SRU #2 & 3 Thermal Oxidizer Emissions

Month	Days in Month	SO2 Emissions Monthly lb/hr	SO2 Emissions Monthly ton/month
January-2004	31	2.812	1.05
February-2004	29	2.940	1.02
March-2004	31	3.284	1.22
April-2004	30	4.459	1.61
May-2004	31	7.390	2.75
June-2004	30	8.131	2.93
July-2004	31	8.547	3.18
August-2004	31	9.645	3.59
September-2004	30	6.954	2.50
October-2004	31	5.526	2.06
November-2004	30	4.466	1.61
December-2004	31	1.127	0.42
	Average	5.4402	23.9263

Limits set by PTI and Title V. DO NOT CHANGE.

LIMIT	**172 tons/rolling 12 months**
Title V (10-13-04)	Part III, A.I.1.RR.5
PTI 04-1046 (8/5/98)	Page 5

Example Calculations

SO2 Emissions (monthly tons) = total flue gas flow (mscfh) * (1000 / m) (560 R/520 R)
* 0.1733 (lb SO2/ft3 SO2) * (SO2 in TO exhaust (ppmv) / 1(
* 24 hours/day * no. days/month / 2000 lb/ton

See SO2 sheet for derivation of this equation.

BP Oil Company, Toledo Refinery **2004 data** avg Updated 2012

SRU 2&3 (P037) Thermal Oxidizer Data 456.77

Month	fc5719 TRP SRU T.O. - Fuel Gas mscfh dry, actual O2	ai5704 TRP T.O. - SO2 ppm dry, actual O2	ai5705 TRP T.O. - O2 % dry	fi5707 TGT Vent Gas mscfh dry, actual O2	Flue Gas Theoretical (w/o excess air) mscfh	Flue Gas Total (w/ excess air) mscfh	Original values Flue Gas Theoretical (w/o excess air) mscfh	Original values Flue Gas Total (w/ excess air) mscfh
January 2004	12.67766346	23.15041321	2.357910296	455.3033412	578	651	604	681
February 2004	12.1527459	25.81724779	3.102577972	403.7256433	520	610	546	641
March 2004	12.47767541	29.50319593	3.361892917	382.5173594	501	596	529	630
April 2004	12.94513944	34.20650548	3.516981966	Failed to retrieve	**582**	698	526	632
May 2004	13.8112734	62.84256808	2.707994912	417.8748536	549	630	580	666
June 2004	13.72689576	69.48936907	2.030861789	435.5552912	566	627	596	660
July 2004	15.48692181	70.93095889	2.751873975	415.7861719	561	646	597	687
August 2004	15.89043275	72.22103234	1.938035617	498.3449065	650	716	684	754
September 2004	15.93684532	52.13591563	2.42508604	481.050358	632	715	667	754
October 2004	16.21215959	41.52611331	2.857899692	463.0802382	616	713	652	755
November 2004	17.68837698	30.5916397	2.155671054	534.240007	702	782	741	826
December 2004	17.37402654	7.630024721	2.370196721	537.0099931	702	791	740	834
January 2005								

Equations:

Flue Gas Theoretical, mscfh = NG fired, mscfh x ft3 flue gas/ft3 fuel gas + TGT vent gas, mscfh x ft3 flue gas / ft3 vent feed
Ratios of flue gas volume to fuel gas and vent feed volumes are calculated on the SO2 sheet.

Flue gas Actual (w/ excess air) = scf flue theoretical * (1 + (1/((21/stack O2) - 1))
This equation is derived on the SO2 sheet.

SRU #2 & 3 Thermal Oxidizer Emissions

Month	Days in Month	SO2 Emissions Monthly lb/hr	Ton/month
January 2005	31	1.862	0.69
February 2005	28	4.241	1.42
March 2005	31	1.188	0.44
April 2005	30	1.810	0.65
May-2005	31	0.879	0.33
June-2005	30	0.943	0.34
July-2005	31	1.554	0.58
August-2005	31	3.595	1.34
September-2005	30	3.075	1.11
October-2005	31	1.029	0.38
November-2005	30	0.529	0.19
December-2005	31	3.953	1.47
	Average	2.0548	8.9437

Limits set by PTI and Title V. DO NOT CHANGE.

LIMIT	**172 tons/rolling 12 months**
Title V (10-13-04)	Part III, A.I.1.RR.5
PTI 04-1046 (8/5/98)	Page 5

Example Calculations

SO2 Emissions (monthly tons) = total flue gas flow (mscfh) * (1000 / m) (560 R/520 R)
* 0.1733 (lb SO2/ft3 SO2) * (SO2 in TO exhaust (ppmv) / 10^6)
* 24 hours/day * no. days/month / 2000 lb/ton

See SO2 sheet for derivation of this equation.

