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erthwrks
AIR EMISSIONS TESTING FOR INDUSTRY

Relative Accuracy Test Audit and Performance Testing

for
Marathon Petroleum Company LP

at the
Marathon Detroit Refinery in Detroit, MI

on the
Coker Heater
Unit: EU70-COKERHTR-S1
Permit No. MI-ROP-A9831-2012c

Prepared for:

MARATHON
Marathon Petroleum Company LP

Test Date: November 28, 2022
Erthwrks Project No. 9049.1.D3

STAC STACK TESTING ACCREDITATION COUNCIL
A2LA ACCREDITED
LELAP Louisiana Environmental Lab Accreditation Program
CARB

Endorsement Page

This report was developed in accordance with the requirements designated in the applicable regulatory permit(s) and/or regulatory rules. To the best of my knowledge the techniques, instrumentation, and calculations presented in this report will serve to accurately and efficiently detail the results of the test campaign requirements.

Erthwrks, Inc.

Name: Jarrod Hoskinson

Title: Senior Project Manager

Signature:

This report has been reviewed for accuracy and completeness. The actions presented in this report are, to the best of my knowledge, an accurate representation of the results and findings of the test campaign. Erthwrks, Inc. operates in conformance with the requirements on ASTM D7036-04 Standard Practice for Competence of Air Emission Testing Bodies and is accredited as such by the Stack Testing Accreditation Council (STAC) and the American Association for Laboratory Accreditation (A2LA).

Erthwrks, Inc.

Name: Jason Dunn

Title: QC Specialist

Signature:

Table of Contents

1.0 INTRODUCTION

1.1 Identification, location and dates of tests

Erthwrks, Inc. was contracted to conduct emissions testing on the Coker Heater in operation at the Marathon Detroit Refinery, located in Detroit Michigan. The testing program was conducted on November 28, 2022.

1.2 Purpose of Testing

The exhaust from Coker Heater was sampled and analyzed to determine the compliance status of the units' emissions for particulate matter (PM) and, condensable particulate matter (CPM).

In addition, oxygen (O_2) and carbon dioxide (CO_2) was also measured to calculate the dry molecular weight of the stack gas.

1.3 Contact Information

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2.0 SUMMARY OF RESULTS

Table 2.1—Marathon Coker Heater (EU70-COKERHTR-S1) Compliance Test Results

Pollutant Measured	Methodology	Measured Results	Applicable Limit	Pass/Fail
PM	EPA Method 5	0.0005 lb/MMBtu	0.0019 lb/MMBtu	Pass
PM/PM_{10}	EPA Method 5/202	0.0020 lb/MMBtu	0.0076 lb/MMBtu	Pass

3.0 SOURCE DESCRIPTION

3.1 Description of the process

Marathon Petroleum Company LP produces refined petroleum products from crude oil and is required to demonstrate that select process emission sources are operating in compliance with permitted emissions limits.

The Coker unit (EU70-COKER) converts Vacuum Resid (Crude Vacuum Tower Bottoms), a product normally sold as asphalt or blended into residual fuel oil, into lighter, more valuable products. The Vacuum Resid feedstock is heated before it enters the main fractionator, where lighter material vaporizes. The fractionator bottoms are routed through a fired heater and then into a coke drum. This emission unit consists of process vessels (fractionators), coke drums, heater (EU70-COKERHTR-S1), cooling tower, compressors, pumps, piping, drains, and various components (pumps and compressor seals, process valves, pressure relief valves, flanges, connectors, etc.). This emission group includes the Coke Handling System, which will collect, size, and transport the petroleum coke created during the coking process. The system consists of a coke pit, storage pad, enclosed crusher, enclosed conveyors, and surge bins. The Coker Heater is fired by refinery fuel gas. Emissions are vented to the atmosphere via the Coker Heater Stack (SV70-H1), where testing will be performed.

3.2 Applicable permit and source designation

Marathon Petroleum Company LP operates the Coker Heater (EU70-COKERHTR-S1) under Michigan Department of Environment, Great Lakes, and Energy (EGLE) Renewable Operating Permit No. MI-ROP-A9831-2012c and is required to periodically conduct PM and CPM testing to determine compliance status.

3.3 Type and quantity of materials processed during tests

During the emission testing on November 28, 2022, at the Marathon Petroleum Company LP Refinery, the Coker Heater was tested while operating at load conditions representative of normal conditions. The load conditions during the testing were documented by Marathon Detroit Refinery and provided in Appendix F.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

4.1 Gaseous Sampling – O_2, and CO_2

For the gaseous sampling, Erthwrks utilized a stainless-steel probe, of sufficient length to reach all sampling points, inserted into a sampling port that is located on the stack in accordance with EPA Method 1. The sample is extracted through the probe, a heated Teflon sampling line, to a heating filter. The sample then enters a minimum contact sample conditioner that cools and removes moisture from the gas matrix prior to entering the Erthwrks sampling manifold.

Erthwrks followed all quality assurance and quality control procedures as defined in US EPA 40 CFR 60 Appendix A. The Calibration Error (CE) Test was conducted as specified in EPA Method 7E §8.2.3. In accordance with this requirement, a three-point analyzer calibration error test was conducted prior to sampling. The CE test was conducted by introducing the low, mid, and high-level calibration gasses (as defined in EPA Method 7E §3.3.1-3) sequentially and the response was recorded. The results of the CE test are acceptable if the calculated calibration error is within ±2.0% of calibration span (or ≤ 0.5 ppmv).

The Initial System Bias and System Calibration Error Check was conducted in accordance with EPA Method 7E §8.2.5. The upscale calibration gas was introduced at the probe upstream of all sample system components and the response recorded. The procedure will was repeated with the low-level gas and the response recorded. During this activity, the sample system response time was also be recorded. This specification is acceptable if the calculated values of the system calibration error check are within ±5.0% of the calibration span value (or ≤0.5 ppmv).

After each test run, the sample system bias check is conducted to validate the run data. The low-level and upscale drift are calculated using Equation 7E-4. The run data is valid if the calculated drift is within ±3.0% of the calibration span value (or ≤0.5 ppmv).

After each test run, the corrected effluent gas concentration was calculated as specified in EPA Method 7E §12.6. The arithmetic average of all valid concentration values are adjusted for bias using equation 7E-5B.

