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

CCR Interheater (CCRPLINTHTR)
Unit: EU14-CCRPLINTHTR-S1
Permit No. MI-ROP-A9831-2012c

Prepared for:

Marathon Petroleum Company LP

Test Date: June 7, 2022
Erthwrks Project No. 9049.1.B4

STAC STACK TESTING ACCREDITATION COUNCIL

A2LA ACCREDITED TO ASTM D7036 ONLY CERT #6147.01

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: Jason Dunn

Title: QC Specialist

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: Trey Chapman

Title: CEO

Signature:

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1.0 INTRODUCTION

1.1 Identification, location and dates of tests

Erthwrks, Inc. was contracted to conduct emission testing on the CCR Interheater (CCRPLINTHTR) in operation at the Marathon Detroit Refinery, located in Detroit Michigan. The testing program was conducted on June 7, 2022.

1.2 Purpose of Testing

The exhaust from the CCR Interheater was sampled and analyzed to determine the relative accuracy of the associated carbon monoxide (CO), oxides of nitrogen (NOx), and oxygen (O_2) continuous emissions monitoring system (CEMS) in accordance with the requirements in the Marathon Permit No. MI-ROP-A9831-2012c and the Title 40 CFR Part 60, Appendix F. In addition, compliance testing was conducted to determine the compliance status of the units' emission for sulfuric acid (H_2SO_4), and particulate matter (PM). The carbon dioxide (CO_2) concentration was also measured in order to determine stack gas molecular weight.

1.3 Description of Source

Marathon Petroleum Company LP operates the CCR Interheater designated as EU14-CCRPLINTHTR-S1 in the refinery. This report addresses the RATA for the CEMS associated with the unit as well as the required compliance test for H_2SO_4 and PM. Table 1.1 below details the CEMS analyzer information.

Table 1.1—Marathon CCR Interheater Stack CEMS Details

Crude/Vac Heater Stack CEMS	Manufacturer	Model No.	S/N	Install Date
NOx	ABB	Limas 11	3.342969.1	2012
CO	ABB	Uras 26	3.342967.1	2012
O_2	ABB	Magnos 206	3.342970.1	2012

1.4 Contact Information

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Facility Location:
Marathon Petroleum Company LP
Detroit Refinery
1300 South Fort Street
Detroit, MI 48217

2.0 SUMMARY OF RESULTS

Table 2.1—Marathon Crude/Vac Heater Stack (SV04-H1-05-H1) CEMS RATA Results

Pollutant Measured	Performance Specification	Relative Accuracy	Applicable Limit	Pass/Fail
NOx	Performance Spec. 2	3.9% RA_{RM}	20%	Pass
CO	Performance Spec. 4A	0.3 ppm RA_{4A}	<5 ppm	Pass
O_2	Performance Spec. 3	0.2% *MD*	1%	Pass

Table 2.2—Marathon Crude/Vac Heater Stack (SV04-H1-05-H1) Compliance Test Results

Pollutant Measured	Methodology	Measured Results	Applicable Limit	Pass/Fail
PM	EPA Method 5	0.0008 lb/MMBtu	0.0019 lb/MMBtu	Pass
PM/PM_{10}	EPA Method 5/202	0.0027 lb/MMBtu	0.0076 lb/MMBtu	Pass
H_2SO_4	EPA Method CTM-013	0.06 ppm	n/a	n/a

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 Continuous Catalytic Regeneration Platformer Unit (EG14-CCRPLATFORMER) is a catalytic reformer that rearranges the structure of low octane naphtha feed into higheroctane reformates. Hydrogen is produced as a product of the reaction and is used in other refinery processes. The CCR Charge Heater (EG14-CCRPLCHARHTR) is the stack for Heater 14H8 and Heater 14H9. The CCR Interheater (EU14-CCRPLINTHTR) is the stack for Heater 14H1-4. Both units are fired by refinery fuel gas. Emissions are vented to the atmosphere via the CCR Charge Heater (SV14-H6) and CCR Interheater Stack (SV14-H4A).

3.2 Applicable permit and source designation

Marathon Petroleum Company LP operates the CCR Interheater (CCRPLINTHTR) (EU14-CCRPLINTHTR-S1) under EGLE Renewable Operating Permit No. MI-ROP-A9831-2012c.

3.3 Type and quantity of materials processed during tests

During the emission testing on June 7, 2022, at the Marathon Petroleum Company LP Refinery, the CCR Interheater (CCRPLINTHTR) was tested while operating at the maximum achievable load condition. This operational data was provided by MPC and is located in Attachment G of this report.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

4.1 Gaseous Emissions – NOx, CO, 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.

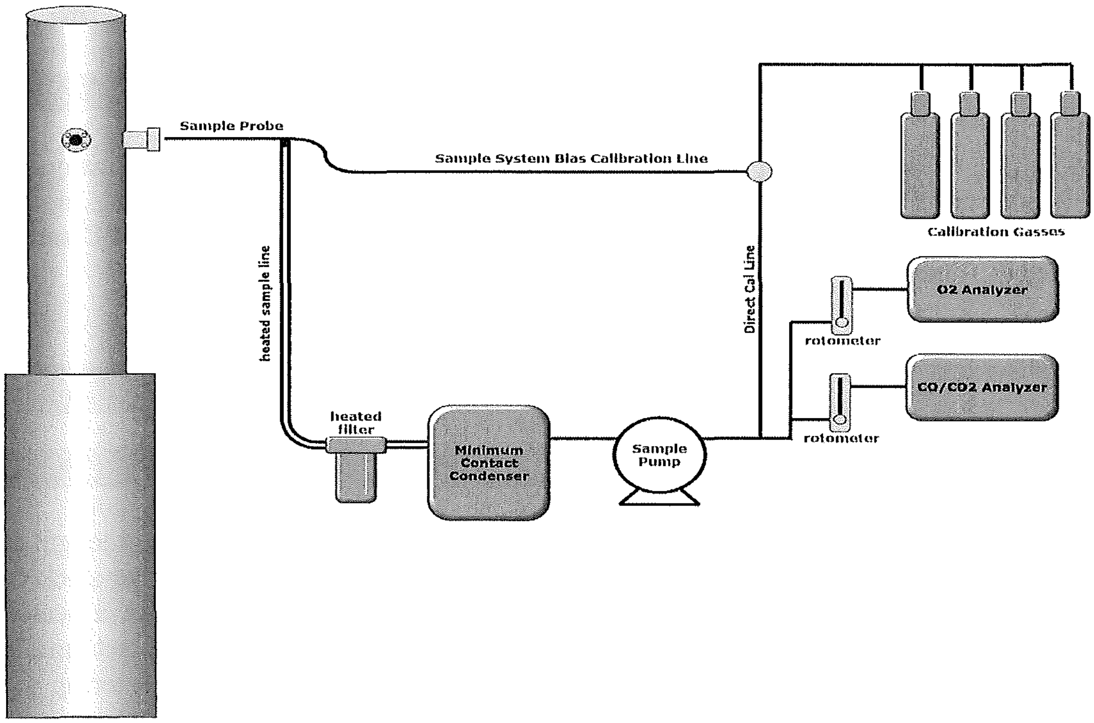

Figure 1: Example Erthwrks Gaseous Sampling System Diagram

4.2 Filterable Particulate Matter Sampling – EPA Method 5

EPA Test Method 1 will be 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 of 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.

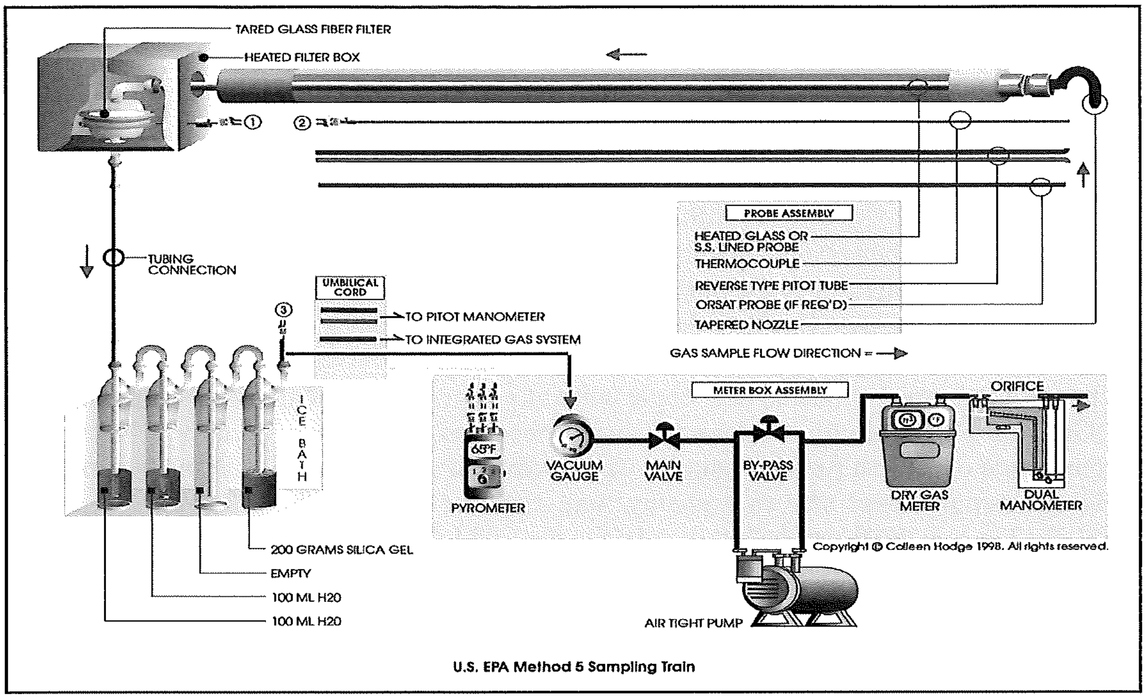

Figure 2: Example Erthwrks PM System Diagram

4.3 Condensible Particulate Matter Sampling – EPA Method 202

For the determination of PM/PM_{10}, condensable particulate matter (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 EPA Method CTM-013 (ALT-133 Analysis) H_2SO_4 Determination

The H_2SO_4 emissions were determined utilizing the conditional test method 13 (CTM-013). The sample was extracted at a constant rate through a quartz lined heated probe (>350 °F), A heated quartz filter holder and filter (>500 °F), and through a Modified Grahm condenser (H_2SO_4 Condenser) with Type C glass frit and 200 cm of 5-mmID glass tubing condenser coil. The H_2SO_4 condenser is maintained between 167 to 185 °F. Because SO_2 was not to be determined via this method, the sample was then passed through four impingers with the specifications delineated in EPA Method 4.

The sampling was conducted at a single point at a constant rate of about 10 L/min and the DGM readings and all temperatures were recorded every five minutes. After the completion of the test run, the samples were recovered in accordance with the test method and the samples were sent to Enthalpy Analytical for analysis via Ion Chromatography (ALT-133). See the figure below that details the CTM-013 Sampling Train.