BP Oil Company, Toledo Refinery **2005** Updated 2012

SRU 2&3 (P037) Thermal Oxidizer Data

	fc5719	ai5704	ai5705	fi5707	Flue Gas		Original values Flue Gas	
Month	TRP SRU T.O. - Fuel Gas mscfh dry, actual O2	TRP T.O. - SO2 ppm dry, actual O2	TRP T.O. - O2 % dry	TGT Vent Gas mscfh dry, actual O2	Theoretical (w/o excess air) mscfh	Total (w/ excess air) mscfh	Theoretical (w/o excess air) mscfh	Total (w/ excess air) mscfh
January 2005	16.3153453	13.25276617	3.082952367	487.5962876	642.1297509	753		
February 2005	15.49256189	33.46302185	4.908909996	376.1995064	520.2893821	679		
March 2005	15.85526857	8.671797756	3.750277748	453.6305883	603.1891119	734		
April 2005	13.86703929	18.72617354	1.962390299	340.4605259	469.5460679	518		
May 2005	13.35757942	7.475668519	2.0769005	440.0517946	567.8175715	630		
June 2005	11.56578151	8.31641237	1.903621457	440.2051411	552.6392946	608		
July 2005	9.635454354	12.70940127	1.870919344	499.2138478	596.9276948	655		
August 2005	10.50629445	30.72855625	3.058996705	432.3742442	535.5009679	627		
September 2005	14.74345355	31.77151756	4.750408562	266.9095594	401.2507725	519		
October 2005	12.77406806	14.87130735	8.315124186	111.1537872	223.8830496	371		
November 2005	12.27795734	4.410882899	2.995051537	432.5203773	550.8155293	642		
December 2005	13.05226289	30.54235833	2.877898424	472.322171	598.4599928	693		
January 2006								

Equations:

Flue Gas Theoretical, mscfh = NG fired, mscfh x ft3 flue gas/ft3 fuel gas + TGT vent gas, mscfh x ft3 flue gas / ft3 vent feed
Ratios of flue gas volume to fuel gas and vent feed volumes are calculated on the SO2 sheet.

Flue gas Actual (w/ excess air) = scf flue theoretical * (1 + (1/((21/stack O2) - 1))
This equation is derived on the SO2 sheet.

SRU SO2 Emissions Equations Updated 3-21-07

This sheet derives the equations used in the Emissions sheets to calculate SO2 emissions in lb/hr and tons/year.

TGT and NG compositions are used to develop ratios of the volume of TO flue gas to the volumes of TGT vent gas and fuel gas/NG entering the TO. Complete combustion of all hydrocarbons, hydrogen, and CO is assumed. Ratios of moles of CO2 and H2O per mole of each molecule burned are listed in Tables 1 and 2. The mole ratios are multiplied by the percentage of each molecule in the fuel gas to give the volumes of CO2 and H2O in flue gas per unit volume of fuel burned.

Combustion air added to the system is accounted for in two calculations. The first (in Tables 1 and 2) accounts for air whose oxygen is combusted. Moles of oxygen needed for combustion of each compound are listed, and the volume of nitrogen that accompanies this oxygen in combustion air is calculated, assuming air is 21% O2 and 79% N2, so that 79/21 or 3.76 ft3 of N2 is added per ft3 of O2 burned.

Tables 3 and 4 add the volume fractions of noncombustibles in the vent gas or fuel gas to the volume fractions of CO2, H2O, and N2 in flue gas that are calculated in Tables 1 and 2 to arrive at the ratio of flue gas volume to vent gas or fuel gas volume. All PI concentration tags are assumed to be on a dry basis, so water is excluded from the flue gas calculations (natural gas is already on a dry basis) and from the nominator of the volume ratios calculated in Tables 3 and 4. These calculations only address the vent or fuel gas and combustion air that is used; the following calculations add in the volume of excess air using the measured oxygen percentage in the stack.