The figure below details the Erthwrks gaseous sampling system:

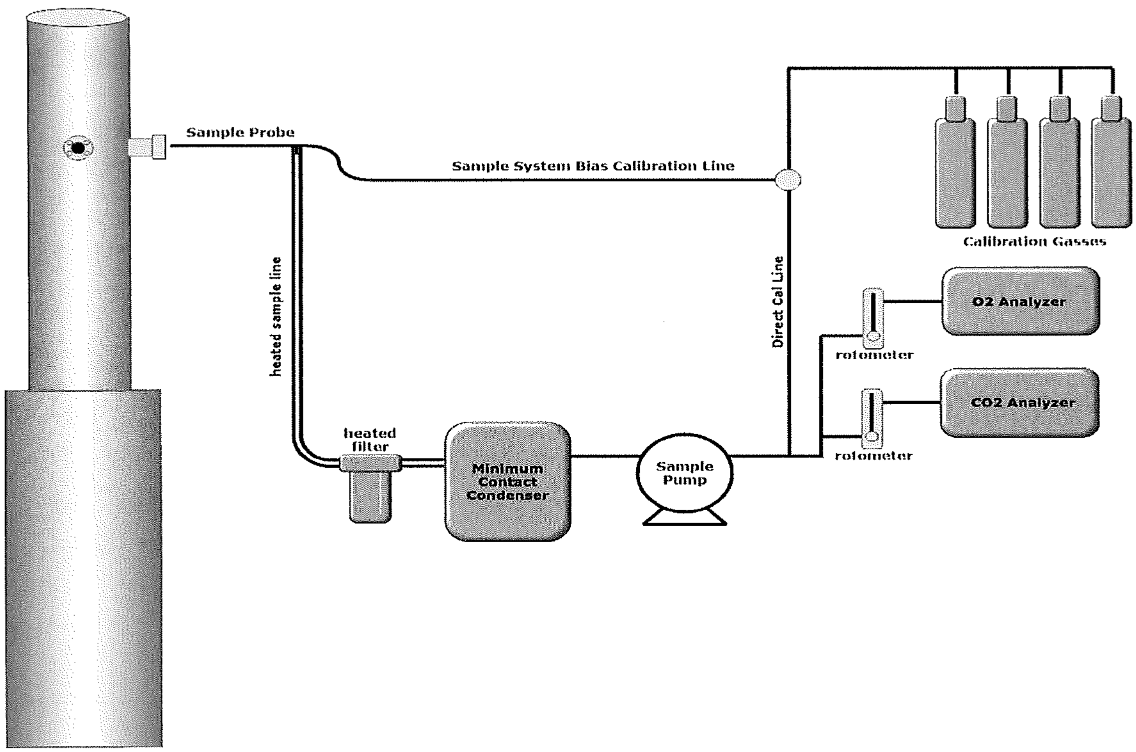


Figure 1: Erthwrks Gaseous Sampling System Diagram

4.2 Filterable Particulate Matter Sampling – EPA Method 5

EPA Test Method 1 was used for the selection of sampling points. Stack dimensions, number of sample ports and sample port locations were confirmed prior to testing to determine the appropriate number diof traverse points for the test.

EPA Test Method 5 was used to determine filterable particulate matter emission rates. Method 5 is the method at which particulate matter is withdrawn isokinetically from the source and collected on a glass fiber filter and on the lining of the isokinetic probe maintained at a temperature of 120 ± 14°C. Upon completion of each test run, the nozzle and probe liner were rinsed and brushed with acetone. The acetone rinse catch will be collected and combined with the filter holder rinse and labeled as “front half rinse”. The total PM mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically. Filterable PM will be calculated by combining the net gravimetric gain of the filter and the net gravimetric gain of the evaporated front half rinse.

Figure 2 below shows the Method 5 sampling system components.

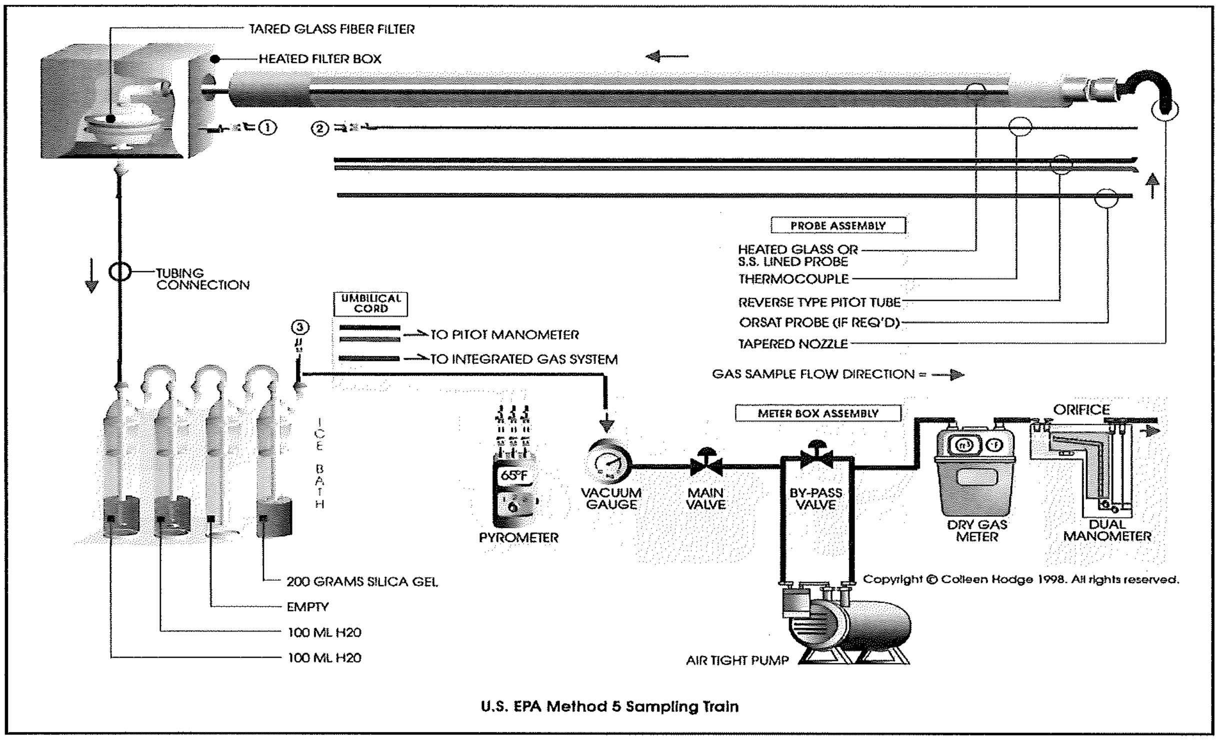


Figure 2: Erthwrks PM Sampling System Diagram

4.3 EPA Method 202 – Condensable Particulate Matter

For the determination of PM/PM10, the CPM was measured via EPA Method 202. The Method 202 components begin at the back half of the Method 5 filter housing. The filterable particulate matter is removed in these “front half” components. The condensable particulate matter is then collected by drawing the filtered gas through a water jacketed, spiral condenser maintained at 65° – 85° F. The cooled effluent gas is then passed through two empty impingers and finally through a hexane extracted Teflon filter. Upon completion of each test run, the moisture collected in this portion of the sampling train is purged with ultra-high purity (UHP) nitrogen gas for one hour to remove any dissolved sulfur dioxide. The moisture is collected in a container and combined with the deionized water used to rinse all Method 202 sampling glassware two times.

The glassware is next rinsed with hexane and acetone. These rinses are collected and combined in an additional container. The Teflon filter is removed from the filter housing, labeled, and collected. Gravimetric analysis is then conducted on the extracted, evaporated samples for each run.

4.4 Discussion of sampling procedure or operational variances

Erthwrks, Inc. sampled effluent gas on the Coker Heater for 120 minutes during run one (1). Runs two (2) and three (3) were both ninety (90) minutes in duration.

