CleanAir

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

Marathon Petroleum Company LP
1001 Oakwood
Detroit, MI 48217

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REPORT ON COMPLIANCE TESTING

Performed for:
MARATHON PETROLEUM COMPANY LP
DETROIT REFINERY

FCCU REGENERATOR STACK (SVFCCU)

Client Reference No: 4101004604
CleanAir Project No: 13181-2
Revision R0: April 5, 2017

To the best of our knowledge, the data presented in this report are accurate, complete, error free, legible and representative of the actual emissions during the test program. Clean Air Engineering operates in conformance with the requirements of ASTM D7036-04 Standard Practice for Competence of Air Emission Testing Bodies.

Submitted by,
Andy Obuchowski 4/5/17
Andy Obuchowski
Midwest Engineering Group
Business Leader
aobuchowski@cleanair.com
(800) 627-0033 ext. 4537

Reviewed by,
Bill Ansell NK 4/5/17
Bill Ansell
Midwest Engineering Group
Technical Leader
bansell@cleanair.com
(800) 627-0033 ext. 4545

PROJECT OVERVIEW

INTRODUCTION

Marathon Petroleum Company LP (MPC) contracted Clean Air Engineering (CleanAir) to perform emission measurements at the Detroit Refinery for compliance purposes.

All testing was conducted in accordance with the regulations set-forth by the United States Environmental Protection Agency (USEPA) and the Michigan Department of Environmental Quality (DEQ). The permit limits are referenced in Michigan Department of Environmental Quality, Renewable Operating Permit No. MI-ROP-A9831-2012c.

Key Project Participants

Individuals responsible for coordinating and conducting the test program were:

Crystal Davis – MPC
Joe Reidy – MPC
Chad Eilering – CleanAir

Test Program Parameters

The testing was performed at the FCCU Regenerator Stack (Emission Unit ID No. EU11-FCCU-S1; Stack ID No. SVFCCU) on February 28 and March 1, 2017, and included the following emissions measurements:

- particulate matter (PM), assumed equivalent to non-sulfate filterable particulate matter (NSFPM)
- total particulate matter less than or equal to 10 microns (μm) in diameter (Total PM_{10}), assumed equivalent to the sum of the following constituents:
  - non-sulfate filterable particulate matter (NSFPM)
  - condensable particulate matter (CPM)
- ammonia (NH_3)
- sulfuric acid (H_2SO_4)
- volatile organic compounds (VOCs), assumed equivalent to total hydrocarbons (THC) minus the following constituents:
  - methane (CH_4)
  - ethane (C_2H_6)
- flue gas composition (e.g., O_2, CO_2, H_2O)
- flue gas flow rate
- flue gas velocity decay (wall-effects)

PROJECT OVERVIEW

TEST PROGRAM SYNOPSIS

Test Schedule

The on-site schedule followed during the test program is outlined in Table 1-1.

Table 1-1:
Schedule of Activities

Run Number	Location	Method	Analyte	Date	Start Time	End Time
1	FCCU Regenerator Stack	USEPA Method 5F/202	NSFPM/CPM	02/28/17	10:35	12:11
2	FCCU Regenerator Stack	USEPA Method 5F/202	NSFPM/CPM	02/28/17	13:33	14:45
3	FCCU Regenerator Stack	USEPA Method 5F/202	NSFPM/CPM	02/28/17	15:57	17:08
1	FCCU Regenerator Stack	CTM-027	NH_3	02/28/17	10:35	12:11
2	FCCU Regenerator Stack	CTM-027	NH_3	02/28/17	13:33	14:45
3	FCCU Regenerator Stack	CTM-027	NH_3	02/28/17	15:57	17:08
1	FCCU Regenerator Stack	USEPA Method 3A/18/25A	$O_2/CO_2/CH_4/C_2H_6$/THC	03/01/17	11:00	12:04
2	FCCU Regenerator Stack	USEPA Method 3A/18/25A	$O_2/CO_2/CH_4/C_2H_6$/THC	03/01/17	12:24	13:26
3	FCCU Regenerator Stack	USEPA Method 3A/18/25A	$O_2/CO_2/CH_4/C_2H_6$/THC	03/01/17	13:53	14:55
1	FCCU Regenerator Stack	Draft ASTM CCM	H_2SO_4	03/01/17	10:53	11:53
2	FCCU Regenerator Stack	Draft ASTM CCM	H_2SO_4	03/01/17	12:19	13:26
3	FCCU Regenerator Stack	Draft ASTM CCM	H_2SO_4	03/01/17	13:46	14:46
1	FCCU Regenerator Stack	USEPA Method 2H	Wall Effects	02/27/17	13:40	13:59
1	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	02/28/17	07:37	07:53
2	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	02/28/17	12:24	12:40
3	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	02/28/17	14:54	15:04
4	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	02/28/17	17:25	17:42
5	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	03/01/17	10:50	11:03
6	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	03/01/17	12:14	12:27
7	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	03/01/17	13:43	13:54

