

1. PROJECT OVERVIEW

Test Program Summary

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 DEQ, Renewable Operating Permit No. MI-ROP-A9831-2012c.

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 3.

**Table 1-1:
 Summary of NSFPM, CPM, and Total PM₁₀ Results (5F/202)**

<u>FCCU Regenerator Stack</u>			NSFPM Rate (lb/Mlb coke)	CPM Rate (lb/Mlb coke)	Total PM₁₀ Rate (lb/Mlb coke)
Test Dates: 3/13/19					
Coke Burn Rate (Mlb/hr)	22.6	Run 1	0.3	0.1	0.4
FCC Rate (bpd)	41,028	Run 2	0.2	0.1	0.3
Aqueous NH₃ Injection (lb/hr)	42.6	Run 3	0.2	0.1	0.3
ESP Operation	Both/LPR	Average	0.2	0.1	0.3
		Limit	0.8		1.1

**Table 1-2:
 Summary of NH₃ Results (CTM-027)**

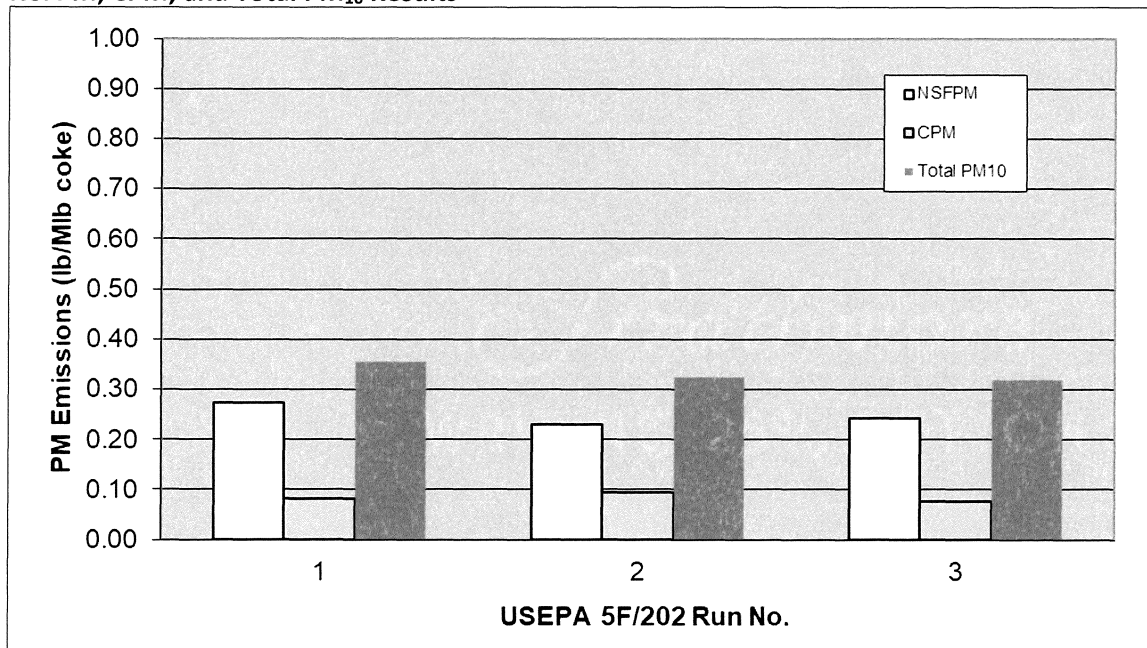
<u>FCCU Regenerator Stack</u>			NH₃ Conc. (ppmdv)	NH₃ Slip (lb/hr)	NH₃ Slip (lb/Mlb coke)
Test Dates: 3/13/19					
Coke Burn Rate (lb/hr)	22.6	Run 1	20	3.8	0.17
FCC Rate (bpd)	41,028	Run 2	20	3.9	0.17
Aqueous NH₃ Injection (lb/hr)	42.6	Run 3	21	4.1	0.18
ESP Operation	Both/LPR	Average	20	3.9	0.18
		Limit		10.9	

