Michigan Refining Division
HESS Department

Marathon Petroleum Company LP

1001 S. Oakwood Ave.
Detroit, MI 48217
Tel: 313.843.9100

Via Federal Express

September 27, 2016

Mr. Jorge Acevedo
Michigan Department of Environmental Quality
Air Quality Division
3058 W. Grand Boulevard
Suite 2300
Detroit, MI 48202

RE: Response to 9/6/2016 Violation Notice Regarding Crude/Vacuum Heater Particulate Matter (PM) Compliance Testing; Marathon Petroleum Company LP, Michigan Refining Division

Dear Mr. Acevedo:

This letter is in response to the September 6, 2016 Violation Notice (VN) issued to Marathon Petroleum Company LP, Michigan Refining Division (MPC). In the VN, Michigan Department of Environmental Quality, Air Quality Division, alleged that the following violations occurred June 15, 2016.

Process Description	Rule/Permit Condition Violated	Comments
Crude/Vacuum Heater (EU05-CRUDEHTR-S1/EU04-VACHTR-S1)	PTI 63-08E, FGHEATERS-S1, Condition I.22 R 336.1205 R 336.2802 40 CFR 52.21	The Particulate Matter permit limit is 0.0019 lb/MMBTU. The stack test result was 0.0020 lb/MMBTU

The VN relates to source testing conducted on the combined Crude/Vacuum heater stack on June 15, 2016. MPC performed a retest on this stack August 23, 2016 and the results (0.0011 lb/MMBtu) were well below the 0.0019 lb/MMBtu permit limit. Further, annual testing conducted over the last three years has shown consistent compliance with the permit limit as indicated below:

Year	Crude/Vacuum Heater PM Test Result (lb/MMBtu)
2013	0.0011
2014	0.0007
2015	0.0012

The remainder of this letter provides information requested in the VN, including: (1) the date the alleged violation occurred; (2) an explanation of the causes and duration of the alleged violation; (3) whether the violation is ongoing; (4) a summary of the actions that have been taken and are proposed to be taken to correct the alleged violation; and (5) what steps are being taken to prevent a reoccurrence.

Date the Violation Occurred: The alleged violation is not on-going. Further, it is unclear whether the June 15 test results actually exceeded the emission limit (see discussion below).

Explanation of the Causes and Duration of the Violation: As mentioned above, the VN references U.S. EPA Method 5 source testing conducted on the combined Crude/Vacuum heater stack on June 15, 2016. The results of this testing showed 0.0020 lb/MMBtu PM versus a permit limit of 0.0019 lb/MMBtu. The following sections discuss this testing and factors contributing to or associated with the test results.

1. **The "uncertainty" associated with U.S. EPA Method 5 renders the June 15 test results statistically indistinguishable as compared to the permit limit.** A December 2013 report by the Electric Power Research Institute titled "Filterable Particulate Matter Stack Test Methods: Performance Characteristics and Potential Improvements"[1] identified an uncertainty range of ± 6% to ±10% in EPA Method 5. As applied to the June 15, 2016 stack test, CleanAir Engineering (MPC's stack test contractor) concluded that the measured FPM value from the recent stack test falls within the uncertainty bounds of the method. In other words, from a statistical standpoint, the results obtained cannot be distinguished from the limit and based on these results, compliance or non-compliance cannot be reliably determined. The difference between the stack test result and the permit limit is 0.0001 lb/MMBtu or 5%, which falls within the stated uncertainty range.

2. **The equivalent lb/hr PM emission rate calculated using the June 15 test results and associated heater firing rates is less than the calculated "permit-allowable" limit.** As shown below, when the permitted heater firing rates for both the Crude and Vacuum heaters are multiplied by the lb/MMBtu permit limit, the effective or "permit-allowable" lb/hr PM emission limit is 0.79 lbs/hr. Using the June 15 stack test result (0.0020 lb/MMBtu), actual heater firing rates, and assuming equal distribution of PM from each heater, an equivalent PM emission rate of 0.47 lbs/hr is calculated, which is 59% of the equivalent "permit-allowable" rate. The same calculation for the August 23 follow-up testing yields an equivalent emission rate of 0.33 lb/hr, which is 42% of "permit-allowable".

