
11/13/2015	0.048	0.498	10%
11/14/2015	0.042	0.507	8%
11/15/2015	0.041	0.558	7%
11/16/2015	0.074	0.575	13%
11/17/2015	0.047	0.475	10%

11/18/2015	0.04	0.48	8%
11/19/2015	0.038	0.452	8%
11/20/2015	0.092	0.452	20%
11/21/2015	0.102	0.424	24%
11/22/2015	0.067	0.415	16%
11/23/2015	0.103	0.432	24%
11/24/2015	0.074	0.417	18%
11/25/2015	0.08	0.45	18%
11/26/2015	0.047	0.51	9%
11/27/2015	0.106	0.549	19%
11/28/2015	0.102	0.366	28%
11/29/2015	0.103	0.319	32%
11/30/2015	0.098	0.33	30%
12/1/2015	0.078	0.434	18%
12/2/2015	0.076	0.351	22%
12/3/2015	0.062	0.462	13%
12/4/2015	0.048	0.531	9%
12/5/2015	0.046	0.516	9%
12/6/2015	0.048	0.574	8%
12/7/2015	0.048	0.568	8%
12/8/2015	0.053	0.517	10%
12/9/2015	0.051	0.517	10%
12/10/2015	0.047	0.452	10%
12/11/2015	0.05	0.67	7%
12/12/2015	0.058	0.585	10%
12/13/2015	0.057	0.672	8%
12/14/2015	0.058	0.614	9%
12/15/2015	0.069	0.561	12%
12/16/2015	0.082	0.55	15%
12/17/2015	0.111	0.723	15%
12/18/2015	0.067	0.605	11%
12/19/2015	0.059	0.599	10%
12/20/2015	0.059	0.548	11%
12/21/2015	0.057	0.608	9%
12/22/2015	0.071	0.586	12%
12/23/2015	0.071	0.598	12%
12/24/2015	0.066	0.645	10%
12/25/2015	0.069	0.647	11%
12/26/2015	0.095	0.608	16%
12/27/2015	0.105	0.656	16%
12/28/2015	0.108	0.517	21%
12/29/2015	0.116	0.628	18%
12/30/2015	0.113	0.589	19%
12/31/2015	0.114	0.575	20%
1/1/2016	0.101	0.581	17%
1/2/2016	0.108	0.576	19%
1/3/2016	0.114	0.55	21%

1/4/2016	0.109	0.584	19%
1/5/2016	0.116	0.615	19%
1/6/2016	0.064	0.569	11%
1/7/2016	0.077	0.645	12%
1/8/2016	0.062	0.581	11%
1/9/2016	0.083	0.578	14%
1/10/2016	0.064	0.63	10%
1/11/2016	0.124	0.606	20%
1/12/2016	0.073	0.628	12%
1/13/2016	0.069	0.561	12%
1/14/2016	0.07	0.629	11%
1/15/2016	0.089	0.809	11%
1/16/2016	0.068	0.59	12%
1/17/2016	0.067	0.626	11%
1/18/2016	0.063	0.643	10%
1/19/2016	0.064	0.623	10%
1/20/2016	0.062	0.596	10%
1/21/2016	0.064	0.638	10%
1/22/2016	0.061	0.622	10%
1/23/2016	0.068	0.619	11%
1/24/2016	0.06	0.63	10%
1/25/2016	0.054	0.68	8%
1/26/2016	0.058	0.715	8%
1/27/2016	0.06	0.759	8%
1/28/2016	0.059	0.627	9%
1/29/2016	0.058	0.565	10%
1/30/2016	0.058	0.648	9%
1/31/2016	0.058	0.621	9%
2/1/2016	0.072	0.628	11%
2/2/2016	0.087	0.683	13%
2/3/2016	0.099	0.682	15%
2/4/2016	0.094	0.677	14%
2/5/2016	0.084	0.655	13%
2/6/2016	0.075	0.639	12%
2/7/2016	0.08	0.705	11%
2/8/2016	0.074	0.669	11%
2/9/2016	0.07	0.674	10%
2/10/2016	0.08	0.625	13%
2/11/2016	0.075	0.686	11%
2/12/2016	0.071	0.648	11%
2/13/2016	0.064	0.666	10%
2/14/2016	0.067	0.691	10%
2/15/2016	0.061	0.646	9%
2/16/2016	0.064	0.603	11%
2/17/2016	0.068	0.579	12%
2/18/2016	0.072	0.625	12%
2/19/2016	0.081	0.601	13%

