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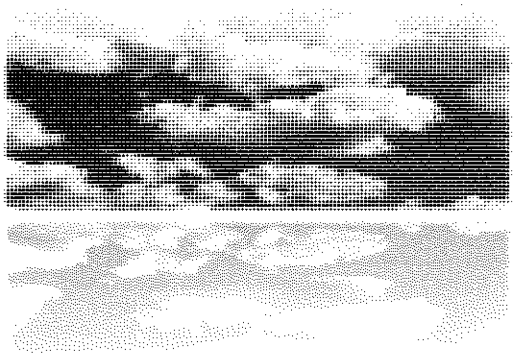

REPORT ON MEASUREMENT SERVICES

Detroit Hydrogen Plant

Hydrogen Plant Heater Stack

Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195
Client Reference No. 4504285902

CleanAir Project No. 13466
A2LA ISO 17025 Certificate No. 4342.01
A2LA / STAC Certificate No. 4342.02
Revision 0, Final Report
April 5, 2018

1. *PROJECT OVERVIEW*

Test Program Summary

Air Products and Chemicals, Inc. (Air Products) contracted CleanAir Engineering (CleanAir) to successfully complete emissions compliance measurements at the Detroit Hydrogen Plant. The testing was performed at the Hydrogen (H_2) Plant Heater Stack. The test program included the following objectives:

- To perform a relative accuracy test audit (RATA) on the continuous emission monitoring system (CEMS);
- To determine compliance for particulate matter (PM) and PM_{10};
- To determine emissions of sulfuric acid mist (H_2SO_4);
- To determine compliance for volatile organic compounds (VOCs).

A summary of the test program results is presented below. Section 2 Results provides a more detailed account of the test conditions and data analysis. Test program information, including the test parameters, on-site schedule and a project discussion, begins on page 2.

Table 1-1:
Summary of Emissions Compliance Test Results

Source **Constituent**	**(Units)**	**Sampling Method**	**Average Emission**	**Permit Limit**[1]
H_2 Plant Heater Stack				
PM	(lb/MMBtu)	USEPA M-5	0.00054	0.0034
PM	(Ton/yr)	USEPA M-5	1.38	6.86
PM_{10}	(lb/MMBtu)	USEPA M-5 / 202	0.0021	0.010
H_2SO_4	(lb/MMBtu)	Draft ASTM CCM	0.00014	N/A
VOC	(lb/MMBtu)	USEPA M-25A/18	<0.00067	0.0055
NO_X	(lb/MMBtu)	USEPA M-7E	0.0067	0.013
NO_X	(ppmdv @ 0% O_2)	USEPA M-7E	6.2	60
CO	(Ton/yr)	USEPA M-10	< 0.89	13

[1] Permit limits obtained from MDEQ Permit to Install No. 63-08D.

Table 1-2:
Summary of RATA Results

Source Constituent (Units)	Reference Method (USEPA)	Relative Accuracy[1]	Units	Applicable Specification	Specification Limit[2]
H_2 Plant Heater Stack					
Flow rate (dscfh)	M-2	8.8	% of RM	PS6	20% of RM
O_2 (% dv)	M-3A	0.03	%dv	PS3	± 1.0% dv
H_2O (% wv)	M-4	1.1	% of RM	N/A	N/A
NOx (ppmdv)	M-7E	2.0	% of RM	PS2	20% of RM
NOx (lb/MMBtu)	M-7E	5.3	% of RM	PS2	20% of RM
NOx (ppmdv @ 0%O2)	M-7E	1.4	% of RM	PS2	20% of RM
CO (ppmdv)	M-10	0.5	ppmdv	PS4A[3]	± 5 ppmdv
CO (lb/hr)	M-10	0.4	% of Std.	PS4A[3]	5% of Standard[4]

[1] Relative Accuracy is expressed in terms of comparison to the reference method (% RM) or applicable emission standard (% Std.), equivalent to the permit limit in Table 1-2. The specific expression used depends on the specification limit.

[2] Specification limits obtained from 40 CFR 60, Appendix B, Performance Specifications, unless otherwise noted.

[3] For any sources emitting less than 200 ppmv of CO, PS4A applies. The PS4A RA limit is either < 10% of RM, <5% of Standard, or ± 5 ppmv (abs. average difference plus 2.5 x confidence coefficient).

[4] CO Standard = 13 Ton/yr = 56.9 lb/hr (assuming 8,760 operating hours/year)

Test Program Details

Parameters

The test program included the following measurements:

- PM, assumed equivalent to filterable particulate matter (FPM)
- condensable particulate matter (CPM)
- particulate matter less than 10 microns in diameter (PM_{10}), assumed to be the sum of:
  - FPM
  - CPM
- H_2SO_4
- VOCs, assumed equivalent to total hydrocarbons (THCs) minus:
  - methane (CH_4)
  - ethane (C_2H_6)
- nitrogen oxide (NO_X)
- carbon monoxide (CO)
- flue gas composition (e.g., O_2, CO_2, H_2O)
- flue gas temperature
- flue gas flow rate

Schedule

Testing was performed on March 6 and 7, 2018. The on-site schedule followed during the test program is outlined in Table 1-3.

Table 1-3:
Test Schedule

Run Number	Location	Method	Analyte	Date	Start Time	End Time
1	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	VOC	03/06/18	11:46	12:46
1	Hydrogen Heater Stack	USEPA Method 5/202	FPM/CPM	03/06/18	11:46	13:59
2	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	VOC	03/06/18	12:53	13:53
2	Hydrogen Heater Stack	USEPA Method 5/202	FPM/CPM	03/06/18	14:39	16:49
3	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	VOC	03/06/18	15:11	16:12
3	Hydrogen Heater Stack	USEPA Method 5/202	FPM/CPM	03/06/18	17:36	19:48
4	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	VOC	03/06/18	17:41	18:41
0	Hydrogen Heater Stack	Draft ASTM CCM	H_2SO_4	03/07/18	10:52	11:52
1	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	$O_2/NO_X/CO$	03/07/18	12:27	12:48
1	Hydrogen Heater Stack	Draft ASTM CCM	H_2SO_4	03/07/18	12:27	13:27
1	Hydrogen Heater Stack	USEPA Method 2	Velocity & Flow Rate	03/07/18	12:29	12:36
2	Hydrogen Heater Stack	USEPA Method 2	Velocity & Flow Rate	03/07/18	12:59	13:06
2	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	$O_2/NO_X/CO$	03/07/18	13:09	13:30
2	Hydrogen Heater Stack	Draft ASTM CCM	H_2SO_4	03/07/18	13:38	14:38
3	Hydrogen Heater Stack	USEPA Method 2	Velocity & Flow Rate	03/07/18	13:41	13:47
3	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	$O_2/NO_X/CO$	03/07/18	13:57	14:18
4	Hydrogen Heater Stack	USEPA Method 2	Velocity & Flow Rate	03/07/18	14:13	14:20
4	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	$O_2/NO_X/CO$	03/07/18	14:30	14:51
3	Hydrogen Heater Stack	Draft ASTM CCM	H_2SO_4	03/07/18	14:51	15:51
5	Hydrogen Heater Stack	USEPA Method 2	Velocity & Flow Rate	03/07/18	14:55	15:04
5	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	$O_2/NO_X/CO$	03/07/18	15:05	15:26
6	Hydrogen Heater Stack	USEPA Method 2	Velocity & Flow Rate	03/07/18	15:24	15:32
6	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	$O_2/NO_X/CO$	03/07/18	15:36	15:57
1	Hydrogen Heater Stack	USEPA Method 4	H_2O	03/07/18	16:12	18:10
7	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	$O_2/NO_X/CO$	03/07/18	16:14	16:35
7	Hydrogen Heater Stack	USEPA Method 2	Velocity & Flow Rate	03/07/18	16:17	16:23
8	Hydrogen Heater Stack	USEPA Method 2	Velocity & Flow Rate	03/07/18	16:44	16:52
8	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	$O_2/NO_X/CO$	03/07/18	16:46	17:07
9	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	$O_2/NO_X/CO$	03/07/18	17:17	17:38
9	Hydrogen Heater Stack	USEPA Method 2	Velocity & Flow Rate	03/07/18	17:18	17:24
10	Hydrogen Heater Stack	USEPA Method 2	Velocity & Flow Rate	03/07/18	17:50	17:56
10	Hydrogen Heater Stack	USEPA Methods 3A/7E/10	$O_2/NO_X/CO$	03/07/18	17:57	18:18

Discussion

Project Synopsis

CleanAir conducted the sample program over a two-day span. During the first test day, three Method 5/202 test runs were conducted along with three Method 25A/18 test runs.

The RATA was conducted during the second test day, along with EPA Method 2 traverses for flow measurements and three draft ASTM Controlled Condensation Method (CCM) test runs. As part of the draft CCM test method, a conditioning test run (Run 0) was conducted prior to the three reported H_2SO_4 test runs. In addition, one Method 4 test run for moisture was conducted to coincide with the final four flow measurements.

Modifications to Test Methodology

USEPA Method 5/202

For this test program, the PM emission rate is assumed equivalent to the FPM emission rate. The PM_{10} emission rate is assumed equivalent to the sum of FPM and CPM emission rates (units of lb/hr, Ton/yr, or lb/MMBtu for all constituents).

The analytical procedures in Method 202 include an ammonium titration of the inorganic sample fractions with pH less than 7.0 to neutralize acids with hygroscopic properties, such as H_2SO_4, that may be present in the sample. This step speeds up the sample desiccation process and allows the samples to come to a constant weight prior to weighing. The weight of ammonium added to the sample as a result of the titration is subtracted from the analytical result.

The laboratory performing the gravimetric analysis (CleanAir Analytical Services) has determined that only samples with an initial pH less than 4.5 require a significant amount of ammonium neutralization, resulting in a correction in excess of 0.5 mg. Based on this observation, the laboratory has altered its procedures to read that a sample must have a pH lower than 4.5 in order to be titrated.

The final results for each parameter were expressed as the average of three runs and were below the permit limits for both PM and PM_{10}.

Draft ASTM Controlled Condensation Method

Prior to the first official test run, a sample conditioning run was performed in order to minimize the absorption capacity of the front-half components of the sample train (upstream of the H_2SO_4 collection portion of the sample train). The conditioning run was recovered in the same manner as the official test runs, but is not included in the results.

Three test runs were performed on March 6. The final result was expressed as the average of three valid runs (Runs 1, 2 and 3).

USEPA Methods 18 and 25A

Three valid Method 25A test runs for THCs were performed concurrently with three (3) 60-minute Method 18 bag collections for CH_4 and C_2H_6 on March 6. The final results for each parameter were expressed as the average of three valid runs (Runs 1, 2 and 4). The third test run was not used for compliance purposes due to the Method 18 bag being contaminated with calibration gas during the post run calibration bias check. It should be noted that the Chain of Custody incorrectly labeled the Run 4 bag as Run 3.