Theoretical flue gas volume (without excess air) = TGT vent gas flow * 1.031 (from T3 below) + NG fuel flow * 8.559 (from T4 below)

The following calculations are derived here, but actually performed on the SRU 2-3 Emissions and SRU1 Emissions sheets:

The portion of air added to the system that is not used for combustion is calculated here:
Total flue gas volume (with excess air) is derived in terms of the theoretical flue gas volume (without excess air) and stack %O2 (from PI):
Stack O2 (%) * (one / 100%) = scf excess O2 / scf total flue gas = scf excess O2 /(scf flue theoretical + scf excess air)
Scf excess O2 = 0.21 * scf excess air (assuming oxygen content of air to be 21%v/v)
Stack O2 (fraction) = 0.21 * 100 * scf excess air /(scf flue theoretical + scf excess air)
Solving this equation for excess air: scf excess air = scf flue theoretical / ((21/stack O2) - 1)
Total scf flue gas (w/excess air) = scf flue theoretical + scf excess air = scf flue theoretical * (1 + (1/((21/stack O2) - 1))

Finally, the weight of SO2 emitted is calculated using SO2 density and the Ideal Gas Law:
Stack SO2 Emissions at 560 R = scf flue gas * 0.1733 lb/ft3 (SO2 density at 520 R) * (560/520) * stack SO2 ppmv / (1e6 part /ppm)
The conversion to 100 F (560 R) is because the SO2 CEM is reported at 100 F.

SO2 concentrations from PI are on a dry basis, actual oxygen, parts per million volume basis.

T1. TGT VENT GAS

This is probably from SRU design basis.

Compound	mole %	mole %, dry basis	ft3 of CO2 in flue gas per ft3 of compound	ft3 of CO2 in flue gas per ft3 dry fuel	ft3 of H2O in flue gas per ft3 of compound	ft3 of H2O in flue gas per ft3 dry fuel	ft3 O2 needed per ft3 of compound	ft3 of N2 in flue gas per ft3 of compound	ft3 of N2 in flue gas per ft3 dry fuel
hydrogen	3.3	3.5	0.0	0.000	1.0	0.035	0.5	1.881	0.065
nitrogen	88.5	94.0	0.0	0.000	0.0	0.000	0.0	0.000	0.000
oxygen	0.0	0.0	0.0	0.000	0.0	0.000	0.0	0.000	0.000
carbon monoxide	0.0	0.0	1.0	0.000	0.0	0.000	0.5	1.881	0.000
methane	0.0	0.0	1.0	0.000	2.0	0.000	2.0	7.524	0.000
carbon dioxide	2.4	2.5	0.0	0.000	0.0	0.000	0.0	0.000	0.000
water	5.92	0	0	0.000	0.0	0.000	0.0	0.000	0.000
Total	100.0	100.0		0.000		0.035			0.065

T2. NATURAL GAS

(typical, from http://www.uniongas.com/aboutus/aboutng

Compound	mole %	(already dry basis)	ft3 of CO2 in flue gas per ft3 of compound	ft3 of CO2 in flue gas per ft3 of fuel	ft3 of H2O in flue gas per ft3 of compound	ft3 of H2O in flue gas per ft3 of fuel	ft3 O2 needed per ft3 of compound	ft3 of N2 in flue gas per ft3 of compound	ft3 of N2 in flue gas per ft3 of fuel
carbon dioxide	0.7		0	0	0	0	0.0	0.000	0
methane	94.9		1	0.949	2	1.898	2.0	7.524	7.140
ethane	2.5		2	0.05	3	0.075	3.5	13.167	0.329
propane	0.2		3	0.006	4	0.008	5.0	18.810	0.038
normal/iso-c4	0.06		4	0.0024	5	0.003	6.5	24.452	0.015
pentane	0.02		5	0.001	6	0.0012	8.0	30.095	0.006
oxygen	0.02		0	0.000	0	0.000	0.0	0.000	0.000
H2	0		0	0.000	1	0.000	0.5	1.881	0.000
H2O	0		0	0.000	0.0	0.000	0.0	0.000	0.000
CO	0		1.0	0.000	0.0	0.000	0.5	1.881	0.000
N2	1.6		0.0	0.000	0.0	0.000	0.0	0.000	0.000
Total	100			1.0084		1.9852			7.528

T3.Flue Gas / Vent Gas Volume Ratio (excluding excess air)

	(ft3/dry fuel ft3)	vent prod (ft3/dry fuel ft3)	(ft3/dry fuel ft3)	Total mole %
carbon dioxide	0.025	0.000	0.025	2.424
water	0.000	0.035	0.000	0.000
nitrogen	0.940	0.065	1.006	97.576
oxygen	0.000	0.000	0.000	0.000
Total			1.031	100.000

T4. Flue Gas / Fuel Gas Volume Ratio (excluding excess air)

	fuel feed (ft3/ft3)	fuel prod (ft3/ft3)	Totals (ft3/ft3)	Totals mole %
carbon dioxide	0.007	1.008	1.015	11.863
water	0.000	1.985	0.000	0.000
nitrogen	0.016	7.528	7.544	88.134
oxygen	0.000	0.000	0.000	0.002
Total			8.559	100.000