**Table 1-3:
 Summary of H₂SO₄ and VOC Results (Draft ASTM CCM & 18/25A)**

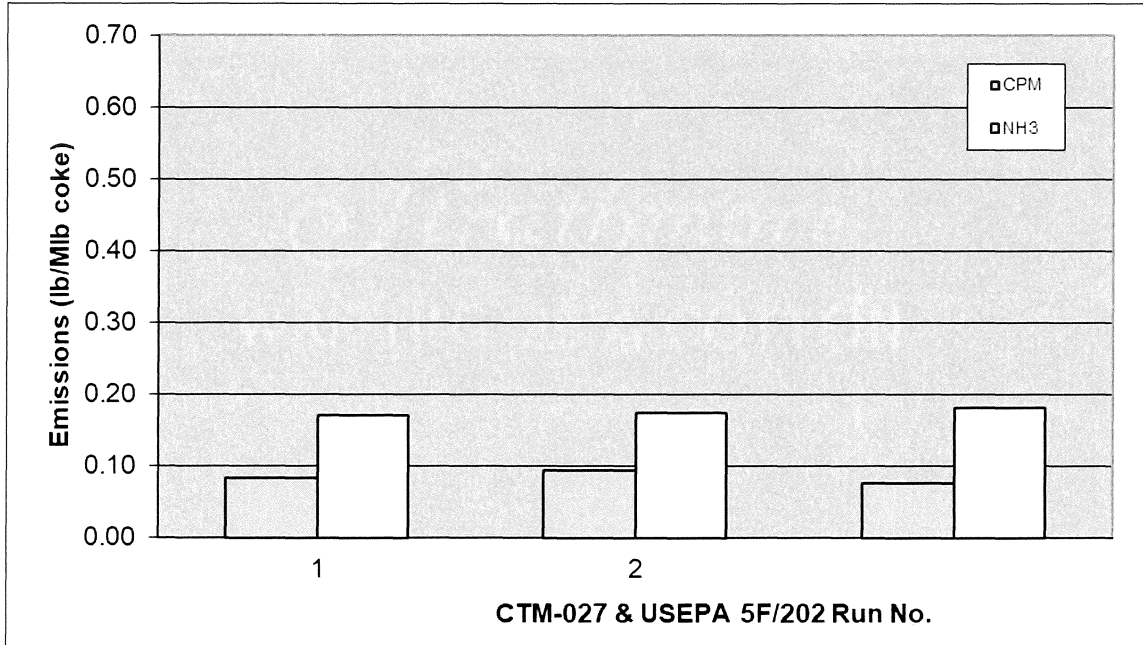
Source		Sampling Method	Average Emission	Permit Limit ¹
Constituent	(Units)			
FCCU Regenerator Stack				
H ₂ SO ₄	(lb/Mlb coke)	Draft ASTM CCM	0.002	N/A
H ₂ SO ₄	(ppmdv)	Draft ASTM CCM	0.041	N/A
VOC	(Ton/yr)	USEPA 25A/ 18	1.3	21
VOC	(lb/Mlb coke)	USEPA 25A/ 18	0.015	N/A

¹ Permit limit obtained from MDEQ Permit No. MI-ROP-A9831-2012c.

**Figure 1-1:
 NSFPM, CPM, and Total PM₁₀ Results**



**Figure 1-2:
CPM and NH₃ Results**



Test Program Details

Parameters

The test program included the following 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 PM₁₀), assumed equivalent to the sum of the following constituents:
 - NSFPM
 - condensable particulate matter (CPM)
- ammonia (NH₃)
- sulfuric acid (H₂SO₄)
- volatile organic compounds (VOCs), assumed equivalent to total hydrocarbons (THCs) minus the following constituents:
 - methane (CH₄)
 - ethane (C₂H₆)
- flue gas composition (e.g., O₂, CO₂, H₂O)
- flue gas flow rate

Schedule

Testing was performed on March 13 and 14, 2019. The on-site schedule followed during the test program is outlined in Table 1-4.