Method 25A states that the mid-range calibration gas should be used for the drift checks between runs. Because the flue gas contained very low levels of hydrocarbons, the operator used the low-level calibration gas for the drift checks.

VOC emission rate is normally equivalent to THC emission rate, minus CH_4 and C_2H_6 emission rate (units of lb/hr, Ton/yr or lb/MMBtu for all constituents). For all runs, the THC concentration was below the reportable instrument response (considered to be 1% of instrument span, 0.5 ppm, vw). For CH_4 and C_2H_6, a non-detectable result was obtained for all runs; therefore, no correction was made to the THC results. VOC emissions are equivalent to THC emission rate.

USEPA Methods 2, 3A, 4, 7E, and 10 – Performance Specifications 2, 3, 4A, and 6

CO_2 Concentration

A review of the reference method (RM) carbon dioxide (CO_2) data, found in Appendix G of this report, shows that a majority of the one minute averages are above the high level calibration gas of 17.9% that was utilized on March 6. Additionally, the high calibration gas cylinder was left open at the end of the test day on March 6 and subsequently drained. No Calibration Error (CE) was performed on the CO_2 analyzer on March 7 during the RATA. No adjustment was made to the analyzer from the previous day and CO_2 data was collected per method, along with all the other gaseous components. A 21.51% CO_2 gas was shipped to the job site and a full CE was performed on the morning of March 8. The high CO_2 gas CE came in slightly above the allowable 2% limit (3.1%) during that CE. This correlates to the CO_2 data collected on March 7 actually being slightly lower than what is reported in this document.

The discrepancies with the CO_2 data does not have a significant effect upon any of the data presented in this report. The CO_2 data is only utilized for molecular weight calculation, which has a negligible effect in the overall volumetric flow rate and isokinetic calculations.

Sample Approach

One-minute average data points for oxygen (O_2), CO_2, NO_X and CO (dry basis) were collected over a period of 21 minutes for each RATA RM run.

The average result for each RM run was calculated and compared to the average result from the facility continuous emissions monitoring system (CEMS) over identical time intervals in order to calculate relative accuracy (RA):

- For O_2 (%dv), RA is expressed as the average absolute difference between the RM and facility CEMS runs. The final result was below the limit of ± 1.0% dv set by Performance Specification (PS) 3.
- For NO_X (ppmdv) concentration, RA is expressed as the percent difference between RM and facility CEMS runs. The final result was below the limit of 20% of the RM set by PS 2.
- For NO_X (lb/MMBtu) emission rate, RA is expressed as the percent difference between RM and facility CEMS runs. The final result was below the limit of 20% of the RM set by PS 2.
- For NO_X (ppmdv @ 0% O_2) concentration, RA is expressed as the percent difference between RM and facility CEMS runs. The final result was below the limit of 20% of the RM set by PS 2.
- For CO (ppmdv) concentration, the RA limit is expressed as the average absolute difference between the RM and facility CEMS runs, plus 2.5 times the confidence coefficient. The final result was below the limit of ± 5 ppmdv set by PS 4A, which is applicable to sources that emit less than 200 ppmv of CO.

- For CO (lb/hr) diluent, RA is expressed as the percent difference between RM and facility CEMS runs. The final result was below the limit of 5% of the standard (permit limit listed in Table 1-2 on page 2) set by PS 4A.
- CO_2 data was collected only as supplemental information.

All CO concentrations measured were below the instrument reportable response (considered to be 1% of instrument span, 0.456 ppm, dv).

Facility flow rate CEMS were evaluated using Method 2 as the RM. A complete flow and temperature traverse was performed during each 21-minute RATA run, converted to units of dry standard cubic feet per hour (dscfh), and then compared to facility CEMS results over the corresponding 21-minute intervals.

The flow rate, RA, is expressed as the percent difference between RM and facility CEMS data. The final results were below the limit of 20% of the RM set by PS 6.

Moisture data was used to convert flow rate from wet basis to dry basis and was obtained from concurrently operated Draft ASTM CCM test runs:

- For RATA Runs 1 and 2, H_2O data was obtained from Draft ASTM CCM Run 1.
- For RATA Runs 3 and 4, H_2O data was obtained from Draft ASTM CCM Run 2.
- For RATA Runs 5 and 6, H_2O data was obtained from Draft ASTM CCM Run 3.
- For RATA Runs 7 through 10, H_2O data was obtained from a single Method 4 test run. The Method 4 was paused between each RATA run.

NO_X and CO results from the RATA were converted from units of dry volume-based concentration (ppmdv) to mass-based emission rate units (lb/hr, Ton/yr, and lb/MMBtu) to demonstrate compliance with permit limits. The final results for each parameter were expressed as the average of nine (9) or ten (10) RATA runs. The final results were below the permit limits.

Calculation of Final Results

Emission results in units of dry volume-based concentration (lb/dscf, ppmdv) were converted to units of lb/MMBtu using the F_d factor method. Fuel F_d factors were provided by Air Products. Flow rates used in calculating lb/hr emissions were obtained in the following manner:

- For Method 5/202, flow rate measurements are incorporated into the sampling procedures.
- For Method 18/25A, flow rate measurements from the most nearly concurrent Method 5/202 test runs were used.
- For Method 7E/10, a flow rate measurement, per Method 2 specifications, was performed concurrently with each test run.
- For Draft ASTM CCM, the flow rate measurements made concurrently with the Method 7E/10 run that most closely corresponded were used.

General Considerations

All run times listed throughout this report correspond to the plant time utilized by Air Products. Plant time is the time of the Air Products CEMS and data acquisition systems. The plant time is 60 minutes earlier than actual Eastern Daylight Savings Time.

End of Section

2. RESULTS

This section summarizes the test program results. Additional results are available in the report appendices, specifically Appendix C Parameters.

Table 2-1:
H_2SO_4 Emissions (Draft ASTM CCM)

Run No.		**1**	**2**	**3**	**Average**
Date (2018)		Mar 7	Mar 7	Mar 7	
Start Time (approx.)		12:27	13:38	14:51	
Stop Time (approx.)		13:27	14:38	15:51	
Process Conditions					
P_1	Hydrogen production (Mscf/day)	56.0	56.0	56.0	**56.0**
P_2	Aqueous NH3 feed to SCR (lb/hr)	29.7	29.9	30.1	**29.8**
P_3	SCR Inlet temperature (°F)	611	611	611	**611**
F_d	Oxygen-based F-factor (dscf/MMBtu)	9,098	9,098	9,097	**9,098**
Cap	Capacity factor (hours/year)	8,760	8,760	8,760	**8,760**
Gas Conditions[1]					
O_2	Oxygen (dry volume %)	3.9	3.6	3.8	**3.8**
CO_2	Carbon dioxide (dry volume %)	17.5	17.7	18.0	**17.7**
T_s	Sample temperature (°F)	320	320	321	**320**
B_w	Actual water vapor in gas (% by volume)	16.2	15.6	15.9	**15.9**
Gas Flow Rate					
Q_a	Volumetric flow rate, actual (acfm)	185,000	184,000	187,000	**185,000**
Q_s	Volumetric flow rate, standard (scfm)	121,000	120,000	122,000	**121,000**
Q_{std}	Volumetric flow rate, dry standard (dscfm)	102,000	102,000	103,000	**102,000**
Sampling Data					
V_{mstd}	Volume metered, standard (dscf)	28.88	29.09	28.82	
Laboratory Data (Ion Chromatography)					
m_n	Total H2SO4 collected (mg)	0.1301	0.1875	0.1816	
Sulfuric Acid Mist (H2SO4) Results					
C_{sd}	H2SO4 Concentration (lb/dscf)	9.9E-09	1.4E-08	1.4E-08	**1.3E-08**
C_{sd}	H2SO4 Concentration (ppmdv)	0.039	0.056	0.055	**0.050**
$E_{lb/hr}$	H2SO4 Rate (lb/hr)	0.061	0.087	0.086	**0.078**
$E_{T/hr}$	H2SO4 Rate (Ton/yr)	0.27	0.38	0.38	**0.34**
E_{Fd}	H2SO4 Rate - Fd-based (lb/MMBtu)	0.00011	0.00016	0.00015	**0.00014**

[1] Oxygen and carbon dioxide concentrations from concurrent Method 3A test runs.

[2] Velocity and volumetric flow from concurrent Method 2 traverses.

Table 2-2:
Uncertainty Analysis – H_2SO_4 (Draft ASTM CCM)

		H_2SO_4 Results (ppmdv)		H_2SO_4 Results (lb/MMBtu)
Method		**CCM**		**CCM**
Run No.	**1**	0.039	**1**	0.00011
	2	0.056	**2**	0.00016
	3	0.055	**3**	0.00015
SD		0.0094		0.0000256
AVG		**0.050**		**0.00014**
RSD		18.8%		18.2%
N		3		3
SE		0.0054		0.000015
RSE		10.9%		10.5%
P		95.0%		95.0%
TINV		4.303		4.303
CI +		0.073		0.00020
AVG		**0.050**		**0.00014**
CI -		0.027		0.000077
TB +		0.12		0.00034

AVG (average) is the mean value of the runs; N is the number of individual runs.

SD (standard deviation) and RSD (relative standard deviation) are measures of the variability of individual run

SE (standard error) and RSE (relative standard error) are measures of the variability of the average of the

P (probability) is the confidence level associated with the two-tailed Student's t-distribution.

TINV (t-value) is the value of the Student's t-distrubution as a function of P (probability) and N-1 (degrees of freedom).

CI (confidence interval) indicates that if the test is conducted again under the same conditions, the average would be expected to fall within the interval (CI- to CI+) about 95% of the time.

TB+ (upper tolerance bound) is the value below which 95% of future runs are expected to fall (assuming testing at the same conditions).