2/20/2016	0.078	0.633	12%
2/21/2016	0.085	0.636	13%
2/22/2016	0.076	0.635	12%
2/23/2016	0.076	0.649	12%
2/24/2016	0.073	0.635	11%
2/25/2016	0.071	0.745	10%
2/26/2016	0.067	0.684	10%
2/27/2016	0.055	0.632	9%
2/28/2016	0.054	0.695	8%
2/29/2016	0.065	0.688	9%
3/1/2016	0.072	0.703	10%
3/2/2016	0.075	0.677	11%
3/3/2016	0.062	0.674	9%
3/4/2016	0.071	0.742	10%
3/5/2016	0.062	0.673	9%
3/6/2016	0.058	0.669	9%
3/7/2016	0.065	0.728	9%
3/8/2016	0.069	0.696	10%
3/9/2016	0.067	0.702	10%
3/10/2016	0.061	0.741	8%
3/11/2016	0.066	0.676	10%
3/12/2016	0.055	0.657	8%
3/13/2016	0.06	0.694	9%
3/14/2016	0.057	0.7	8%
3/15/2016	0.072	0.761	9%
3/16/2016	0.063	0.709	9%
3/17/2016	0.059	0.752	8%
3/18/2016	0.059	0.695	8%
3/19/2016	0.059	0.725	8%
3/20/2016	0.055	0.655	8%
3/21/2016	0.054	0.565	10%
3/22/2016	0.054	0.624	9%
3/23/2016	0.055	0.605	9%
3/24/2016	0.057	0.627	9%
3/25/2016	0.053	0.662	8%
3/26/2016	0.056	0.663	8%
3/27/2016	0.052	0.639	8%
3/28/2016	0.054	0.63	9%
3/29/2016	0.053	0.631	8%
3/30/2016	0.06	0.657	9%
3/31/2016	0.063	0.577	11%
4/1/2016	0.058	0.554	10%
4/2/2016	0.049	0.506	10%
4/3/2016	0.049	0.54	9%
4/4/2016	0.05	0.525	10%
4/5/2016	0.046	0.594	8%
4/6/2016	0.052	0.592	9%

4/7/2016	0.055	0.65	8%
4/8/2016	0.053	0.529	10%
4/9/2016	0.05	0.56	9%
4/10/2016	0.048	0.546	9%
4/11/2016	0.047	0.507	9%
4/12/2016	0.044	0.422	10%
4/13/2016	0.048	0.482	10%
4/14/2016	0.056	0.591	9%
4/15/2016	0.045	0.583	8%
4/16/2016	0.046	0.662	7%
4/17/2016	0.043	0.599	7%
4/18/2016	0.044	0.576	8%
4/19/2016	0.044	0.574	8%
4/20/2016	0.041	0.586	7%
4/21/2016	0.036	0.578	6%
4/22/2016	0.035	0.615	6%
4/23/2016	0.039	0.58	7%
4/24/2016	0.038	0.53	7%
4/25/2016	0.034	0.589	6%
4/26/2016	0.034	0.578	6%
4/27/2016	0.035	0.53	7%
4/28/2016	0.037	0.496	7%
4/29/2016	0.037	0.486	8%
4/30/2016	0.035	0.547	6%
5/1/2016	0.037	0.533	7%
5/2/2016	0.037	0.522	7%
5/3/2016	0.039	0.491	8%
5/4/2016	0.042	0.54	8%
5/5/2016	0.046	0.561	8%
5/6/2016	0.044	0.567	8%
5/7/2016	0.042	0.512	8%
5/8/2016	0.036	0.49	7%
5/9/2016	0.039	0.484	8%
5/10/2016	0.042	0.527	8%
5/11/2016	0.042	0.572	7%
5/12/2016	0.044	0.515	9%
5/13/2016	0.046	0.578	8%
5/14/2016	0.047	0.534	9%
5/15/2016	0.049	0.564	9%
5/16/2016	0.041	0.545	8%
5/17/2016	0.045	0.505	9%
5/18/2016	0.044	0.495	9%
5/19/2016	0.045	0.459	10%
5/20/2016	0.044	0.614	7%
5/21/2016	0.045	0.559	8%
5/22/2016	0.044	0.538	8%
5/23/2016	0.042	0.523	8%