Attachment A
Detailed Results of Emission Test

Erthwrks Particulate Matter Summary of Results

Client: Marathon Petroleum
Project: 9049.1.D3
Facility: Detroit
Unit ID: Coker Heater

Run Designation						
Run Number		1	2	3	Average	
Date		11/28/2022	11/28/2022	11/28/2022		mm:dd:yyyy
Run Start Time		11:52	14:33	16:36		hh:mm
Run End Time		14:05	16:13	18:16		hh:mm
Operating Conditions						
Firing Rate (MMbtu/hr)		253.08	255.70	258.32	255.70	MMBtu/hr
Stack Gas Composition						
Oxygen Concentration	($\%O_2$)	5.09	5.02	5.02	5.04	%
Carbon Dioxide Concentration	($\%CO_2$)	9.56	9.62	9.53	9.57	%
Stack Moisture Content	(B_{ws})	12.44	11.24	12.22	11.97	%
Stack Dry Molecular Weight	(M_d)	29.73	29.74	29.73	29.73	lb/lb-mole
Stack Wet Molecular Weight	(M_s)	28.27	28.42	28.29	28.33	lb/lb-mole
Stack Gas Volumetric Flow Calculations						
Absolute Stack Pressure	(P_s)	29.79	29.78	29.80	29.79	in Hg
Average Stack Temperature	$(t_s)_{avg}$	845.1	851.3	853.0	849.8	°R
Average Square Root of ΔP's	$(\Delta p^{1/2})_{avg}$	0.3270	0.3435	0.3428	0.3378	%
Average Stack Gas Velocity	(v_s)	1411.05	1484.42	1485.34	1460.27	ft/min
Average Stack Gas Flow	(Q_{aw})	8.89E+04	9.36E+04	9.36E+04	9.20E+04	acfm
Wet Standard Stack Flow Rate	(Q_{sw})	3.32E+06	3.47E+06	3.46E+06	3.42E+06	wscfh
Dry Standard Stack Flow Rate	(Q_{sd})	2.91E+06	3.08E+06	3.04E+06	3.01E+06	dscfh
Particulate Matter Emission Rate Calculations						
Mass of Filterable PM (M.5)	mg	1.60	1.1	1.0	1.23	mg
Mass of Condensible PM (M.202)	mg	3.60	3.3	5.2	4.03	mg
Total Mass of Particulates	mg	5.20	4.40	6.20	5.27	mg
Filterable PM Mass Concentration	lb/dscf	4.40E-08	3.89E-08	3.58E-08	3.96E-08	lb/dscf
Total PM Mass Concentration	lb/dscf	1.43E-07	1.55E-07	2.22E-07	1.74E-07	lb/dscf
Filterable PM Mass Emission Rate	lb/hr	0.13	0.12	0.11	0.12	lb/hr
Total PM Mass Emission Rate	lb/hr	0.42	0.48	0.67	0.52	lb/hr
Filterable PM Mass Emission Rate	lb/day	3.07	2.87	2.61	2.85	lb/day
Total PM Mass Emission Rate	lb/day	9.99	11.48	16.19	12.55	lb/day
Filterable PM Mass Emission Rate	lb/MMbtu	**0.0005**	**0.0005**	**0.0004**	**0.0005**	lb/MMbtu
Total PM Mass Emission Rate	lb/MMbtu	**0.0016**	**0.0019**	**0.0026**	**0.0020**	lb/MMbtu

Attachment B
Quality Control Documentation

Erthwrks Method 1 Traverse Point Location Worksheet

Client:	Marathon Petroleum
Project #:	9049.1.D3
Facility:	Detroit
Unit ID:	Coker Heater
Technician:	Jarrod Hoskinson

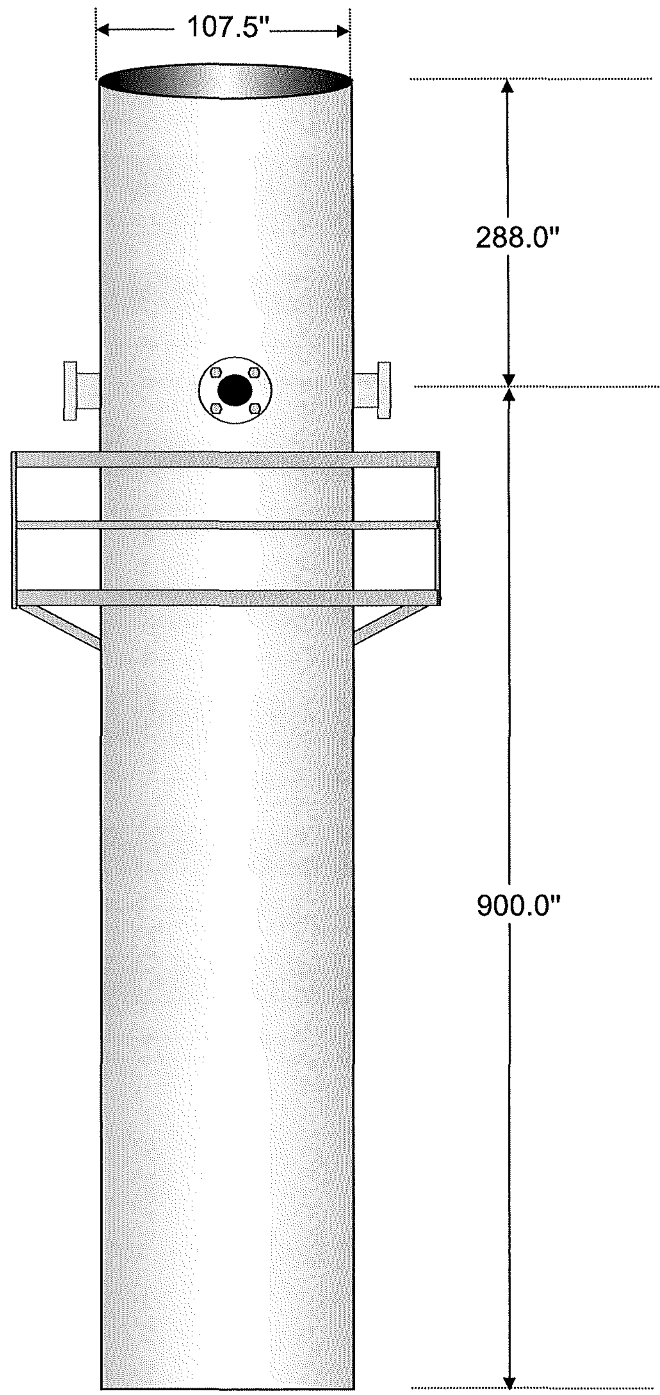
Stack ID Measurements

Stack ID + Port (inches):	**118.25**
Port Extension (inches):	**10.75**
Stack Diameter (inches):	107.5

Port Location Measurements

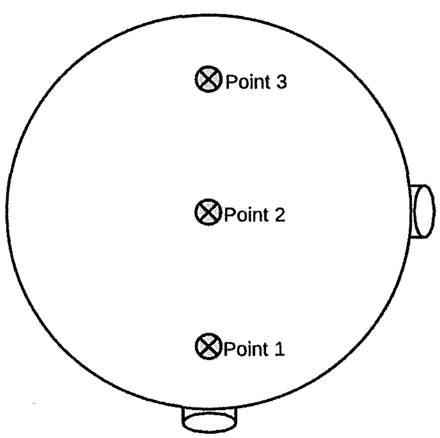
Distance Upstream (A) (inches):	**288**
Distance Downstream (B) (inches):	**900**
Stack Diameters Upstream (A):	2.7
Stack Diameters Downstream (B):	8.4

Total Traverse Points to be used:	**3**
Traverse Points per Diameter:	**3**



Traverse Point Locations[(1)(2)]	
Point 1:	15.75"
Point 2:	47.24"
Point 3:	78.74"

Stack Cross Section View



[(1)] For stack diameter >4.0" and <2.4 meters, stratification is measured at 16.7%, 50.0%, and 83.3" of stack diameter (M7E, §8.1.2).
[(2)] For stack diameter >2.4 meters, stratification is measured at 0.4, 1.2, and 2.0 meters from stack wall (M7E, §8.1.2).