$$Crude\ Heater\ PM = 240\ (\text{MMBtu/Hr})\ \text{X}\ 0.0019\ (\text{lb/MMBtu}) = 0.34\ \text{lb/hr}$$
$$Vacuum\ Heater\ PM = 177\ (\text{MMBtu/Hr})\ \text{X}\ 0.0019\ (\text{lb/MMBtu}) = 0.46\ \text{lb/hr}$$
$$\text{"Permit} - \text{allowable"}\ PM\ Limit = 0.79\ \text{lb/hr}$$

3. **Ambient PM levels contribute to the Method 5 PM results.** U.S. EPA Method 5 does not distinguish between PM generated by poor combustion in a fuel-fired heater or boiler and PM present in the influent combustion air. As described in item 4, there was no indication of incomplete combustion in either the Crude or Vacuum Unit heaters during the testing. A portion of the Method 5 PM lb/MMBtu result is attributed to ambient PM in the inlet air. During the test period on June 15, 2016, ambient PM levels measured at the refinery's 4-East PAMS station (closest to the Crude/Vacuum Unit heaters) averaged approximately 36.1 $\mu g/m^3$. Note that these PM levels have not undergone QA/QC and are preliminary in nature. If the Method 5 calculations from the June 15 testing are adjusted to account for ambient PM levels, the results would be 0.0016 lb/MMBtu (see attached CleanAir letter and supporting information).

[1] EPRI report can be accessed via the following link:
http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002000975

4. **Combustion characteristics in the Crude/Vacuum Unit heaters during the test were not conducive to excessive PM formation.** The 0.0019 lb/MMBtu emission limit applicable to these heaters is based on the U.S. EPA AP-42 emission factor for PM from natural gas combustion. According to AP-42[4], PM *"in natural gas combustion are usually larger molecular weight hydrocarbons that are not fully combusted. Increased PM emissions may result from poor air/fuel mixing or maintenance problems."* During the stack test period on June 15, excess oxygen levels in both the Crude and Vacuum Unit heaters were greater than 3%. In addition, exhaust gas CO concentrations remained below 5 ppm. Both of these indicators show that the fuel fired in these heaters was being combusted completely and smoke or soot formation was unlikely. Further, annual tune-ups of both heaters were conducted in July 2016 with no significant issues identified.

Summary of Corrective/Preventative Actions Taken: MPC re-tested the combined Crude/Vacuum heaters during the week of August 23, 2016. The results of this re-test (0.0011 lb/MMBtu) showed compliance with the applicable emission limit. MPC will continue to conduct Method 5 source testing annually as required by ROP MI-ROP-A9831-2012c. Further, MPC will continue to perform annual tune-ups of both heaters as required by 40 CFR 63, Subpart DDDDD and to conduct routine operator inspections to ensure proper combustion characteristics.

MPC appreciates this opportunity to respond to the VN. If you would like further information please do not hesitate to contact Ms. Crystal Davis at (313) 297-6115.

Sincerely,

Marathon Petroleum Company LP
By: MPC Investment LLC, its General Partner

Ms. Honor Sheard, Deputy Assistant Secretary

cc: Ms. LaReina Wheeler, City of Detroit, Department of Environmental Affairs
Ms. Lynn Fiedler, DEQ
Ms. Teresa Seidel, DEQ
Mr. Thomas Hess, DEQ
Ms. Wilhemina McLemore, DEQ
Mr. Jeff Korniski, DEQ
Mr. Todd Zynda, DEQ

Attachments: Renewable Operating Permit Report Certification
9/26/16 CleanAir letter and supporting information

[4]See AP-42, section 1.4; https://www3.epa.gov/ttn/chief/ap42/ch01/index.html

MICHIGAN DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENT
AIR QUALITY DIVISION

RENEWABLE OPERATING PERMIT
REPORT CERTIFICATION

Authorized by 1994 P.A. 451, as amended. Failure to provide this information may result in civil and/or criminal penalties.

Reports submitted pursuant to R 336.1213 (Rule 213), subrules (3)(c) and/or (4)(c), of Michigan's Renewable Operating Permit (ROP) program must be certified by a responsible official. Additional information regarding the reports and documentation listed below must be kept on file for at least 5 years, as specified in Rule 213(3)(b)(ii), and be made available to the Department of Natural Resources and Environment, Air Quality Division upon request.