5/24/2016	0.039	0.538	7%
5/25/2016	0.039	0.5	8%
5/26/2016	0.04	0.555	7%
5/27/2016	0.039	0.57	7%
5/28/2016	0.044	0.699	6%
5/29/2016	0.039	0.58	7%
5/30/2016	0.037	0.561	7%
5/31/2016	0.042	0.537	8%
6/1/2016	0.044	0.534	8%
6/2/2016	0.046	0.55	8%
6/3/2016	0.044	0.518	8%
6/4/2016	0.045	0.536	8%
6/5/2016	0.042	0.514	8%
6/6/2016	0.043	0.526	8%
6/7/2016	0.049	0.499	10%
6/8/2016	0.044	0.452	10%
6/9/2016	0.047	0.394	12%
6/10/2016	0.043	0.47	9%
6/11/2016	0.042	0.467	9%
6/12/2016	0.045	0.491	9%
6/13/2016	0.046	0.51	9%
6/14/2016	0.042	0.683	6%
6/15/2016	0.044	0.592	7%
6/16/2016	0.047	0.607	8%
6/17/2016	0.045	0.507	9%
6/18/2016	0.045	0.341	13%
6/19/2016	0.042	0.451	9%
6/20/2016	0.043	0.424	10%
6/21/2016	0.045	0.418	11%
6/22/2016	0.045	0.37	12%
6/23/2016	0.045	0.29	16%
6/24/2016	0.049	0.292	17%
6/25/2016	0.049	0.303	16%
6/26/2016	0.053	0.326	16%
6/27/2016	0.051	0.359	14%
6/28/2016	0.052	0.392	13%
6/29/2016	0.05	0.354	14%
6/30/2016	0.053	0.348	15%
7/1/2016	0.051	0.413	12%
7/2/2016	0.049	0.442	11%
7/3/2016	0.046	0.417	11%
7/4/2016	0.046	0.371	12%
7/5/2016	0.05	0.463	11%
7/6/2016	0.049	0.433	11%
7/7/2016	0.05	0.425	12%
7/8/2016	0.048	0.453	11%
7/9/2016	0.04	0.492	8%

7/10/2016	0.043	0.435	10%
7/11/2016	0.045	0.446	10%
7/12/2016	0.055	0.464	12%
7/13/2016	0.05	0.429	12%
7/14/2016	0.048	0.416	12%
7/15/2016	0.044	0.405	11%
7/16/2016	0.042	0.438	10%
7/17/2016	0.041	0.468	9%
7/18/2016	0.041	0.433	9%
7/19/2016	0.041	0.431	10%
7/20/2016	0.043	0.414	10%
7/21/2016	0.043	0.499	9%
7/22/2016	0.042	0.429	10%
7/23/2016	0.04	0.449	9%
7/24/2016	0.044	0.5	9%
7/25/2016	0.044	0.55	8%
7/26/2016	0.043	0.522	8%
7/27/2016	0.047	0.549	9%
7/28/2016	0.046	0.568	8%
7/29/2016	0.045	0.507	9%
7/30/2016	0.044	0.402	11%
7/31/2016	0.038	0.446	9%
8/1/2016	0.038	0.434	9%
8/2/2016	0.041	0.465	9%
8/3/2016	0.042	0.449	9%
8/4/2016	0.042	0.426	10%
8/5/2016	0.037	0.462	8%
8/6/2016	0.038	0.433	9%
8/7/2016	0.042	0.529	8%
8/8/2016	0.042	0.475	9%
8/9/2016	0.046	0.499	9%
8/10/2016	0.045	0.545	8%
8/11/2016	0.051	0.564	9%
8/12/2016	0.053	0.513	10%
8/13/2016	0.051	0.524	10%
8/14/2016	0.05	0.537	9%
8/15/2016	0.047	0.48	10%
8/16/2016	0.049	0.465	11%
8/17/2016	0.047	0.517	9%
8/18/2016	0.052	0.575	9%
8/19/2016	0.049	0.525	9%
8/20/2016	0.047	0.571	8%
8/21/2016	0.044	0.567	8%
8/22/2016	0.046	0.526	9%
8/23/2016	0.046	0.522	9%
8/24/2016	0.048	0.531	9%
8/25/2016	0.05	0.515	10%

8/26/2016	0.05	0.52	10%	
8/27/2016	0.053	0.528	10%	
8/28/2016	0.049	0.531	9%	
8/29/2016	0.049	0.603	8%	
8/30/2016	0.047	0.492	10%	
8/31/2016	0.05	0.503	10%	
9/1/2016	0.046	0.404	11%	
9/2/2016	0.041	0.352	12%	
9/3/2016	0.043	0.362	12%	
9/4/2016	0.04	0.386	10%	
9/5/2016	0.037	0.438	8%	
9/6/2016	-0.027	0.436	-6%	Spurious H2S data
9/7/2016		0.436	0%	Missing H2S data
9/8/2016		0.396	0%	Missing H2S data
9/9/2016		0.451	0%	Missing H2S data
9/10/2016		0.422	0%	Missing H2S data
9/11/2016		0.345	0%	Missing H2S data
9/12/2016		0.343	0%	Missing H2S data
9/13/2016	33.738	0.394	8563%	Spurious H2S data
9/14/2016	5.128	0.306	1676%	Spurious H2S data
9/15/2016	-0.101	0.289	-35%	Spurious H2S data
9/16/2016	0.028	0.286	10%	
9/17/2016	0.04	0.31	13%	
9/18/2016	0.039	0.363	11%	
9/19/2016	0.039	0.353	11%	
9/20/2016	0.038	0.332	11%	
9/21/2016	0.038	0.327	12%	
9/22/2016	0.04	0.311	13%	
9/23/2016	0.041	0.338	12%	
9/24/2016	0.042	0.345	12%	
9/25/2016	0.044	0.337	13%	
9/26/2016	0.044	0.327	13%	
9/27/2016	0.041	0.297	14%	
9/28/2016	0.046	0.289	16%	
9/29/2016	0.043	0.349	12%	
9/30/2016	0.047	0.318	15%	
10/1/2016	0.048	0.348	14%	
10/2/2016	0.027	0.363	7%	
10/3/2016	0	0.401	0%	Spurious H2S data
10/4/2016	0.037	0.362	10%	
10/5/2016	0.057	0.38	15%	
10/6/2016	0.054	0.432	13%	
10/7/2016	0.056	0.376	15%	
10/8/2016	0.055	0.351	16%	
10/9/2016	0.051	0.357	14%	
10/10/2016	0.051	0.351	15%	
10/11/2016	0.053	0.365	15%	