**Table 1-4:
Test Schedule**

Run Number	Location	Method	Analyte	Date	Start Time	End Time
1	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	03/13/19	10:32	10:44
1	FCCU Regenerator Stack	USEPA Method 5F/202	NSFPM/CPM	03/13/19	11:18	12:27
1	FCCU Regenerator Stack	CTM-027	Ammonia	03/13/19	11:18	12:27
2	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	03/13/19	12:52	13:05
2	FCCU Regenerator Stack	USEPA Method 5F/202	NSFPM/CPM	03/13/19	13:44	14:54
2	FCCU Regenerator Stack	CTM-027	Ammonia	03/13/19	13:44	14:54
3	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	03/13/19	15:36	15:51
3	FCCU Regenerator Stack	USEPA Method 5F/202	NSFPM/CPM	03/13/19	16:45	17:57
3	FCCU Regenerator Stack	CTM-027	Ammonia	03/13/19	16:45	17:57
4	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	03/13/19	18:10	18:23
0	FCCU Regenerator Stack	CTM-013 (mod) / Draft ASTM CCM	H ₂ SO ₄	03/14/19	08:55	10:48
5	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	03/14/19	11:22	11:39
1	FCCU Regenerator Stack	CTM-013 (mod) / Draft ASTM CCM	H ₂ SO ₄	03/14/19	11:23	12:23
1	FCCU Regenerator Stack	3A / 18 / 25A	O ₂ / CO ₂ / CH ₄ / C ₂ H ₆ / THC	03/14/19	11:33	12:33
6	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	03/14/19	12:47	12:59
2	FCCU Regenerator Stack	CTM-013 (mod) / Draft ASTM CCM	H ₂ SO ₄	03/14/19	12:48	13:51
2	FCCU Regenerator Stack	3A / 18 / 25A	O ₂ / CO ₂ / CH ₄ / C ₂ H ₆ / THC	03/14/19	12:59	13:59
7	FCCU Regenerator Stack	USEPA Method 2F	3-D Velocity & Flow Rate	03/14/19	14:13	14:25
3	FCCU Regenerator Stack	CTM-013 (mod) / Draft ASTM CCM	H ₂ SO ₄	03/14/19	14:13	15:13
3	FCCU Regenerator Stack	3A / 18 / 25A	O ₂ / CO ₂ / CH ₄ / C ₂ H ₆ / THC	03/14/19	14:21	15:21

Discussion

Flow Rate Measurements

Three-dimensional (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

Three (3) 60-minute Method 5F/202 test runs were performed on March 13.

For this test program, PM emission rate is assumed equivalent to NSFPM emission rate and PM₁₀ 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.

NH₃ Testing

Three (3) 60-minute CTM-027 test runs were performed on March 13. Each test run was performed concurrently with Method 5F/202 testing.

H₂SO₄ Testing

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 H₂SO₄-collecting portion of the sample train). The conditioning run was recovered in the same manner as the official test runs but was not included in the final results.

The average O₂/CO₂ concentrations of Runs 2 and 3 were used as the O₂/CO₂ concentrations for Run 1. During recovery of the IGS, the seal was compromised and the sample was partially diluted with ambient air.

Following the conditioning run on March 14, three (3) official 60-minute test runs were performed. The results were expressed as the average of three official runs.

VOC Testing

Three (3) approximately 60-minute Method 25A test runs for THC were performed concurrently with three (3) 60-minute Method 18 IGS collections for CH₄ and C₂H₆.

VOC emission rate is normally equivalent to THC emission rate minus CH₄ and C₂H₆ emission rate (units of lb/hr, Ton/yr, or lb/Mlb coke for all constituents). Since THC emission rates were already less than the limit for VOC, CH₄ and C₂H₆ analysis was not conducted and VOC emissions for Runs 1 through 3 were considered equivalent to THC emissions only. The final VOC results were expressed as the average of three runs.

Calculation of Final Results

Sample flow rates measured during the run, as determined by EPA Method 2, 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. Mass-based emission rates in units of lb/hr for Method 18/25A and Draft ASTM CCM were calculated using the applicable concurrent flow rate determined by Method 2F. Wall-effects adjustment factor (WAF) correction respective to specifications outlined in EPA Method 2H produced negligible effects and were not included in final calculations for flow rates.