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Results Summary

Tables 1-2 through 1-4 and Figures 1-1 and 1-2 (on the following pages) summarize the results of the test program. A more detailed presentation of the test conditions and results of analysis are shown on pages 2-1 through 2-4.

Table 1-2:
Summary of NSFPM, CPM and Total PM_{10} Results (USEPA 5F/202)

FCCU Regenerator Stack			NSFPM Rate (lb/Mlb coke)	CPM Rate (lb/Mlb coke)	Total PM_{10} Rate (lb/Mlb coke)
Test Dates: 2/28/17					
Coke Burn Rate (lb/hr)	24,666	Run 1	0.2	0.6	0.8
FCC Rate (bpd)	40,998	Run 2	0.2	0.6	0.8
Aqueous NH_3 Injection (lb/hr)	31.0	Run 3	0.2	0.6	0.8
ESP Operation	Both/LPR				
		Average	**0.2**	**0.6**	**0.8**
		Limit	**0.8**		**1.1**

Note: Average includes 3 runs for all parameters. 3/21/2017 16:57

Table 1-3:
Summary of NH_3 Results (USEPA CTM-027)

FCCU Regenerator Stack			NH_3 Conc. (ppmdv)	NH_3 Slip (lb/hr)	NH_3 Slip (lb/Mlb coke)
Test Dates: 2/28/17					
Coke Burn Rate (lb /hr)	24,666	Run 1	17	3.4	0.14
FCC Rate (bpd)	40,998	Run 2	16	3.3	0.13
Aqueous NH_3 Injection (lb/hr)	31.0	Run 3	16	3.2	0.13
ESP Operation	Both/LPR				
		Average	**16**	**3.3**	**0.13**

Note: Average includes 3 runs for all parameters. 3/23/2017 16:58

Table 1-4:
Summary of H_2SO_4 and VOC Results (Draft ASTM CCM & USEPA 18/25A)

Source Constituent	(Units)	Sampling Method	Average Emission	Permit Limit[1]
FCCU Regenerator Stack				
H_2SO_4	(lb/Mlb coke)	Draft ASTM CCM	9.3E-03	N/A
H_2SO_4	(ppmdv)	Draft ASTM CCM	0.20	N/A
VOC	(Ton/yr)	USEPA 25A / 18	5.4	21
VOC	(lb/Mlb coke)	USEPA 25A / 18	0.050	N/A