10/12/2016	0.061	0.374	16%
10/13/2016	0.059	0.364	16%
10/14/2016	0.055	0.357	15%
10/15/2016	0.058	0.376	15%
10/16/2016	0.055	0.369	15%
10/17/2016	0.052	0.418	12%
10/18/2016	0.051	0.434	12%
10/19/2016	0.05	0.41	12%
10/20/2016	0.049	0.371	13%
10/21/2016	0.05	0.34	15%
10/22/2016	0.057	0.321	18%
10/23/2016	0.056	0.356	16%
10/24/2016	0.058	0.38	15%
10/25/2016	0.056	0.418	13%
10/26/2016	0.061	0.394	15%
10/27/2016	0.056	0.392	14%
10/28/2016	0.055	0.35	16%
10/29/2016	0.053	0.357	15%
10/30/2016	0.059	0.361	16%
10/31/2016	0.059	0.379	16%
11/1/2016	0.054	0.39	14%
11/2/2016	0.056	0.448	13%
11/3/2016	0.064	0.418	15%
11/4/2016	0.066	0.468	14%
11/5/2016	0.065	0.46	14%
11/6/2016	0.065	0.32	20%
11/7/2016	0.062	0.334	19%
11/8/2016	0.062	0.305	20%
11/9/2016	0.067	0.305	22%
11/10/2016	0.063	0.307	21%
11/11/2016	0.061	0.359	17%
11/12/2016	0.059	0.331	18%
11/13/2016	0.061	0.338	18%
11/14/2016	0.058	0.302	19%
11/15/2016	0.054	0.332	16%
11/16/2016	0.057	0.33	17%
11/17/2016	0.056	0.356	16%
11/18/2016	0.052	0.326	16%
11/19/2016	0.062	0.393	16%
11/20/2016	0.062	0.387	16%
11/21/2016	0.059	0.336	18%
11/22/2016	0.055	0.369	15%
11/23/2016	0.058	0.323	18%
11/24/2016	0.056	0.29	19%
11/25/2016	0.056	0.315	18%
11/26/2016	0.054	0.31	17%
11/27/2016	0.048	0.38	13%

11/28/2016	0.049	0.402	12%
11/29/2016	0.049	0.368	13%
11/30/2016	0.052	0.373	14%
12/1/2016	0.057	0.392	15%
12/2/2016	0.053	0.356	15%
12/3/2016	0.051	0.369	14%
12/4/2016	0.047	0.399	12%
12/5/2016	0.045	0.406	11%
12/6/2016	0.057	0.395	14%
12/7/2016	0.066	0.424	16%
12/8/2016	0.067	0.402	17%
12/9/2016	0.065	0.357	18%
12/10/2016	0.055	0.412	13%
12/11/2016	0.048	0.396	12%
12/12/2016	0.046	0.401	11%
12/13/2016	0.046	0.364	13%
12/14/2016	0.046	0.446	10%
12/15/2016	0.063	0.394	16%
12/16/2016	0.064	0.384	17%
12/17/2016	0.065	0.444	15%
12/18/2016	0.062	0.46	13%
12/19/2016	0.064	0.43	15%
12/20/2016	0.052	0.412	13%
12/21/2016	0.05	0.405	12%
12/22/2016	0.054	0.433	12%
12/23/2016	0.052	0.452	12%
12/24/2016	0.041	0.444	9%
12/25/2016	0.035	0.459	8%
12/26/2016	0.039	0.445	9%
12/27/2016	0.048	0.418	11%
12/28/2016	0.049	0.412	12%
12/29/2016	0.045	0.442	10%
12/30/2016	0.052	0.502	10%
12/31/2016	0.057	0.425	13%
1/1/2017	0.046	0.48	10%
1/2/2017	0.059	0.447	13%
1/3/2017	0.055	0.487	11%
1/4/2017	0.063	0.481	13%
1/5/2017	0.065	0.451	14%
1/6/2017	0.066	0.469	14%
1/7/2017	0.067	0.475	14%
1/8/2017	0.061	0.458	13%
1/9/2017	0.065	0.505	13%
1/10/2017	0.066	0.489	13%
1/11/2017	0.073	0.474	15%
1/12/2017	0.066	0.409	16%
1/13/2017	0.062	0.458	14%

