Todd, Robert

From: Bergmann, Edwin [EJBERGMANN@eprod.com]
Sent: Monday, January 20, 2014 7:30 PM
To: Todd, Robert
Cc: Sartor, Rodney; Steve Langevin
Subject: RE: GHG Permit - Enterprise Products Mont Belvieu Propane Dehydrogenation Unit
Attachments: PDH Emission Calcs - with CO2perMMBTU.pdf.pdf

January 20, 2014

Mr. Robert Todd
Environmental Protection Agency

Robert:

Please find attached a spreadsheet showing the how the value 125 lb CO_2/MMBtu of fuel was derived for CO_2/CO_{2e} as represented in the GHG application. This Btu value reflects the use of a combination of methane (118 lb CO2/MMBtu), Ethane (131 lb CO2/MMBtu), Deethanizer Offgas (131 lb CO2/MMBtu) and PSA Tail Gas 96 lb CO2/MMBtu) in the combustion units at PDH. These BTU values are based on the compositions included in the attached Table A-1.

Natural Gas is used in the Regeneration Air Compressor Turbines, as these turbines are design to be fired on natural gas and not waste gas or ethane. PSA Tail Gas and Deethanizer Off gas are byproducts of the propylene manufacturing, and are utilized as fuel rather than the undesirable alternative of flaring this material. In addition ethane is available as a fuel from fractionation processes in the Mont Belvieu area due to the over- abundance of this hydrocarbon from natural gas production facilities. Thus, the flexibility in design of this to use various fuels, allows the plant to better utilize locally available fuels with minimal environmental impact.

If you have any questions, please feel free call me at any of the numbers below.

Ed Bergmann
Enterprise Products – Permits
Senior Environmental Engineer
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From: Todd, Robert [mailto:Todd.Robert@epa.gov]
Sent: Wednesday, January 15, 2014 9:11 AM
To: Bergmann, Edwin
Cc: Sartor, Rodney; Steve Langevin
Subject: RE: GHG Permit - Enterprise Products Mont Belvieu Propane Dehydrogenation Unit

Thanks Ed,
Can you provide me the calculations for these results, please?
Also, can you provide your expected CO2 and and CO2e emissions in terms of energy input?
I'll call you later this morning to talk about the permit.
Thanks, Robert

From: Bergmann, Edwin [mailto:EJBERGMANN@eprod.com]
Sent: Tuesday, January 14, 2014 6:35 PM
To: Todd, Robert
Cc: Sartor, Rodney; Steve Langevin
Subject: GHG Permit - Enterprise Products Mont Belvieu Propane Dehydrogenation Unit

Robert:

This is to respond to the questions you had per our conversation of January 3, 2014. The questions are listed below.

Q: Does Enterprise have fugitives for sulfur hexaflouride (SF_6) such as represented by PL for circuit breakers?

A: The circuit breakers that Enterprise will use are Vacuum Breakers and will not use SF_6.

Q: Does Enterprise have a number that demonstrates the energy used per lb of product produced?

A: Enterprise utilizes a waste heat boiler (WHB) to produce steam from the exhaust of the turbines, hot gas from the regeneration of the reactors. This system also has a duct burner system that utilizes several waste gas streams form the PDH process. This WHB provides steam to operate the PDH plant during normal operating conditions. (see attached .pdf) Since the rest of the Mont Belvieu complex uses hot oil systems the PDH plant has 2 Auxiliary Boilers that run in stand- by mode that are used to start up and shut down the unit when the WHB cannot provide sufficient steam due to the reduction in waste heat and gas sources during these temporary conditions. The numbers provided reflect operation of the 2 auxiliary boilers in the normal stand-by mode of operation. Also, 2 cases will be given that reflect the normal operation of this unit. Case 1 represents the natural gas fuel required to operate the unit, and Case 2 represents the total fuel usage which represents natural gas usage and process generated off-gas fuel which is used in some form in all the unit combustion systems with the exception of the regeneration air compressor gas turbines (A/B) which use natural gas as a fuel.

Case 1 : Natural gas usage only – 6060 BTU/lb product
Case 2 : Total fuel usage (natural gas and process generated off-gas fuel)- 9075 – Btu/ lb product

Should you have any questions, please do not hesitate to call me at any of the numbers below. Thank you for your time and consideration in this matter.