[1] Permit limit obtained from MDEQ Permit No. MI-ROP-A9831-2012c. 032117 165723

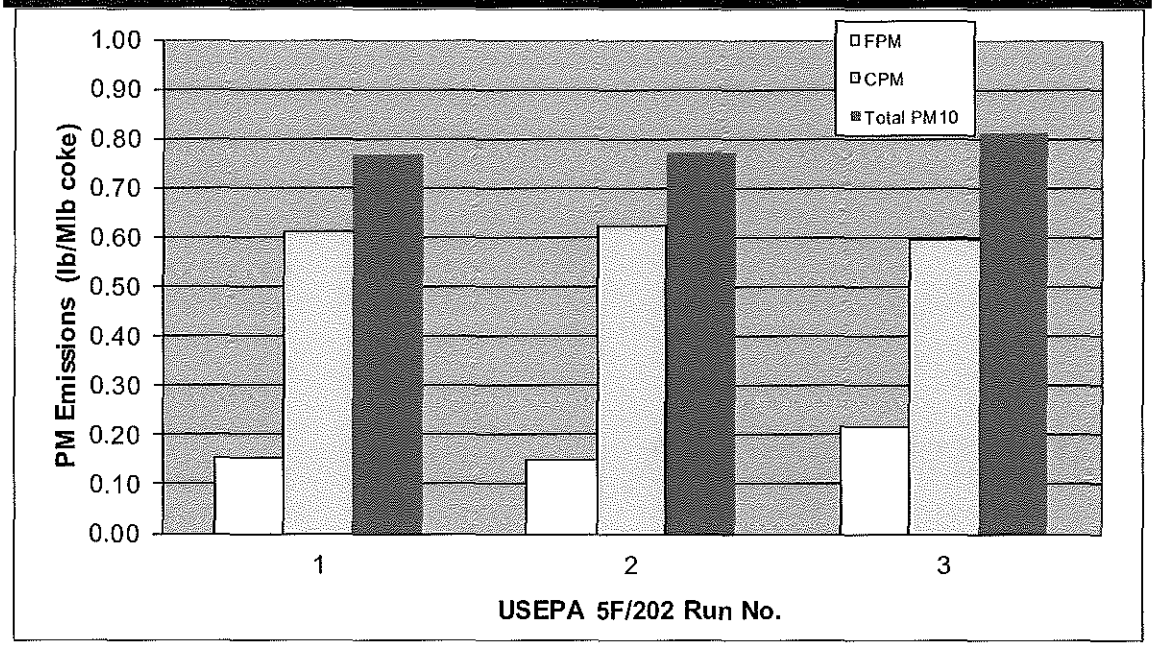

Figure 1-1: NSFPM, CPM and Total PM_{10} Results

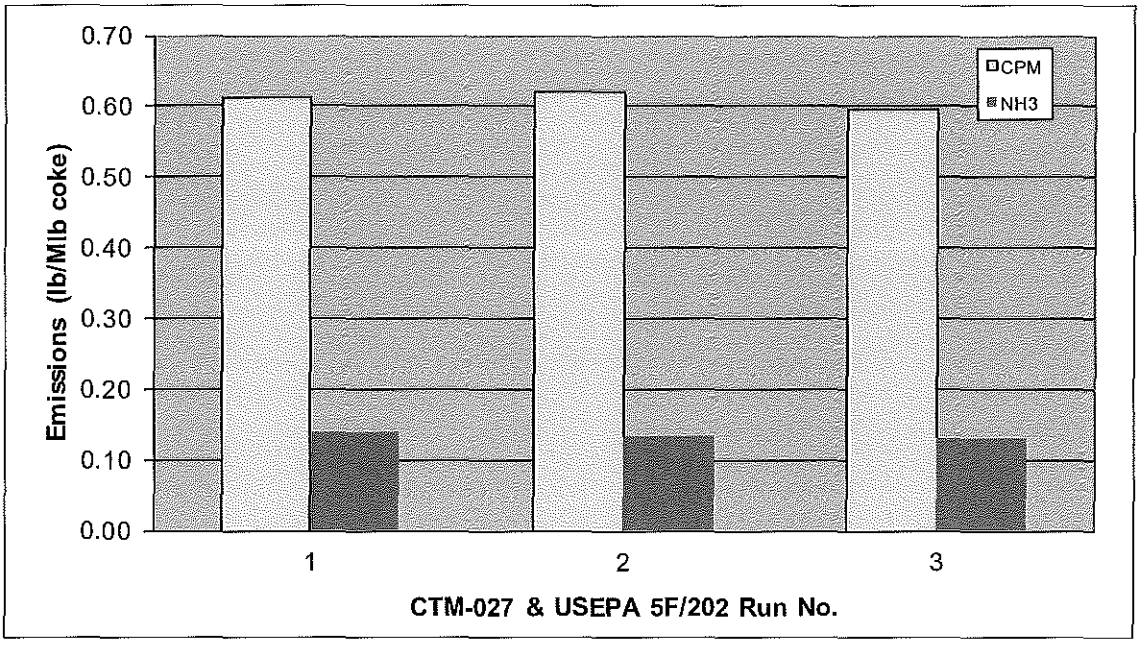

Figure 1-2: CPM and NH_3 Results

Discussion of Test Program

Flow Rate Measurements

A wall-effects adjustment factor (WAF) was determined per EPA Method 2H prior to the start of the first test run.