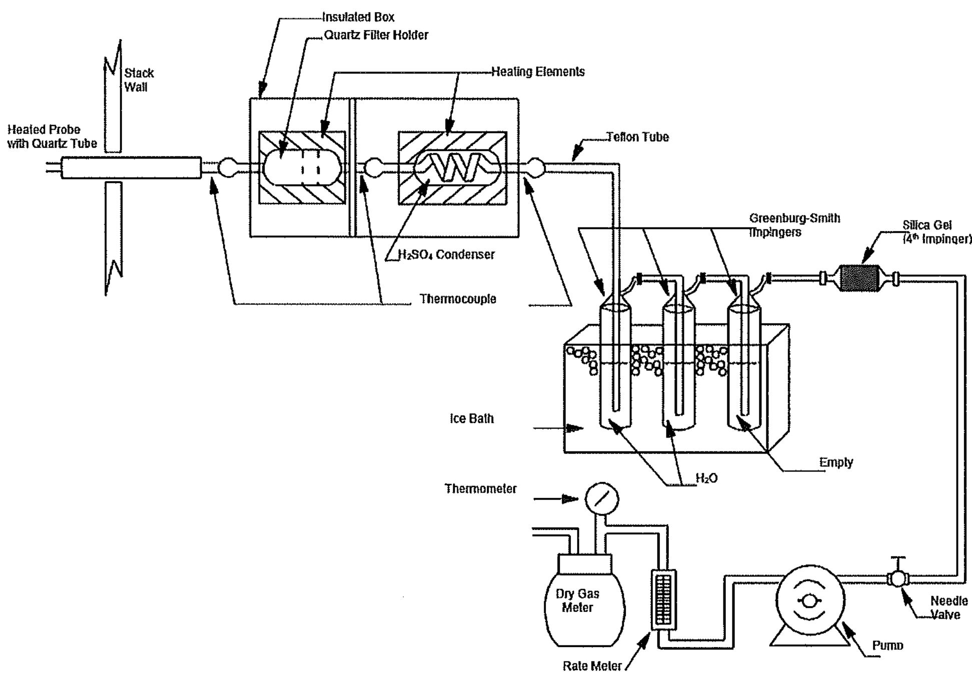

Figure 3: Example Erthwrks H_2SO_4 System Diagram

4.5 RATA Procedures

The RATA testing was conducted following the sampling and measurement procedures found in the EPA Part 60, Appendix B, Performance Specifications which requires that EPA Reference Methods, from EPA Part 60, Appendix A, be utilized to conduct independent stack emissions measurements for comparison with installed CEMS readings. The following performance specifications will be used during this testing program.

- EPA Performance Specification 2 for NOx relative accuracy
- EPA Performance Specification 3 for O_2 relative accuracy
- EPA Performance Specification 4A for CO relative accuracy

As required by these methods, the use EPA Protocol 1 gases are mandatory and were used for this portion of the project.

A minimum of nine (9) RATA test runs were conducted at each exhaust stack for a minimum duration of twenty-one (21) minutes for each run. A 3-point traverse located at 16.7%, 50.0%, and 83.3% of the way across the stack (or 0.4, 1.2, and 2.0 meters from the stack wall) was conducted during each RATA test run (7 minutes per point). A maximum of twelve (12) RATA test runs will be conducted and up to three test runs may be discarded and not used to determine relative accuracy. The results of the reference method tests were compared to CEMS measurement data from the same time periods to determine the relative accuracy of the CEMS.

For NOx, the results of the RATA test are considered acceptable if the calculated relative accuracy does not exceed 20.0% as calculated by Equation 2-6 in Performance Specification 2. Alternatively, for affected units where the average of the reference method measurements is less than 50 percent of the emission standard (emission limit), the relative accuracy must not exceed 10% when the applicable emission standard is used in the denominator of Eq. 2-6.

For O_2, the results of the RATA test are considered acceptable if the calculated relative accuracy does not exceed 20.0% as calculated by Equation 3.1 in Performance Specification 3. The results are also acceptable if the result of Equation 3-2 is less than or equal to 1.0 percent.

For CO, the results of the RATA test are considered acceptable if the calculated relative accuracy does not exceed 10.0% as calculated by Equation 2-6 in Performance Specification 2. Alternatively, for affected units where the average of the reference method measurements is less than 50 percent of the emission standard (emission limit), the relative accuracy must not exceed 5% when the applicable emission standard is used in the denominator of Eq. 2-6. Performance Specification 4A criteria may be used to determine relative accuracy for CEMS with low emission standards (less than 200 ppmv). In these cases, the results of the RATA test are considered acceptable if the absolute average difference between the RM and CEMS is within 5 ppmv.

4.6 Discussion of sampling procedure or operational variances

Erthwrks, Inc. conducted the emissions testing with no sampling or procedural variances.

Attachment A
Detailed Results of Emission Test

Erthwrks Relative Accuracy Test Audit--NOx RATA
Performance Specification 2

CCR InterHtr											NO$_x$ CEMS RATA - lb/MMBtu
							Fuel F-Factor	8595.3	scf/MMBtu		
Test Run	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11
Date	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**
Start Time	10:27	10:57	11:27	12:03	12:59	13:29	13:59	14:30	15:02	15:32	16:04
End Time	10:48	11:18	11:48	12:24	13:20	13:50	14:20	14:51	15:23	15:53	16:25
RM NOx (ppmvd)	21.80	22.08	21.74	21.89	21.37	21.64	21.82	22.11	22.64	22.99	22.97
RM O_2 Results (%vd)	6.21	6.26	6.21	6.32	6.23	6.31	6.25	6.17	6.20	6.32	6.29
RM NOx (lb/MMBtu)	**0.0318**	**0.0323**	**0.0317**	**0.0322**	**0.0312**	**0.0318**	**0.0319**	**0.0322**	**0.0330**	**0.0338**	**0.0337**
CEMS NOx (lb/MMBtu)	**0.0329**	**0.0331**	**0.0329**	**0.0330**	**0.0325**	**0.0333**	**0.0336**	**0.0333**	**0.0342**	**0.0348**	**0.0349**
Difference	-0.0011	-0.0008	-0.0012	-0.0008	-0.0013	-0.0015	-0.0017	-0.0011	-0.0012	-0.0010	-0.0012
Accept or Reject	*Accept*	*Accept*	*Accept*	*Accept*	*Reject*	*Accept*	*Reject*	*Accept*	*Accept*	*Accept*	*Accept*

Applicable Standard (lb/MMBtu)	0.05	
Mean of the Difference (d_{avg})	-0.0011	
Standard Deviation (S_d)	0.0002	
Confidence Coefficient (CC)	0.0002	
Relative Accuracy via RM, *RA_{RM}* *	**3.88%**	← ***Pass***

**RA_{RM} (Reference Method) must be less than 20%*

Erthwrks Relative Accuracy Test Audit--O_2 RATA
Performance Specification 3

CCR InterHtr											O_2 CEMS RATA
Test Run	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11
Date	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**
Start Time	10:27	10:57	11:27	12:03	12:59	13:29	13:59	14:30	15:02	15:32	16:04
End Time	10:48	11:18	11:48	12:24	13:20	13:50	14:20	14:51	15:23	15:53	16:25
RM O_2 Result (%vd)	**6.21**	**6.26**	**6.21**	**6.32**	**6.23**	**6.31**	**6.25**	**6.17**	**6.20**	**6.32**	**6.29**
CEMS O_2 Data (%vd)	**6.37**	**6.47**	**6.41**	**6.51**	**6.43**	**6.52**	**6.49**	**6.40**	**6.42**	**6.53**	**6.50**
Difference	-0.16	-0.21	-0.20	-0.19	-0.20	-0.21	-0.24	-0.23	-0.22	-0.21	-0.21
Accept or Reject	*Accept*	*Accept*	*Accept*	*Accept*	*Accept*	*Accept*	*Reject*	*Reject*	*Accept*	*Accept*	*Accept*

Relative Accuracy via RM, $RA_{RM-CEMS}$* **0.20%** ← Pass

*$RA_{RM-CEMS}$ *(Reference Method - CEMS) Absolute difference must be less than 1.0%*

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Erthwrks, Inc. EPA 40CFR60 RATA Worksheet
Version 2.1 (Rev. 5/26/2021)

Erthwrks Relative Accuracy Test Audit--CO RATA
Performance Specification 4

CCR InterHtr	CO CEMS RATA at Stack Conditions

Test Run	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11
Date	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**	**6/7/2022**
Start Time	10:27	10:57	11:27	12:03	12:59	13:29	13:59	14:30	15:02	15:32	16:04
End Time	10:48	11:18	11:48	12:24	13:20	13:50	14:20	14:51	15:23	15:53	16:25
RM CO Result (ppmvd)	**0.34**	**-0.01**	**0.09**	**-0.10**	**-0.02**	**0.09**	**0.22**	**0.11**	**0.02**	**-0.09**	**-0.06**
CEMS CO Data (ppmvd)	**-0.17**	**-0.20**	**-0.18**	**-0.20**	**-0.17**	**-0.19**	**-0.20**	**-0.22**	**-0.22**	**-0.22**	**-0.23**
Difference	0.51	0.19	0.27	0.10	0.15	0.28	0.42	0.33	0.24	0.13	0.17
Accept or Reject	*Reject*	*Accept*	*Accept*	*Accept*	*Accept*	*Accept*	*Reject*	*Accept*	*Accept*	*Accept*	*Accept*

Mean of the Difference (d_{avg})	0.21	
Standard Deviation (S_d)	0.08	
Confidence Coefficient (CC)	0.06	
Relative Accuracy via M.4A, *RA_{4A}* ‡	**0.27**	← *Pass*

‡RA_{4A} must be less than 5 ppmv

Erthwrks Particulate Matter Summary of Results

Project: Marathon Petroleum Company
Facility: Detroit Refinery
Location: Detroit, MI
Unit ID: CRR Inter Heater