Source Name Marathon Petroleum Company LP County Wayne

Source Address 1300 South Fort Street City Detroit

AQD Source ID (SRN) A9831 ROP No. MI-ROP-A9831-2012c ROP Section No. 01

Please check the appropriate box(es):

☐ **Annual Compliance Certification (Pursuant to Rule 213(4)(c))**

Reporting period (provide inclusive dates): From ________ To ________

☐ 1. During the entire reporting period, this source was in compliance with **ALL** terms and conditions contained in the ROP, each term and condition of which is identified and included by this reference. The method(s) used to determine compliance is/are the method(s) specified in the ROP.

☐ 2. During the entire reporting period this source was in compliance with all terms and conditions contained in the ROP, each term and condition of which is identified and included by this reference, **EXCEPT** for the deviations identified on the enclosed deviation report(s). The method used to determine compliance for each term and condition is the method specified in the ROP, unless otherwise indicated and described on the enclosed deviation report(s).

☐ **Semi-Annual (or More Frequent) Report Certification (Pursuant to Rule 213(3)(c))**

Reporting period (provide inclusive dates): From ________ To ________

☐ 1. During the entire reporting period, **ALL** monitoring and associated recordkeeping requirements in the ROP were met and no deviations from these requirements or any other terms or conditions occurred.

☐ 2. During the entire reporting period, all monitoring and associated recordkeeping requirements in the ROP were met and no deviations from these requirements or any other terms or conditions occurred, **EXCEPT** for the deviations identified on the enclosed deviation report(s).

☒ **Other Report Certification**

Reporting period (provide inclusive dates): From 9/27/16 To 9/27/16

Additional monitoring reports or other applicable documents required by the ROP are attached as described:

Response to 9/6/2016 Violation Notice Regarding Crude/Vacuum Heater Particulate Matter(PM)Compliance Testing.

I certify that, based on information and belief formed after reasonable inquiry, the statements and information in this report and the supporting enclosures are true, accurate and complete

Honor Sheard	MPC Investment LLC, its General Partner Deputy Assistant Secretary	313-843-9100
Name of Responsible Official (print or type)	Title	Phone Number

Honor Sheard (signature) 9/27/16
Signature of Responsible Official Date

* Photocopy this form as needed.

EQP 5736 (Rev 2-10)

CleanAir

CleanAir Engineering
500 W. Wood Street
Palatine, IL 60067-4975
800-627-0033
www.cleanair.com

September 26[th], 2016

Marathon Petroleum Company LP
1300 South Fort Street
Detroit, MI 48217

Re: Particulate Testing at the Crude/Vacuum Heater Stack

During particulate testing of the Crude/Vacuum Heater Stack on June 15[th], 2016, an ambient monitor in close proximity to the stack measured several ambient pollutants, including "PM10". As part of the heater process, ambient air is pulled into a duct prior to combustion in order to ensure sufficient oxygen for complete fuel combustion.

During each of the three runs, a dry CO_2 stack concentration was measured. The molar flow rate of CO_2 out of the stack can be determined from total stack volumetric flow rate, the dry CO_2 stack concentration, the stack H_2O concentration, the density of CO_2, and the molar weight of CO_2. The molar flow rate of fuel can be determined from the CO_2 stack flow rate and the fuel composition. The molar flow rate of fuel can be used to determine the amount of oxygen (and air) required for complete combustion of the fuel. Fuel composition was reported on a molar basis. The fuel included constituents such as hydrogen, nitrogen, carbon monoxide, carbon dioxide, and hydrocarbons (C1-C6). Using the generic stoichiometric relationship for combustion reactions,

$$C_\alpha H_\beta S_\gamma O_\delta N_\varepsilon + \left(\alpha + \frac{\beta}{4} + \gamma - \frac{\delta}{2}\right)(O_2 + 3.76N_2) \rightarrow$$
$$\alpha CO_2 + \frac{\beta}{2} H_2O + \gamma CO_2 + \left[\frac{\varepsilon}{2} + 3.76\left(\alpha + \frac{\beta}{4} + \gamma - \frac{\delta}{2}\right)\right] N_2$$

every mole of compound $C_\alpha H_\beta S_\gamma O_\delta N_\varepsilon$ combusted will require $\left(\alpha + \frac{\beta}{4} + \gamma - \frac{\delta}{2}\right)$ moles of oxygen (or air) for complete combustion.