Table 2-3:
FPM, CPM and Total PM_{10} Emissions (EPA Method 5/202)

Run No.		1	2	3	Average
Date (2018)		Mar 6	Mar 6	Mar 6	
Start Time (approx.)		11:46	14:39	17:36	
Stop Time (approx.)		13:59	16:49	19:48	
Process Conditions					
P_1	Hydrogen production (Mscf/day)	56.0	56.0	56.0	**56.0**
P_2	Aqueous NH3 feed to SCR (lb/hr)	29.6	29.4	29.2	**29.4**
P_3	SCR Inlet temperature (°F)	610	609	608	**609**
F_d	Oxygen-based F-factor (dscf/MMBtu)	9,087	9,085	9,081	**9,084**
Cap	Capacity factor (hours/year)	8,760	8,760	8,760	**8,760**
Gas Conditions					
O_2	Oxygen (dry volume %)	3.3	3.5	3.3	**3.4**
CO_2	Carbon dioxide (dry volume %)	18.2	17.9	18.5	**18.2**
T_s	Sample temperature (°F)	318	317	315	**317**
B_w	Actual water vapor in gas (% by volume)	15.5	15.7	15.9	**15.7**
Gas Flow Rate					
Q_a	Volumetric flow rate, actual (acfm)	190,000	191,000	190,000	**191,000**
Q_s	Volumetric flow rate, standard (scfm)	125,000	126,000	126,000	**126,000**
Q_{std}	Volumetric flow rate, dry standard (dscfm)	106,000	106,000	106,000	**106,000**
Sampling Data					
V_{mstd}	Volume metered, standard (dscf)	85.82	86.47	84.67	**85.65**
%I	Isokinetic sampling (%)	100.2	100.2	98.8	**99.7**
Laboratory Data					
m_n	Total FPM (g)	0.00238	0.00186	0.00154	
m_{CPM}	Total CPM (g)	0.00636	0.00514	0.00506	
m_{Part}	Total particulate matter (g)	0.00874	0.00700	0.00660	
FPM Results					
$E_{lb/hr}$	Particulate Rate (lb/hr)	0.39	0.30	0.25	**0.32**
$E_{T/yr}$	Particulate Rate (Ton/yr)	1.7	1.3	1.1	**1.4**
E_{Fd}	Particulate Rate - F_d-based (lb/MMBtu)	0.00066	0.00052	0.00043	**0.00054**
CPM Results					
$E_{lb/hr}$	Particulate Rate (lb/hr)	1.0	0.84	0.84	**0.90**
$E_{T/yr}$	Particulate Rate (Ton/yr)	4.5	3.7	3.7	**4.0**
E_{Fd}	Particulate Rate - F_d-based (lb/MMBtu)	0.0018	0.0014	0.0014	**0.0015**
Total Particulate Matter Results					
$E_{lb/hr}$	Particulate Rate (lb/hr)	1.4	1.1	1.1	**1.2**
$E_{T/yr}$	Particulate Rate (Ton/yr)	6.2	5.0	4.8	**5.3**
E_{Fd}	Particulate Rate - F_d-based (lb/MMBtu)	0.0024	0.0019	0.0019	**0.0021**

Table 2-4:
Uncertainty Analysis – FPM, CPM and Total PM$_{10}$ (EPA Method 5/202)

		FPM Results (lb/MMBtu)		**CPM Results (lb/MMBtu)**		**Total PM (as PM$_{10}$) Results (lb/MMBtu)**
Method		**5**		**202**		**5/202**
Run No.	**1**	0.0007	**1**	0.0018	**1**	0.0024
	2	0.00052	**2**	0.0019	**2**	0.0019
	3	0.00043	**3**	0.0014	**3**	0.0019
SD		0.00011		0.000268		0.00031
AVG		**0.0005**		**0.0017**		**0.0021**
RSD		21.4%		15.6%		14.7%
N		3		3		3
SE		0.00007		0.00015		0.0002
RSE		12.4%		9.0%		8.5%
P		95.0%		95.0%		95.0%
TINV		4.303		4.303		4.303
CI +		0.0008		0.0024		0.0028
AVG		**0.0005**		**0.0017**		**0.0021**
CI -		0.0003		0.0010		0.00131
TB +		0.001		0.0038		0.004

AVG (average) is the mean value of the runs; N is the number of individual runs.

SD (standard deviation) and RSD (relative standard deviation) are measures of the variability of individual runs.

SE (standard error) and RSE (relative standard error) are measures of the variability of the average of the runs.

P (probability) is the confidence level associated with the two-tailed Student's t-distribution.

TINV (t-value) is the value of the Student's t-distrubution as a function of P (probability) and N-1 (degrees of freedom).

CI (confidence interval) indicates that if the test is conducted again under the same conditions, the average would be expected to fall within the interval (CI- to CI+) about 95% of the time.

TB+ (upper tolerance bound) is the value below which 95% of future runs are expected to fall (assuming testing at the same conditions).

Table 2-5: THC, CH_4, C_2H_6 and VOC Emissions (EPA Method 25A/18)

Run No.		1	2	4	Average
Date (2018)		Mar 6	Mar 6	Mar 6	
Start Time (approx.)		11:46	12:53	17:41	
Stop Time (approx.)		12:46	13:53	18:41	
Process Conditions					
P_1	Hydrogen Production (Mscf/day)	56.0	55.9	56.0	**56.0**
P_2	Aqueous NH_3 feed to SCR (lb/hr)	35.9	29.4	29.2	**31.5**
P_3	SCR Inlet Temperature	610	609	609	**609**
F_d	Oxygen-based F-factor (dscf/MMBtu)	9,086	9,088	9,080	**9,085**
Cap	Capacity factor (hours/year)	8,760	8,760	8,760	**8,760**
Gas Conditions					
O_2	Oxygen (dry volume %)	3.2	3.2	3.2	**3.2**
CO_2	Carbon dioxide (dry volume %)	18.4	18.5	18.5	**18.5**
B_w	Actual water vapor in gas (% by volume)[1]	15.5	15.5	15.9	**15.6**
Gas Flow Rate[2]					
Q_{std}	Volumetric flow rate, dry standard (dscfm)	106,000	106,000	106,000	**106,000**
THC Results (as Propane)[3]					
C_{sd}	Concentration (ppmdv)	<0.55	<0.55	<0.55	**<0.55**
C_{sd}	Concentration (lb/dscf)	<6.2E-08	<6.2E-08	<6.3E-08	**<6.3E-08**
$E_{lb/hr}$	Emission Rate (lb/hr)	<0.40	<0.40	<0.40	**<0.40**
$E_{T/yr}$	Emission Rate (Ton/yr)	<1.7	<1.7	<1.7	**<1.7**
E_{Fd}	Emission Rate - F_d-based (lb/MMBtu)	<0.00067	<0.00067	<0.00067	**<0.00067**
Methane Results[4]					
C_{sd}	Concentration (ppmdv)	0.63	0.61	0.57	**0.60**
C_{sd}	Concentration (lb/dscf)	2.6E-08	2.5E-08	2.37E-08	**2.51E-08**
$E_{lb/hr}$	Emission Rate (lb/hr)	0.17	0.16	0.15	**0.16**
$E_{T/yr}$	Emission Rate (Ton/yr)	0.73	0.71	0.66	**0.70**
E_{Fd}	Emission Rate - F_d-based (lb/MMBtu)	0.00028	0.00027	0.00025	**0.00027**
Ethane Results[4]					
C_{sd}	Concentration (ppmdv)	<0.20	<0.20	<0.20	**<0.20**
C_{sd}	Concentration (lb/dscf)	<1.6E-08	<1.6E-08	<1.55E-08	**<1.6E-08**
$E_{lb/hr}$	Emission Rate (lb/hr)	< 0.10	< 0.10	< 0.10	**< 0.10**
$E_{T/yr}$	Emission Rate (Ton/yr)	< 0.43	< 0.43	< 0.43	**< 0.43**
E_{Fd}	Emission Rate - F_d-based (lb/MMBtu)	<0.00017	<0.00017	<0.00017	**<0.00017**
VOC Results					
C_{sd}	Concentration (ppmdv)	<0.55	<0.55	<0.55	**<0.55**
$E_{lb/hr}$	Emission Rate (lb/hr)	<0.40	<0.40	<0.40	**<0.40**
$E_{T/yr}$	Emission Rate (Ton/yr)	<1.7	<1.7	<1.7	**<1.7**
E_{Fd}	Emission Rate - F_d-based (lb/MMBtu)	<0.00067	<0.00067	<0.00067	**<0.00067**

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[1] Moisture data used for ppmwv to ppmdv correction obtained from nearly-concurrent M-5/202 runs.

[2] Flow data used in lb/hr calculations was obtained from nearly-concurrent Method 5/202 runs .

[3] '<' indicates a measured response below the detection limit (assumed to be 1% of instrument span).

[4] '<' indicates a measured response below the analytical detection limit determined by the laboratory.

Table 2-6:
NO_X and CO Emissions (EPA Method 7E/10)

Run No.		**1**	**2**	**3**	**4**	**5**	**6**
Date (2018)		Mar 7	Mar 7	Mar 7	Mar 7	Mar 7	Mar 7
Start Time (approx.)		12:27	13:09	13:57	14:30	15:05	15:36
Stop Time (approx.)		12:48	13:30	14:18	14:51	15:26	15:57
Process Conditions							
P_1	Hydrogen Production (Mscf/day)	57.1	57.1	57.1	57.1	57.1	57.1
P_2	Aqueous NH_3 feed to SCR (lb/hr)	35.9	35.9	35.9	35.9	35.9	35.9
P_3	SCR Inlet Temperature	629	629	629	629	629	629
F_d	Oxygen-based F-factor (dscf/MMBtu)	9,098	9,098	9,099	9,096	9,096	9,097
Cap	Capacity factor (hours/year)	8,760	8,760	8,760	8,760	8,760	8,760
Gas Conditions							
O_2	Oxygen (dry volume %)	3.19	3.24	3.25	3.25	3.31	3.26
CO_2	Carbon dioxide (dry volume %)	18.5	18.5	18.5	18.4	18.4	18.4
B_w	Actual water vapor in gas (% by volume)[1]	16.2	16.2	15.6	15.6	15.9	15.9
Gas Flow Rate[2]							
Q_a	Volumetric flow rate, actual (acfm)	185,000	184,000	184,000	185,000	187,000	186,000
Q_s	Volumetric flow rate, standard (scfm)	121,000	121,000	120,000	121,000	122,000	122,000
Q_{std}	Volumetric flow rate, dry standard (dscfm)	102,000	101,000	102,000	102,000	103,000	102,000
Nitrogen Oxides Results							
C_{sd}	Concentration (ppmdv)	5.1	5.3	5.2	5.3	5.2	5.1
$C_{sd\text{-}x}$	Concentration @ 0% O_2 (ppmdv)	6.1	6.2	6.2	6.3	6.2	6.1
C_{sd}	Concentration (lb/dscf)	6.1E-07	6.3E-07	6.2E-07	6.3E-07	6.2E-07	6.1E-07
$E_{lb/hr}$	Emission Rate (lb/hr)	3.7	3.8	3.8	3.9	3.8	3.8
$E_{T/yr}$	Emission Rate (Ton/yr)	16	17	17	17	17	16
E_{Fd}	Emission Rate - F_d-based (lb/MMBtu)	0.0066	0.0068	0.0067	0.0068	0.0067	0.0066
Carbon Monoxide Results[3]							
C_{sd}	Concentration (ppmdv)	<0.46	<0.46	<0.46	<0.46	<0.46	<0.46
$C_{sd\text{-}x}$	Concentration @ 0% O_2 (ppmdv)	<0.54	<0.54	<0.54	<0.54	<0.54	<0.54
C_{sd}	Concentration (lb/dscf)	<3.3E-08	<3.3E-08	<3.3E-08	<3.3E-08	<3.3E-08	<3.3E-08
$E_{lb/hr}$	Emission Rate (lb/hr)	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
$E_{T/yr}$	Emission Rate (Ton/yr)	< 0.89	< 0.88	< 0.89	< 0.89	< 0.89	< 0.89
E_{Fd}	Emission Rate - F_d-based (lb/MMBtu)	<3.6E-04	<3.6E-04	<3.6E-04	<3.6E-04	<3.6E-04	<3.6E-04

[1] Moisture data obtained from nearly-concurrent Draft ASTM CCM runs.