Run Designation						
Run Number		1	2	3	Average	
Date		6/7/2022	6/7/2022	6/7/2022		mm:dd:yyyy
Run Start Time		10:28	13:00	15:02		hh:mm
Run End Time		12:09	14:35	16:36		hh:mm
Operating Conditions						
Firing Rate (MMbtu/hr)		94.55	95.59	94.29	94.81	MMbtu/hr
Stack Gas Composition						
Oxygen Concentration	($\%O_2$)	6.23	6.26	6.27	6.25	%
Carbon Dioxide Concentration	($\%CO_2$)	8.82	8.75	8.79	8.79	%
Stack Moisture Content	(B_{ws})	11.01	9.92	14.29	11.74	%
Stack Dry Molecular Weight	(M_d)	29.66	29.65	29.66	29.66	lb/lb-mole
Stack Wet Molecular Weight	(M_s)	28.38	28.49	27.99	28.29	lb/lb-mole
Stack Gas Volumetric Flow Calculations						
Absolute Stack Pressure	(P_s)	29.04	29.04	29.04	29.04	in Hg
Average Stack Temperature	($(t_s)_{avg}$)	1100.4	1104.3	1098.6	1101.1	°R
Average Square Root of ΔP's	($(\Delta p^{1/2})_{avg}$)	0.4944	0.5021	0.5031	0.4999	%
Average Stack Gas Velocity	(v_s)	2461.57	2498.96	2519.89	2493.47	ft/min
Average Stack Gas Flow	(Q_{aw})	5.85E+04	5.94E+04	5.99E+04	5.92E+04	acfm
Wet Standard Stack Flow Rate	(Q_{sw})	1.63E+06	1.65E+06	1.68E+06	1.65E+06	wscfh
Dry Standard Stack Flow Rate	(Q_{sd})	1.45E+06	1.49E+06	1.44E+06	1.46E+06	dscfh
Particulate Matter Emission Rate Calculations						
Mass of Filterable PM (M.5)	mg	1.83	1.99	1.2	1.67	mg
Mass of Condensible PM (M.202)	mg	4.27	3.94	4.58	4.26	mg
Total Mass of Particulates	mg	6.10	5.93	5.78	5.94	mg
Filterable PM Mass Concentration	lb/dscf	5.49E-08	5.78E-08	3.47E-08	4.91E-08	lb/dscf
Total PM Mass Concentration	lb/dscf	1.83E-07	1.72E-07	1.67E-07	1.74E-07	lb/dscf
Filterable PM Mass Emission Rate	lb/hr	0.08	0.09	0.05	0.07	lb/hr
Total PM Mass Emission Rate	lb/hr	0.27	0.26	0.24	0.25	lb/hr
Filterable PM Mass Emission Rate	lb/day	1.92	2.06	1.20	1.73	lb/day
Total PM Mass Emission Rate	lb/day	6.38	6.15	5.77	6.10	lb/day
Filterable PM Mass Emission Rate	lb/MMbtu	0.0008	0.0009	0.0005	0.0008	lb/MMbtu
Total PM Mass Emission Rate	lb/MMbtu	0.0028	0.0027	0.0025	0.0027	lb/MMbtu

Detailed Summary of Results

Client: Marathon Petroleum
Facility: Detroit
Unit ID: CCR Inter Heater
Erthwrks Tech: MK, JW

Run Information				
Run Number	**Run 1**	**Run 2**	**Run 3**	
Date	6/7/2022	6/7/2022	6/7/2022	
Run Start Time	16:53	17:44	18:36	
Run End Time	17:23	18:14	19:06	
Unit Fuel Flow Data				**Averages**
Fuel F Factor (F_d) (scf/MMBtu)	8595.3	8595.3	8595.3	**8595.3**
Emission Concentrations				
H_2SO_4 (ug)	82.9	93.2	33.3	**69.80**
Train volume (scf)	10.26	10.05	10.20	**10.17**
Emission Rates				
H_2SO_4 (lb/scf)	1.78E-08	2.04E-08	7.20E-09	**1.51E-08**
H_2SO_4 (ppm)	0.07	0.08	0.03	**0.06**

Attachment B
Quality Control Documentation

Erthwrks Method 1 Traverse Point Location Worksheet

Client: MPC Detroit
Project #: 9049.1.B4
Facility: Detroit Refinery
Unit ID: CCR Interheater
Technician: jmw

Stack ID Measurements

Stack ID + Port (inches):	73.5
Port Extension (inches):	7.5
Stack Diameter (inches):	66

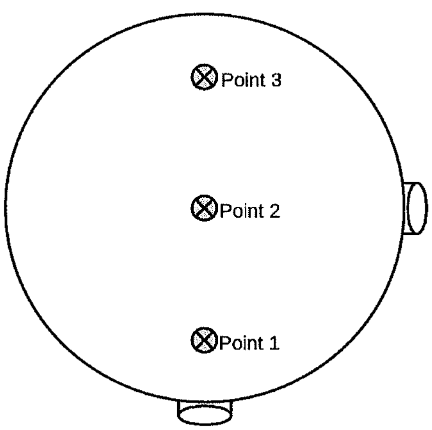
Port Location Measurements

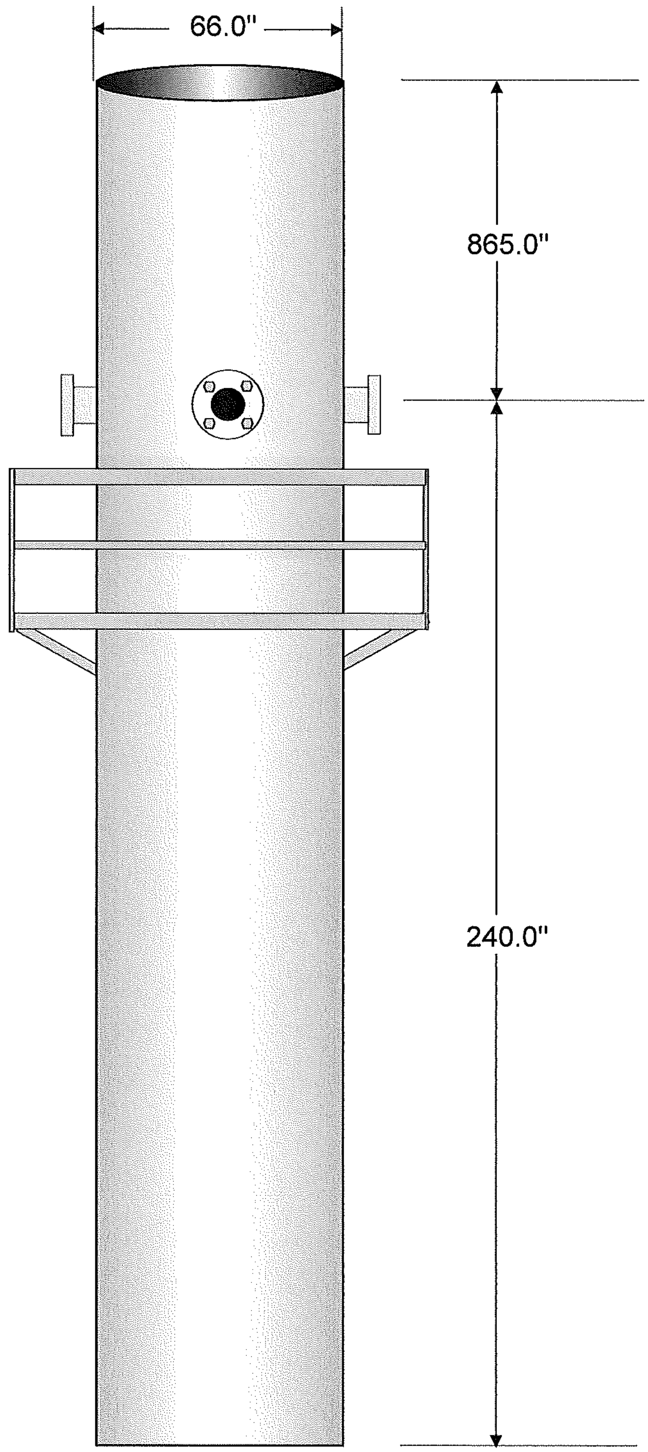
Distance Upstream (A) (inches):	865
Distance Downstream (B) (inches):	240
Stack Diameters Upstream (A):	13.1
Stack Diameters Downstream (B):	3.6

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

Traverse Point Locations[(1)(2)]	
Point 1:	11.02"
Point 2:	33.00"
Point 3:	54.98"

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: 6/7/2022
Client: MPC
Facility: Detroit
Project No: 9049.1.B4
Unit ID: CCR InterHtr
Erthwrks Tech: John Wood

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
NO_X	n/a	n/a	24.77	CC446268	53.76	CC339873	NA
CO	n/a	n/a	25.43	CC446268	50.83	CC339873	NA
O_2	n/a	n/a	10.13	CC287657	19.92	ALM038955	NA
CO_2	n/a	n/a	10.00	CC287657	19.69	ALM038955	NA

Reference Method Analyzer Info

Make	Model	Serial No.
Teledyne	T200H	802
Teledyne	T300M	734
Teledyne	T200H	802
Teledyne	T300M	734

Direct 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)*
NO_X	0.03	0.05%	n/a	n/a	24.78	0.02%	53.43	-0.62%
CO	-0.09	-0.18%	n/a	n/a	25.33	-0.19%	50.98	0.30%
O_2	0.01	0.06%	n/a	n/a	10.00	-0.65%	19.86	-0.29%
CO_2	0.00	0.01%	n/a	n/a	10.10	0.49%	19.77	0.41%

*Unless otherwise noted in protocol or report, THC's calibration error test is conducted using the entire sample system and must be less than 5% of applicable calibration gas

** ACE must either be within ± 2.0% or ≤ 0.5 ppmv absolute difference*

NO_2 to NO Conversion Efficiency Test	
NO_2 Cal Gas Cyl. Number	CC502181
NO_2 Cal Gas Concentration	60.52
NO_X Analyzer Response	57.68
NO_2-NO Conv. Efficiency (Eff_{NO2})[1]	95.3%

[1] Eff_{NO2} must be ≥ 90%

Method 7E Traverse Point Determination			
Stack ID (inches)		Trav. Location	Inside ID + Port
66	Point 1	11.02	18.52
Port Ext. (inches)	Point 2	33.00	40.50
7.5	Point 3	54.98	62.48

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)
NO_X	24.77	24.78	24.74	-0.07%	60	0.11	0.15%	60
CO	25.43	25.33	25.42	0.17%	60	-0.10	-0.01%	60
O_2	10.13	10.00	9.97	-0.16%	60	0.10	0.45%	60
CO_2	10.00	10.10	9.96	-0.68%	60	0.00	0.01%	60

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

Erthwrks Gaseous Sample Collection and Quality Assurance Worksheet

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

Run #: **Run 1**
Start Time: 10:27
End Time: 10:48

Pollutant	Initial Zero SSC (C_{Si})	Initial Upscale SSC (C_{Si})	Raw Results (C_{Avg})	Final Zero SSC (C_{Sf})	Final Upscale SSC (C_{Sf})
NO_X	-0.06	24.76	21.79	-0.05	24.76
CO	-1.00	25.40	-0.28	-0.27	25.40
O_2	0.04	9.97	6.13	0.04	9.97
CO_2	0.00	10.11	8.95	0.00	10.11

Run #: **Run 2**
Start Time: 10:57
End Time: 11:18

Initial Zero SSC (C_{Si})	Initial Upscale SSC (C_{Si})	Raw Results (C_{Avg})	Final Zero SSC (C_{Sf})	Final Upscale SSC (C_{Sf})
-0.05	24.76	22.11	0.02	24.85
-0.27	25.40	-0.32	-0.34	25.04
0.04	9.97	6.19	0.06	10.00
0.00	10.11	8.91	0.02	10.15

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

Run #: **Run 3**
Start Time: 11:27
End Time: 11:48

Pollutant	Initial Zero SSC (C_{Si})	Initial Upscale SSC (C_{Si})	Raw Results (C_{Avg})	Final Zero SSC (C_{Sf})	Final Upscale SSC (C_{Sf})
NO_X	0.02	24.85	21.92	0.01	25.11
CO	-0.34	25.04	-0.28	-0.40	25.13
O_2	0.06	10.00	6.15	0.05	9.99
CO_2	0.02	10.15	8.93	0.01	10.12