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.

NH₃ injection rates shown in Tables 2-1 through 2-4 are the aqueous NH₃ (11FC2032) multiplied by a factor of 0.2.

2. RESULTS

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

**Table 2-1:
NSFPM, CPM, and Total PM₁₀ (5F/202)**

Run No.		1	2	3	Average
Date (2019)		Mar 13	Mar 13	Mar 13	
Start Time (approx.)		11:18	13:44	16:45	
Stop Time (approx.)		12:27	14:54	17:57	
Process Conditions					
R _p	Production rate (Mlb coke/hr)	22.6	22.6	22.5	22.6
P ₁	FCC charge rate (bpd)	41,066	41,021	40,998	41,028
P ₂	Ammonia Injection (lb/hr)	8.5	8.5	8.5	8.5
P ₃	ESP Operation	Both/LPR	Both/LPR	Both/LPR	
Gas Conditions					
O ₂	Oxygen (dry volume %)	2.5	2.5	2.8	2.6
CO ₂	Carbon dioxide (dry volume %)	15.7	15.6	15.3	15.5
T _s	Sample temperature (°F)	517	518	516	517
B _w	Actual water vapor in gas (% by volume)	9.8	10.2	10.2	10.1
Gas Flow Rate					
Q _a	Volumetric flow rate, actual (acfm)	153,000	152,000	153,000	153,000
Q _s	Volumetric flow rate, standard (scfm)	81,600	81,500	82,000	81,700
Q _{std}	Volumetric flow rate, dry standard (dscfm)	73,700	73,200	73,600	73,500
Sampling Data					
V _{mstd}	Volume metered, standard (dscf)	38.35	39.40	39.02	38.93
%I	Isokinetic sampling (%)	100.8	101.5	101.3	101.2
Laboratory Data					
m _n	Total NSFPM (g)	0.02431	0.02103	0.02191	
m _{CPM}	Total CPM (g)	0.00740	0.00864	0.00687	
NSFPM Results					
C _{sd}	Particulate Concentration (lb/dscf)	1.40E-06	1.18E-06	1.24E-06	1.27E-06
E _{lb/hr}	Particulate Rate (lb/hr)	6.18	5.17	5.47	5.60
E _{T/yr}	Particulate Rate (Ton/yr)	27.1	22.6	23.9	24.5
E _{Rp}	Particulate Rate - Production-based (lb/Mlb coke)	0.273	0.229	0.243	0.248
CPM Results					
C _{sd}	Particulate Concentration (lb/dscf)	4.25E-07	4.84E-07	3.88E-07	4.32E-07
E _{lb/hr}	Particulate Rate (lb/hr)	1.88	2.12	1.71	1.91
E _{T/yr}	Particulate Rate (Ton/yr)	8.23	9.30	7.51	8.35
E _{Rp}	Particulate Rate - Production-based (lb/Mlb coke)	0.083	0.094	0.076	0.084
Total Particulate Matter Results					
C _{sd}	Particulate Concentration (lb/dscf)	1.82E-06	1.66E-06	1.63E-06	1.70E-06
E _{lb/hr}	Particulate Rate (lb/hr)	8.06	7.29	7.18	7.51
E _{T/yr}	Particulate Rate (Ton/yr)	35.3	31.9	31.5	32.9
E _{Rp}	Particulate Rate - Production-based (lb/Mlb coke)	0.356	0.323	0.320	0.333