[2] Flow data used in lb/hr calculations was obtained from nearly-concurrent Method 2 runs.

[3] For CO, '<' indicates a measured response below the detection limit (assumed to be 1% of the instrument calibration span).

Table 2-6 (Continued):
NO_X and CO Emissions (EPA Method 7E/10)

Run No.		7	8	9	10	Average
Date (2018)		Mar 7	Mar 7	Mar 7	Mar 7	(all Runs)
Start Time (approx.)		16:14	16:46	17:17	17:57	
Stop Time (approx.)		16:35	17:07	17:38	18:18	
Process Conditions						
P_1	Hydrogen Production (Mscf/day)	57.1	57.1	57.1	57.1	**57.1**
P_2	Aqueous NH_3 feed to SCR (lb/hr)	35.9	35.9	35.9	35.9	**35.9**
P_3	SCR Inlet Temperature	629	629	629	629	**629**
F_d	Oxygen-based F-factor (dscf/MMBtu)	9,097	9,096	9,097	9,097	**9,097**
Cap	Capacity factor (hours/year)	8,760	8,760	8,760	8,760	**8,760**
Gas Conditions						
O_2	Oxygen (dry volume %)	3.26	3.28	3.26	3.27	**3.26**
CO_2	Carbon dioxide (dry volume %)	18.5	18.4	18.4	18.4	**18.4**
B_w	Actual water vapor in gas (% by volume)[1]	16.1	16.1	16.1	16.1	**16.0**
Gas Flow Rate[2]						
Q_a	Volumetric flow rate, actual (acfm)	186,000	187,000	183,000	186,000	**185,000**
Q_s	Volumetric flow rate, standard (scfm)	122,000	123,000	120,000	123,000	**122,000**
Q_{std}	Volumetric flow rate, dry standard (dscfm)	102,000	103,000	101,000	103,000	**102,000**
Nitrogen Oxides Results						
C_{sd}	Concentration (ppmdv)	5.0	5.4	5.2	5.1	**5.2**
$C_{sd\text{-}x}$	Concentration @ 0% O_2 (ppmdv)	6.0	6.4	6.2	6.1	**6.2**
C_{sd}	Concentration (lb/dscf)	6.0E-07	6.4E-07	6.2E-07	6.1E-07	**6.2E-07**
$E_{lb/hr}$	Emission Rate (lb/hr)	3.7	4.0	3.8	3.8	**3.8**
$E_{T/yr}$	Emission Rate (Ton/yr)	16	17	16	17	**17**
E_{Fd}	Emission Rate - F_d-based (lb/MMBtu)	0.0065	0.0069	0.0067	0.0066	**0.0067**
Carbon Monoxide Results[3]						
C_{sd}	Concentration (ppmdv)	<0.46	<0.46	<0.46	<0.46	**<0.46**
$C_{sd\text{-}x}$	Concentration @ 0% O_2 (ppmdv)	<0.54	<0.54	<0.54	<0.54	**<0.54**
C_{sd}	Concentration (lb/dscf)	<3.3E-08	<3.3E-08	<3.3E-08	<3.3E-08	**<3.3E-08**
$E_{lb/hr}$	Emission Rate (lb/hr)	< 0.20	< 0.21	< 0.20	< 0.20	**< 0.20**
$E_{T/yr}$	Emission Rate (Ton/yr)	< 0.89	< 0.90	< 0.88	< 0.90	**< 0.89**
E_{Fd}	Emission Rate - F_d-based (lb/MMBtu)	< 0.00036	< 0.00036	< 0.00036	< 0.00036	**< 0.00036**

[1] Moisture data obtained from nearly-concurrent Method 4 run.

[2] Flow data used in lb/hr calculations was obtained from nearly-concurrent Method 2 runs.

[3] For CO, '<' indicates a measured response below the detection limit (assumed to be 1% of the instrument calibration span).

Table 2-7:
Dry Standard Flow Rate RATA (EPA Method 2 / PS 6)

Run No.	Start Time	Date (2018)	RM Data (dscf/hr)	CEMS Data (dscf/hr)	Difference (dscf/hr)	Difference Percent
1	12:27	Mar 7	6,097,000	5,593,000	504,000	8.3%
2	12:59	Mar 7	6,056,000	5,598,000	458,000	7.6%
3	13:38	Mar 7	6,091,000	5,593,000	498,000	8.2%
4	14:10	Mar 7	6,136,000	5,618,000	518,000	8.4%
5	14:51	Mar 7	6,160,000	5,624,000	536,000	8.7%
6	15:24	Mar 7	6,135,000	5,623,000	512,000	8.3%
7	16:12	Mar 7	6,137,000	5,592,000	545,000	8.9%
8	16:44	Mar 7	6,180,000	5,610,000	570,000	9.2%
9	17:16	Mar 7	6,052,000	5,617,000	435,000	7.2%
10 *	17:48	Mar 7	6,165,000	5,582,000	583,000	9.5%
Average			**6,116,000**	**5,607,556**	**508,444**	**8.3%**

Relative Accuracy Test Audit Results

		Limit
Standard Deviation of Differences	41,917	
Confidence Coefficient (CC)	32,220	
t-Value for 9 Data Sets	2.306	
Relative Accuracy (as % of RM)	**8.8%**	**20.0%**

RM = Reference Method (CleanAir Data) 032318 082753
CEMS = Continuous Emissions Monitoring System (Air Products and Chemicals Inc. Data)
RATA calculations are based on 9 of 10 runs. * indicates the excluded run.

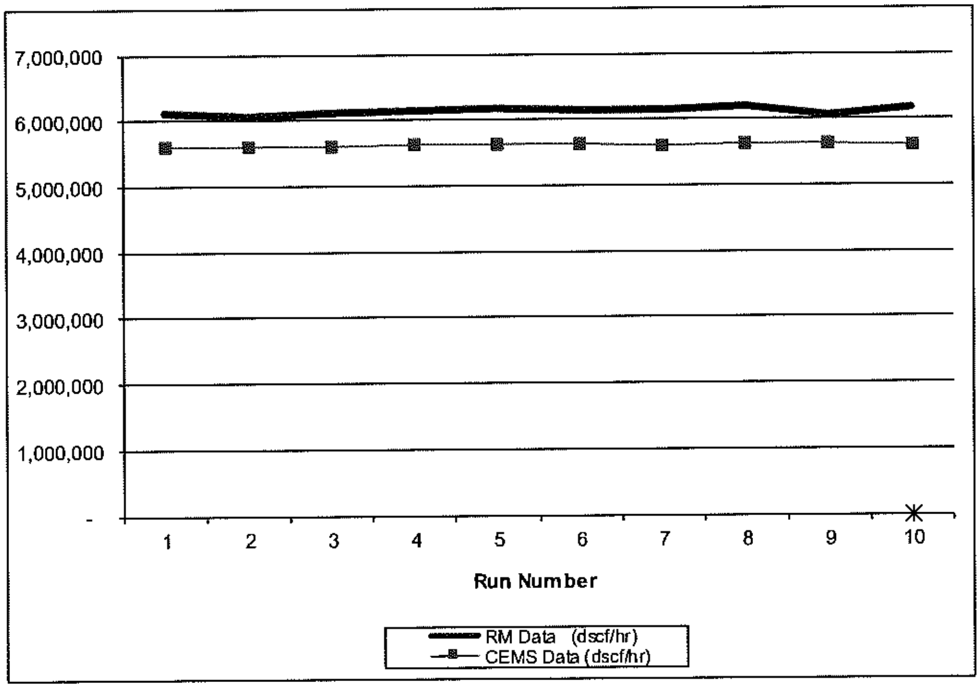


Table 2-8:
H_2O Concentration RATA (EPA Method 4)

Run No.	Start Time	Date (2018)	RM Data (%v)	CEMS Data (%v)	Difference (%v)	Difference Percent
1	12:27	Mar 7	16.2	16.0	0.20	1.2%
2	12:59	Mar 7	16.2	16.0	0.20	1.2%
3	13:38	Mar 7	15.6	16.0	-0.40	-2.6%
4	14:10	Mar 7	15.6	16.0	-0.40	-2.6%
5	14:51	Mar 7	15.9	16.0	-0.10	-0.6%
6	15:24	Mar 7	15.9	16.0	-0.10	-0.6%
7	16:12	Mar 7	16.1	16.0	0.10	0.6%
8	16:44	Mar 7	16.1	16.0	0.10	0.6%
9	17:16	Mar 7	16.1	16.0	0.10	0.6%
10	17:48	Mar 7	16.1	16.0	0.10	0.6%
Average			**16.0**	**16.0**	**-0.02**	**-0.1%**

Relative Accuracy Test Audit Results

Standard Deviation of Differences	0.2251	
Confidence Coefficient (CC)	0.1610	
t-Value for 10 Data Sets	2.262	
		Limit
Relative Accuracy (as % of RM)	**1.1%**	**NA**

RM = Reference Method (CleanAir Data) 031618 125843
CEMS = Continuous Emissions Monitoring System (Air Products and Chemicals Inc. Data)
RATA calculations are based on all 10 runs.

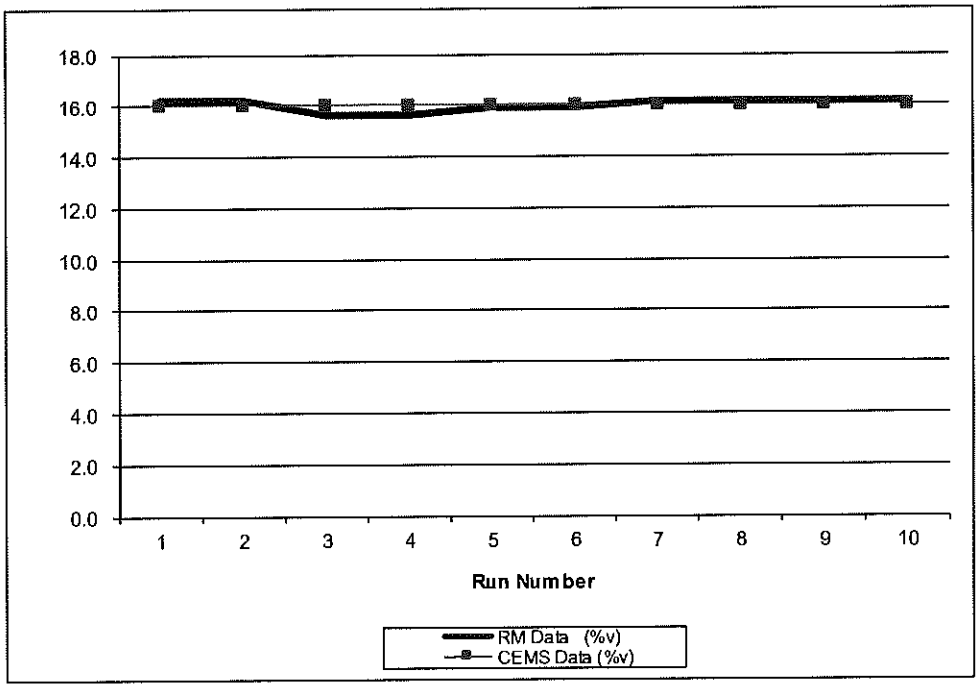


Table 2-9:
O_2 (%dv) RATA (EPA Method 3A / PS 3)