Run #: **Run 4**
Start Time: 12:03
End Time: 12:24

Initial Zero SSC (C_{Si})	Initial Upscale SSC (C_{Si})	Raw Results (C_{Avg})	Final Zero SSC (C_{Sf})	Final Upscale SSC (C_{Sf})
0.01	25.11	22.04	0.01	24.77
-0.40	25.13	-0.36	-0.12	25.25
0.05	9.99	6.24	0.04	9.98
0.01	10.12	8.84	0.01	10.12

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

Run #: **Run 5**
Start Time: 12:59
End Time: 13:20

Pollutant	Initial Zero SSC (C_{Si})	Initial Upscale SSC (C_{Si})	Raw Results (C_{Avg})	Final Zero SSC (C_{Sf})	Final Upscale SSC (C_{Sf})
NO_X	0.01	24.77	21.28	0.04	24.56
CO	-0.12	25.25	-0.31	-0.46	24.99
O_2	0.04	9.98	6.16	0.05	9.99
CO_2	0.01	10.12	8.89	0.02	10.13

Run #: **Run 6**
Start Time: 13:29
End Time: 13:50

Initial Zero SSC (C_{Si})	Initial Upscale SSC (C_{Si})	Raw Results (C_{Avg})	Final Zero SSC (C_{Sf})	Final Upscale SSC (C_{Sf})
0.04	24.56	21.54	-0.03	24.73
-0.46	24.99	-0.45	-0.61	24.92
0.05	9.99	6.24	0.05	9.98
0.02	10.13	8.84	0.01	10.15

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

Run #: **Run 7**
Start Time: 13:59
End Time: 14:20

Pollutant	Initial Zero SSC (C_{Si})	Initial Upscale SSC (C_{Si})	Raw Results (C_{Avg})	Final Zero SSC (C_{Sf})	Final Upscale SSC (C_{Sf})
NO_X	-0.03	24.73	21.81	-0.02	24.78
CO	-0.61	24.92	-0.32	-0.48	24.96
O_2	0.05	9.98	6.18	0.05	9.99
CO_2	0.01	10.15	8.88	0.00	10.13

Run #: **Run 8**
Start Time: 14:30
End Time: 14:51

Initial Zero SSC (C_{Si})	Initial Upscale SSC (C_{Si})	Raw Results (C_{Avg})	Final Zero SSC (C_{Sf})	Final Upscale SSC (C_{Sf})
-0.02	24.78	22.38	-0.07	25.36
-0.48	24.96	-0.43	-0.61	24.86
0.05	9.99	6.10	0.04	9.99
0.00	10.13	8.94	0.00	10.12

Erthwrks Gaseous Sample Collection and Quality Assurance Worksheet

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

Run #: **Run 9**
Start Time: 15:02
End Time: 15:23

Pollutant	Initial Zero SSC ($C_{S,i}$)	Initial Upscale SSC ($C_{S,i}$)	Raw Results (C_{Avg})	Final Zero SSC ($C_{S,f}$)	Final Upscale SSC ($C_{S,f}$)
NO_X	-0.07	25.36	22.82	0.04	24.56
CO	-0.61	24.86	-0.52	-0.46	24.99
O_2	0.04	9.99	6.13	0.05	9.99
CO_2	0.00	10.12	8.94	0.02	10.13

Run #: **Run 10**
Start Time: 15:32
End Time: 15:53

Initial Zero SSC ($C_{S,i}$)	Initial Upscale SSC ($C_{S,i}$)	Raw Results (C_{Avg})	Final Zero SSC ($C_{S,f}$)	Final Upscale SSC ($C_{S,f}$)
0.04	24.56	23.12	-0.05	25.26
-0.46	24.99	-0.72	-0.78	24.83
0.05	9.99	6.24	0.04	9.95
0.02	10.13	8.87	0.02	10.10

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

Run #: **Run 11**
Start Time: 16:04
End Time: 16:25

Pollutant	Initial Zero SSC ($C_{S,i}$)	Initial Upscale SSC ($C_{S,i}$)	Raw Results (C_{Avg})	Final Zero SSC ($C_{S,f}$)	Final Upscale SSC ($C_{S,f}$)
NO_X	-0.05	25.26	23.17	-0.05	24.73
CO	-0.78	24.83	-0.73	-0.55	25.62
O_2	0.04	9.95	6.19	0.05	9.95
CO_2	0.02	10.10	8.88	0.02	10.12

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_O)	Avg. Upscale Sys. Bias (C_M)	Zero Drift Assessment (D)†	Upscale Drift Assessment (D)†	Corrected Results (C_{Gas})
NO_X	-0.17%	-0.03%	-0.14%	-0.03%	-0.05	24.76	0.03%	0.00%	**21.80**
CO	-1.79%	0.13%	-0.34%	0.13%	-0.63	25.40	1.45%	0.00%	**0.34**
O_2	0.16%	-0.13%	0.16%	-0.13%	0.04	9.97	0.00%	0.00%	**6.21**
CO_2	0.01%	0.06%	0.01%	0.06%	0.00	10.11	0.00%	0.00%	**8.85**

** 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_O)	Avg. Upscale Sys. Bias (C_M)	Zero Drift Assessment (D)†	Upscale Drift Assessment (D)†	Corrected Results (C_{Gas})
NO_X	-0.14%	-0.03%	-0.02%	0.14%	-0.01	24.81	0.12%	0.17%	**22.08**
CO	-0.34%	0.13%	-0.50%	-0.58%	-0.30	25.22	0.16%	0.71%	**-0.01**
O_2	0.16%	-0.13%	0.22%	-0.01%	0.05	9.99	0.07%	0.13%	**6.26**
CO_2	0.01%	0.06%	0.09%	0.25%	0.01	10.13	0.08%	0.19%	**8.80**

** 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

Erthwrks Gaseous Sample Collection and Quality Assurance Worksheet

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})
NO_X	-0.02%	0.14%	-0.03%	0.62%	0.02	24.98	0.01%	0.49%	**21.74**
CO	-0.50%	-0.58%	-0.61%	-0.41%	-0.37	25.08	0.12%	0.17%	**0.09**
O_2	0.22%	-0.01%	0.22%	-0.08%	0.05	9.99	0.01%	0.07%	**6.21**
CO_2	0.09%	0.25%	0.05%	0.10%	0.01	10.13	0.04%	0.15%	**8.81**

** 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 4 **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})
NO_X	-0.03%	0.62%	-0.04%	-0.01%	0.01	24.94	0.01%	0.63%	**21.89**
CO	-0.61%	-0.41%	-0.06%	-0.17%	-0.26	25.19	0.56%	0.24%	**-0.10**
O_2	0.22%	-0.08%	0.15%	-0.12%	0.05	9.98	0.07%	0.04%	**6.32**
CO_2	0.05%	0.10%	0.05%	0.10%	0.01	10.12	0.00%	0.00%	**8.74**

** 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 5 **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})
NO_X	-0.04%	-0.01%	0.02%	-0.40%	0.02	24.67	0.06%	0.39%	**21.37**
CO	-0.06%	-0.17%	-0.73%	-0.68%	-0.29	25.12	0.68%	0.51%	**-0.02**
O_2	0.15%	-0.12%	0.22%	-0.07%	0.05	9.98	0.07%	0.05%	**6.23**
CO_2	0.05%	0.10%	0.11%	0.17%	0.02	10.12	0.06%	0.08%	**8.78**

** 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 6 **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})
NO_X	0.02%	-0.40%	-0.10%	-0.09%	0.01	24.65	0.12%	0.31%	**21.64**
CO	-0.73%	-0.68%	-1.02%	-0.81%	-0.54	24.96	0.29%	0.13%	**0.09**
O_2	0.22%	-0.07%	0.18%	-0.10%	0.05	9.98	0.04%	0.03%	**6.31**
CO_2	0.11%	0.17%	0.02%	0.26%	0.01	10.14	0.09%	0.09%	**8.72**

** 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 7 **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})
NO_X	-0.10%	-0.09%	-0.09%	0.00%	-0.02	24.76	0.01%	0.09%	**21.82**
CO	-1.02%	-0.81%	-0.76%	-0.74%	-0.54	24.94	0.27%	0.07%	**0.22**
O_2	0.18%	-0.10%	0.19%	-0.04%	0.05	9.99	0.01%	0.06%	**6.25**
CO_2	0.02%	0.26%	0.02%	0.15%	0.00	10.14	0.01%	0.11%	**8.76**

** 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

Erthwrks Gaseous Sample Collection and Quality Assurance Worksheet

Run 8 **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})
NO_X	-0.09%	0.00%	-0.18%	1.08%	-0.04	25.07	0.09%	1.08%	**22.11**
CO	-0.76%	-0.74%	-1.02%	-0.93%	-0.54	24.91	0.27%	0.19%	**0.11**
O_2	0.19%	-0.04%	0.14%	-0.08%	0.04	9.99	0.05%	0.04%	**6.17**
CO_2	0.02%	0.15%	0.01%	0.11%	0.00	10.12	0.01%	0.05%	**8.84**

** 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 9 **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})
NO_X	-0.18%	1.08%	0.02%	-0.40%	-0.01	24.96	0.20%	1.48%	**22.64**
CO	-1.02%	-0.93%	-0.73%	-0.68%	-0.54	24.92	0.29%	0.25%	**0.02**
O_2	0.14%	-0.08%	0.22%	-0.07%	0.05	9.99	0.08%	0.01%	**6.20**
CO_2	0.01%	0.11%	0.11%	0.17%	0.01	10.12	0.10%	0.07%	**8.83**

** 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 10 **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})
NO_X	0.02%	-0.40%	-0.15%	0.89%	-0.01	24.91	0.16%	1.29%	**22.99**
CO	-0.73%	-0.68%	-1.36%	-1.00%	-0.62	24.91	0.63%	0.31%	**-0.09**
O_2	0.22%	-0.07%	0.14%	-0.23%	0.05	9.97	0.08%	0.17%	**6.32**
CO_2	0.11%	0.17%	0.08%	0.03%	0.02	10.12	0.03%	0.15%	**8.76**

** 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 11 **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})
NO_X	-0.15%	0.89%	-0.14%	-0.09%	-0.05	24.99	0.01%	0.97%	**22.97**
CO	-1.36%	-1.00%	-0.90%	0.57%	-0.67	25.22	0.45%	1.56%	**-0.06**
O_2	0.14%	-0.23%	0.19%	-0.26%	0.04	9.95	0.05%	0.03%	**6.29**
CO_2	0.08%	0.03%	0.10%	0.14%	0.02	10.11	0.03%	0.11%	**8.77**

** 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
Sampling Datasheets

Erthwrks Method 2 Traverse Point Location Worksheet

Client: Marathon Petroleum Company
Project #: 9049.1.B4
Facility: Detroit Refinery
Unit ID: CRR Inter Heater
Technician: jmw, jh, mk, jt