Erthwrks Gaseous Sample Collection and Quality Assurance Worksheet

Date: 11/28/2022
Client: Marathon Petroleum
Facility: Detroit
Project No: 9049.1.D3
Unit ID: Coker Heater
Erthwrks Tech: Jarrod Hoskinson

Calibration Gas Verification

Pollutant	Low-Level Gas Conc. (C_V)	Cylinder Serial #	Mid-Level Gas Conc. (C_V)	Cylinder Serial #	High-Level Gas Conc. (C_V/CS)	Cylinder Serial #	Dilutor Root Gas
O_2	n/a	n/a	10.19	CC171439	19.98	CC498073	NA
CO_2	n/a	n/a	9.978	CC171439	19.61	CC498073	NA

Reference Method Analyzer Info

Make	Model	Serial No.
Teledyne	T200H	896
Teledyne	T300M	820

Calibration Error Test

Pollutant	Zero Gas Response (C_{Dir})	Calibration Error (ACE)*	Low-Level Response (C_{Dir})	Calibration Error (ACE)*	Mid-Level Response (C_{Dir})	Calibration Error (ACE)*	High-Level Response (C_{Dir})	Calibration Error (ACE)*
O_2	0.00	-0.01%	n/a	n/a	9.94	-1.24%	19.98	-0.01%
CO_2	0.03	0.15%	n/a	n/a	9.78	-1.02%	19.72	0.58%

** ACE must either be within ± 2.0% or ≤ 0.5 ppmv absolute difference, or +-5 % for THC for the mid and low gas*

Initial Sample System Bias and Response Time

Pollutant	Upscale Gas Cert. Conc. (C_{MA})	Upscale Gas Direct (C_{Dir})	Upscale Response (C_S)	Sample System Bias (SB)*	Response Time (sec)	Downscale Response (C_S)	Sample System Bias (SB)*	Response Time (sec)
O_2	10.19	9.94	9.81	-0.68%	80	0.10	0.51%	80
CO_2	9.98	9.78	9.69	-0.44%	80	0.15	0.64%	80

** SB must either be within ± 5.0% or ≤ 0.5 ppmv absolute difference*

Sample Collection Raw Data--Pre and Post Sample System Calibration (SSC) and Raw Run Results

Run #: Run 1
Start Time: 11:52
End Time: 14:05

Pollutant	Initial Zero SSC (C_{Oi})	Initial Upscale SSC (C_{Mi})	Raw Results (C_{Avg})	Final Zero SSC (C_{Of})	Final Upscale SSC (C_{Mf})
O_2	0.10	9.81	4.93	0.09	9.74
CO_2	0.15	9.69	9.23	0.21	9.58

Run #: Run 2
Start Time: 14:33
End Time: 16:13

Pollutant	Initial Zero SSC (C_{Oi})	Initial Upscale SSC (C_{Mi})	Raw Results (C_{Avg})	Final Zero SSC (C_{Of})	Final Upscale SSC (C_{Mf})
O_2	0.09	9.74	4.84	0.08	9.73
CO_2	0.21	9.58	9.26	0.22	9.60

Sample Collection Raw Data--Pre and Post Sample System Calibration (SSC) and Raw Run Results

Run #: Run 3
Start Time: 16:36
End Time: 18:17

Pollutant	Initial Zero SSC (C_{Oi})	Initial Upscale SSC (C_{Mi})	Raw Results (C_{Avg})	Final Zero SSC (C_{Of})	Final Upscale SSC (C_{Mf})
O_2	0.08	9.73	4.83	0.09	9.71
CO_2	0.22	9.60	9.24	0.23	9.73

Run 1 Sample Collection Calculations--Pre- and Post-Run Sample System Bias Check, Drift Assessment, Corrected Results

Pollutant	Initial Zero Sys. Bias (SB)*	Initial Upscale Sys. Bias (SB)*	Final Zero Sys. Bias (SB)*	Final Upscale Sys. Bias (SB)*	Avg. Zero Sys. Bias (C_0)	Avg. Upscale Sys. Bias (C_M)	Zero Drift Assessment (D)†	Upscale Drift Assessment (D)†	Corrected Results (C_{gas})
O_2	0.51%	-0.68%	0.45%	-1.04%	0.09	9.77	0.06%	0.37%	5.09
CO_2	0.64%	-0.44%	0.91%	-1.02%	0.18	9.63	0.27%	0.58%	9.56

** SB must either be within ± 5.0% or ≤ 0.5 ppmv absolute difference*
† D must either be within ± 3.0% or the pre- and post-run bias responses are ≤ 0.5 ppmv absolute difference

Run 2 Sample Collection Calculations--Pre- and Post-Run Sample System Bias Check, Drift Assessment, Corrected Results

Pollutant	Initial Zero Sys. Bias (SB)*	Initial Upscale Sys. Bias (SB)*	Final Zero Sys. Bias (SB)*	Final Upscale Sys. Bias (SB)*	Avg. Zero Sys. Bias (C_0)	Avg. Upscale Sys. Bias (C_M)	Zero Drift Assessment (D)†	Upscale Drift Assessment (D)†	Corrected Results (C_{gas})
O_2	0.45%	-1.04%	0.42%	-1.06%	0.09	9.73	0.03%	0.02%	5.02
CO_2	0.91%	-1.02%	0.97%	-0.89%	0.21	9.59	0.07%	0.13%	9.62

** SB must either be within ± 5.0% or ≤ 0.5 ppmv absolute difference*
† D must either be within ± 3.0% or the pre- and post-run bias responses are ≤ 0.5 ppmv absolute difference

Run 3 Sample Collection Calculations--Pre- and Post-Run Sample System Bias Check, Drift Assessment, Corrected Results

Pollutant	Initial Zero Sys. Bias (SB)*	Initial Upscale Sys. Bias (SB)*	Final Zero Sys. Bias (SB)*	Final Upscale Sys. Bias (SB)*	Avg. Zero Sys. Bias (C_0)	Avg. Upscale Sys. Bias (C_M)	Zero Drift Assessment (D)†	Upscale Drift Assessment (D)†	Corrected Results (C_{gas})
O_2	0.42%	-1.06%	0.45%	-1.15%	0.09	9.72	0.03%	0.09%	5.02
CO_2	0.97%	-0.89%	1.03%	-0.27%	0.23	9.66	0.06%	0.63%	9.53

** SB must either be within ± 5.0% or ≤ 0.5 ppmv absolute difference*
† D must either be within ± 3.0% or the pre- and post-run bias responses are ≤ 0.5 ppmv absolute difference

Attachment C
Example Calculations

Erthwrks QAQC Example Calculations

Example Calculations for System QA : Run 1, Coker Heater

Example Calculations for Pollutant : O2

Variable:	Description:
C_0	Average of the pre- and post-run system cal bias responses from zero gas, ppmv.
C_{Avg}	Average unadjusted gas concentration for test run, ppmv.
C_{Dir}	Measured concentration of the cal gas when introduced in direct mode, ppmv.
C_M	Average of the pre- and post-run system cal bias responses from the upscale gas, ppmv.
C_{MA}	Actual concentration of the upscale calibration gas, ppmv.
CS	Calibration span, ppmv.
C_S	Measured concentration of the cal gas when introduced in the system cal mode, ppmv.
C_V	Manufacturer certified concentration of calibration gas, ppmv.
SB_f	Post-run system bias, percent of calibration span.
SB_i	Pre-run system bias, percent of calibration span.