Run No.	Start Time	Date (2018)	RM Data (%dv)	CEMS Data (%dv)	Difference (%dv)	Difference Percent
1	12:27	Mar 7	3.19	3.20	-0.01	-0.4%
2	12:59	Mar 7	3.24	3.20	0.04	1.2%
3	13:38	Mar 7	3.25	3.30	-0.05	-1.6%
4	14:10	Mar 7	3.25	3.30	-0.05	-1.4%
5	14:51	Mar 7	3.31	3.30	0.01	0.3%
6	15:24	Mar 7	3.26	3.30	-0.04	-1.3%
7 *	16:12	Mar 7	3.26	3.20	0.06	1.8%
8	16:44	Mar 7	3.28	3.30	-0.02	-0.7%
9	17:16	Mar 7	3.26	3.30	-0.04	-1.2%
10	17:48	Mar 7	3.27	3.30	-0.03	-0.9%
Average			**3.26**	**3.28**	**-0.02**	**-0.6%**

Relative Accuracy Test Audit Results

Standard Deviation of Differences	0.0295	
Confidence Coefficient (CC)	0.0227	
t-Value for 9 Data Sets	2.306	
		Limit
Avg. Abs. Diff. (%dv)	**0.033**	**1.0**

RM = Reference Method (CleanAir Data) 031618 125843
CEMS = Continuous Emissions Monitoring System (Air Products and Chemicals Inc. Data)
RATA calculations are based on 9 of 10 runs. * indicates the excluded run.

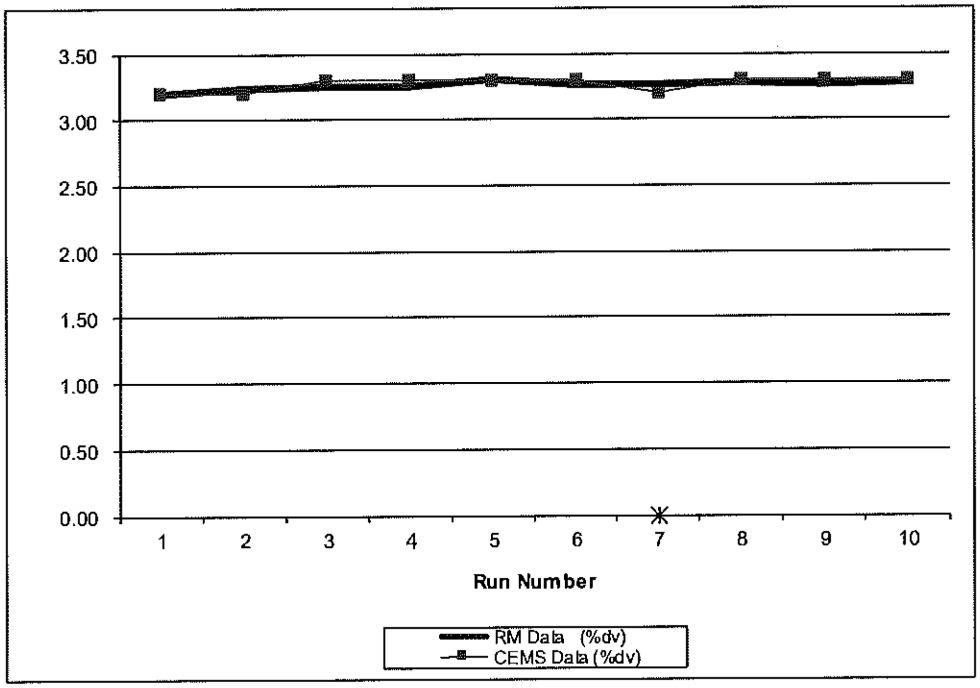


Table 2-10:
NOx (ppmdv) Concentration RATA (EPA Method 7E / PS 2)

Run No.	Start Time	Date (2018)	RM Data (ppmdv)	CEMS Data (ppmdv)	Difference (ppmdv)	Difference Percent
1	12:27	Mar 7	5.14	5.10	0.04	0.8%
2	12:59	Mar 7	5.25	5.20	0.05	1.0%
3	13:38	Mar 7	5.20	5.10	0.10	1.9%
4	14:10	Mar 7	5.31	5.20	0.11	2.1%
5 *	14:51	Mar 7	5.23	5.10	0.13	2.4%
6	15:24	Mar 7	5.12	5.00	0.12	2.4%
7	16:12	Mar 7	5.04	5.00	0.04	0.9%
8	16:44	Mar 7	5.38	5.30	0.08	1.5%
9	17:16	Mar 7	5.20	5.10	0.10	1.9%
10	17:48	Mar 7	5.13	5.10	0.03	0.6%
Average			**5.20**	**5.12**	**0.08**	**1.4%**

Relative Accuracy Test Audit Results

Standard Deviation of Differences	0.0338	
Confidence Coefficient (CC)	0.0260	
t-Value for 9 Data Sets	2.306	
		Limit
Relative Accuracy (as % of RM)	**2.0%**	**20.0%**

RM = Reference Method (CleanAir Data) 032318 082753
CEMS = Continuous Emissions Monitoring System (Air Products and Chemicals Inc. Data)
RATA calculations are based on 9 of 10 runs. * indicates the excluded run.

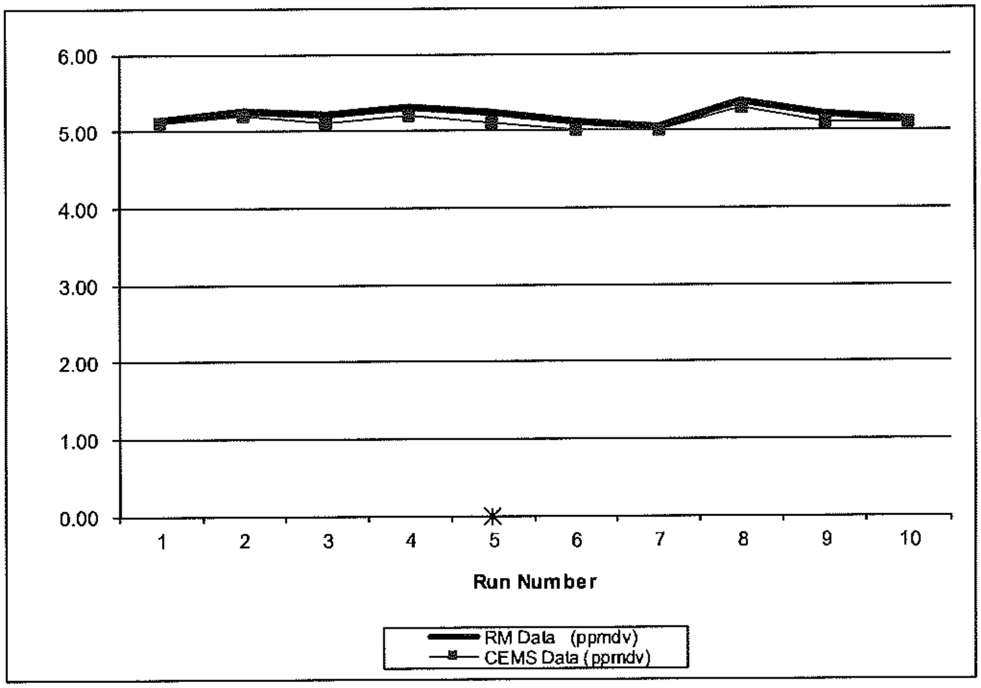


Table 2-11:
NO_X (ppmdv @ 0% O_2) Concentration RATA (EPA Method 7E / PS 2)

Run No.	Start Time	Date (2018)	RM Data (ppm@0%O2)	CEMS Data (ppm@0%O2)	Difference (ppm@0%O2)	Difference Percent
1	12:27	Mar 7	6.06	6.00	0.06	1.0%
2	12:59	Mar 7	6.22	6.20	0.02	0.3%
3	13:38	Mar 7	6.15	6.10	0.05	0.9%
4	14:10	Mar 7	6.29	6.20	0.09	1.5%
5	14:51	Mar 7	6.21	6.10	0.11	1.8%
6	15:24	Mar 7	6.07	6.00	0.07	1.1%
7	16:12	Mar 7	5.98	5.90	0.08	1.3%
8 *	16:44	Mar 7	6.38	6.20	0.18	2.8%
9	17:16	Mar 7	6.16	6.10	0.06	1.0%
10	17:48	Mar 7	6.08	6.10	-0.02	-0.3%
Average			**6.14**	**6.08**	**0.06**	**0.9%**

Relative Accuracy Test Audit Results

Standard Deviation of Differences	0.0384	
Confidence Coefficient (CC)	0.0295	
t-Value for 9 Data Sets	2.306	
		Limit
Relative Accuracy (as % of RM)	**1.4%**	**20.0%**

RM = Reference Method (CleanAir Data) 031618 125843
CEMS = Continuous Emissions Monitoring System (Air Products and Chemicals Inc. Data)
RATA calculations are based on 9 of 10 runs. * indicates the excluded run.