If only the required stoichiometric air was pulled into the duct to participate in the combustion process, than all of the O_2 in that air would be consumed in the reaction and the O_2 stack concentration would be 0%. However, an average of 8.7% (dry) O_2 was measured in the stack during the three runs. This excess O_2 is assumed to be pulled into the duct prior to combustion, flow through the process unreacted, and carried with the combustion products to the stack. The dry O_2 concentration can be used with the stack H_2O concentration and total stack volumetric flow rate to determine the volumetric flow rate of oxygen exiting the stack.

The total volumetric flow rate of oxygen exiting the stack can be used with the total volumetric oxygen requirement to determine the total volumetric flow rate of O2 entering the duct. This can be used to determine the total volumetric flow rate of air entering the duct.

Both the air used in the combustion process and the excess air measured in the stack were pulled into the duct from the same ambient air that was monitored for "PM10" during testing. The average concentration of particulate in the ambient air during testing was 36.1 $\mu g/m^3$.

The volumetric flow rate of air entering the duct can be used with the ambient PM10 concentration to determine the mass flow rate of PM10 into the duct during the three test runs. The PM10 mass flow rate can be subtracted from the measured FPM mass flow rate in the stack to obtain the mass flow rate of FPM in the stack that formed as a result of the combustion process. This adjusted FPM mass flow rate can be used with the measured FPM mass flow rate to determine the fraction of FPM that formed as a result of the combustion process.

The fraction of FPM formed as a result of the combustion process can be used to adjust the total mass of FPM collected on the filters and in solvent rinses. The new FPM mass can be used to determine a more representative FPM stack concentration and FPM Fd-based rate.

When the ambient PM10 is not accounted for, the average FPM emissions for the three runs was 0.0020 lb/MMBtu. The process described in this document can be used to more accurately report the FPM emissions resulting from the combustion process. Using this procedure, the average FPM emissions for the three runs was 0.0016 lb/MMBtu.

The attached spreadsheet contains the calculations referenced in this document.