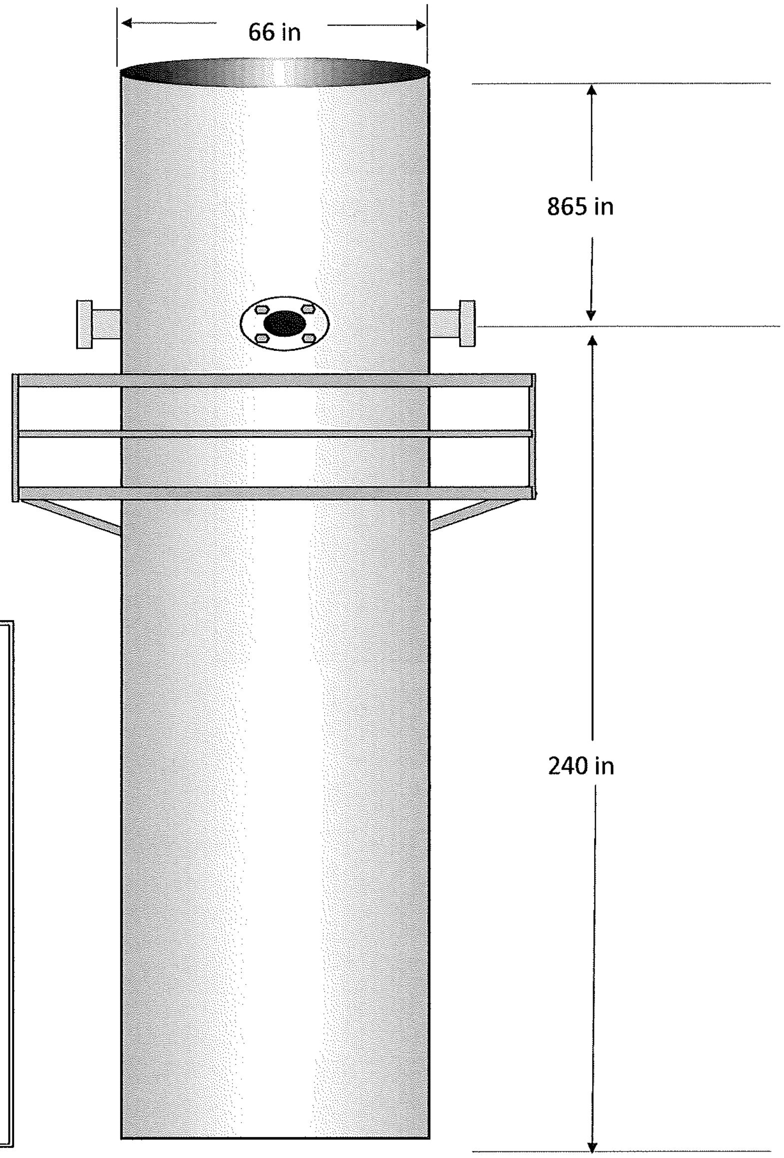
Stack ID Measurements

Stack ID + Port (inches):	73.5
Port Extension (inches):	7.5
Stack Diameter (inches):	66

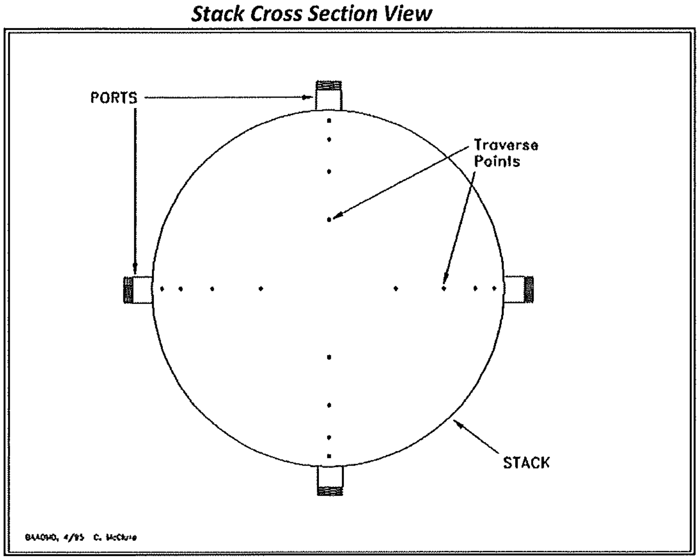
Port Location Measurements

Distance Upstream (A) (inches):	865
Distance Downstream (B) (inches):	240
Stack Diameters Upstream (A):	13.1
Stack Diameters Downstream (B):	3.6

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	17.14	11.92	10.40	9.61	9.22	**8.89**
2	63.86	24.00	17.14	14.43	12.91	**11.92**
3		57.00	27.04	20.30	17.14	**15.29**
4		69.08	53.96	28.82	22.42	**19.18**
5			63.86	52.18	30.07	**24.00**
6			70.60	60.70	50.93	**31.00**
7				66.57	58.58	**50.00**
8				71.39	63.86	**57.00**
9					68.09	**61.82**
10					71.78	**65.71**
11						**69.08**
12						**72.11**

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

Erthwrks Isokenetic Sampling Field Data and Calculation Worksheet

Client:	Marathon Petroleum Company	**Run ID:**	1	**Meterbox ID:**	M5-2
Facility:	Detroit Refinery	**Date:**	6/7/22	**DGM Y Factor:**	0.989
Location:	Detroit, MI	**Amb Temp:**	67	**DGM ΔH @:**	1.816
Unit ID:	CRR Inter Heater	**Baro. Press:**	29.11		

Pre and Post DGM Leak Checks				
Pre	0.000	**ft3/min @**	14	**inHg**
Post	0.002	**ft3/min @**	10	**inHg**
Pitot Not Damaged & Leak Checks Good?				
Pre	Yes	**Post**	Yes	

Isokinetic Sampling Data			
Meter K Factor	(NA)	9.34	unitless
Pitot Tube Factor	(C_{ps})	0.84	unitless
Stack Static Pressure	(P_{static})	-0.90	in H2O
Dry Gas Fraction	(NA)	0.860	unitless
Stack Gas Wet MW	(Ms)	27.95	lb/lb-mole
Actual Nozzle Area	(NA)	8.73E-04	ft²
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	358.3	525.2
Impinger 2	Empty	613.4	616.2
Impinger 3	DI H2O	739.6	743.5
Impinger 4	Silica Gel	914.3	933.7
Total Weights		**2625.6**	**2818.6**
Filter ID:	51329		

Post Sampling Moisture and MW Determination			
O_2 Concentration	(%O_2)	6.23	%
CO_2 Concentration	(%CO_2)	8.82	%
Sample Volume Metered	(V_m)	77.21	dcf
Standard Volume at STP	(V_{std})	73.53	dscf
Moisture Content	(B_{ws})	11.013	%
Final Dry Gas Fraction	(B_{ws})	0.890	unitless
Stack Gas Wet MW	(Ms)	28.38	lb/lb-mole
Stack Gas Velocity	(v_s)	41.03	ft/sec
Stack Gas Vol. Flow Rate	(Qd)	**1.45E+06**	dscfh
Final Isokinetic Calc.	(%iso)	**91.8**	%
Post -Test Meter Cal (M.5 §16.3)	(Y_{qa})	0.994	

	Start 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 →	10:28:00	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)	(inHg)	in H2O	in H2O	ft³	869.666	unitless	unitless
Point 1	10:31:45	630	250	239	70	64	73	4	0.16	**1.51**	**872.428**	872.250	**93.6**	**93.6**
Point 2	10:35:30	637	248	249	66	63	74	4	0.22	**2.08**	**875.480**	875.350	**96.0**	**94.8**
Point 3	10:39:15	644	250	236	68	63	74	5	0.19	**1.79**	**878.344**	878.200	**95.2**	**95.0**
Point 4	10:43:00	645	247	264	66	60	75	5	0.21	**1.99**	**881.351**	881.150	**93.6**	**94.6**
Point 5	10:46:45	647	245	261	67	59	75	6	0.30	**2.84**	**884.904**	885.030	**103.3**	**96.6**
Point 6	10:50:30	648	246	231	68	64	76	6	0.35	**3.32**	**889.086**	888.750	**91.7**	**95.6**
Point 7	10:54:15	649	248	233	68	65	76	7	0.38	**3.60**	**892.971**	892.650	**92.4**	**95.0**
Point 8	10:58:00	646	248	234	67	66	76	8	0.33	**3.13**	**896.594**	896.510	**97.9**	**95.4**
Point 9	11:01:45	645	247	236	66	62	76	8	0.27	**2.56**	**900.084**	899.840	**93.2**	**95.2**
Point 10	11:05:30	641	244	234	70	57	76	6	0.28	**2.65**	**903.485**	903.350	**96.3**	**95.3**
Point 11	11:09:15	636	244	234	70	55	77	6	0.25	**2.37**	**906.811**	906.650	**95.3**	**95.3**
Point 12	11:13:00	633	245	234	70	53	78	5	0.22	**2.09**	**909.910**	909.771	**95.7**	**95.3**
Port 2 Start →	11:24:00													
Point 13	11:27:45	624	247	233	67	53	76	5	0.27	**2.56**	**913.380**	913.080	**91.7**	**95.0**
Point 14	11:31:30	638	245	247	67	47	77	4	0.18	**1.71**	**916.019**	915.750	**90.8**	**94.8**
Point 15	11:35:15	643	244	247	67	49	77	4	0.20	**1.90**	**918.840**	918.660	**94.2**	**94.7**
Point 16	11:39:00	647	245	249	66	51	77	5	0.24	**2.28**	**922.035**	921.720	**90.7**	**94.5**
Point 17	11:42:45	647	246	248	65	51	77	6	0.27	**2.56**	**925.298**	925.050	**93.1**	**94.4**
Point 18	11:46:30	651	249	251	65	53	78	8	0.33	**3.14**	**929.000**	928.700	**92.4**	**94.3**
Point 19	11:50:15	649	248	256	68	55	78	8	0.33	**3.14**	**932.653**	932.440	**94.6**	**94.3**
Point 20	11:54:00	646	246	254	69	56	78	7	0.29	**2.76**	**936.154**	935.940	**94.2**	**94.3**
Point 21	11:57:45	644	246	255	69	57	78	5	0.21	**2.00**	**939.110**	938.970	**95.6**	**94.3**
Point 22	12:01:30	639	245	256	69	58	79	5	0.20	**1.91**	**942.077**	941.860	**93.0**	**94.3**
Point 23	12:05:15	614	246	253	68	58	79	4	0.15	**1.43**	**944.585**	944.435	**94.5**	**94.3**
Point 24	12:09:00	626	243	252	68	57	79	4	0.14	**1.33**	**947.054**	946.872	**93.1**	**94.2**
Average Values		**640.4**	**246.3**	**245.3**	**67.7**	**57.3**	**76.6**	**5.6**	**0.25**	**2.36**		**77.206**		**94.2**

Erthwrks Isokenetic Sampling Field Data and Calculation Worksheet

Client:	Marathon Petroleum Company	**Run ID:**	2	**Meterbox ID:**	M5-2
Facility:	Detroit Refinery	**Date:**	6/7/22	**DGM Y Factor:**	0.989
Location:	Detroit, MI	**Amb Temp:**	75	**DGM ΔH @:**	1.816
Unit ID:	CRR Inter Heater	**Baro. Press:**	29.11		

Pre and Post DGM Leak Checks				
Pre	0.002	ft3/min @	15	inHg
Post	0.001	ft3/min @	19	inHg
Pitot Not Damaged & Leak Checks Good?				
Pre	Yes	Post	Yes	