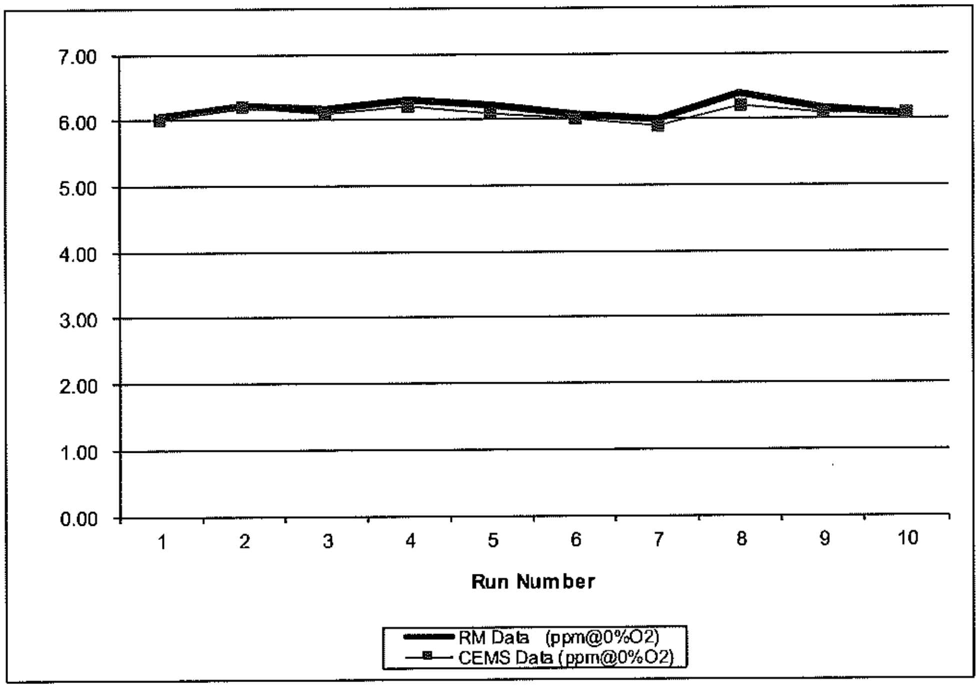


Table 2-12:
NO$_X$ (lb/MMBtu) Emission Rate RATA (EPA Method 7E / PS 2)

Run No.	Start Time	Date (2018)	RM Data (lb/MMBtu)	CEMS Data (lb/MMBtu)	Difference (lb/MMBtu)	Difference Percent
1 *	12:27	Mar 7	0.0066	0.0070	-0.0004	-6.3%
2	12:59	Mar 7	0.0068	0.0070	-0.0002	-3.6%
3	13:38	Mar 7	0.0067	0.0070	-0.0003	-4.7%
4	14:10	Mar 7	0.0068	0.0070	-0.0002	-2.4%
5	14:51	Mar 7	0.0067	0.0070	-0.0003	-3.7%
6	15:24	Mar 7	0.0066	0.0060	0.0006	9.0%
7	16:12	Mar 7	0.0065	0.0060	0.0005	7.6%
8	16:44	Mar 7	0.0069	0.0070	-0.0001	-1.0%
9	17:16	Mar 7	0.0067	0.0070	-0.0003	-4.6%
10	17:48	Mar 7	0.0066	0.0070	-0.0004	-5.9%
Average			**0.0067**	**0.0068**	**-0.0001**	**-1.1%**

Relative Accuracy Test Audit Results

Standard Deviation of Differences	0.000362	
Confidence Coefficient (CC)	0.000278	
t-Value for 9 Data Sets	2.306	
		Limit
Relative Accuracy (as % of RM)	**5.3%**	**20.0%**

RM = Reference Method (CleanAir Data) 031618 125843

CEMS = Continuous Emissions Monitoring System (Air Products and Chemicals Inc. Data)

RATA calculations are based on 9 of 10 runs. * indicates the excluded run.

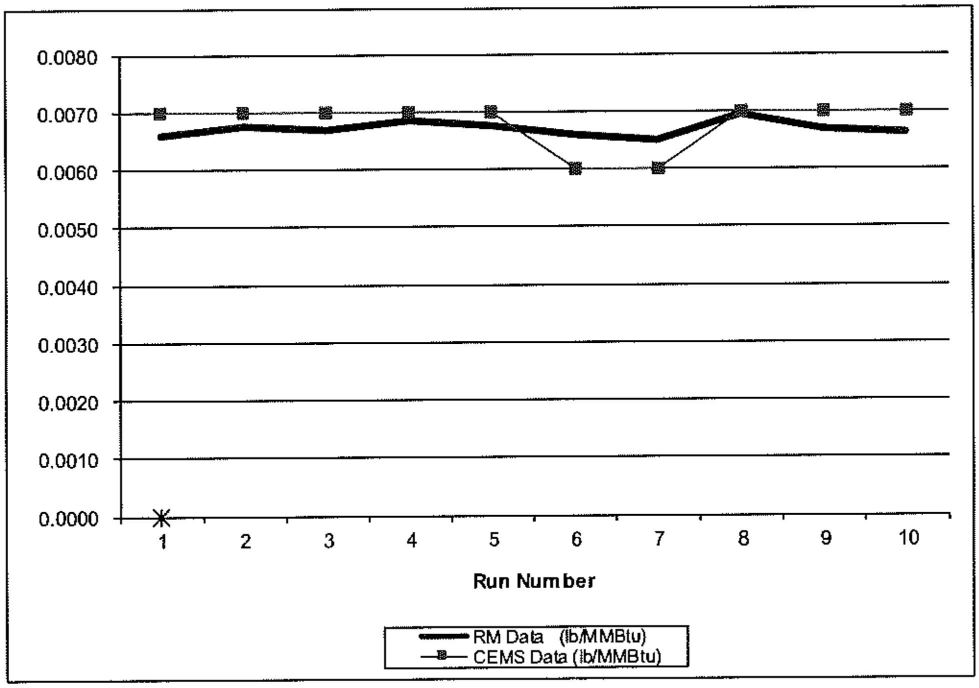


Table 2-13:
CO (ppmdv) Concentration RATA (EPA Method 10 / PS 4A)

Run No.	Start Time	Date (2018)	RM Data (ppmdv)	CEMS Data (ppmdv)	Difference (ppmdv)	Difference Percent
1	12:27	Mar 7	0.00	0.50	-0.50	N/A
2	12:59	Mar 7	0.00	0.50	-0.50	N/A
3	13:38	Mar 7	0.00	0.50	-0.50	N/A
4	14:10	Mar 7	0.00	0.50	-0.50	N/A
5	14:51	Mar 7	0.00	0.50	-0.50	N/A
6	15:24	Mar 7	0.00	0.50	-0.50	N/A
7	16:12	Mar 7	0.00	0.50	-0.50	N/A
8	16:44	Mar 7	0.00	0.50	-0.50	N/A
9	17:16	Mar 7	0.00	0.50	-0.50	N/A
10	17:48	Mar 7	0.00	0.50	-0.50	N/A
	Average		**0.00**	**0.50**	**-0.50**	

Relative Accuracy Test Audit Results

		Limit
Standard Deviation of Differences	0.0000	
Confidence Coefficient (CC)	0.0000	
t-Value for 10 Data Sets	2.262	
Avg. Abs. Diff. + CC (ppmdv)	**0.500**	**5.0**

031618 125843

RM = Reference Method (CleanAir Data)
CEMS = Continuous Emissions Monitoring System (Air Products and Chemicals Inc. Data)
RATA calculations are based on all 10 runs.

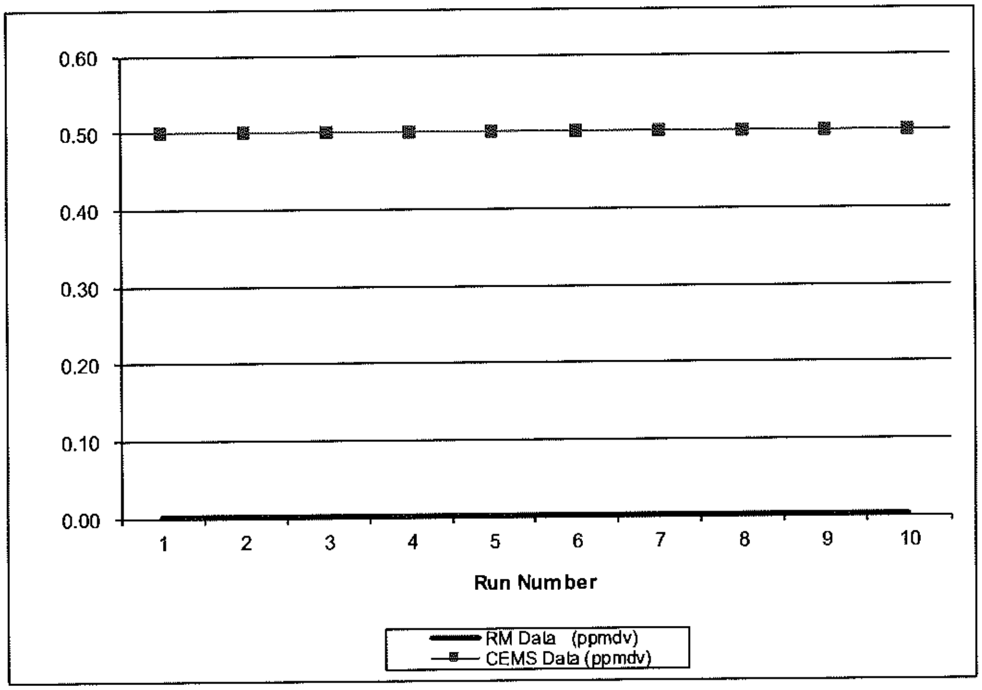


Table 2-14:
CO (lb/hr) Emission Rate RATA (EPA Method 10 / PS 4A)

Run No.	Start Time	Date (2018)	RM Data (lb/hr)	CEMS Data (lb/hr)	Difference (lb/hr)	Difference Percent
1	12:27	Mar 7	0.00	0.20	-0.20	N/A
2	12:59	Mar 7	0.00	0.20	-0.20	N/A
3	13:38	Mar 7	0.00	0.20	-0.20	N/A
4	14:10	Mar 7	0.00	0.20	-0.20	N/A
5	14:51	Mar 7	0.00	0.20	-0.20	N/A
6	15:24	Mar 7	0.00	0.20	-0.20	N/A
7	16:12	Mar 7	0.00	0.20	-0.20	N/A
8	16:44	Mar 7	0.00	0.20	-0.20	N/A
9	17:16	Mar 7	0.00	0.20	-0.20	N/A
10	17:48	Mar 7	0.00	0.20	-0.20	N/A
	Average		**0.00**	**0.20**	**-0.20**	

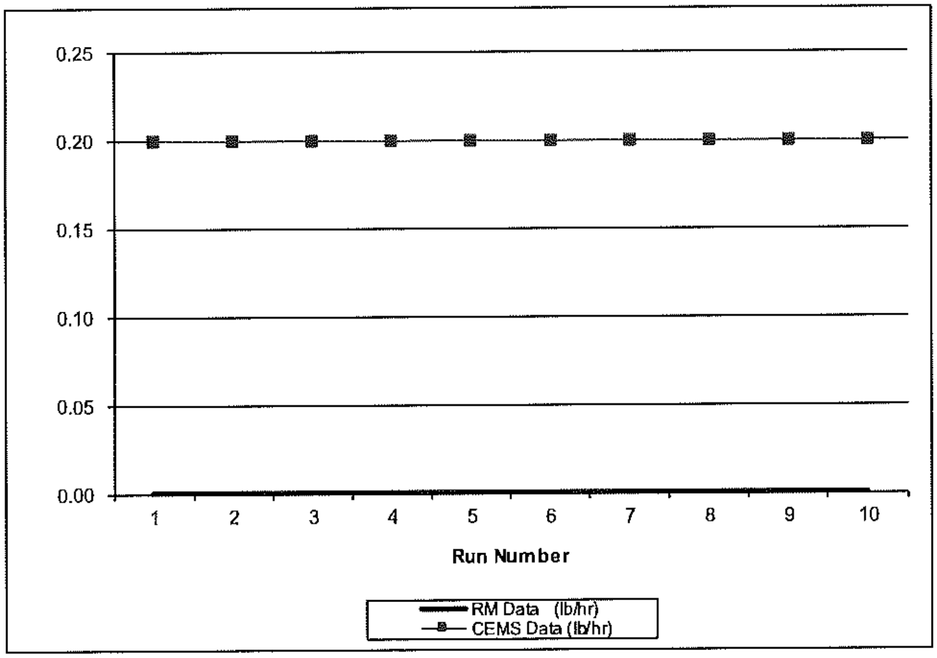
Relative Accuracy Test Audit Results

Standard Deviation of Differences	0.0000	
Confidence Coefficient (CC)	0.0000	
t-Value for 10 Data Sets	2.262	
		Limit
Relative Accuracy (as % of Appl. Std.)	**0.4%**	**5.0%**
Appl. Std. = 56.9 lb/hr		

RM = Reference Method (CleanAir Data) 031618 125843

CEMS = Continuous Emissions Monitoring System (Air Products and Chemicals Inc. Data)

RATA calculations are based on all 10 runs.