Analyzer Calibration Error, ACE — Eq. 7E-1

$$ACE = \frac{C_{Dir} - C_V}{CS} \times 100$$

ACE = -1.24%

C_{Dir} = 9.94 %
C_V = 10.19 %
CS= 19.98 %

Initial Upscale System Bias, SB_i — Eq. 7E-2

$$SB_i = \frac{C_S - C_{Dir}}{CS} \times 100$$

SB_i = -0.68%

CS= 19.98 %
C_S = 9.81 %
C_{Dir} = 9.94 %

Upscale Drift Assessment, D — Eq. 7E-4

$$D = ABS|SB_f - SB_i|$$

D = 0.37%

SBi = -0.68%
SB_f = -1.04%

Effluent Gas Concentration, C_{Gas} — Eq. 7E-5

$$C_{Gas} = (C_{Avg} - C_O)\frac{C_{MA}}{C_M - C_O}$$

C_{Gas} = 5.09

C_{Avg}= 4.93 %
C_o = 0.09 %
C_{MA} = 10.19 %
C_M = 9.77 %

Example Calcs for Run : Run 1 Coker Heater

Variable:	Description:
B_{ws}	Proportion of water vapor, by volume, in the gas stream
C_f	Conversion factor, sec/hr
C_p	Pilot coefficient, 0.84
K_p	Velocity equation constant, 5129.4 (ft/min) $[(lb/lb\text{-}mole)(in\ Hg) / (R)(in\ H_2O)]^{0.5}$
M_d	Molecular weight of stack gas, dry
M_s	Molecular weight of stack gas, dry, g/g-mole (lb/lb-mole)
M_w	Molecular weight of water, g/g-mole (lb/lb-mole)
P_m	Absolute pressure at the dry gas meter = Barometric Pressure + Δh_{avg} / 13.6, in Hg
T_m	Absolute Temperature at Meter, °R
V_m	Volume measured by DGM, dcf
$V_{m(std)}$	Dry gas volume measured by the dry gas meter, corrected to standard conditions, dscm (dscf)
V_s	Measured concentration of the cal gas when introduced in the system cal mode, ppmv
$V_{wc(std)}$	Volume of water vapor condensed, corrected to standard conditions, scm (scf)
W_f	Final imp weight, g
W_i	Initial imp weight, g
Y	Dry gas meter calibration factor, unitless

Dry Molecular Weight of Stack Gas, M_d — Eq. 3-1

$$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2 + \%CO)$$

M_d = 29.73 lb/lb-mol

$\%O_2$ = 5.09
$\%CO_2$ = 9.56
$\%N_2$ = 85.35
%CO = 0.00

Volume of Water Vapor Collected, $V_{wc(std)}$ — Eq. 4-2

$$V_{wc(std)} = K_3(W_f - W_i)$$

$V_{wc(std)}$ = 11.38 ft^3

K_3 = 0.04715 (ft^3/g)
W_i = 2528.00 (g)
W_f = 2769.40 (g)

Sample Gas Volume, $V_{m(std)}$ — Eq. 4-3

$$V_{m(std)} = (\frac{T_{std}}{P_{std}} * Y)\left(\frac{V_m * P_m}{T_m}\right)$$

$V_{m(std)}$ = 80.09 ft^3

T_{std} = 528 (°R)
P_{std} = 29.920 (inHg)
V_m = 79.03 (ft^3)
P_m = 29.88 (in H_2O)
T_m = 520.5 (°R)
Y= 1.0003 (unitless)

Moisture Content, B_{ws} — Eq. 4-4

$$B_{ws} = \frac{V_{wc(std)}}{V_{wc(std)} + V_{m(std)}}$$

B_{ws} = 12.44%

Molecular Weight of Stack Gas, M_s — Eq. 2-6

$$M_S = M_d(1 - B_{ws}) + (M_w * B_{ws})$$

M_w = 18.00 (lb/lb-mole)

M_S = 28.27

Example Calcs for Run : Run 1 Coker Heater

Variable:	Description:
Δp_{avg}	Average velocity head of stack gas, mm H_2O (in H_2O)
A_n	Cross-sectional area of nozzel, ft^2
A	Cross-sectional area of stack, ft^2
B_{ws}	Proportion of water vapor, by volume, in the gas stream
C_f	Conversion factor, sec/hr
C_p	Pilot coefficient, 0.84
K_p	Velocity equation constant, 5129.4 (ft/min) $[(lb/lb\text{-}mole)(in\ Hg) / (R)(in\ H_2O)]^{0.5}$
K_5	Constant, 0.09450 for English units
ΔH@	Orifice meter calibration coefficient, in H_2O
M_s	Dry molecular weight of stack gas, lb/lb-mole
Q	Dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dscf/hr)
P_s	Stack Pressure (Pbar + Pg)(in Hg)
Y_{qa}	Dry gas meter calibration check value, dimensionless
P_{bar}	Barometric pressure at the sampling site, mm Hg (in. Hg)
P_{std}	Standard absolute pressure, 760 mm Hg (29.92 in. Hg)
T_m	Absolute average DGM temperature, K (°R)
T_s	Absolute average stack gas temperature, 293 °K (528 °R)
$T_{s(abs)}$	Average Stack Temperature (°F) + 460, °R
V_m	Volume of gas sample as measured by dry gas meter, dcm (dcf)
$V_{m(std)}$	Dry gas volume measured by the dry gas meter, corrected to standard conditions, dscm (dscf)
θ	Total sampling time, min
V_S	Measured concentration of the cal gas when introduced in the system cal mode, ppmv.

Average Stack Gas Velocity, V_s — Eq. 2-7

$$V_S = K_p * C_p * \sqrt{\Delta p_{avg}} * \sqrt{\frac{T_{s(abs)}}{P_s * M_s}}$$

K_p = 5129.4
C_p = 0.84 unitless
P_s = 29.79 in H_2O
$T_{s(abs)}$= 845.0833 °R
$(\Delta p_{avg})^{1/2}$ = 0.3270
M_s = 28.27 lb/lb-mole

V_S = 1411.05 ft/min
V_S = 23.52 ft/sec

Average Stack Gas Flow, Q_a

$$Q_a = V_s * A$$

A = 63.03 ft^2
V_s = 1411.05 ft/min

Q_a = 8.89E+04 acfm

Wet Standard Stack Gas Flow, Q_{sw}

$$Q_{sw} = Q_a * 60 * \left(\frac{T_{std}}{P_{std}}\right) * \left(\frac{P_s}{T_{s(abs)}}\right)$$