Isokinetic Sampling Data			
Meter K Factor	(NA)	9.34	unitless
Pitot Tube Factor	(C_{ps})	0.84	unitless
Stack Static Pressure	(P_{static})	-0.90	in H2O
Dry Gas Fraction	(NA)	0.860	unitless
Stack Gas Wet MW	(Ms)	27.95	lb/lb-mole
Actual Nozzle Area	(NA)	8.73E-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	365.4	589.6
Impinger 2	Empty	713.2	613.8
Impinger 3	DI H2O	729.0	755.5
Impinger 4	Silica Gel	833.5	859.7
	Total Weights	2641.1	2818.6
	Filter ID:	51324	

Post Sampling Moisture and MW Determination			
O_2 Concentration	($\%O_2$)	6.26	%
CO_2 Concentration	($\%CO_2$)	8.75	%
Sample Volume Metered	(V_m)	79.68	dcf
Standard Volume at STP	(V_{std})	75.96	dscf
Moisture Content	(B_{ws})	9.924	%
Final Dry Gas Fraction	(B_{ws})	0.901	unitless
Stack Gas Wet MW	(Ms)	28.49	lb/lb-mole
Stack Gas Velocity	(v_s)	41.65	ft/sec
Stack Gas Vol. Flow Rate	(Qd)	1.49E+06	dscfh
Final Isokinetic Calc.	(%iso)	92.6	%
Post -Test Meter Cal (M.5 §16.3)	(Y_{qa})	0.976	

	Start 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 →	13:00:00	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)	(inHg)	in H2O	in H2O	ft^3	947.442	unitless	unitless
Point 1	13:03:45	633	252	247	75	55	73	5	0.15	1.41	950.113	950.050	97.6	97.6
Point 2	13:07:30	639	247	259	71	52	73	5	0.18	1.70	952.966	952.760	92.9	95.2
Point 3	13:11:15	642	246	262	70	52	74	6	0.19	1.79	955.757	955.460	90.1	93.4
Point 4	13:15:00	649	244	273	71	55	75	7	0.23	2.18	958.750	958.540	93.6	93.4
Point 5	13:18:45	649	240	270	70	55	75	7	0.24	2.27	961.900	961.750	95.5	93.9
Point 6	13:22:30	649	250	267	70	58	75	10	0.31	2.93	965.562	965.330	93.9	93.9
Point 7	13:26:15	653	249	258	71	58	76	10	0.33	3.13	969.262	969.070	95.1	94.1
Point 8	13:30:00	646	247	250	72	60	76	9	0.27	2.56	972.643	972.540	97.1	94.5
Point 9	13:33:45	642	246	248	71	60	76	9	0.24	2.28	975.917	975.940	100.7	95.2
Point 10	13:37:30	647	246	247	73	60	76	7	0.23	2.18	979.239	979.080	95.2	95.2
Point 11	13:41:15	639	247	255	73	60	76	7	0.17	1.61	981.931	981.820	96.1	95.2
Point 12	13:45:00	634	245	255	74	59	76	6	0.16	1.52	984.592	984.460	95.2	95.2
Port 2 Start →	13:50:00													
Point 13	13:53:45	631	248	255	72	61	75	6	0.19	1.80	987.478	987.370	96.4	95.3
Point 14	13:57:30	642	245	255	71	61	76	7	0.22	2.09	990.605	990.430	94.6	95.3
Point 15	14:01:15	644	245	251	71	61	76	9	0.26	2.46	993.940	993.800	96.0	95.3
Point 16	14:05:00	646	247	257	71	64	76	9	0.28	2.65	997.437	997.240	94.6	95.3
Point 17	14:08:45	647	247	257	70	63	77	9	0.28	2.66	1000.882	1000.730	95.8	95.3
Point 18	14:12:30	651	248	252	72	60	77	10	0.31	2.94	1004.553	1004.470	97.8	95.5
Point 19	14:16:15	651	246	249	72	60	78	10	0.35	3.33	1008.536	1008.350	95.4	95.4
Point 20	14:20:00	652	242	247	73	61	78	11	0.36	3.43	1012.470	1012.400	98.3	95.6
Point 21	14:23:45	648	243	244	74	62	78	11	0.34	3.23	1016.413	1016.300	97.2	95.7
Point 22	14:27:30	646	246	241	73	63	78	10	0.31	2.95	1020.139	1020.020	96.9	95.8
Point 23	14:31:15	643	247	240	73	63	79	9	0.28	2.67	1023.682	1023.570	96.9	95.8
Point 24	14:35:00	640	248	234	72	63	79	9	0.26	2.48	1027.106	1027.121	100.4	96.0
Average Values		644.3	246.3	253.0	71.9	59.4	76.2	8.3	0.26	2.43		79.679		96.0

Erthwrks Isokenetic Sampling Field Data and Calculation Worksheet

Client:	Marathon Petroleum Company	**Run ID:**	3	**Meterbox ID:**	M5-2
Facility:	Detroit Refinery	**Date:**	6/7/22	**DGM Y Factor:**	0.989
Location:	Detroit, MI	**Amb Temp:**	75	**DGM ΔH @:**	1.816
Unit ID:	CRR Inter Heater	**Baro. Press:**	29.11		

Pre and Post DGM Leak Checks				
Pre	0.00	**ft3/min @**	17	**inHg**
Post	0.05	**ft3/min @**	12	**inHg**
Pitot Not Damaged & Leak Checks Good?				
Pre	Yes	**Post**	Yes	

Isokinetic Sampling Data			
Meter K Factor	(NA)	9.34	unitless
Pitot Tube Factor	(C_{ps})	0.84	unitless
Stack Static Pressure	(P_{static})	-0.90	in H2O
Dry Gas Fraction	(NA)	0.860	unitless
Stack Gas Wet MW	(Ms)	27.95	lb/lb-mole
Actual Nozzle Area	(NA)	8.73E-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	358.8	583.5
Impinger 2	Empty	614.5	614.1
Impinger 3	DI H2O	743.1	761.6
Impinger 4	Silica Gel	933.6	960
	Total Weights	**2650.0**	**2919.2**
	Filter ID:	51330	

Post Sampling Moisture and MW Determination			
O_2 Concentration	(%O_2)	6.27	%
CO_2 Concentration	(%CO_2)	8.79	%
Sample Volume Metered	(V_m)	80.26	dcf
Standard Volume at STP	(V_{std})	76.15	dscf
Moisture Content	(B_{ws})	14.286	%
Final Dry Gas Fraction	(B_{ws})	0.857	unitless
Stack Gas Wet MW	(Ms)	27.99	lb/lb-mole
Stack Gas Velocity	(v_s)	42.00	ft/sec
Stack Gas Vol. Flow Rate	(Qd)	**1.44E+06**	**dscfh**
Final Isokinetic Calc.	(%iso)	**96.2**	**%**
Post -Test Meter Cal (M.5 §16.3)	(Y_{qa})	0.977	

	Clock 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 →	15:02:00	(°F)	(°F)	(°F)	(°F)	(°F)	(°F)	(inHg)	in H2O	in H2O	ft^3	27.527	unitless	unitless
Point 1	15:05:45	634	245	227	71	59	74	4	0.17	**1.61**	**30.373**	30.170	**92.9**	**92.9**
Point 2	15:09:30	638	251	233	69	53	75	5	0.22	**2.08**	**33.404**	33.190	**93.4**	**93.1**
Point 3	15:13:15	644	249	236	68	51	75	5	0.18	**1.70**	**36.110**	36.020	**96.9**	**94.4**
Point 4	15:17:00	645	246	255	68	53	75	6	0.28	**2.65**	**39.652**	39.400	**93.1**	**94.0**
Point 5	15:20:45	646	243	263	69	54	75	6	0.31	**2.93**	**43.217**	43.140	**98.0**	**94.9**
Point 6	15:24:30	648	248	257	69	55	76	8	0.32	**3.03**	**47.021**	46.960	**98.4**	**95.5**
Point 7	15:28:15	648	248	255	70	57	76	9	0.37	**3.51**	**51.128**	50.910	**94.8**	**95.4**
Point 8	15:32:00	648	241	251	73	59	76	8	0.34	**3.22**	**54.909**	54.750	**96.0**	**95.5**
Point 9	15:35:45	642	248	249	72	60	77	7	0.29	**2.75**	**58.464**	58.380	**97.7**	**95.7**
Point 10	15:39:30	633	246	246	71	60	78	7	0.27	**2.57**	**61.987**	62.020	**100.9**	**96.3**
Point 11	15:43:15	622	246	241	70	60	79	5	0.17	**1.62**	**64.909**	64.770	**95.2**	**96.1**
Point 12	15:47:00	613	245	239	70	58	79	5	0.17	**1.62**	**67.671**	67.705	**101.2**	**96.5**
Port 2 Start →	15:51:00													
Point 13	15:54:45	629	245	228	73	59	78	5	0.15	**1.43**	**70.406**	70.250	**94.2**	**96.3**
Point 14	15:58:30	641	243	245	72	56	79	6	0.21	**2.00**	**73.430**	73.240	**94.0**	**96.2**
Point 15	16:02:15	643	247	253	72	57	80	6	0.24	**2.29**	**76.640**	76.440	**94.1**	**96.0**
Point 16	16:06:00	646	249	261	72	58	80	7	0.30	**2.86**	**80.231**	80.000	**93.9**	**95.9**
Point 17	16:09:45	647	243	261	73	60	80	9	0.35	**3.34**	**84.088**	83.750	**91.7**	**95.6**
Point 18	16:13:30	648	245	260	72	61	82	9	0.35	**3.35**	**87.851**	87.550	**92.7**	**95.4**
Point 19	16:17:15	645	248	261	73	62	82	9	0.33	**3.16**	**91.540**	91.430	**97.3**	**95.5**
Point 20	16:21:00	642	247	265	72	63	82	8	0.31	**2.97**	**95.304**	95.150	**96.0**	**95.5**
Point 21	16:24:45	644	247	264	72	63	83	7	0.27	**2.59**	**98.772**	98.650	**96.6**	**95.6**
Point 22	16:28:30	635	246	269	73	64	83	6	0.24	**2.30**	**102.081**	101.950	**96.2**	**95.6**
Point 23	16:32:15	629	246	270	74	65	83	5	0.19	**1.82**	**105.015**	104.880	**95.6**	**95.6**
Point 24	16:36:00	617	243	261	75	66	83	5	0.16	**1.54**	**107.711**	107.784	**102.6**	**95.8**
Average Values		**638.6**	**246.0**	**252.1**	**71.4**	**58.9**	**78.8**	**6.5**	**0.26**	**2.46**		**80.257**		**95.8**

Erthwrks Method 8A (CTM-013) Sampling Worksheet

Date: 6/7/2022
Client: Marathon Petroleum
Facility: Detroit
Unit ID: CCR Inter Heater
Erthwrks Tech: MK, JW
Run No: 1

DGM Pre-Test Leak Check			DGM Post-Test Leak Check		
Vac ("H_2O)	cubic feet	Time (s)	Vac ("H2O)	cubic feet	Time (s)
14	0.00	60	12	0.000	60