End of Section

3. DESCRIPTION OF INSTALLATION

Process Description

Air Products owns and operates the Detroit Hydrogen Plant located within the Marathon Petroleum Company Detroit Refinery. The Hydrogen Plant supplies hydrogen (H_2) to the Detroit Refinery, which is utilized in the petroleum refining process. Natural gas, refinery fuel gas and/or a high-pentane (C_5H_{12}) refinery stream are converted into 99.9% pure H_2 and high-pressure steam through the use of steam/methane reforming technology. The unit consists of process vessels, a heater, compressors, pumps, piping, drains and other various components (pump and compressor seals, process valves, pressure relief valves, flanges, connectors, etc.).

The Hydrogen Plant Heater (EG71-H2HTR) is fired by a combination of refinery gas, pressure swing absorption gas, syngas and/or natural gas. The heater is equipped with a selective catalytic reduction (SCR) system to control emissions, which are vented to the atmosphere via the Hydrogen Plant Heater Stack (SV71-H1).

The testing described in this document was performed at the Hydrogen Plant Heater Stack.

Test Location

EPA Method 1 specifications determined the sample point location. Table 3-1 presents the sampling information for the test location. The figures shown on pages 23 and 24 represent the layout of the test location.

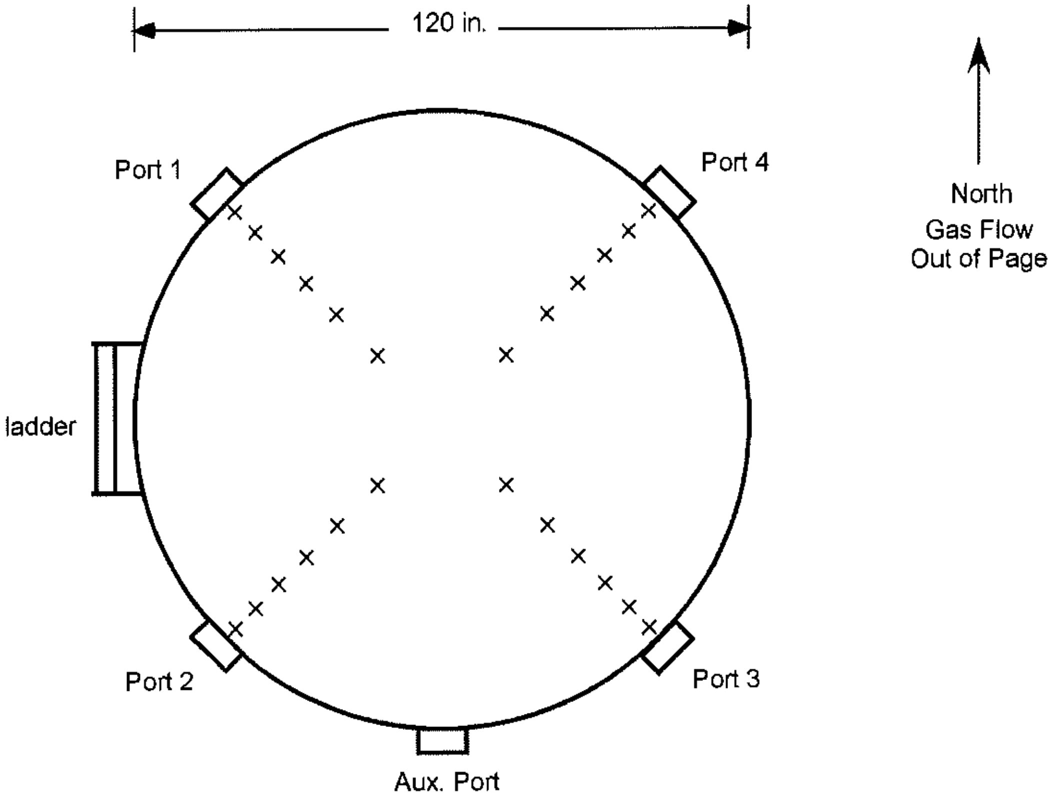
Table 3-1:
Sampling Information

Source Constituent	Method (USEPA)	Run No.	Ports	Points per Port	Minutes per Point	Total Minutes	Figure
H_2 Plant Heater Stack							
Velocity & Flow Rate	M-2	1-10	4	6	varied	varied	3-1
FPM / CPM	M-5/202	1-3	4	6	5	120	3-1
H_2SO_4	Draft ASTM CCM	1-3	1	1	60	60	N/A[1]
O_2 / CO_2 / CH_4 / C_2H_6 / THC	M-3A / 18 / 25A	1-4	1	1	60	60	3-2[2]
O_2 / NO_X / CO (RATAs)	M-3A+PS3 / 7E+PS2 / 10+PS4A	1-10	1	3	7	21	3-2

[1] Sampling occurred at a single point at least 3.3 feet from the duct wall in a port on a lower test plane.

[2] Sampling occurred at a single point at least 3.3 feet from the duct wall.

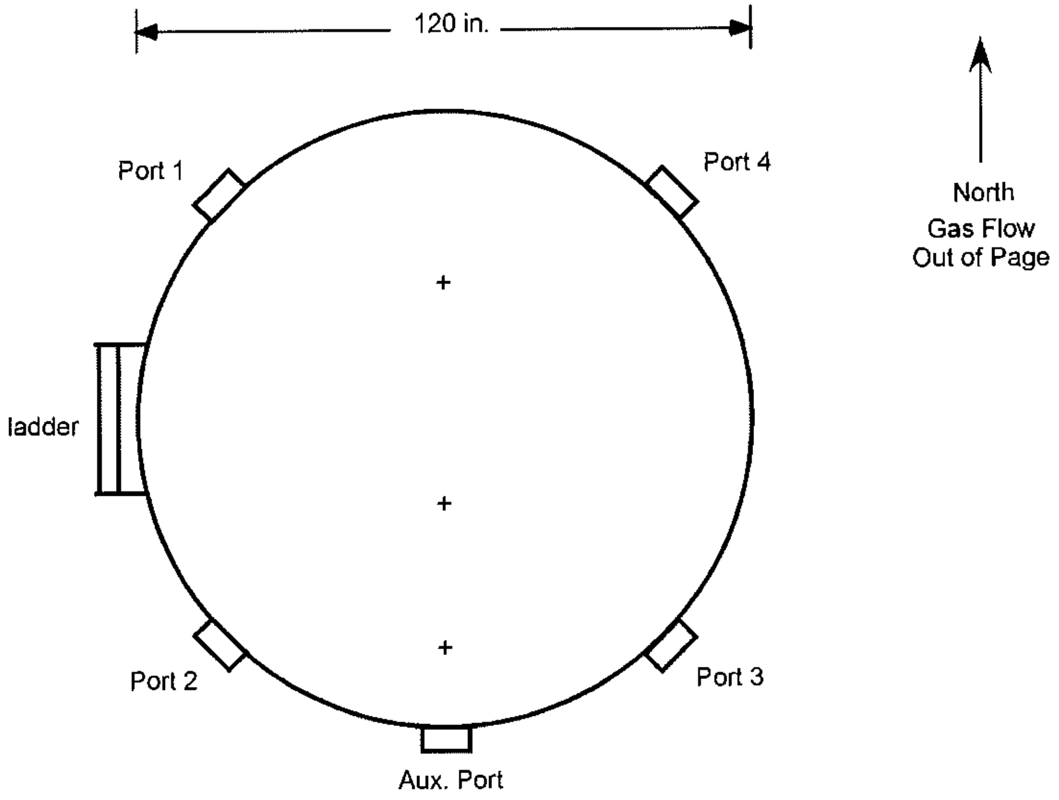
Figure 3-1:
H_2 Plant Heater Stack, EPA Method 5/202 Sample Point Layout (EPA Method 1)



Sampling Point	% of Stack Diameter	Port to Point Distance (inches)
1	35.6	42.7
2	25.0	30.0
3	17.7	21.2
4	11.8	14.2
5	6.7	8.0
6	2.1	2.5

Duct diameters upstream from flow disturbance (A): 1.9	Limit: 0.5
Duct diameters downstream from flow disturbance (B): 5.93	Limit: 2.0

Figure 3-2:
H_2 Plant Heater Stack, RATA Sample Point Layout (EPA PS 2)



Sampling Point	% of Stack Diameter	Port to Point Distance (inches)
1		15.7
2		47.2
3		78.7

Duct diameters upstream from flow disturbance (A): 1.9	Limit: 0.5
Duct diameters downstream from flow disturbance (B): 5.93	Limit: 2.0

End of Section

4. METHODOLOGY

Procedures and Regulations

The test program sampling measurements followed procedures and regulations outlined by the United States Environmental Protection Agency (USEPA) and the Michigan Department of Environmental Quality (DEQ). These methods appear in detail in Title 40 of the CFR and at https://www.epa.gov/emc.

Appendix A includes diagrams of the sampling apparatus, as well as specifications for sampling, recovery, and analytical procedures. Any modifications to standard test methods are explicitly indicated in this appendix.

In accordance with ASTM D7036 requirements, CleanAir included a description of any such modifications, along with the full context of the objectives and requirements of the test program in the test protocol submitted prior to the measurement portion of this project. Modifications to standard methods are not covered by the ISO 17025 and TNI portions of CleanAir's A2LA accreditation.

CleanAir follows specific QA/QC procedures outlined in the individual methods and in USEPA "Quality Assurance Handbook for Air Pollution Measurement Systems: Volume III Stationary Source-Specific Methods," EPA/600/R-94/038C. Appendix D contains additional QA/QC measures, as outlined in CleanAir's internal Quality Manual.