3-D flow traverses per EPA Method 2F were performed before and after each EPA Method 5F/202 and CTM-027 test run and during each EPA Method 18/25A and Draft ASTM CCM test run.

NSFPM and CPM Testing - USEPA Method 5F/202

Three 60-minute Method 5F/202 test runs were performed on February 28.

For this test program, PM emission rate is assumed equivalent to NSFPM emission rate and PM_{10} emission rate is assumed equivalent to the sum of NSFPM and CPM emission rates (units of lb/hr, ton/yr, or lb/Mlb coke for all constituents). For emissions inventory purposes, MPC applies a correction factor to NSFPM to eliminate particles with a diameter less than 10 microns. Application of that correction factor is not included in this test report.

The analytical procedures in EPA 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 reach 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.

CleanAir Analytical Services performed the gravimetric analysis and 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. Only samples with a pH lower than 4.5 are titrated.

All of the inorganic sample fractions analyzed from Runs 1 through 3 had a pH less than 4.5 and were titrated. The field train reagent blanks had a pH above 4.5 and were not titrated. The train blanks were observed to reach a constant weight without having to titrate the sample.

NH_3 Testing – USEPA Conditional Test Method (CTM)-027 - Stack

Three 60-minute CTM-027 test runs were performed on February 28. Each test run was performed concurrently with Method 5F/202 testing.

H_2SO_4 Testing – Draft ASTM Controlled Condensation Method

Prior to the first official test run, a 60-minute sample conditioning run (Run 0) 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 was recovered in the same manner as the official test runs, but was not analyzed or included in the final results.

Following the conditioning run on March 1, three official 60-minute test runs were performed. The results were expressed as the average of three official runs.

VOC Testing – USEPA Method 25A and Method 18

Three approximately 60-minute Method 25A test runs for THC were performed concurrently with three approximately 60-minute Method 18 integrated gas sample (IGS) collections for CH_4 and C_2H_6.

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/Mlb coke for all constituents). For CH_4 and C_2H_6, a non-detectable result was obtained for Runs 1 through 3, so no correction was made to the THC results. Therefore, VOC emissions for Runs 1 through 3 were equivalent to THC emissions only. The final VOC results were expressed as the average of three runs.

Calculation of Final Results

Sample flow rates as determined by EPA Method 2, which is incorporated into Method 5F/202 and CTM-027, without the WAF corrections factor were used to calculate isokinetic sampling conditions.

Mass-based emission rates in units of pounds per hour (lb/hr) for Method 5F/202 and CTM-027 were calculated using the applicable average pre-run and post-run flow rate determined by Method 2F combined with the respective WAF correction factor. Mass-based emission rates in units of pounds per hour (lb/hr) for Method 18/25A and Draft ASTM CCM were calculated using the applicable concurrent flow rate determined by Method 2F combined with the respective WAF correction factor.

Emission rates in units of tons per year (Ton/yr) were calculated using an assumed capacity factor of 8,760 operating hours per year. Emission rates in units of pounds per 1,000 pounds of coke burn (lb/Mlb coke) were calculated using coke burn rate data provided by MPC.

Ammonia (NH_3) injection rates shown in Section 2 tables are the aqueous NH_3 (11FC2032) times a factor of 0.2.

End of Section 1 – Project Overview

RESULTS

Table 2-1:
NSFPM, CPM, and Total PM_{10} (USEPA M5F/202)