Sincerely,
CLEAN AIR ENGINEERING

Dan Pearson
Project Engineer, Consulting Services

DP/dp

Attachments: Marathon Ambient Air Emission Calculation am1_dp4

USEPA Method 5 (FPM)
Results Table for FPM

Run No.			1	2	3	Average
Date (2016)			Jun 15	Jun 15	Jun 15	
Start Time (approx.)			10:28	14:22	17:03	
Stop Time (approx.)			13:35	16:32	19:45	
Process Conditions						
	RP	Production rate (XXXX/hr)				
	P1	Charge rate (BPD)	134,594	132,073	133,993	**133,553**
	Fd	Oxygen-based F-factor (dscf/MMBtu)	8,123	8,123	8,123	**8,123**
	Cap	Capacity factor (hours/year)	8,760	8,760	8,760	**8,760**
Gas Conditions						
	O2	Oxygen (dry volume %)	8.6	8.5	9.0	**8.7**
	CO2	Carbon dioxide (dry volume %)	6.5	6.8	6.1	**6.5**
	Ts	Sample temperature (°F)	290	288	289	**289**
	Bw	Actual water vapor in gas (% by volume)	13.4	14.1	14.0	**13.9**
Gas Flow Rate						
	Qa	Volumetric flow rate, actual (acfm)	93,786	84,745	92,551	**90,360**
	Qa	Volumetric flow rate, actual (m3/hr)	159,364	144,001	157,266	**153,544**
Sampling Data						
	Vmstd	Volume metered, standard (dscf)	67.98	61.75	66.80	**65.51**
	%I	Isokinetic sampling (%)	97.8	98.9	97.9	**98.2**
Laboratory Data						
	mfilter	Matter collected on filter(s) (g)	0.00311	0.00242	0.00267	**0.00273**
	ms	Matter collected in solvent rinse(s) (g)	0.00164	0.00075	0.00237	**0.00159**
	mn	Total FPM (g)	0.00475	0.00317	0.00504	**0.00432**
	nMDL	Number of non-detectable fractions	N/A	N/A	N/A	
	DLC	Detection level classification	ADL	ADL	ADL	
FPM Results						
	Elb/hr	Particulate Rate (lb/hr)	0.515	0.340	0.545	**0.466**
	Ekg/hr	Particulate Rate (kg/hr)	0.2334	0.1540	0.2472	**0.2115**
	ET/yr	Particulate Rate (Ton/yr)	2.25	1.49	2.39	**2.04**
	EFd	Particulate Rate - Fd-based (lb/MMBtu)	0.00213	0.00155	0.00237	**0.00202**
Ambient FPM Concentration						
		Ambient PM 10 Concentration (ug/m3)	38.0	33.5	36.8	36.1
Stack Concentrations						
		Oxygen (volume %)	7.4	7.3	7.7	7.5
		CO2 (volume %)	5.6	5.8	5.2	5.6
Fuel Rate						
		Fuel Rate (lbmol/hr)	619	581	569	590
		Fuel Rate (lb/hr)	9,804	9,197	9,016	9,339
Stoich. Air / O2 Required						
		Oxygen Required (lbmol/hr)	1,150	1,079	1,058	1,096
		Oxygen Required (lb/hr)	36,814	34,535	33,856	35,068
		Oxygen Required (m3/hr)	12,545	11,768	11,537	11,950
		Air Required (lbmol/hr)	5,478	5,139	5,038	5,219
		Air Required (lb/hr)	158,680	148,854	145,929	151,154
		Air Required (m3/hr)	59,911	56,201	55,097	57,069
Stack O2						
		O2 Flow Out Stack (m3/hr)	11,863	10,513	12,166	11,514
Air / O2 Fed						
		Total O2 Feed (m3/hr)	24,407	22,281	23,702	23,464
		Total Air Feed (m3/hr)	116,564	106,411	113,197	112,057