Title 40 CFR Part 60, Appendix A

Method 1	"Sample and Velocity Traverses for Stationary Sources"
Method 2	"Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)"
Method 3	"Gas Analysis for the Determination of Dry Molecular Weight"
Method 3A	"Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)"
Method 4	"Determination of Moisture Content in Stack Gases"
Method 5	"Determination of Particulate Matter Emissions from Stationary Sources"
Method 7E	"Determination of Nitrogen Oxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)"
Method 10	"Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)"
Method 18	"Measurement of Gaseous Organic Compound Emissions by Gas Chromatography"
Method 25A	"Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer"

Title 40 CFR Part 60, Appendix B Performance Specifications

PS 2	"Specifications and Test Procedures for SO_2 and NOx Continuous Emission Monitoring Systems in Stationary Sources"
PS 3	"Specifications and Test Procedures for O_2 and CO_2 Continuous Emission Monitoring Systems in Stationary Sources"

PS 4A	"Specifications and Test Procedures for Carbon Monoxide Continuous Emission Monitoring Systems in Stationary Sources"
PS 6	"Specifications and Test Procedures for Continuous Emission Rate Monitoring Systems in Stationary Sources"

Title 40 CFR Part 51, Appendix M

Method 202	"Dry Impinger Method for Determining Condensable Particulate Emissions from Stationary Sources"

CTM-013 (Mod.)/Draft ASTM Controlled Condensation Method (Draft ASTM CCM)

"Determination of Sulfur Oxides Including Sulfur Dioxide, Sulfur Trioxide and Sulfuric Acid Vapor and Mist from Stationary Sources Using a Controlled Condensation Sampling Apparatus"

Methodology Discussion

PM and PM_{10} Testing – USEPA Method 5/202

PM and PM_{10} emissions were determined using Method 5/202.

- For this test program, PM is assumed equivalent to FPM.
- PM_{10} is equivalent to the sum of FPM less than 10 micrometers (µm) in diameter (FPM_{10}) and CPM. The Method 5/202 sample train yields a front-half, FPM result and a back-half, CPM result. Where appropriate, the total PM result (FPM plus CPM) from Method 5/202 can be used as a worst-case estimation of as Total PM_{10} since Method 5 will collect all FPM present in the flue gas (regardless of particle size). Since the Hydrogen Plant Heater is fired by a combination of refinery gas, pressure swing absorption gas, syngas and/or natural gas, the worst-case assumption can safely be made that any FPM in the flue gas exists as FPM_{10} and can be collected using standard front-half filtration methods without additional 10 µm speciation.

The front-half (Method 5) of the sampling train consisted of a glass nozzle, glass liner and filter holder heated to 250°F, and a quartz fiber filter. Flue gas samples were extracted isokinetically per Method 5 requirements.

The back-half (Method 202) of the sampling train is designed to mimic ambient conditions and collect only the particles that would truly form CPM in the atmosphere. It minimizes the sulfur dioxide (SO_2) and NO_X interferences observed with earlier versions of the method, in which flue gas was bubbled through cold water and SO_2 and NO_X were absorbed and partially oxidized before they could be purged out with nitrogen (N_2).

Flue gas exiting the front-half heated filter passed through a coiled condenser and dry impinger system jacketed by water continually circulated at ambient temperature. Moisture was removed from the flue gas without bubbling through the condensed water. Flue gas then passed through a tetrafluoroethane (TFE) membrane filter at ambient temperature. The temperature of the flue gas at the exit of the filter was directly measured with an in-line thermocouple and maintained in the temperature range of 65°F to 85°F.

After exiting the ambient filter, the flue gas passed through two additional impingers surrounded by ice in a "cold" section of the impinger bucket. The moisture collected in these impingers was not analyzed for CPM and was only collected to determine the flue gas moisture and thoroughly dry the gas. The sample gas then flowed into a calibrated dry gas meter where the collected sample gas volume was determined.

The front-half portion of the sample train (nozzle, probe and heated filter) was recovered per Method 5 requirements, using acetone as the recovery solvent. The back-half of the sample train (heated filter outlet, condenser, dry impingers and TFE membrane filter) was recovered per Method 202 requirements. The impinger train was purged with N_2 at a rate of 14 liters per minute (lpm) for one hour following each test run and prior to recovery.

A field train blank was assembled, purged and recovered as if it were an actual test sample; analysis of the field train blank was used to blank-correct the test run results. Reagent blanks were also collected to quantify background contamination. All samples and blanks were returned to CleanAir Analytical Services for gravimetric analysis. Method 202 samples were maintained at a temperature < 85°F during transport to the laboratory.

H_2SO_4 Testing – Draft ASTM Controlled Condensation Method

H_2SO_4 emissions were determined referencing the Draft ASTM CCM.

A gas sample was extracted from the source at a constant flow rate using a quartz-lined probe maintained at 650°F and a quartz fiber filter maintained at 650°F to remove particulate matter.

The sample then passed through a glass coil condenser for collection of sulfuric acid vapor and/or mist. A second quartz fiber filter (referred to as the sulfuric acid mist (SAM) filter) located at the condenser outlet collected any residual H_2SO_4 that passed through the condenser. The condenser temperature was regulated by a circulating water jacket; the SAM filter temperature was regulated by a closed oven. Both the water jacket and SAM filter oven were maintained at 140°F ± 9°F plus 2°F for each 1% moisture above 16% flue gas moisture (above the water dew point, which eliminates the oxidation of dissolved SO_2 into the H_2SO_4-collecting fraction of the sample train).

After exiting the SAM filter, the sample gas then continued through a series of four glass knock-out jars; two containing water, one empty and one containing silica gel for residual moisture removal. The exit temperature from the knock-out jar set was maintained below 68°F. The sample gas then flowed into a calibrated dry gas meter where the collected sample gas volume was determined.

The H_2SO_4-collecting portion of the sample train (condenser and SAM filter) was recovered into a single fraction using DI H_2O as the recovery/extraction solvent; any H_2SO_4 disassociated into sulfate ion (SO_4^{2-}) was stabilized in the H_2O matrix until analysis.

Prior to the first official test run, a 60-minute sample conditioning run was performed in order to minimize the absorption capacity of the front-half components of the sample train (upstream of the H_2SO_4-collecting portion of the sample train). The conditioning run (Run 0) was recovered in the same manner as the official test runs, but the condenser rinse and SAM filter were not analyzed.

A field train blank was assembled, transported to the location, heated, leak-checked and recovered as if it were an actual test sample. Reagent blanks were collected to quantify background contamination.

Samples and blanks were returned to CleanAir Analytical Services for ion chromatography (IC) analysis.

O_2, CO_2, and VOC Testing – USEPA Methods 3A, 18, and 25A

O_2 and CO_2 concentrations were determined using a paramagnetic / NDIR analyzer per Method 3A. VOC emissions were determined using Method 25A to quantify THC emissions and Method 18 to quantify CH_4 and C_2H_6 emissions.

The Method 3A/18/25A sampling system consisted of a heated probe, heated filter and heated sample line. Flue gas was extracted at a constant rate and delivered at 250°F to a tee at the end of the heated sample line:

- One leg of the tee was connected to a flame ionization analyzer (FIA), which continuously measured minute-average THC concentration expressed in terms of propane (C_3H_8) on an actual (wet) basis.
- The other leg of the tee was connected to a gas conditioner, which removed moisture before delivering the gas to a flow panel and the O_2/CO_2 analyzers, which measured concentration on a dry basis (units of %dv or ppmdv).
- The Method 18 gas sample was collected by pulling a slipstream from the flow panel and delivered it into a FlexFoil bag at a constant rate. The moisture condensate was not collected for analysis as CH_4 and C_2H_6 are insoluble in water. Each bag was filled over a period of one hour for each test run.

The THC analyzer calibration was performed by introducing zero air, high, mid- and low range C_3H_8 calibration gases to the inlet of the sampling system's heated filter. Bias checks were performed before and after each sampling run in a similar manner.

O_2/CO_2 calibration error checks were performed by introducing zero N_2, high range and mid-range calibration gases to the inlet of each analyzer. Bias checks were performed before and after each sampling run by introducing calibration gas to the inlet of the sampling system's heated filter. Per Method 3A, the average results for each run were drift-corrected.

Gas chromatography (GC) calibration was performed by generating a calibration curve from triplicate injections of three distinct CH_4 and C_2H_6 concentrations introduced directly into the GC. Upon completion of calibration, a recovery study was performed by spiking two of the bag samples with a known concentration of CH_4 and C_2H_6, storing the bags for the same period of time prior to analysis as the field samples, and analyzing the bags to determine percent recovery. A full report of the GC analytical procedures is included with the lab data in Appendix I of this report.

Flow Rate, Moisture, O_2, CO_2, and NO_X – USEPA Methods 3A, 4, 7E, and 10; Performance Specifications 2, 3, 4A, and 6

RM flow rate measurements and RA were determined from Type-S Pitot tube traverses per Method 2 and PS 6. RM O_2 and CO_2 emissions and RA were determined using a paramagnetic/NDIR analyzer per Method 3A and PS 3. RM NO_X emissions and RA were determined using a chemiluminescent analyzer per Method 7E and PS 2. RM CO emissions and RA were determined using an infrared analyzer per Method 10 and PS 4 and/or PS 4A.

The Method 3A/7E/10 sampling system consisted of a heated probe, heated filter and heated sample line. Flue gas was extracted at a constant rate at the points specified by the performance specification and delivered at 250°F to a gas conditioner which removed moisture. The flue gas was then delivered via a flow panel to an analyzer bank. Each analyzer measured concentration on a dry basis (units of %dv or ppmdv).

Calibration error checks were performed by introducing zero N_2, high range and mid-range calibration gases to the inlet of each analyzer. Bias checks were performed before and after each sampling run by introducing calibration gas to the inlet of the sampling system's heated filter. Per Method 3A, 7E and 10, the average results for each run were drift-corrected. Documentation of interference checks and NO_2 converter efficiency checks are included in Appendix D of this report.

General Considerations

A verification of the absence of cyclonic flow was performed at the Hydrogen Plant Heater Stack on March 6, following Method 1 specifications. Documentation is included in Appendix E of this report.

O_2 and CO_2 data for the non-instrumental (wet) sampling methods (used in molecular weight calculations and calculation of F_d-based emissions) was obtained using concurrently operated Method 3A sampling.

H_2O data used for moisture correction of concentration data was obtained (when required) in the following manner during the test program:

- For Method 5/202, Method 4 measurements are incorporated into the sampling and recovery procedures.
- For Draft ASTM CCM, a modified Method 4 measurement is incorporated into the sampling and recovery procedures.
    - Sample gas was extracted through a heated probe at a single point at least one meter from the stack wall. Moisture stratification is not expected at test locations without free water droplets present in the flue gas.
    - Sample gas was extracted at a constant rate no greater than 0.75 cfm and at least 21 scf of flue gas was sampled.
    - After passing through the SAM condenser and filter, the sample gas was drawn through gum rubber tubing and into four iced knock-out jars for moisture collection and measurement. The knock-out jars were arranged in a series and contain identical contents as the impinger train prescribed by Method 4, but with gum rubber connections and stainless-steel internal components.
- For Methods 18 and 25A, H_2O data was obtained from concurrently-operated Method 5/202 trains.

For RATA testing, H_2O data was obtained from concurrently-operated Draft ASTM CCM trains, as outlined above.

End of Section