Ed Bergmann, P.E.
Enterprise Products – Permits
Senior Environmental Engineer
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P.O. Box 4324
Houston, TX 77002-5227

Phone: 713/381-5807
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Flare Gas Recovery
Enterprise Products - Mont Belvieu, Texas
EPA Propane Dehydro Application

Capital Cost		NOTES	REFERENCES
Direct Capital Costs			
Equipment Cost (FOB)	$3,000,000	Estimated Cost	1
Freight	$150,000	5% of Equipment Cost	2(a)
Sales Tax	$90,000	3% of Equipment Cost	2(a)
Total Direct Capital Costs	*$3,240,000*	A	2(b)
Indirect Installation Costs			
Labor Costs	$20,000	Estimated cost	1
Retrofit Costs			2(c)
- Disposal of demolition/construction debris	$0	Vendor notes purchaser responsible for disposal bins and disposal	1 & 2(c)
- Handling and Erection	$0	Vendor notes all lifting equipment to be provided by purchaser	1 & 2(c)
- Lost Production	$0		1, 2(c) & 3
Total Indirect Installation Costs	*$20,000*	B	2(b)
Project Contingency	*$489,000*	C = 0.15 x (A + B)	2(b)
Total Capital Investment (TCI)	**$3,749,000**	TCI = A + B + C	2(b)
Operating Cost			
Direct Annual Costs			2(d)
See Notes	$0		
Total Direct Annual Costs (DAC)	*$0*		2(d)
Indirect Annual Costs			
Administrative Charges	$74,980	2% of TCI	2(e)
Property Tax	$37,490	1% of TCI	2(e)
Insurance	$37,490	1% of TCI	2(e)
Annual Interest Rate	7%		
Economic Life of Compressors	20	Years	
Capital Recovery Factor (CRF)	0.094		2(f)
Total Capital Recovery Costs (TCRC)	$353,879	TCRC = CRF x TCI	2(g)
Total Indirect Annual Costs (IDAC)	*$503,839*	IDAC = TCRC + Admin Charges + Property Tax + Insurance	2(d)
Total Annual Cost	**$503,839**	TAC = DAC + IDAC	2(d)

Note: FG recovered would be used as fuel therefore CO_2e emissions based on natural gas fuel combustion avoided
The cost effectiveness in terms of CO_2e eliminated can be calculated by dividing the Total Annual Cost by incremental change in annual CO_2e emissions avoided as follows:

CO_2e Emission Rate	2,812.00	tpy
CO_2 Emission Rate	~~0.00~~	tpy
Incremental Emissions Reduction	2,812.00	tpy
Cost Effectiveness ($/ton)	**$179**	**per ton of CO_2e reduction**

2812 ? why not 4426 => $114 or 7238 => $69/ton

References:

1 EPA Air Pollution Control Cost Manual, Sixth Edition, January 2002; EPA/452/B-02-001
a. Table 2.4: Cost Ranges for Freight, Sales Tax, and Instruments.
b. Section 2.3.1 Elements of Total Capital Investment; Chapter 2 Cost Estimating Concepts and Methodology.
c. Section 2.5.4.2 Retrofit Cost Considerations; Chapter 2 Cost Estimating Concepts and Methodology.
d. Section 2.3.2 Elements of Total Annual Cost; Chapter 2 Cost Estimating Concepts and Methodology.
e. Section 2.5.5.8 Property Taxes, Insurance, and Administrative Charges; Chapter 2 Cost Estimating Concepts and Methodology.
f. Table A.2: Capital Recovery Factors for Equal Payments on a Dollar over a number of years; Chapter 2 Cost Estimating Concepts and Methodology.
g. Section 2.4.4 Financial Analysis; Chapter 2 Cost Estimating Concepts and Methodology.

2 The net revenue (i.e., gross revenue minus the direct costs of generating it) lost during this unanticipated shutdown period. Pursuant to the EPA Air Pollution Control Cost Manual, "Unanticipated problems with the installation due to retrofit-related conditions can impose significant costs on the system." Assumes that unanticipated problems lead to additional unplanned outage of operating unit for 1/2 day. The vendor estimates 9 days to conduct the retrofit. Enterprise is conservatively representing only 1/2 day of lost production in this analysis.

Table A-1 GHG Emission Calculations

Enterprise Operating Products LLC
Mont Belvieu Complex - PDH Unit
GHG Emissions - Individual Combustion Unit Limts

Carbon Factor Calculations:

Component	Molecular Weight (lb/lb-mol)	Number of Carbons per mole	Composition (mole %) Natural Gas[1]	DeEth Offgas (SOR)[2]	PSA Tail Gas (SOR)[2]	LTRU Offgas[2]	Import Ethane	MSS Flaring	Reactor VOC
Nitrogen	28.013	0	0.683	0.490	6.760	1.490	0.000	0.000	0.000
Carbon Dioxide	44.010	1	1.797	2.200	0.520	0.120	0.000	0.000	0.000
Carbon Monoxide	28.010	1	0.035	1.630	12.470	2.750	0.000	0.000	0.000
Helium	4.003	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Argon	39.95	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hydrogen	2.02	0	0.000	8.860	60.070	91.190	0.000	0.000	0.000
Methane	16.04	1	93.361	7.680	13.960	3.080	0.000	0.000	0.000
Ethane	30.07	2	3.043	71.330	3.470	0.770	100.000	0.000	1.530
Propane	44.10	3	0.557	0.060	0.760	0.170	0.000	50.000	8.113
Iso-Butane	58.12	4	0.191	0.000	0.000	0.000	0.000	0.000	0.000
n-Butane	58.12	4	0.143	0.000	0.000	0.000	0.000	0.000	9.672
Iso-Pentane	72.15	5	0.039	0.000	0.000	0.000	0.000	0.000	0.000
n-Pentane	72.15	5	0.027	0.000	0.000	0.000	0.000	0.000	7.792
n-Hexane	86.18	6	0.088	0.000	0.000	0.000	0.000	0.000	14.234
n-Heptane	100.20	7	0.000	0.000	0.000	0.000	0.000	0.000	12.241
C10+	140.00	10	0.000	0.000	0.000	0.000	0.000	0.000	43.807
Ethylene	28.05	2	0.000	7.170	0.970	0.210	0.000	0.000	0.182
Propylene	42.08	3	0.000	0.310	1.010	0.220	0.000	50.000	2.429
neo-Pentane	72.15	5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Acetylene	26.04	2	0.000	0.220	0.010	0.000	0.000	0.000	0.000
Hydrogen Sulfide	34.00	0	0.000	0.050	0.000	0.000	0.000	0.000	0.000
Oxygen	32.00	0	0.037	0.000	0.000	0.000	0.000	0.000	0.000
Water	18.02	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MW (lb/lbmole):			**17.46**	**26.66**	**11.14**	**4.03**	**30.07**	**43.09**	**102.22**
Carbon Content (kg C/kg Fuel):			**0.723**	**0.765**	**0.443**	**0.270**	**0.798**	**0.835**	**0.847**
Heating Value (btu/scf, HHV):			**1028.6**	**1501.2**	**495.5**	**362.0**	**1769.7**	**NA**	**NA**
CO2 emission factor (lb/mmbtu,HHV):			118.55	131.39	96.35	29.10	131.04		

1 Natural gas composition is based on historical analyses of gas received at the Mt. Belvieu Complex.

2 These fuels are process offgases, and compositions were provided by Lummus, the licensor of the proposed technology.

Emission Factors:

Eq. C-5 from 40 CFR Part 98 Chapter C

$$CO_2 = \frac{44}{12} * Fuel * CC * \frac{MW}{MVC} * 0.001 \quad \text{(Eq. C-5)}$$

CO2 =	CO2 emissions, metric tons/yr
Fuel =	firing rate in mmscf/yr
MVC =	836.6 (per Part 98)
CC =	as calculated above
MW =	as calculated above

CH4 and N2O Emission factors from Table C-2 of Appendix A to 40 CFR Part 98 Chapter C

	kg CH4 /mmBtu	kg N2O/mmBtu
Natural Gas	0.001	0.0001
Process Gas	0.003	0.0006
kg to lb conversion factor:		2.20462

CO2e Equivalents:

CO2	1.0
CH4	25.0
N2O	298.0

Table A-2 GHG Emission Calculations

Enterprise Operating Products LLC
Mont Belvieu Complex - PDH Unit
GHG Emissions - Combustion Unit Caps

EPN	FIN	Description	Firing Rate (mmBtu/yr)
HR15.101	HR15.101	Reactor Charge Heater	4,267,060
DW37.101	All of Below:	Waste Heat Boiler:	
	HR15.103	Waste Heat Boiler Burner	297,241
	HR15.102	Regeneration Air Heater	10,417,999
	GT26.101A	Regen Air Comp. Gas Turbine A	2,107,571
	GT26.101B	Regen Air Comp. Gas Turbine B	2,107,571
BO10.103A	BO10.103A	Auxiliary Boiler A	248,500
BO10.103B	BO10.103B	Auxiliary Boiler B	
Total from Above Combustion Units			**19,445,942**

Available Fuels:

Fuel[1]	Firing Rate (mmBtu/yr)
DeEth Offgas	3,758,478
PSA Tail Gas	2,167,662
Ethane	9,304,660
Natural Gas	4,215,142
Fuel Total	**19,445,942**

1. DeEth Offgas and PSA Tail Gas firing rates are all of these fuels that are projected to be produced annual in the process. All of these fuel gases will be burned in the PDH Unit combustion devices and the balance of the fuel requirements will be made up with either ethane or natural gas. Natural gas is the only fuel that will be fired in the Gas Turbines, and the natural gas firing rate shown is the fuel required for the two Gas Turbines. For the maximum annual GHG emissions calculations all remaining fuel requirements are assumed to be provided by ethane as ethane results in higher GHG emissions per btu than natural gas.