Ambient FPM Fed						
		Ambient Particulate Feed Rate (ug/hr)	4,429,443	3,564,759	4,159,975	4,051,392
		Ambient Particulate Feed Rate (kg/hr)	0.0443	0.0356	0.0416	0.0405
Particulate Adjustments						
		Adjusted Particulate Rate (kg/hr)	0.1891	0.1184	0.2056	0.1710
		Adjusted Particulate Rate (lb/hr)	0.4169	0.2610	0.4534	0.3771
		Particulate Adjustment Factor	0.8102	0.7685	0.8317	0.8035
		Combusiton PM	0.00385	0.00244	0.00419	0.00349
		Adjusted Particulate Concentration (lb/dscf)	1.2482E-07	8.6995E-08	1.3838E-07	1.1673E-07
		Adjusted Particulate Rate - Fd-based (lb/MMBtu)	0.0017	0.0012	0.0020	0.0016

Density Assumptions	
Density of CO2 @290	0.08096 lb/ft3
Density of O2	0.08310 lb/ft3
Density of Air	0.07500 lb/ft3

Date	Time	4-East	4-East	4-East	4-East	4-East	4-East	4-East	4-East
		SO2	CO	TRS	PM10	Wind Speed V	Wind Dir V	Temp_15m	RH
		ppb	ppm	ppb	ug/m3(S)	mph	Deg	DegF	%RH
6/15/2016	12:00 AM	2	0.2	0	11	4.2	116	65.63	39.7
6/15/2016	1:00 AM	12	0.9	4	11	5	90.5	64.95	40.1
6/15/2016	2:00 AM	18	1.5	8	29	4.7	85	64.22	43.6
6/15/2016	3:00 AM	20	1.1	4	43	4.8	80.3	64.72	43.9
6/15/2016	4:00 AM	24	0.9	11	44	5.3	95.4	64.76	50.4
6/15/2016	5:00 AM	20	0.9	6	49	5	99.2	65.18	56.3
6/15/2016	6:00 AM	12	0.5	3	71	4.3	107.4	66.38	58.5
6/15/2016	7:00 AM	4	0.4	1	95	4.2	124.5	67.05	61.1
6/15/2016	8:00 AM	2	0.3	0	83	4.8	126.1	66.13	68.8
6/15/2016	9:00 AM	1	0.3	0	43	7.2	140	69.12	67.5
6/15/2016	10:00 AM	1	0.3	0	30	6.9	170.1	73.85	59.8
6/15/2016	11:00 AM	1	0.3	0	55	6.8	186.7	76.28	57.6
6/15/2016	12:00 PM	1	0.3	0	38	7.4	183.6	77.8	58.3
6/15/2016	1:00 PM	1	0.3	0	29	9.3	192.3	78.65	57.6
6/15/2016	2:00 PM	1	0.3	0	38	7.2	163.5	80.82	55.9
6/15/2016	3:00 PM	1	0.3	0	34	6.6	164.2	82.86	53.3
6/15/2016	4:00 PM	1	0.3	0	34	5.8	164.7	83.2	52.5
6/15/2016	5:00 PM	1	0.4	0	28	5.6	175.1	82.85	54.6
6/15/2016	6:00 PM	0	0.3	0	30	5.4	167.1	82.8	55
6/15/2016	7:00 PM	1	0.4	0	29	7.2	79.5	78.32	55.3
6/15/2016	8:00 PM	1	0.3	0	60	7.4	119.7	74.02	56.5
6/15/2016	9:00 PM	1	0.3	0	26	5.7	128.8	70.96	58.7
6/15/2016	10:00 PM	1	0.2		24	4.4	148.3	68.28	63.8
6/15/2016	11:00 PM	1	0.3	0	16	2.8	133.2	66.47	68.1
Minimum		0	0.2	0	2	1.6 (155.9 Deg)	No Data	61.35	26.2
MinDate		15-Jun	14-Jun	14-Jun	14-Jun	16-Jun	14-Jun	14-Jun	14-Jun
MinTime		6:00	12:00	12:00	3:00	3:00	1:00	4:00	4:00
Maximum		24	2.2	11	96	13.1 (349.2 Deg)	No Data	83.2	88.9
MaxDate		15-Jun	16-Jun	15-Jun	14-Jun	16-Jun	14-Jun	15-Jun	16-Jun
MaxTime		4:00	7:00	4:00	7:00	2:00	1:00	4:00	6:00
Avg		2	0.3	0	31	5.9	119	69.57	58.8
Num		72	72	69	72	72	72	72	72
Data[%]		98	98	94	98	98	98	98	98
STD		4.7	0.3	2	17.6	2	102.6	5.8	17.3