P_s = 29.79 in Hg
P_{std} = 29.92 in Hg
$T_{s(abs)}$= 845.1 °R
T_{std} = 528 °R

Q_a = 3.32E+06 wscfh

Average Stack Gas Dry Volumetric Flow Rate, Q — Eq. 2-8

$$Q = C_f * B_{ws} * A * V_s * \frac{T_{std} * P_s}{P_{std} * T_{s(abs)}}$$

Q = 2.91E+06 dscfh

C_f =	3600	sec/hr
A=	63.03	ft^2
B_{ws} =	0.876	unitless
P_s =	29.79	in Hg
P_{std} =	29.92	in Hg
$T_{s(abs)}$=	845.1	°R
T_{std} =	528	°R
V_s =	23.52	ft/sec

Percent Isokinetic, *I* — Eq. 5-8

$$I = \frac{T_s * V_{m(std)} * Ps_{(std)} * 100}{T_{(std)} * vs * \theta * An * Ps * 60 * (1 - Bws)}$$

I = 98.9 %

T_s =	845.0833	°R
$V_{m(std)}$ =	80.09	dscf
P_s=	29.79	in Hg
v_s =	23.52	ft/sec
A_n =	8.78E-04	ft^2
θ =	120	min
B_{ws} =	0.876	unitless

Post-Test Metering Calibration — Eq. 5-15

$$Y_{qa} = \frac{\theta}{V_m}\sqrt{\frac{0.0319T_m}{\Delta H@\left(P_{bar} + \frac{\Delta H_{avg}}{13.6}\right)}\left(\frac{29}{M_s}\right)}\sqrt{\Delta H}_{avg}$$

$Y_{run\ 1}$ =	0.957
$Y_{run\ 2}$ =	0.969
$Y_{run\ 3}$ =	0.980
$Y_{qa\ (avg)}$ =	0.969

Run 1:	ΔH@ =	1.869	unitless
	T_m =	520.5	°R
	P_{bar} =	29.78	in H_2O
	V_m =	79.03	dcf
	ΔH_{avg} =	1.41	in H_2O
Run 2:	ΔH@ =	1.869	unitless
	T_m =	516.6667	°R
	P_{bar} =	29.77	in H_2O
	V_m =	61.10	dfc
	ΔH_{avg} =	1.54	in H_2O
Run 3:	ΔH@ =	1.869	unitless
	T_m =	514.6667	°R
	P_{bar} =	29.79	in H_2O
	V_m =	60.06	dcf
	ΔH_{avg} =	1.53	in H_2O

Example Calcs for Run : Run 1 Coker Heater

Variable:	Description:
m_t	Total mass of particulates, mg
V_{std}	Standard gas volume, %
Q_{sd}	Dry standard stack flow rate, dscfh

Particulate Matter Mass Concentration, C_m

m_t = 5.20 (mg)
V_{std} = 80.09 (dscf)

$$C_m = \frac{m_t}{453592} * \frac{1}{V_{std}}$$

C_m = 1.43E-07 lb/dscf

Particulate Matter Mass Emission Rate per Hour, E_d

Q_{sd} = 2.91E+06 (dscfh)

$$E_h = C_m * Q_{sd}$$

E_h = 0.42 lb/hr

Particulate Matter Mass Emission Rate per Day, E_d

$$E_d = E_h * 24$$

E_d = 9.99 lb/day

Particulate Matter Mass Emission Rate per process rate, E_{TC}

Process Rate (E_h)= 253.0794 MMBtu/hr

$$E_{TC} = \frac{E_h}{\text{Process Rate}}$$

E_{TC} = 0.0016 lb/MMBtu

Attachment D
Sampling Datasheets

Erthwrks Method 2 Traverse Point Location Worksheet

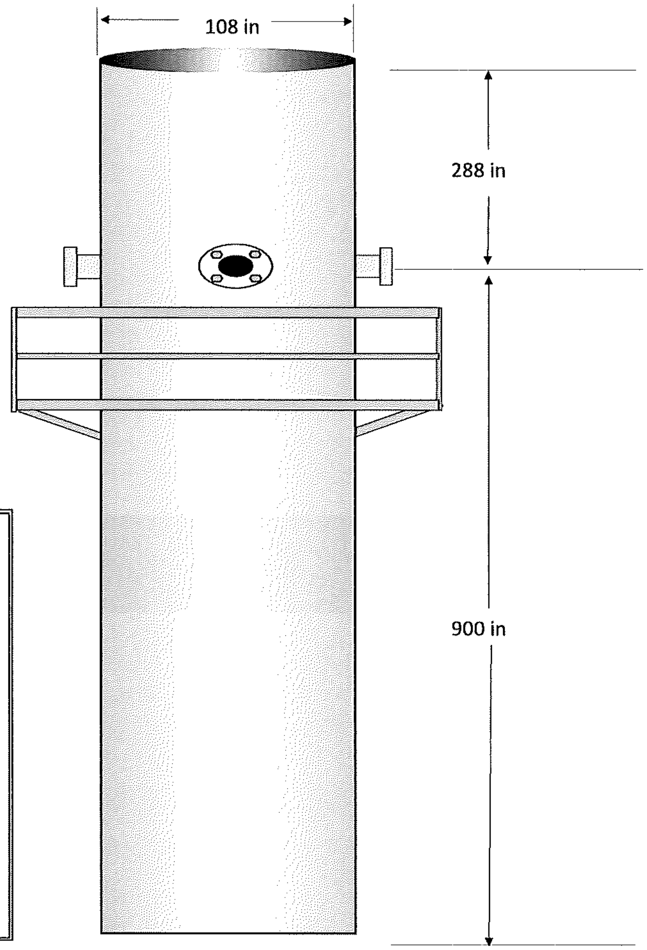
Client: Marathon Petroleum
Project #: 9049.1.D3
Facility: Detroit
Unit ID: Coker Heater
Technician: Austin Squires, Oscar Sanchez, Jarrod Hoskinson

Stack ID Measurements

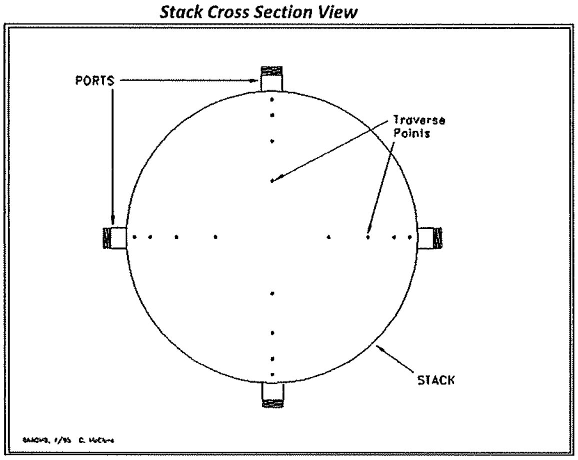
Stack ID + Port (inches):	118.25
Port Extension (inches):	10.75
Stack Diameter (inches):	107.5

Port Location Measurements

Distance Upstream (A) (inches):	288
Distance Downstream (B) (inches):	900
Stack Diameters Upstream (A):	2.7
Stack Diameters Downstream (B):	8.4
Total Traverse Points to be used:	24
Traverse Points per Diameter:	12