GHG Emission Calculation

Fuel	Firing Rate (mmBtu/yr)	Firing Rate (scf/yr)	Carbon Content (CC)	MW (lb/lbmol)	Emission Rates (tpy)[2]			
					CO_2	CH_4	N_2O	CO_2e
DeEth Offgas	3,758,478	2,503,713,725	0.765	26.66	246,846	12.43	2.49	247,897
PSA Tail Gas	2,167,662	4,374,841,594	0.443	11.14	104,394	7.17	1.43	105,001
Ethane	9,304,660	5,257,761,370	0.798	30.07	609,635	30.77	6.15	612,238
Natural Gas	4,215,142	4,097,866,106	0.723	17.46	249,794	13.94	2.79	250,973
Fuel Total	**19,445,942**	NA	NA	NA	**1,210,669**	**64.31**	**12.86**	**1,216,109**
VOC from Reactors	NA	13,333,260	0.847	102.22	5,580	-	-	5,580
Coke Burn[3]	NA	NA	NA	NA	60,000	-	-	60,000
Cap Total	NA	NA	NA	NA	**1,276,248**	**64.31**	**12.86**	**1,281,689**

2. Note all emission rates are in units of short tons. Eq. C-5 in 40 CFR Part 98 Chapter C yields emissions in metric tons. Metric tons were converted to short tons by multiplying by 1.102311 short tons per metric ton.

3. CO2 from coke burn based on Lummus EOR estimate of 58,000 tpy, rounded to 60,000 tpy.

Table A-4 Pipeline Fugitive GHG Emission

Enterprise Operating Products LLC

Mont Belvieu Complex - PDH Unit

			EPN	LDAR		EPN	LDAR	
			FUG-NGAS	AVO		FUG-PDH	28LAER	
Component Type	Stream Type	Emission Factor SOCMI without Ethylene	Number of Components	Control Eff.	Annual Emissions (tpy)	Number of Components	Control Eff.	Annual Emissions (tpy)
Valves	Gas/Vapor	0.0089	140	30%	3.8202	1,119	97%	1.3086
	Light Liquid	0.0035	0	0%	0.0000	1495	97%	0.6876
	Heavy Liquid	0.0007	0	0%	0.0000	0	97%	0.0000
Pumps	Light Liquid	0.0386	0	0%	0.0000	51	93%	0.6036
	Heavy Liquid	0.0161	0	0%	0.0000	0	93%	0.0000
Flanges	Gas/Vapor	0.0029	350	30%	3.1120	3,851	97%	1.4675
	Light Liquid	0.0005	0	0%	0.0000	5263	97%	0.3458
	Heavy Liquid	0.00007	0	0%	0.0000	0	97%	0.0000
Compressors	Gas/Vapor	0.5027	0	0%	0.0000	4	95%	0.4404
Relief Valves	Gas/Vapor	0.2293	10	30%	7.0303	45	100%	0.0000
Open Ends		0.004	0	0%	0.0000	0	97%	0.0000
Sample Con.		0.033	0	0%	0.0000	32	97%	0.1388
Other	Gas/Vapor	0	0	0%	0.0000	0	97%	0.0000
	Lt/Hvy Liquid	0	0	0%	0.0000	0	97%	0.0000
Process Drains		0.07	0	0%	0.0000	0	97%	0.0000
TOTAL			500	Total Loss	**13.96**	11,860	Total Loss	**4.99**
Operating Hours: 8,760				% CH4	93%		% CH4	5%
				Total CH4	**13.04**	13.03	Total CH4	**0.25**
				GWP	25		GWP	25
				CO2e	**325.89**		CO2e	**6.24**

325.8298 TPY CO_2e

Table A-5 GHG Emission Calculations

Enterprise Operating Products LLC
Mont Belvieu Complex - PDH Unit
Diesel Engines

EPN	FIN	Description	Fuel	Firing Rate (mmbtu/hr)	Usage (hrs/yr)	Firing Rate (mmbtu/yr)	Emission Rates (tpy)[1]			
							CO_2	CH_4	N_2O	CO_2e
PM18.803	PM18.803	Fire Water Pump Engine	No. 2 Diesel	3.79	52	197	16.1	0.0007	0.0001	16.1
PM18.850C	PM18.850C	Raw Water Pump Engine	No. 2 Diesel	1.97	52	103	8.4	0.0003	0.0001	8.4

Emission Factors:

Emission factors from Tables C-1 & C-2 of Appendix A to 40 CFR Part 98 Chapter C

Fuel	kg CO2/mmBtu	kg CH4 /mmBtu	kg N2O/mmBtu
No. 2 Distillate	73.96	0.003	0.0006

kg to lb conversion factor: 2.20462

CO2e Equivalents:

CO2	1.0
CH4	25.0
N2O	298.0