Client: Marathon Petroleum Company
CleanAir Project No: 13019
Location: Detroit Refinery
Source: Crude/Vacuum Heater
Fuel Gas Sample ID: 446477
Test Date: 6/15/2016
Test Time: 15:30

Heat Content: 986.0 **Btu/scf**
Specific Gravity: 0.5469 **(air =1 at 14.696 psia, 60°F)**

Compound	Formula	Mol. Wt.	Mole Comp %	Total lb/Mole	C lb/Mole	H lb/Mole	O lb/Mole	N lb/Mole	S lb/Mole	Total lb/mole	Specific Gravity	Heating Value Btu/lb	Net Heating Value Btu/scf	Gross Heating Value Btu/scf	Net Heating Value Btu	Gross Value Btu
HYDROGEN	H_2	2.02	39.48	0.796		0.796				0.796	0.070	51,571	269.8	329.2	106.53	129.96
NITROGEN	N_2	28.01	2.57	0.720				0.720		0.720	0.967	0	0.0	0.0	0.00	0.00
CARBON MONOXIDE	CO	28.01	0.55	0.154	0.066		0.088			0.154	0.967	4,344	315.8	325.4	1.74	1.79
CARBON DIOXIDE	CO_2	44.01	0.07	0.031	0.008		0.022			0.031	1.519	0	0.0	0.0	0.00	0.00
METHANE	CH_4	16.04	32.70	5.246	3.927	1.318				5.246	0.554	21,502	895.3	1,025.5	292.75	335.35
ETHYLENE	C_2H_4	28.05	4.22	1.184	1.014	0.170				1.184	0.969	20,276	1,476.3	1,624.4	62.30	68.55
ETHANE	C_2H_6	30.07	13.43	4.038	3.226	0.812				4.038	1.038	20,416	1,593.3	1,796.8	213.98	241.31
PROPYLENE	C_3H_6	42.08	1.16	0.488	0.418	0.070				0.488	1.453	19,683	2,149.6	2,368.6	24.94	27.48
PROPANE	C_3H_8	44.10	2.69	1.186	0.969	0.217				1.186	1.522	19,929	2,280.8	2,554.8	61.35	68.72
ISOBUTANE	C_4H_{10}	58.12	0.53	0.308	0.255	0.053				0.308	2.007	19,614	2,958.8	3,301.9	15.68	17.50
ISOBUTYLENE	C_4H_8	56.11	0.11	0.062	0.053	0.009				0.062	1.937	19,367	2,820.2	3,108.2	3.10	3.42
1-BUTENE	C_4H_8	56.11	0.14	0.079	0.067	0.011				0.079	1.937	19,484	2,837.2	3,127.3	3.97	4.38
BUTA-1,3-DIENE	C_4H_6	54.09	0.00	0.000	0.000	0.000				0.000	1.867			3,122.3	0.00	0.00
N-BUTANE	C_4H_{10}	58.12	1.10	0.639	0.528	0.111				0.639	2.007	19,665	2,966.5	3,312.5	32.63	36.44
TRS-2-BUTENE	C_4H_8	56.11	0.12	0.067	0.058	0.010				0.067	1.937	19,397	2,824.6	3,115.2	3.39	3.74
CIS-2-BUTENE	C_4H_8	56.11	0.09	0.050	0.043	0.007				0.050	1.937	19,431	2,829.6	3,119.5	2.55	2.81
3-METHYLBUTENE-1	C_4H_8	56.11	0.00	0.000	0.000	0.000				0.000	1.937			4,046.0	0.00	0.00
ISOPENTANE	C_5H_{12}	72.15	0.42	0.303	0.252	0.051				0.303	2.491	19,451	3,642.3	4,062.5	15.30	17.06
N-PENTANE	C_5H_{12}	72.15	0.39	0.281	0.234	0.047				0.281	2.491	19,499	3,651.3	4,070.6	14.24	15.88
C6+(AS HEXANE)	C_{6+}	86.18	0.24	0.207	0.173	0.034				0.207	2.975	19,391	4,336.9	4,829.1	10.41	11.59
HYDROGEN SULFIDE	H_2S	34.08	0.00	0.000		0.000			0.000	0.000	1.177			646.9	0.00	0.00
OXYGEN	O_2	32.00	0.00	0.000			0.000			0.000	1.105	0	0.0	0.0	0.00	0.00
HELIUM	He	4.00		0.000						0.000	0.138	0	0.0	0.0	0.00	0.00
ACETYLENE	C_2H_6	30.07		0.000	0.000	0.000				0.000	1.038	20,734	1,618.1	1,496.2	0.00	0.00
CARBON OXYSULFIDE	COS	60.08		0.000	0.000		0.000		0.000	0.000	2.074	0	0.0	0.0	0.00	0.00
SULFUR DIOXIDE	SO_2	64.06		0.000			0.000		0.000	0.000	2.212	0	0.0	0.0	0.00	0.00
CARBON DISULFIDE	CS_2	76.14		0.000	0.000				0.000	0.000	2.629	0	0.0	0.0	0.00	0.00
BENZENE	C_6H_6	78.11		0.000	0.000	0.000				0.000	2.697	17,446	3,536.8	3,799.4	0.00	0.00
HEXANE	C_6H_{14}	86.18		0.000	0.000	0.000				0.000	2.975	19,391	4,336.9	4,829.1	0.00	0.00
ISOHEXANE	C_6H_{14}	86.18		0.000	0.000	0.000				0.000	2.975	19,391	4,336.9	4,829.1	0.00	0.00
		TOTAL	100.0	15.840	11.292	3.717	0.110	0.720	0.000	15.840	0.5469	N/A	N/A	N/A	864.85	986.0

%C = 71.29
%H = 23.47
%O = 0.70
%N = 4.55
%S = 0.00

Net Heat Content (NCV_w) = 21,037.4 Btu/lb
Net Heat Content (NCV_V) = 864.8 Btu/scf
Gross Heat Content (GCV_w) = 23,981.4 Btu/lb
Gross Heat Content (GCV_V) = 986.0 Btu/scf
Specific Gravity = 0.5469 (air =1 at 14.696 psia, 60°F)

F_d Factor = 8,123 dscf/MMBtu
F_c Factor = 954.3 dscf/MMBtu

Unless otherwise noted, net heating values (Btu/lb) obtained from Chemical Engineer's Handbook, Perry and Chilton, Fifth Edition.