Run No.		1	2	3	Average
Date (2017)		Feb 28	Feb 28	Feb 28	
Start Time (approx.)		10:35	13:33	15:57	
Stop Time (approx.)		12:11	14:45	17:08	
Process Conditions					
R_P	Production rate (Mlb coke/hr)	24.7	24.6	24.7	**24.7**
P_1	FCC charge rate (bpd)	40,992	40,997	41,006	**40,998**
P_2	Ammonia Injection (lb/hr)	6.2	6.2	6.2	**6.2**
P_3	ESP Operation	Both/LPR	Both/LPR	Both/LPR	
Cap	Capacity factor (hours/year)	8,760	8,760	8,760	**8,760**
Gas Conditions					
O_2	Oxygen (dry volume %)	2.5	1.9	1.9	**2.1**
CO_2	Carbon dioxide (dry volume %)	15.7	16.3	16.2	**16.1**
T_s	Sample temperature (°F)	522	523	522	**522**
B_w	Actual water vapor in gas (% by volume)	9.9	9.9	11.5	**10.4**
Gas Flow Rate[1]					
Q_a	Volumetric flow rate, actual (acfm)	161,000	162,000	161,000	**162,000**
Q_s	Volumetric flow rate, standard (scfm)	85,100	85,700	84,900	**85,200**
Q_{std}	Volumetric flow rate, dry standard (dscfm)	76,700	77,300	75,100	**76,300**
Sampling Data					
V_{mstd}	Volume metered, standard (dscf)	40.29	40.82	40.45	**40.52**
%I	Isokinetic sampling (%)[2]	98.9	98.9	100.3	**99.4**
Laboratory Data					
m_n	Total NSFPM (g)	0.01517	0.01475	0.02174	
m_{CPM}	Total CPM (g)	0.06006	0.06111	0.05985	
NSFPM Results					
C_{sd}	Particulate Concentration (lb/dscf)	8.30E-07	7.97E-07	1.19E-06	**9.37E-07**
$E_{lb/hr}$	Particulate Rate (lb/hr)	3.82	3.69	5.34	**4.28**
$E_{T/yr}$	Particulate Rate (Ton/yr)	16.7	16.2	23.4	**18.8**
E_{Rp}	Particulate Rate - Production-based (lb/Mlb coke)	0.155	0.150	0.216	**0.174**
CPM Results					
C_{sd}	Particulate Concentration (lb/dscf)	3.29E-06	3.30E-06	3.26E-06	**3.28E-06**
$E_{lb/hr}$	Particulate Rate (lb/hr)	15.1	15.3	14.7	**15.0**
$E_{T/yr}$	Particulate Rate (Ton/yr)	66.2	67.0	64.4	**65.9**
E_{Rp}	Particulate Rate - Production-based (lb/Mlb coke)	0.612	0.622	0.595	**0.610**
Total Particulate Matter Results					
C_{sd}	Particulate Concentration (lb/dscf)	4.12E-06	4.10E-06	4.45E-06	**4.22E-06**
$E_{lb/hr}$	Particulate Rate (lb/hr)	18.9	19.0	20.0	**19.3**
$E_{T/yr}$	Particulate Rate (Ton/yr)	82.9	83.2	87.8	**84.7**
E_{Rp}	Particulate Rate - Production-based (lb/Mlb coke)	0.767	0.772	0.812	**0.784**

Average includes 3 runs.

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[1] Gas flow rates obtained from bracketing Method 2F test runs combined with the WAF determined by Method 2H.

[2] Sample flow rates as determined by EPA Method 2 were used to calculate isokinetic sampling conditions.

RESULTS

Table 2-2:
NH_3 (USEPA CTM-027)