1/14/2017	0.058	0.532	11%
1/15/2017	0.055	0.489	11%
1/16/2017	0.058	0.481	12%
1/17/2017	0.063	0.467	13%
1/18/2017	0.068	0.45	15%
1/19/2017	0.063	0.454	14%
1/20/2017	0.057	0.442	13%
1/21/2017	0.064	0.446	14%
1/22/2017	0.022	0.441	5%
1/23/2017	0.099	0.481	21%
1/24/2017	0.06	0.499	12%
1/25/2017	0.058	0.518	11%
1/26/2017	0.063	0.47	13%
1/27/2017	0.06	0.469	13%
1/28/2017	0.062	0.484	13%
1/29/2017	0.06	0.446	13%
1/30/2017	0.058	0.437	13%
1/31/2017	0.062	0.464	13%
2/1/2017	0.074	0.42	18%
2/2/2017	0.068	0.419	16%
2/3/2017	0.076	0.429	18%
2/4/2017	0.068	0.4	17%
2/5/2017	0.064	0.408	16%
2/6/2017	0.074	0.43	17%
2/7/2017	0.077	0.415	19%
2/8/2017	0.074	0.475	16%
2/9/2017	0.07	0.474	15%
2/10/2017	0.062	0.412	15%
2/11/2017	0.062	0.419	15%
2/12/2017	0.058	0.457	13%
2/13/2017	0.058	0.571	10%
2/14/2017	0.061	0.501	12%
2/15/2017	0.061	0.461	13%
2/16/2017	0.06	0.432	14%
2/17/2017	0.063	0.462	14%
2/18/2017	0.058	0.435	13%
2/19/2017	0.061	0.457	13%
2/20/2017	0.065	0.481	14%
2/21/2017	0.062	0.42	15%
2/22/2017	0.06	0.437	14%
2/23/2017	0.058	0.434	13%
2/24/2017	0.067	0.469	14%
2/25/2017	0.057	0.446	13%
2/26/2017	0.057	0.352	16%
2/27/2017	0.067	0.458	15%
2/28/2017	0.062	0.432	14%
3/1/2017	0.062	0.419	15%

3/2/2017	0.061	0.427	14%
3/3/2017	0.076	0.397	19%
3/4/2017	0.069	0.431	16%
3/5/2017	0.068	0.442	15%
3/6/2017	0.075	0.472	16%
3/7/2017	0.077	0.427	18%
3/8/2017	0.073	0.43	17%
3/9/2017	0.084	0.444	19%
3/10/2017	0.076	0.455	17%
3/11/2017	0.076	0.411	18%
3/12/2017	0.069	0.39	18%
3/13/2017	0.079	0.424	19%
3/14/2017	0.074	0.436	17%
3/15/2017	0.068	0.414	16%
3/16/2017	0.06	0.455	13%
3/17/2017	0.067	0.373	18%
3/18/2017	0.061	0.394	15%
3/19/2017	0.058	0.394	15%
3/20/2017	0.063	0.427	15%
3/21/2017	0.067	0.42	16%
3/22/2017	0.065	0.405	16%
3/23/2017	0.065	0.42	15%
3/24/2017	0.073	0.41	18%
3/25/2017	0.07	0.397	18%
3/26/2017	0.072	0.418	17%
3/27/2017	0.069	0.411	17%
3/28/2017	0.064	0.407	16%
3/29/2017	0.068	0.381	18%
3/30/2017	0.06	0.395	15%
3/31/2017	0.06	0.415	14%
4/1/2017	0.067	0.398	17%
4/2/2017	0.061	0.405	15%
4/3/2017	0.052	0.429	12%
4/4/2017	0.057	0.42	14%
4/5/2017	0.058	0.373	16%
4/6/2017	0.058	0.383	15%
4/7/2017	0.062	0.35	18%
4/8/2017	0.056	0.379	15%
4/9/2017	0.05	0.386	13%
4/10/2017	0.048	0.336	14%
4/11/2017	0.02	0.294	7%
4/12/2017	0.706	0.428	165%
4/13/2017	0.976	0.409	239%
4/14/2017	0.238	0.381	62%
4/15/2017	0.056	0.434	13%
4/16/2017	0.057	0.49	12%
4/17/2017	0.059	0.4	15%