Stack Cross Section View



Traverse Point Location Table From EPA Method 1, Table 1-2

Traverse Point Number per Diameter	Total Number of Traverse Points to be Used (from EPA M.1 Table 1-2) 4	8	12	16	20	24
	Traverse Point Location per Diameter (percent of stack ID)					
1	14.60	6.70	4.40	3.20	2.60	2.10
2	85.40	25.00	14.60	10.50	8.20	6.70
3		75.00	29.60	19.40	14.60	11.80
4		93.30	70.40	32.30	22.60	17.70
5			85.40	67.70	34.20	25.00
6			95.60	80.60	65.80	35.60
7				89.50	77.40	64.40
8				96.80	85.40	75.00
9					91.80	82.30
10					97.40	88.20
11						93.30
12						97.90

Calculated Traverse Point Locations per Diameter

Traverse Point Number per Diameter	Total Number of Traverse Points Used 4	8	12	16	20	24
	Traverse Point Location per Diameter (inches from outside of port)					
1	26.45	17.95	15.48	14.19	13.55	**13.01**
2	102.56	37.63	26.45	22.04	19.57	**17.95**
3		91.38	42.57	31.61	26.45	**23.44**
4		111.05	86.43	45.47	35.05	**29.78**
5			102.56	83.53	47.52	**37.63**
6			113.52	97.40	81.49	**49.02**
7				106.96	93.96	**79.98**
8				114.81	102.56	**91.38**
9					109.44	**99.22**
10					115.46	**105.57**
11						**111.05**
12						**115.99**

Measurements in bold will be the traverse points used for the emission test

Erthwrks Isokenetic Sampling Field Data and Calculation Worksheet

Client:	Marathon Petroleum	**Run ID:**	1	**Meterbox ID:**	1404002
Project #:	9049.1.D3	**Date:**	11/28/22	**DGM Y Factor:**	1.0003
Facility:	Detroit	**Amb Temp:**	40	**DGM ΔH @:**	1.869
Unit ID:	Coker Heater	**Baro. Press:**	29.78	**S-Type Pitot ID:**	A9533
				Nozzle ID:	EW-04-13

Pre and Post DGM Leak Checks				
Pre	0.00	**ft3/min @**	15	**inHg**
Post	0.00	**ft3/min @**	8	**inHg**
Pitot Not Damaged & Leak Checks Good?				
Pre	Yes	**Post**	Yes	

Isokinetic Sampling Data			
Meter K Factor	(NA)	13.31	unitless
Pitot Tube Factor	(C_{ps})	0.84	unitless
Stack Static Pressure	(P_{static})	0.20	in H2O
Dry Gas Fraction	(NA)	0.870	unitless
Stack Gas Wet MW	(Ms)	28.13	lb/lb-mole
Actual Nozzle Area	(NA)	8.78E-04	ft²
Total Sample Time	(NA)	120	min
Number of Traverse Points	(NA)	24	points
Time per Traverse Point	(NA)	0:05:00	time

Post Sample Moisture Determination			
Impinger Weights (g)			
Impinger ID	**contents**	**Pre Run**	**Post Run**
Impinger 1	Empty	358.1	564.1
Impinger 2	Empty	610.4	620.0
Impinger 3	DI H2O	638.4	642.3
Impinger 4	Silica Gel	921.1	943.0
	Total Weights	**2528.0**	**2769.4**
	Filter ID:	51888	

Post Sampling Moisture and MW Determination			
O_2 Concentration	(%O_2)	5.09	%
CO_2 Concentration	(%CO_2)	9.56	%
Sample Volume Metered	(V_m)	79.03	dcf
Standard Volume at STP	(V_{std})	80.09	dscf
Moisture Content	(B_{ws})	12.443	%
Final Dry Gas Fraction	(B_{ws})	0.876	unitless
Stack Gas Wet MW	(Ms)	28.27	lb/lb-mole
Stack Gas Velosity	(v_s)	23.52	ft/sec
Stack Gas Vol. Flow Rate	(Qd)	**2.91E+06**	dscfh
Final Isokinetic Calc.	(%iso)	**98.9**	%
Post -Test Meter Cal (M.5 §16.3)	(Y_{qa})	0.957	

	End Time	Stack Temp	Probe Temp	M.5 Filter Temp	202 Filter Temp	Exit Temp	DGM Temp	Pump Vacuum	ΔP	ΔH	Target DGM Reading	Obs. DGM Reading	% ISO Point	% ISO Total
Port 1 Start →	11:52:00	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)	(inHg)	in H2O	in H2O	ft³	109.977	unitless	unitless
Point 1	11:57:00	381	251	265	68	53	47	1	0.13	**1.66**	**113.548**	113.700	**104.3**	**104.3**
Point 2	12:02:00	389	250	249	68	47	53	1	0.11	**1.42**	**117.010**	116.900	**96.7**	**100.7**
Point 3	12:07:00	384	247	242	68	47	54	1	0.10	**1.30**	**120.072**	119.800	**91.4**	**97.8**
Point 4	12:12:00	385	248	247	68	47	55	1	0.10	**1.30**	**122.976**	123.000	**100.7**	**98.5**
Point 5	12:17:00	379	251	247	68	49	57	1	0.10	**1.30**	**126.200**	126.000	**93.7**	**97.6**
Point 6	12:22:00	382	250	245	69	52	60	1	0.10	**1.31**	**129.213**	129.000	**93.4**	**96.9**
Port 2 Start →	12:27:00													
Point 7	12:32:00	380	249	256	69	51	60	1	0.11	**1.44**	**132.373**	132.400	**100.8**	**97.4**
Point 8	12:37:00	392	247	244	66	54	60	1	0.11	**1.44**	**135.749**	135.700	**98.5**	**97.6**
Point 9	12:42:00	389	250	247	72	55	60	1	0.10	**1.31**	**138.900**	138.700	**93.8**	**97.2**
Point 10	12:47:00	387	251	246	74	56	60	1	0.10	**1.31**	**141.903**	141.700	**93.7**	**96.8**
Point 11	12:52:00	380	248	242	73	57	61	1	0.10	**1.31**	**144.923**	145.100	**105.5**	**97.6**
Point 12	12:57:00	382	250	243	74	59	62	1	0.10	**1.32**	**148.325**	148.300	**99.2**	**97.7**
Port 3 Start →	13:00:00													
Point 13	13:05:00	380	247	251	72	56	65	1	0.11	**1.46**	**151.705**	151.900	**105.7**	**98.4**
Point 14	13:10:00	391	249	248	72	62	65	1	0.11	**1.46**	**155.283**	155.300	**100.5**	**98.5**
Point 15	13:15:00	391	247	252	73	62	64	1	0.11	**1.45**	**158.676**	158.900	**106.6**	**99.1**
Point 16	13:20:00	389	250	251	74	62	65	1	0.11	**1.46**	**162.287**	162.100	**94.5**	**98.8**
Point 17	13:25:00	384	250	246	73	62	65	1	0.10	**1.32**	**165.340**	165.400	**101.9**	**99.0**
Point 18	13:30:00	374	250	245	74	64	64	1	0.10	**1.32**	**168.653**	168.600	**98.4**	**98.9**
Port 4 Start →	13:35													
Point 19	13:40:00	378	250	250	68	54	63	1	0.11	**1.45**	**171.996**	172.000	**100.1**	**99.0**
Point 20	13:45:00	393	250	251	69	59	63	1	0.12	**1.58**	**175.515**	175.700	**105.3**	**99.3**
Point 21	13:50:00	393	248	251	69	57	63	1	0.13	**1.71**	**179.357**	179.400	**101.2**	**99.4**
Point 22	13:55:00	386	247	250	68	56	63	1	0.11	**1.45**	**182.780**	182.600	**94.7**	**99.2**
Point 23	14:00:00	386	250	250	68	56	62	1	0.10	**1.32**	**185.818**	186.000	**105.7**	**99.5**
Point 24	14:05:00	387	250	251	69	56	61	1	0.10	**1.31**	**189.210**	189.002	**93.5**	**99.2**
Average Values		**385.1**	**249.2**	**248.7**	**70.3**	**55.5**	**60.5**	**1.0**	**0.11**	**1.41**		**79.025**		**99.2**