Run No.		1	2	3	Average
Date (2017)		Feb 28	Feb 28	Feb 28	
Start Time (approx.)		10:35	13:33	15:57	
Stop Time (approx.)		12:11	14:45	17:08	
Process Conditions					
R_P	Production rate - (Mlb coke/hr)	24.7	24.6	24.7	**24.7**
P_1	FCC charge rate - (bpd)	40,992	40,997	41,006	**40,998**
P_2	Ammonia Injection - (lb/hr)	6.2	6.2	6.2	**6.2**
P_3	ESP Operation	Both/LPR	Both/LPR	Both/LPR	
Cap	Capacity factor (hours/year)	8,760	8,760	8,760	**8,760**
Gas Conditions					
O_2	Oxygen (dry volume %)	2.4	3.2	3.8	**3.1**
CO_2	Carbon dioxide (dry volume %)	15.8	15.1	14.2	**15.0**
T_s	Sample temperature (°F)	523	523	523	**523**
B_w	Actual water vapor in gas (% by volume)	10.35	10.36	10.29	**10.33**
Gas Flow Rate[1]					
Q_a	Volumetric flow rate, actual (acfm)	161,000	162,000	161,000	**162,000**
Q_s	Volumetric flow rate, standard (scfm)	85,100	85,700	84,900	**85,200**
Q_{std}	Volumetric flow rate, dry standard (dscfm)	76,700	77,300	75,100	**76,300**
Sampling Data					
V_{mstd}	Volume metered, standard (dscf)	40.91	41.83	40.21	**40.98**
%I	Isokinetic sampling (%)[2]	100.7	101.3	102.1	**101.3**
Laboratory Data					
m_n	Total NH_3 collected (mg)	13.77	13.59	13.00	
Ammonia (NH_3) Results					
C_{sd}	Ammonia Concentration (lb/dscf)	7.42E-07	7.17E-07	7.13E-07	**7.24E-07**
C_{sd}	Ammonia Concentration (ppmdv)	16.8	16.2	16.1	**16.4**
$E_{lb/hr}$	Ammonia Rate (lb/hr)	3.42	3.32	3.21	**3.32**
$E_{T/yr}$	Ammonia Rate (Ton/yr)	15.0	14.5	14.1	**14.5**
E_{Rp}	Ammonia Rate - Production-based (lb/Mlb coke)	0.138	0.135	0.130	**0.134**

Average includes 2 runs.

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[1] Gas flow rates obtained from bracketing Method 2F test runs combined with the WAF determined by Method 2H.

[2] Sample flow rates as determined by EPA Method 2 were used to calculate isokinetic sampling conditions.

RESULTS

Table 2-3:
H_2SO_4 Emissions (Draft ASTM CCM)

Run No.		1	2	3	Average
Date (2017)		Mar 1	Mar 1	Mar 1	
Start Time (approx.)		10:53	12:19	13:46	
Stop Time (approx.)		11:53	13:26	14:46	
Process Conditions					
R_P	Coke burn rate (lb/hr)	24.6	24.6	24.7	**24.6**
P_1	FCC charge rate (bpd)	40,995	40,989	41,010	**40,998**
P_2	NH3 Injection (lb/hr)	6.2	6.1	6.0	**6.1**
Cap	Capacity factor (hours/year)	8,760	8,760	8,760	**8,760**
Gas Conditions					
O_2	Oxygen (dry volume %)	2.2	2.8	2.1	**2.4**
CO_2	Carbon dioxide (dry volume %)	17.7	15.6	16.2	**16.5**
T_s	Sample temperature (°F)	522	521	519	**520**
B_w	Actual water vapor in gas (% by volume)	10.4	9.9	10.8	**10.4**
Gas Flow Rate[1]					
Q_a	Volumetric flow rate, actual (acfm)	158,000	165,400	164,000	162,500
Q_s	Volumetric flow rate, standard (scfm)	82,000	85,800	85,200	84,300
Q_{sld}	Volumetric flow rate, dry standard (dscfm)	73,500	77,300	75,900	75,600
Sampling Data					
V_{mstd}	Volume metered, standard (dscf)	25.66	25.82	25.51	**25.66**
Laboratory Data (Ion Chromatography)					
m_n	Total H2SO4 collected (mg)	0.6757	0.3670	0.7298	
Sulfuric Acid Vapor (H2SO4) Results					
C_{sd}	H2SO4 Concentration (lb/dscf)	5.81E-08	3.13E-08	6.31E-08	5.08E-08
C_{sd}	H2SO4 Concentration (ppmdv)	0.228	0.123	0.248	0.200
$E_{lb/hr}$	H2SO4 Rate (lb/hr)	0.256	0.145	0.287	0.230
$E_{T/yr}$	H2SO4 Rate (Ton/yr)	1.12	0.637	1.26	1.01
E_{Rp}	H2SO4 Rate - Production-based (lb/Mlb coke)	1.04E-02	5.91E-03	1.16E-02	9.32E-03

Average includes 3 runs.

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[1] Gas flow rates obtained from concurrent Method 2F test runs combined with the WAF determined by Method 2H.