4/18/2017	0.048	0.404	12%
4/19/2017	0.056	0.482	12%
4/20/2017	0.053	0.376	14%
4/21/2017	0.052	0.418	12%
4/22/2017	0.059	0.468	13%
4/23/2017	0.061	0.451	14%
4/24/2017	0.056	0.42	13%
4/25/2017	0.059	0.515	11%
4/26/2017	0.05	0.477	10%
4/27/2017	0.048	0.497	10%
4/28/2017	0.05	0.466	11%
4/29/2017	0.059	0.485	12%
4/30/2017	0.055	0.428	13%
5/1/2017	0.065	0.434	15%
5/2/2017	0.069	0.503	14%
5/3/2017	0.066	0.478	14%
5/4/2017	0.07	0.465	15%
5/5/2017	0.067	0.448	15%
5/6/2017	0.062	0.47	13%
5/7/2017	0.064	0.468	14%
5/8/2017	0.055	0.455	12%
5/9/2017	0.057	0.498	11%
5/10/2017	0.058	0.469	12%
5/11/2017	0.06	0.444	14%
5/12/2017	0.059	0.456	13%
5/13/2017	0.063	0.494	13%
5/14/2017	0.058	0.455	13%
5/15/2017	0.06	0.391	15%
5/16/2017	0.054	0.396	14%
5/17/2017	0.056	0.429	13%
5/18/2017	0.053	0.421	13%
5/19/2017	0.058	0.423	14%
5/20/2017	0.064	0.469	14%
5/21/2017	0.067	0.483	14%
5/22/2017	0.066	0.512	13%
5/23/2017	0.057	0.508	11%
5/24/2017	0.056	0.485	12%
5/25/2017	0.074	0.527	14%
5/26/2017	0.065	0.492	13%
5/27/2017	0.065	0.481	14%
5/28/2017	0.075	0.511	15%
5/29/2017	0.072	0.464	16%
5/30/2017	0.074	0.41	18%
5/31/2017	0.073	0.46	16%
6/1/2017	0.062	0.481	13%
6/2/2017	0.061	0.484	13%
6/3/2017	0.055	0.413	13%

6/4/2017	0.052	0.389	13%
6/5/2017	0.058	0.381	15%
6/6/2017	0.058	0.299	19%
6/7/2017	0.063	0.324	19%
6/8/2017	0.062	0.311	20%
6/9/2017	0.059	0.308	19%
6/10/2017	0.064	0.296	22%
6/11/2017	0.056	0.338	17%
6/12/2017	0.069	0.34	20%
6/13/2017	0.062	0.367	17%
6/14/2017	0.059	0.359	16%
6/15/2017	0.063	0.397	16%
6/16/2017	0.056	0.38	15%
6/17/2017	0.059	0.382	15%
6/18/2017	0.062	0.377	16%
6/19/2017	0.058	0.369	16%
6/20/2017	0.07	0.377	19%
6/21/2017	0.063	0.375	17%
6/22/2017	0.056	0.394	14%
6/23/2017	0.064	0.398	16%
6/24/2017	0.068	0.38	18%
6/25/2017	0.064	0.38	17%
6/26/2017	0.068	0.373	18%
6/27/2017	0.063	0.305	21%
6/28/2017	0.062	0.347	18%
6/29/2017	0.084	0.361	23%
6/30/2017	0.074	0.372	20%
7/1/2017	0.07	0.36	19%
7/2/2017	0.067	0.348	19%
7/3/2017	0.066	0.286	23%
7/4/2017	0.066	0.286	23%
7/5/2017	0.066	0.32	21%
7/6/2017	0.071	0.316	22%
7/7/2017	0.077	0.336	23%
7/8/2017	0.069	0.371	19%
7/9/2017	0.075	0.386	19%
7/10/2017	0.064	0.396	16%
7/11/2017	0.068	0.333	20%
7/12/2017	0.064	0.296	22%
7/13/2017	0.05	0.325	15%
7/14/2017	0.05	0.304	16%
7/15/2017	0.053	0.341	16%
7/16/2017	0.052	0.39	13%
7/17/2017	0.051	0.397	13%
7/18/2017	0.047	0.348	14%
7/19/2017	0.045	0.267	17%

Table 1
 Natural Gas Analytical Data – January 23, 2014
 Northwest Pipeline
 Sumner Compressor Station
 3104 166th Avenue E, Sumner, Washington