Hydrogen	1.00794
Helium	4.002602
Carbon	12.0107
Nitrogen	14.0067
Oxygen	15.9994
Sulfur	32.065
Argon	39.948

Fuel Gas Analysis

Compound	Formula	MW (lb/lbmol)	Concentration (Mole %	lb/Mole	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Mole O2/Mole Constituent	Mole O2 / Mole Fue	MW Contribution	Specific Gravity	Mole C / Mole Fuel
HYDROGEN	H2	2.01588	39.48	0.79586942	0	2	0	0	0	0.5	0.1974	0.795869424	0.0695971	0
NITROGEN	N2	28.0134	2.57	0.71994438	0	0	0	2	0	0	0.0000	0.71994438	0.967146556	0
CARBON MONOXIDE	CO	28.0101	0.55	0.15405555	1	0	1	0	0	0.5	0.0028	0.15405555	0.967032626	0.0055
CARBON DIOXIDE	CO2	44.0095	0.07	0.03080665	1	0	2	0	0	0	0.0000	0.03080665	1.519402727	0.0007
METHANE	CH4	16.04246	32.7	5.24588442	1	4	0	0	0	2	0.6540	5.24588442	0.553856724	0.327
ETHYLENE	C2H4	28.05316	4.22	1.18384335	2	4	0	0	0	3	0.1266	1.183843352	0.968519247	0.0844
ETHANE	C2H6	30.06904	13.43	4.03827207	2	6	0	0	0	3.5	0.4701	4.038272072	1.038116347	0.2686
PROPYLENE	C3H6	42.07974	1.16	0.48812498	3	6	0	0	0	4.5	0.0522	0.488124984	1.452778871	0.0348
PROPANE	C3H8	44.09562	2.69	1.18617218	3	8	0	0	0	5	0.1345	1.186172178	1.522375971	0.0807
ISOBUTANE	C4H10	58.1222	0.53	0.30804766	4	10	0	0	0	6.5	0.0345	0.30804766	2.006635595	0.0212
ISOBUTYLENE	C4H8	56.10632	0.11	0.06171695	4	8	0	0	0	6	0.0066	0.061716952	1.937038495	0.0044
1-BUTENE	C4H8	56.10632	0.14	0.07854885	4	8	0	0	0	6	0.0084	0.078548848	1.937038495	0.0056
BUTA-1,3-DIENE	C4H6	54.09044	0	0	4	6	0	0	0	5.5	0.0000	0	1.867441395	0
N-BUTANE	C4H10	58.123	1.1	0.639353	4	10	0	0	0	6.5	0.0715	0.639353	2.006663214	0.044
TRS-2-BUTENE	C4H8	56.108	0.12	0.0673296	4	8	0	0	0	6	0.0072	0.0673296	1.937096496	0.0048
CIS-2-BUTENE	C4H8	56.108	0.09	0.0504972	4	8	0	0	0	6	0.0054	0.0504972	1.937096496	0.0036
3-METHYLBUTENE-1	C4H8	56.108	0	0	5	12	0	0	0	8	0.0000	0	1.937096496	0
ISOPENTANE	C5H12	72.14878	0.42	0.30302488	5	12	0	0	0	8	0.0336	0.303024876	2.490895218	0.021
N-PENTANE	C5H12	72.14878	0.39	0.28138024	5	12	0	0	0	8	0.0312	0.281380242	2.490895218	0.0195
C6+(AS HEXANE)	C6+	86.17536	0.24	0.20682086	6	14	0	0	0	9.5	0.0228	0.206820864	2.975154842	0.0144
HYDROGEN SULFIDE	H2S	34.08088	0	0	0	2	0	0	1	1.5	0.0000	0	1.176622821	0
OXYGEN	O2	31.9988	0	0	0	0	2	0	0	-1	0.0000	0	1.104740204	0
HELIUM	He	4.002602	0	0	0	0	0	0	0	0	0.0000	0	0.138187537	0
ACETYLENE	C2H6	30.06904	0	0	2	6	0	0	0	3.5	0.0000	0	1.038116347	0
CARBON OXYSULFIDE	COS	60.0751	0	0	1	0	1	0	1	1.5	0.0000	0	2.074058346	0
SULFUR DIOXIDE	SO2	64.0638	0	0	0	0	2	0	1	0	0.0000	0	2.211765924	0
CARBON DISULFIDE	CS2	76.1407	0	0	1	0	0	0	2	3	0.0000	0	2.628713965	0
BENZENE	C6H6	78.11184	0	0	6	6	0	0	0	7.5	0.0000	0	2.696766442	0
HEXANE	C6H14	86.17536	0	0	6	14	0	0	0	9.5	0.0000	0	2.975154842	0
ISOHEXANE	C6H14	86.17536	0	0	6	14	0	0	0	9.5	0.0000	0	2.975154842	0
				15.8396923					Total		1.8587	15.8397	0.546856284	0.9402

Carbon Fraction From CO 0.000744522