RESULTS

Table 2-4:
THC, CH_4, C_2H_6, and VOC Emissions (USEPA 25A/18)

Run No.		1	2	3	Average
Date (2017)		Mar 1	Mar 1	Mar 1	
Start Time (approx.)		11:00	12:24	13:53	
Stop Time (approx.)		12:04	13:26	14:55	
Process Conditions					
R_P	Coke burn rate (Mlb/hr)	24.6	24.6	24.7	**24.6**
P_1	FCC charge rate (bpd)	40,993	40,989	41,013	**40,999**
P_2	NH_3 injection (lb/hr)	6.1	6.1	6.0	**6.1**
Cap	Capacity factor (hours/year)	8,760	8,760	8,760	**8,760**
Gas Conditions					
O_2	Oxygen (dry volume %)	1.6	1.6	1.5	**1.6**
CO_2	Carbon dioxide (dry volume %)	16.6	16.5	16.5	**16.5**
B_w	Actual water vapor in gas (% by volume)[1]	10.4	9.9	10.8	**10.4**
Gas Flow Rate[2]					
Q_a	Volumetric flow rate, actual (acfm)	158,000	165,000	164,000	**162,000**
Q_s	Volumetric flow rate, standard (scfm)	82,000	85,800	85,200	**84,300**
Q_{std}	Volumetric flow rate, dry standard (dscfm)	73,500	77,300	75,900	**75,600**
THC Results					
C_{sd}	Concentration (ppmdv as C_3H_8)	3.17	1.98	2.00	**2.38**
C_{sd}	Concentration (lb/dscf)	3.62E-07	2.27E-07	2.29E-07	**2.73E-07**
$E_{lb/hr}$	Emission Rate (lb/hr)	1.60	1.05	1.04	**1.23**
$E_{T/yr}$	Emission Rate (Ton/yr)	7.00	4.61	4.57	**5.39**
E_{Rp}	Emission Rate - Production-based (lb/Mlb coke)	0.0650	0.0427	0.0422	**0.0500**
Methane Results					
C_{sd}	Concentration (ppmdv)	<0.210	<0.210	<0.210	**<0.210**
C_{sd}	Concentration (lb/dscf)	<8.74E-09	<8.74E-09	<8.74E-09	**<8.74E-09**
$E_{lb/hr}$	Emission Rate (lb/hr)	< 0.0385	< 0.0406	< 0.0398	**< 0.0397**
$E_{T/yr}$	Emission Rate (Ton/yr)	< 0.169	< 0.178	< 0.174	**< 0.174**
E_{Rp}	Emission Rate - Production-based (lb/Mlb coke)	< 0.00157	< 0.00165	< 0.00161	**< 0.00161**
Ethane Results					
C_{sd}	Concentration (ppmdv)	<0.227	<0.227	<0.227	**<0.227**
C_{sd}	Concentration (lb/dscf)	<1.77E-08	<1.77E-08	<1.77E-08	**<1.77E-08**
$E_{lb/hr}$	Emission Rate (lb/hr)	< 0.0781	< 0.0822	< 0.0807	**< 0.0803**
$E_{T/yr}$	Emission Rate (Ton/yr)	< 0.342	< 0.360	< 0.354	**< 0.352**
E_{Rp}	Emission Rate - Production-based (lb/Mlb coke)	< 0.00318	< 0.00334	< 0.00327	**< 0.00326**
VOC Results					
$E_{lb/hr}$	Emission Rate (lb/hr)	1.60	1.05	1.04	**1.23**
$E_{T/yr}$	Emission Rate (Ton/yr)	7.00	4.61	4.57	**5.39**
E_{Rp}	Emission Rate - Production-based (lb/Mlb coke)	0.0650	0.0427	0.0422	**0.0500**

Average includes 3 runs.

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[1] Moisture data used for ppmwv to ppmdv correction obtained from nearly-concurrent Draft ASTM CCM runs.

[2] Gas flow rates obtained from concurrent Method 2F test runs combined with the WAF determined by Method 2H.
For methane and ethane, '<' indicates a measured response below the analytical detection limit determined by the laboratory.

For all calcuated averages, "<" values are treated as the entire value of the detection limit.

End of Section 2 – Results