		Three Tests			Wt.% of total excluding nondetects
Carbon Disulfide	ppbv	< 20 c	< 20	< 20	
	µg/m3	< 62.3	< 62.3	< 62.3	
Carbonyl Sulfide	ppbv	< 20	< 20	< 20	
	µg/m3	< 49.1	< 49.1	< 49.1	
Dimethyl Disulfide	ppbv	< 20	< 20	< 20	
	µg/m3	< 76.9	< 76.9	< 76.9	
Dimethyl Sulfide	ppbv	155	259	167	
	µg/m3	394	657	425	5%
Ethyl Mercaptan	ppbv	1330	3080	3270	
	µg/m3	3380	7820	8310	59%
Hydrogen Sulfide	ppbv	< 20	< 20	< 20	
	µg/m3	< 27.2	< 27.2	< 27.2	
Isobutyl Mercaptan	ppbv	< 20	< 20	< 20	
	µg/m3	< 73.6	< 73.6	< 73.6	
Isopropyl Mercaptan	ppbv	805	1460	1500	
	µg/m3	2500	4520	4680	37%
Methyl Mercaptan	ppbv	< 20	< 20	< 20	
	µg/m3	< 39.3	< 39.3	< 39.3	
n-Butyl Mercaptan	ppbv	< 20	< 20	< 20	
	µg/m3	< 73.8	< 73.8	< 73.8	
n-Propyl Mercaptan	ppbv	< 20	< 20	< 20	
	µg/m3	< 62.2	< 62.2	< 62.2	
t-Butyl Mercaptan	ppbv	< 20	< 20	< 20	
	µg/m3	< 73.6	< 73.6	< 73.6	
Total Sulfur detected	ppbv	2290	4790	4940	

	Wt. %	lb/MMscf	molw	S lb/MMscf	S gr/100scf
SCENTINEL*S-20		0.3			
Methyl Ethyl Sulfide	21.2	0.06	76.157	0.027	0.019
t-Butyl Mercaptan	78.5	0.24	90.18	0.084	0.058
			Total:	0.110	0.077

		lb/MMscf	molw	S lb/MMscf	S gr/100scf
M Chemical RPV-1007		0.6			
Methyl Ethyl Sulfide	20.5	0.12	76.157	0.052	0.036
t-Butyl Mercaptan	79.5	0.48	90.18	0.169	0.12
			Total:	0.221	0.15

		lb/MMscf		S lb/MMscf	S gr/100scf
ODORANT SULFUR					
Methyl Ethyl Sulfide		0.19		0.078	0.055
t-Butyl Mercaptan		0.71		0.253	0.18
TOTAL		0.90		0.33	0.23

From: Faretra, Keith
[mailto:keith.faretra@p
se.com]

Sent: Wednesday, July
26, 2017 1:21 PM

1) Injected by: Williams

Concentration: approx. 0.6 lbs/MMscf

Manufacturer: M Chemical

Blend: RPV - 1007 (t-Butyl mercaptan & Methyl Ethyl Sulfide)

2) Injected by: PSE

Concentration: approx. 0.3 lbs/MMscf

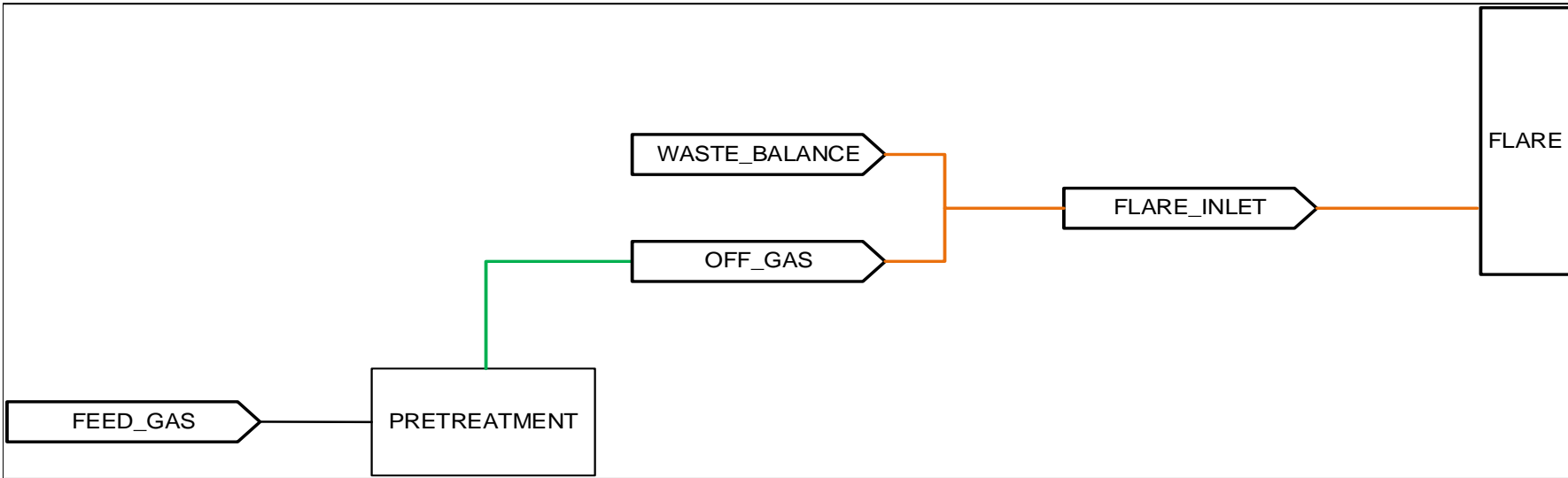
Manufacturer: Chevron Phillips Specialty Chemical