Start Time:	16:53
Meter Box ID:	M5-2
DGM y-fact:	0.9890
Atm Press ("Hg)	29.227

Sampling Point	Sample Time (min:sec)	ΔH	DGM Reading (ft^3)	ΔV_m (ft^3)	DGM Temp (°F)	Probe Temp (°F)	Filter Temp (°F)	H2SO4 Temp (°F)	Imp Exit Temp (°F)	DGM Vac (inHg)
Start: 16:53	16:53		112.670	<--- Starting Reading		(>350 °F)	(>500 °F)	(167-185 °F)	(<68 °F)	
1	16:58:00	0.42	114.481	1.811	74	360	515	182	64	2
2	17:03:00	0.42	116.281	1.800	75	361	516	183	65	2
3	17:08:00	0.42	118.071	1.790	75	362	516	175	62	2
4	17:13:00	0.42	119.925	1.854	75	366	518	175	62	2
5	17:18:00	0.42	121.658	1.733	76	366	516	176	63	2
6	17:23:00	0.42	123.450	1.792	78	365	518	176	63	2
Totals		**0.4**	**10.780**		**75.5**	**363.3**	**516.5**	**177.8**	**63.2**	**2.0**

Sample Gas Volume, $V_{m(std)}$

$V_{m(std)}$ = 10.26

Erthwrks Method 8A (CTM-013) Sampling Worksheet

Date: 6/7/2022
Client: Marathon Petroleum
Facility: Detroit
Unit ID: CCR Inter Heater
Erthwrks Tech: MK, JW
Run No: 2

DGM Pre-Test Leak Check			DGM Post-Test Leak Check		
Vac ("H_2O)	cubic feet	Time (s)	Vac ("H2O)	cubic feet	Time (s)
8	0.00	60	9	0.000	60

Start Time:	17:44
Meter Box ID:	M5-2
DGM y-fact:	0.9890
Atm Press ("Hg)	29.227

Sampling Point	Sample Time (min:sec)	ΔH	DGM Reading (ft^3)	ΔV_m (ft^3)	DGM Temp (°F)	Probe Temp (°F)	Filter Temp (°F)	H2SO4 Temp (°F)	Imp Exit Temp (°F)	DGM Vac (inHg)
Start: 17:44	17:44		125.400	<--- Starting Reading		(>350 °F)	(>500 °F)	(167-185 °F)	(<68 °F)	
1	17:49:00	0.42	127.140	1.740	78	357	511	168	63	2
2	17:54:00	0.42	128.937	1.797	78	363	519	175	58	2
3	17:59:00	0.42	130.691	1.754	79	366	520	175	58	2
4	18:04:00	0.42	132.469	1.778	78	366	519	175	57	2
5	18:09:00	0.43	134.221	1.752	78	367	520	175	58	2
6	18:14:00	0.43	136.007	1.786	78	366	524	178	60	2
Totals		**0.4**	**10.607**		**78.2**	**364.2**	**518.8**	**174.3**	**59.0**	**2.0**

Sample Gas Volume, $V_{m(std)}$

$V_{m(std)}$ = 10.05

Erthwrks Method 8A (CTM-013) Sampling Worksheet

Date: 6/7/2022
Client: Marathon Petroleum
Facility: Detroit
Unit ID: CCR Inter Heater
Erthwrks Tech: MK, JW
Run No: 3

DGM Pre-Test Leak Check			DGM Post-Test Leak Check		
Vac ("H_2O)	cubic feet	Time (s)	Vac ("H2O)	cubic feet	Time (s)
8	0.00	60	10	0.000	60

Start Time:	18:36
Meter Box ID:	M5-2
DGM y-fact:	0.9890
Atm Press ("Hg)	29.227

Sampling Point	Sample Time (min:sec)	ΔH	DGM Reading (ft³)	ΔV_m (ft³)	DGM Temp (°F)	Probe Temp (°F)	Filter Temp (°F)	H2SO4 Temp (°F)	Imp Exit Temp (°F)	DGM Vac (inHg)
Start: 18:36	18:36		137.928	<--- Starting Reading		(>350 °F)	(>500 °F)	(167-185 °F)	(<68 °F)	
1	18:41:00	0.40	139.780	1.852	74	366	518	177	64	2
2	18:46:00	0.40	141.590	1.810	75	365	519	175	64	2
3	18:51:00	0.40	143.358	1.768	75	366	520	176	65	2
4	18:56:00	0.40	145.120	1.762	76	366	519	177	65	2
5	19:01:00	0.40	146.870	1.750	76	367	521	178	66	2
6	19:06:00	0.40	148.638	1.768	76	366	517	178	66	2
Totals		**0.4**	**10.710**		**75.3**	**366.0**	**519.0**	**176.8**	**65.0**	**2.0**

Sample Gas Volume, $V_{m(std)}$

$V_{m(std)}$ = 10.20

Attachment D
Example Calculations

Erthwrks QAQC Example Calculations

Example Calculations for System QA : Run 1, CCR InterHtr
Example Calculations for Pollutant : NOx

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 = 0.02%

C_{Dir} = 24.78 ppmv
C_V = 24.77 ppmv
CS= 53.76 ppmv

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

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

SB_i = -0.07%

CS= 53.76 ppmv
C_S = 24.74 ppmv
C_{Dir} = 24.78 ppmv

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

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

D = 0.00%

SBi = -0.03%
SB_f = -0.03%

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

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

C_{Gas} = 21.80

C_{Avg}= 21.79 ppmv
C_o = -0.05 ppmv
C_{MA} = 24.77 ppmv
C_M = 24.76 ppmv

NO_2 - NO Conversion Efficiency, Eff_{NO2} — Eq. 7E-7

$$Eff_{NO_2} = \frac{C_{Dir}}{C_V} x100$$

Eff_{NO2} = 95.3%

C_{Dir} = 57.68 ppmv
C_V = 60.52 ppmv

Erthwrks Emission Rate Example Calculations

Example Calculations for Emissions : Run 1, CCR InterHtr

Example Calculations for Pollutant : NOx

Variable:	Description:
$\%O_2d$	Oxygen concentration measured on a dry basis, %
F_d	Fuel F Factor for Natural Gas--Method 19 value, scf/MMBtu
MGV	Molar gas volume, volume of gas at standard conditions, scf/lbmol
MW_{NOx}	Molecular Weight of NOx, lb/lbmol
n	Moles, lbmol
PPM_{NOx}	Parts per million, NOx
p_s	Standard Pressure, psi
R	Universal gas constant, ft^3 psi / R lbmol
T_s	Standard Temperature, R
V	Volume, ft^3

Molar Gas Volume (MGV) calculation at standard conditions — Ideal Gas Law

$$MGV = \frac{V}{n} = \frac{R * T_S}{p}$$

T_s = 527.67 R
p = 14.696 psi
R = 10.7316 (ft^3*psi/(R* lbmoll)

MGV= 385.325 $\frac{scf}{lbmol}$

Emission Concentration, C_d

$$C_d = \frac{PPM * MW}{MGV} / 10^6$$

PPM - NOx = 21.80 parts per million
MW - NOx = 46.0055 lb/lb-mol

C_d= 2.60E-06 $\frac{lb}{scf}$

Emission Rate Calculation, $E_{(lb/MMBtu)}$ — Eq. 19-1

$$E_{(lb/MMBtu)} = C_d * F_d \frac{20.9}{20.9 - \%O_2d}$$

F_d= 8595 scf/MMBtu
$\%O_2d$= 6.21 %

$E_{(lb/MMBtu)}$= 0.0318 $\frac{lb}{MMBtu}$

Erthwrks RATA Example Calculations

Example Calculations for Relative Accuracy: CCR InterHtr

Example Calculations for Pollutant : NOx - lb/MMBtu

Variable:	Description:
d	Absolute difference between reference method and client CEMS
i	Run number
n	Number of runs
d_{avg}	Mean of the difference between reference method and client CEMS
RM_{avg}	Average of the reference method results for each run
AS	The unit's permit limit or applicable standard

Arithmetic Mean, d_{avg} Eq. 2-3

$$d_{avg} = \frac{1}{n}\sum_{i=1}^{n} d_i$$

d_1 =	-0.0011	d_4 =	-0.0008	d_7 =	0	d_{10} =	-0.0010
d_2 =	-0.0008	d_5 =	0	d_8 =	-0.0011	d_{11} =	-0.0012
d_3 =	-0.0012	d_6 =	-0.0015	d_9 =	-0.0012	d_{12} =	0
					n=	9	

d_{avg} = -0.0011

Standard Deviation, S_d Eq. 2-4

$$S_d = \sqrt{\frac{\sum_{i=1}^{n} d_i^{\,2} - \frac{\left[\sum_{i=1}^{n} di\right]^2}{n}}{n-1}}$$

S_d = 0.0002

Confidence Coefficient, CC Eq. 2-5

$$CC = t_{0.975}\,\frac{S_d}{n^{1/2}}$$

$t_{0.975}$ = 2.306

CC = 0.0002

Relative Accuracy, RA_{RM} Eq. 2-6

$$RA_{RM} = \frac{|d_{avg}| + |CC|}{RM_{avg}} \times 100$$

RM_1 =	0.0318	RM_4 =	0.0322	RM_7 =	0	RM_{10} =	0.0338
RM_2 =	0.0323	RM_5 =	0	RM_8 =	0.0322	RM_{11} =	0.0337
RM_3 =	0.0317	RM_6 =	0.0318	RM_9 =	0.0330	RM_{12} =	0
RM_{avg} =	0.0325						

RA_{RM} = 3.88%

Example Calcs for Run : CRR Inter Heater Run 1

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-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 = 29.66 lb/lb-mol

$\%O_2$ = 6.23
$\%CO_2$ = 8.82
$\%N_2$ = 84.95
%CO = 0.00

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

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

$V_{wc(std)}$ = 9.10 ft^3

K_3 = 0.04715 (ft^3/g)
W_i = 2625.60 (g)
W_f = 2818.60 (g)

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

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

$V_{m(std)}$ = 73.53 ft^3

T_{std} = 528 (°R)
P_{std} = 29.920 (inHg)
V_m = 77.21 (ft^3)
P_m = 29.28 (in H_2O)
T_m = 536.625 (°R)
Y= 0.989 (unitless)

Moisture Content, B_{ws} — Eq. 4-4

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

B_{ws} = 11.01%

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

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

M_S = 28.38

M_w = 18.00 (lb/lb-mole)

Example Calcs for Run : CRR Inter Heater Run 1

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 = 29.04 in H_2O
$T_{s(abs)}$ = 1100.375 °R
$(\Delta p_{avg})^{1/2}$ = 0.4944
M_s = 28.38 lb/lb-mole

V_S = 2461.57 ft/min

V_S = 41.026148 ft/sec

Average Stack Gas Flow, Q_a

$$Q_a = V_s * A$$

A = 23.76 ft^2
V_s = 2461.57 ft/min

Q_a = 5.85E+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 = 29.04 in Hg
P_{std} = 29.92 in Hg
$T_{s(abs)}$ = 1100.4 °R
T_{std} = 528 °R

Q_a = 1.63E+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 = 1.45E+06 dscfh