Erthwrks Isokenetic Sampling Field Data and Calculation Worksheet

Client:	Marathon Petroleum	**Run ID:**	2	**Meterbox ID:**	1404002
Project #:	9049.1.D3	**Date:**	11/28/22	**DGM Y Factor:**	1.0003
Facility:	Detroit	**Amb Temp:**	43	**DGM ΔH @:**	1.869
Unit ID:	Coker Heater	**Baro. Press:**	29.77	**S-Type Pitot ID:**	A9533
				Nozzle ID:	EW-04-13

Pre and Post DGM Leak Checks				
Pre	0.01	**ft3/min @**	15	**inHg**
Post	0.00	**ft3/min @**	6	**inHg**
Pitot Not Damaged & Leak Checks Good?				
Pre	Yes	**Post**	Yes	

Isokinetic Sampling Data			
Meter K Factor	(NA)	13.31	unitless
Pitot Tube Factor	(C_{ps})	0.84	unitless
Stack Static Pressure	(P_{static})	0.20	in H2O
Dry Gas Fraction	(NA)	0.870	unitless
Stack Gas Wet MW	(Ms)	28.13	lb/lb-mole
Actual Nozzle Area	(NA)	8.78E-04	ft^2
Total Sample Time	(NA)	90	min
Number of Traverse Points	(NA)	24	points
Time per Traverse Point	(NA)	0:03:45	time

Post Sample Moisture Determination			
	Impinger Weights (g)		
Impinger ID	**contents**	**Pre Run**	**Post Run**
Impinger 1	Empty	364.3	512.2
Impinger 2	Empty	611.7	614.7
Impinger 3	DI H2O	644.8	645.5
Impinger 4	Silica Gel	885.2	901.1
	Total Weights	**2506.0**	**2673.5**
	Filter ID:	51889	

Post Sampling Moisture and MW Determination			
O_2 Concentration	($\%O_2$)	5.02	%
CO_2 Concentration	($\%CO_2$)	9.62	%
Sample Volume Metered	(V_m)	61.10	dcf
Standard Volume at STP	(V_{std})	62.39	dscf
Moisture Content	(B_{ws})	11.237	%
Final Dry Gas Fraction	(B_{ws})	0.888	unitless
Stack Gas Wet MW	(Ms)	28.42	lb/lb-mole
Stack Gas Velocity	(v_s)	24.74	ft/sec
Stack Gas Vol. Flow Rate	(Qd)	**3.08E+06**	**dscfh**
Final Isokinetic Calc.	(%Iso)	**98.3**	**%**
Post -Test Meter Cal (M.5 §16.3)	(Y_{qa})	0.969	

	End Time	Stack Temp	Probe Temp	M.5 Filter Temp	202 Filter Temp	Exit Temp	DGM Temp	Pump Vacuum	ΔP	ΔH	Target DGM Reading	Obs. DGM Reading	% ISO Point	% ISO Total
Port 1 Start →	14:33:00	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)	(inHg)	in H2O	In H2O	ft^3	190.597	unitless	unitless
Point 1	14:36:45	387	250	252	68	49	58	1	0.13	**1.70**	**193.324**	193.600	**110.1**	**110.1**
Point 2	14:40:30	388	249	250	68	45	56	1	0.13	**1.69**	**196.315**	196.000	**88.4**	**99.3**
Point 3	14:44:15	386	250	250	69	45	55	1	0.13	**1.69**	**198.713**	198.300	**84.8**	**94.4**
Point 4	14:48:00	385	251	250	68	45	56	1	0.11	**1.43**	**200.803**	200.900	**103.9**	**96.7**
Point 5	14:51:45	381	247	245	68	48	55	1	0.10	**1.30**	**203.288**	203.900	**125.6**	**102.0**
Point 6	14:55:30	381	248	246	68	49	55	1	0.10	**1.30**	**206.288**	206.200	**96.3**	**101.1**
Port 2 Start →	14:58:00							1						
Point 7	15:01:45	397	250	246	68	49	55	1	0.13	**1.69**	**208.895**	208.500	**85.3**	**98.7**
Point 8	15:05:30	397	251	247	69	48	55	1	0.13	**1.69**	**211.195**	211.300	**103.9**	**99.4**
Point 9	15:09:15	396	247	252	68	49	55	1	0.13	**1.69**	**213.997**	214.000	**100.1**	**99.5**
Point 10	15:13:00	395	248	253	68	50	55	1	0.13	**1.69**	**216.698**	216.800	**103.8**	**99.9**
Point 11	15:16:45	391	250	252	69	51	55	1	0.11	**1.43**	**219.289**	219.500	**108.5**	**100.6**
Point 12	15:20:30	390	251	249	68	52	56	1	0.10	**1.30**	**221.880**	221.800	**96.6**	**100.3**
Port 3 Start →	15:25:00													
Point 13	15:28:45	381	249	250	68	50	56	1	0.12	**1.56**	**224.420**	224.500	**103.1**	**100.6**
Point 14	15:32:30	395	250	247	69	53	57	1	0.13	**1.69**	**227.209**	226.900	**88.6**	**99.7**
Point 15	15:36:15	391	250	252	68	54	57	1	0.13	**1.69**	**229.615**	229.800	**106.8**	**100.2**
Point 16	15:40:00	393	249	251	69	55	57	1	0.12	**1.56**	**232.406**	232.200	**92.1**	**99.7**
Point 17	15:43:45	394	247	250	69	55	58	1	0.11	**1.44**	**234.699**	234.600	**96.0**	**99.5**
Point 18	15:47:30	398	250	251	69	56	58	1	0.11	**1.44**	**237.094**	236.900	**92.2**	**99.1**
Port 4 Start →	15:51:00													
Point 19	15:54:45	398	250	251	68	57	58	1	0.11	**1.44**	**239.394**	239.200	**92.2**	**98.7**
Point 20	15:58:30	401	250	247	69	56	58	1	0.14	**1.83**	**242.006**	242.000	**99.8**	**98.8**
Point 21	16:02:15	397	250	243	68	57	58	1	0.12	**1.57**	**244.605**	244.800	**107.5**	**99.2**
Point 22	16:06:00	395	251	231	69	56	59	1	0.11	**1.44**	**247.303**	247.100	**91.9**	**98.9**
Point 23	16:09:45	387	250	227	68	55	59	1	0.11	**1.44**	**249.615**	249.400	**91.5**	**98.6**
Point 24	16:13:30	388	247	229	68	55	59	1	0.10	**1.31**	**251.797**	251.700	**96.0**	**98.5**
Average Values		**391.3**	**249.4**	**246.7**	**68.4**	**51.6**	**56.7**	**1.0**	**0.12**	**1.54**		**61.103**		**98.5**