Blend: Scentinel S-20 (t-Butyl mercaptan & Methyl Ethyl Sulfide)

Flare Sulfur Balance

The following is for illustrative purposes and represents a sulfur balance from the feed pipeline to the flare assuming tariff levels of total sulfur, for simplicity assumed to be all H₂S.

This balance will not be the basis for the flare design itself. Previously provided cases will form the basis for the flare design.



The following cases represent a worst-case sulfur balance from the natural gas distribution line feed through to the flare. It is assumed that feed gas sulfur consists of 0.24 grains S/100SCF from H₂S and 0.56 grains S/100scf from other sulfur compounds. All H₂S sulfur and 80% of other sulfur is conservatively assumed to report to waste gases and the flare (0.70 grains S/100scf reports to flare).

- Case 1 Design Feed Composition / High Flow
- Case 2 Design Feed Composition / Low Flow
- Case 3 Alternative Feed Composition / High Flow
- Case 4 Alternative Feed Composition w/ 2% CO₂ / High Flow
- Case 5 Alternative Feed Composition / Instantaneous Low Off-Gas Flow

Flare Inlet Waste Gas Characteristics Summary

Molar volume 24.14 L/mole
 Conversion 28.31 L/cf
 Molar volume 0.852637 cf/mole

Feed Gas

		Case 1	Case 2	Case 3	Case 4	Case 5
Molar Flow	MMSCFD	25.60	11.00	23.20	24.00	25.00
Sulfur from H2S	gr/hscf	0.24	0.24	0.24	0.24	0.24
	lbs/hr	0.36	0.15	0.32	0.34	0.35
Sulfur from other	gr/hscf	0.56	0.56	0.56	0.56	0.56
	lbs/hr	0.86	0.37	0.78	0.81	0.84

Flare Inlet

		Case 1	Case 2	Case 3	Case 4	Case 5	Holding
Flare Inlet Flow	MMSCFD	0.74	0.13	0.49	0.97	0.48	0.023
Molecular Weight		39.17	35.26	33.99	37.63	33.50	19.10
Sulfur from H2S	lbs/hr	0.36	0.15	0.32	0.34	0.35	0.00024
Sulfur from other	lbs/hr	0.69	0.30	0.62	0.64	0.67	0.00057
Total Sulfur ^(a)	lbs/hr	1.05	0.45	0.95	0.98	1.02	0.00081
	SCFD	303	130	275	284	296	0.23
	ppmv	412	1,005	556	294	615	10
	ppmw	337	912	524	250	587	17

Flare Exhaust Emission Factors

		Case 1	Case 2	Case 3	Case 4	Case 5	Holding
Flare SO2 Emission Factor ^(b)	lbs/MMscf	68	165	91	48	101	1.6
Flare H2S Emission Factor ^(c)	lbs/MMscf	0.36	0.88	0.49	0.26	0.54	0.0088

Equations

(a) Flare Inlet S (lbs/hr) = ([Feed Gas Sulfur from H₂S (gr/hscf)] + [Off Gas Sulfur Partition (%)] x [Feed Gas Sulfur from Other (gr/hscf)]) / [7,000 gr/lb] / [100 scf/hscf] * [Molar Flow (MMSCFD)] / [24 hr/day] / [10⁶ scf/MMscf]

x

Off Gas Sulfur Partition (%) = 80%

(b) SO₂ Emission Factor (lb/MMcf) = [Total Sulfur (lb/hr)] / ([Molar Flow (MMSCFD)] * [24 hr/day]) x [64 g-SO₂/32 g-S] x [Destruction Efficiency (%)]

x

Destruction Efficiency (%) = 99%

(c) H₂S Emission Factor (lb/MMcf) = [Total Sulfur (lb/hr)] / ([Molar Flow (MMSCFD)] * [24 hr/day]) x [34 g-H₂S/32 g-S] x [1 - Destruction Efficiency (%)]

x

Definitions

gr = grains

ppmv = parts per million by volume

H₂S = hydrogen sulfide

ppmw = parts per million by weight

hscf = hundred standard cubic feet

SCFD = standard cubic feet per day

lbs = pounds

SO₂ = Sulfur Dioxide

MMSCFD = million SCFD