C_f =	3600	sec/hr
A=	23.76	ft^2
B_{ws} =	0.890	unitless
P_s =	29.04	in Hg
P_{std} =	29.92	in Hg
$T_{s(abs)}$=	1100.4	°R
T_{std} =	528	°R
V_s =	41.03	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 = 91.760936 %

T_s =	1100.375	°R
$V_{m(std)}$ =	73.53	dscf
P_s =	29.04	in Hg
v_s =	41.03	ft/sec
A_n =	8.73E-04	ft^2
θ =	90	min
B_{ws} =	0.890	unitless

Post-Test Metering Calibration — Eq. 5-15

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

$Y_{run\ 1}$ =	0.9935342
$Y_{run\ 2}$ =	0.9759803
$Y_{run\ 3}$ =	0.9770747
$Y_{qa\ (avg)}$ =	0.9821964

Run 1:	ΔH@ =	1.816	unitless
	T_m =	536.625	°R
	P_{bar} =	29.11	in H_2O
	V_m =	77.21	dcf
	ΔH_{avg} =	2.36	in H_2O
Run 2:	ΔH@ =	1.816	unitless
	T_m =	536.1667	°R
	P_{bar} =	29.11	in H_2O
	V_m =	79.68	dfc
	ΔH_{avg} =	2.43	in H_2O
Run 3:	ΔH@ =	1.816	unitless
	T_m =	538.75	°R
	P_{bar} =	29.11	in H_2O
	V_m =	80.26	dcf
	ΔH_{avg} =	2.46	in H_2O

Example Calcs for Run : CRR Inter Heater Run 1

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

Particulate Matter Mass Concentration, C_m

m_t = 6.10 (mg)
V_{std} = 73.53 (dscf)

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

C_m = 1.83E-07 lb/dscf

Particulate Matter Mass Emission Rate per Hour, E_d

Q_{sd} = 1.45E+06 (dscfh)

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

E_h = 0.27 lb/hr

Particulate Matter Mass Emission Rate per Day, E_d

$$E_d = E_h * 24$$

E_d = 6.38 lb/day

Particulate Matter Mass Emission Rate per Ton Clinker, E_{TC}

Firing Rate = 94.55 (MMbtu/hr)

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

E_{TC} = 0.00 lb/MMbtu

Erthwrks Emission Rate Example Calculations

Example Calculations for Emissions : Run 1, CCR Inter Heater

Example Calculations for Pollutant : H_2SO_4

Variable:	Description:
$\%O_2d$	Oxygen concentration measured on a dry basis, %
F_d	Fuel F Factor for Natural Gas--Method 19 value, scf/MMBtu
MGV	Molar gas volume, volume of gas at standard conditions, scf/lbmol
MW	Molecular Weight, lb/lbmol
n	Moles, lbmol
PPM	Parts per million
m_t	Weight of H_2SO_4, from lab analysis
p_s	Standard Pressure, psi
R	Universal gas constant, ft^3 psi / R lbmol
T_s	Standard Temperature, R
V	Volume, ft^3

Molar Gas Volume (MGV) calculation at standard conditions — Ideal Gas Law

$$MGV = \frac{V}{n} = \frac{R * T_S}{p}$$

T_s = 527.67 R
p = 14.696 psi
R = 10.7316 (ft^3 *psi/(R* lbmol))

MGV= 385.325 $\frac{scf}{lbmol}$

Emission Concentration, $C_{d-(lb/scf)}$

$$C_{d-lb/scf} = \frac{mt(lb)}{\text{Train Volume}}$$

Train Volume = 10.26 scf
$m_{t-(}ug)$ = 82.9 ug
m_t-(lb) 1.83E-07 lb

C_d(lb/scf)= 1.781E-08 $\frac{lb}{scf}$

Emission Concentration, $C_{d-(ppm)}$

$$C_d = \frac{Cd\left(\frac{lb}{scf}\right) * 10^6 * MGV}{MW}$$

Cd-(lb/scf) 1.78E-08 lb/scf
MGV = 385.325 scf/lbmol
MW = 98.079 lb/lb-mol

C_d= 0.07 ppm

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AIR EMISSIONS TESTING FOR INDUSTRY

Attachment E
Raw Data Log Records

Erthwrks Datalog Records

TimeStamp	Project Number	Client	Facility	Unit	Test Period	NO_X	CO	O_2	CO_2
6/7/22 6:51	9049.1.B4	MPC	Detroit	CCR InterHtr		0.02	-0.07	0.00	0.00
6/7/22 6:52	9049.1.B4	MPC	Detroit	CCR InterHtr		0.03	-0.33	10.16	3.36
6/7/22 6:53	9049.1.B4	MPC	Detroit	CCR InterHtr		0.08	-1.60	19.87	8.82
6/7/22 6:54	9049.1.B4	MPC	Detroit	CCR InterHtr		0.06	-1.67	19.87	17.02
6/7/22 6:54	9049.1.B4	MPC	Detroit	CCR InterHtr		0.03	-0.06	19.87	19.72
6/7/22 6:55	9049.1.B4	MPC	Detroit	CCR InterHtr	Direct Cal	0.03	-0.09	19.86	19.77
6/7/22 6:56	9049.1.B4	MPC	Detroit	CCR InterHtr		3.65	9.88	12.38	12.38
6/7/22 6:57	9049.1.B4	MPC	Detroit	CCR InterHtr		46.44	50.75	0.02	0.10
6/7/22 6:58	9049.1.B4	MPC	Detroit	CCR InterHtr		55.26	53.19	0.00	0.00
6/7/22 6:59	9049.1.B4	MPC	Detroit	CCR InterHtr		54.62	52.40	0.01	0.00
6/7/22 7:00	9049.1.B4	MPC	Detroit	CCR InterHtr	Direct Cal	53.43	50.98	0.01	0.00
6/7/22 7:01	9049.1.B4	MPC	Detroit	CCR InterHtr		45.66	48.90	8.88	0.07
6/7/22 7:02	9049.1.B4	MPC	Detroit	CCR InterHtr		19.56	17.92	6.93	6.91
6/7/22 7:03	9049.1.B4	MPC	Detroit	CCR InterHtr		19.47	0.64	6.12	8.33
6/7/22 7:04	9049.1.B4	MPC	Detroit	CCR InterHtr		19.53	-0.20	6.07	8.36
6/7/22 7:05	9049.1.B4	MPC	Detroit	CCR InterHtr		19.68	-0.31	6.07	8.39
6/7/22 7:06	9049.1.B4	MPC	Detroit	CCR InterHtr		19.90	-0.30	6.07	8.38
6/7/22 7:07	9049.1.B4	MPC	Detroit	CCR InterHtr		20.03	-0.25	6.05	8.38
6/7/22 7:08	9049.1.B4	MPC	Detroit	CCR InterHtr		19.95	-0.32	6.04	8.38
6/7/22 7:09	9049.1.B4	MPC	Detroit	CCR InterHtr		19.84	-0.37	6.04	8.41
6/7/22 7:10	9049.1.B4	MPC	Detroit	CCR InterHtr		20.00	-0.45	6.04	8.42
6/7/22 7:11	9049.1.B4	MPC	Detroit	CCR InterHtr		20.21	-0.50	6.00	8.47
6/7/22 7:12	9049.1.B4	MPC	Detroit	CCR InterHtr		20.32	-0.52	6.02	8.49
6/7/22 7:13	9049.1.B4	MPC	Detroit	CCR InterHtr		20.30	-0.52	6.00	8.48
6/7/22 7:14	9049.1.B4	MPC	Detroit	CCR InterHtr		14.96	-0.29	9.95	8.17
6/7/22 7:15	9049.1.B4	MPC	Detroit	CCR InterHtr		1.50	-0.16	18.39	2.09
6/7/22 7:16	9049.1.B4	MPC	Detroit	CCR InterHtr		1.09	-0.43	10.27	8.40
6/7/22 7:17	9049.1.B4	MPC	Detroit	CCR InterHtr		0.62	-0.61	9.92	9.73
6/7/22 7:18	9049.1.B4	MPC	Detroit	CCR InterHtr		0.23	-0.38	9.94	9.75
6/7/22 7:18	9049.1.B4	MPC	Detroit	CCR InterHtr		0.20	-0.27	10.00	9.75
6/7/22 7:19	9049.1.B4	MPC	Detroit	CCR InterHtr	Direct Cal	0.18	-0.28	10.00	10.10
6/7/22 7:20	9049.1.B4	MPC	Detroit	CCR InterHtr		8.45	7.57	2.40	3.25
6/7/22 7:21	9049.1.B4	MPC	Detroit	CCR InterHtr		24.66	24.25	0.03	0.00
6/7/22 7:22	9049.1.B4	MPC	Detroit	CCR InterHtr	Direct Cal	24.78	25.33	0.02	0.00
6/7/22 7:23	9049.1.B4	MPC	Detroit	CCR InterHtr		22.44	20.33	8.88	0.00
6/7/22 7:24	9049.1.B4	MPC	Detroit	CCR InterHtr		3.48	2.42	21.03	0.00
6/7/22 7:25	9049.1.B4	MPC	Detroit	CCR InterHtr		49.35	0.20	21.05	0.00
6/7/22 7:26	9049.1.B4	MPC	Detroit	CCR InterHtr	NOx Conv Eff.	57.68	0.18	21.04	0.00
6/7/22 7:27	9049.1.B4	MPC	Detroit	CCR InterHtr		55.07	0.87	14.89	2.39
6/7/22 7:28	9049.1.B4	MPC	Detroit	CCR InterHtr		25.86	3.30	6.07	8.54
6/7/22 7:29	9049.1.B4	MPC	Detroit	CCR InterHtr		20.34	-0.80	6.01	8.81
6/7/22 7:30	9049.1.B4	MPC	Detroit	CCR InterHtr		18.92	0.29	8.74	8.08
6/7/22 7:31	9049.1.B4	MPC	Detroit	CCR InterHtr		1.95	2.75	9.87	9.64
6/7/22 7:31	9049.1.B4	MPC	Detroit	CCR InterHtr		0.51	-0.85	9.87	9.95
6/7/22 7:32	9049.1.B4	MPC	Detroit	CCR InterHtr	Sys Bias	0.11	-0.10	9.97	9.96
6/7/22 7:33	9049.1.B4	MPC	Detroit	CCR InterHtr		-0.07	-0.08	9.97	10.10
6/7/22 7:34	9049.1.B4	MPC	Detroit	CCR InterHtr		4.17	3.54	4.10	5.62
6/7/22 7:35	9049.1.B4	MPC	Detroit	CCR InterHtr		23.70	22.18	0.14	0.12
6/7/22 7:36	9049.1.B4	MPC	Detroit	CCR InterHtr		23.86	24.64	0.11	0.02
6/7/22 7:37	9049.1.B4	MPC	Detroit	CCR InterHtr	Sys Bias	24.74	25.42	0.10	0.00
6/7/22 7:38	9049.1.B4	MPC	Detroit	CCR InterHtr		24.87	25.20	1.00	0.59
6/7/22 7:39	9049.1.B4	MPC	Detroit	CCR InterHtr		24.35	9.62	6.08	8.20
6/7/22 7:40	9049.1.B4	MPC	Detroit	CCR InterHtr		22.84	0.16	6.16	8.85