**Table 2-2:
NH₃ (CTM-027)**

Run No.	1	2	3	Average
Date (2019)	Mar 13	Mar 13	Mar 13	
Start Time (approx.)	11:18	13:44	16:45	
Stop Time (approx.)	12:27	14:54	17:57	
Process Conditions				
R _p Production rate (Mlb coke/hr)	22.6	22.6	22.5	22.6
P ₁ FCC charge rate (bpd)	41,066	41,021	40,998	41,028
P ₂ Ammonia Injection (lb/hr)	8.5	8.5	8.5	8.5
P ₃ ESP Operation	Both/LPR	Both/LPR	Both/LPR	
Gas Conditions				
O ₂ Oxygen (dry volume %)	2.4	2.4	2.5	2.4
CO ₂ Carbon dioxide (dry volume %)	15.8	15.8	15.6	15.7
T _s Sample temperature (°F)	520	520	519	520
B _w Actual water vapor in gas (% by volume)	10.0	10.3	10.4	10.3
Gas Flow Rate				
Q _a Volumetric flow rate, actual (acfm)	153,000	152,000	153,000	153,000
Q _s Volumetric flow rate, standard (scfm)	81,600	81,500	82,000	81,700
Q _{std} Volumetric flow rate, dry standard (dscfm)	73,700	73,200	73,600	73,500
Sampling Data				
V _{mstd} Volume metered, standard (dscf)	37.68	36.40	37.83	37.30
%I Isokinetic sampling (%)	99.6	99.3	100.0	99.6
Laboratory Data				
m _n Total NH ₃ collected (mg)	14.84967	14.73506	15.87725	
Ammonia (NH₃) Results				
C _{sd} Ammonia Concentration (lb/dscf)	8.69E-07	8.93E-07	9.25E-07	8.96E-07
C _{sd} Ammonia Concentration (ppmdv)	19.7	20.2	20.9	20.3
E _{lb/hr} Ammonia Rate (lb/hr)	3.84	3.92	4.09	3.95
E _{T/yr} Ammonia Rate (Ton/yr)	16.8	17.2	17.9	17.3
E _{Rp} Ammonia Rate - Production-based (lb/Mlb coke)	0.170	0.174	0.182	0.175

**Table 2-3:
H₂SO₄ (Draft ASTM CCM)**

Run No.	1	2	3	Average
Date (2019)	Mar 14	Mar 14	Mar 14	
Start Time (approx.)	11:23	12:48	14:13	
Stop Time (approx.)	12:23	13:51	15:13	
Process Conditions				
R _P Coke burn rate (Mlb/hr)	20.3	20.3	20.2	20.3
P ₁ FCC charge rate (bpd)	40,996	41,003	40,984	40,995
P ₂ NH ₃ Injection (lb/hr)	6.0	6.0	6.1	6.0
Gas Conditions				
O ₂ Oxygen (dry volume %)	2.5	2.4	2.5	2.5
CO ₂ Carbon dioxide (dry volume %)	15.6	15.6	15.5	15.6
T _s Sample temperature (°F)	506	507	507	507
B _w Actual water vapor in gas (% by volume)	10.8	10.2	13.7	11.6
Gas Flow Rate				
Q _a Volumetric flow rate, actual (acfm)	141,000	141,000	140,000	141,000
Q _s Volumetric flow rate, standard (scfm)	75,100	75,600	74,600	75,100
Q _{std} Volumetric flow rate, dry standard (dscfm)	67,000	67,900	64,400	66,400
Sampling Data				
V _{mstd} Volume metered, standard (dscf)	27.00	26.93	27.01	26.98
Laboratory Data (Ion Chromatography)				
m _n Total H ₂ SO ₄ collected (mg)	0.1425	0.1267	0.1182	
Sulfuric Acid Vapor (H₂SO₄) Results				
C _{sd} H ₂ SO ₄ Concentration (lb/dscf)	1.16E-08	1.04E-08	9.65E-09	1.06E-08
C _{sd} H ₂ SO ₄ Concentration (ppmdv)	0.0457	0.0408	0.0379	0.0415
E _{lb/hr} H ₂ SO ₄ Rate (lb/hr)	0.0468	0.0423	0.0373	0.0421
E _{T/yr} H ₂ SO ₄ Rate (Ton/yr)	0.205	0.185	0.163	0.184
E _{Rp} H ₂ SO ₄ Rate - Production-based (lb/Mlb)	0.00230	0.00208	0.00185	0.00208

**Table 2-4:
THC, CH₄, C₂H₆, and VOC Emissions (USEPA 25A/18)**

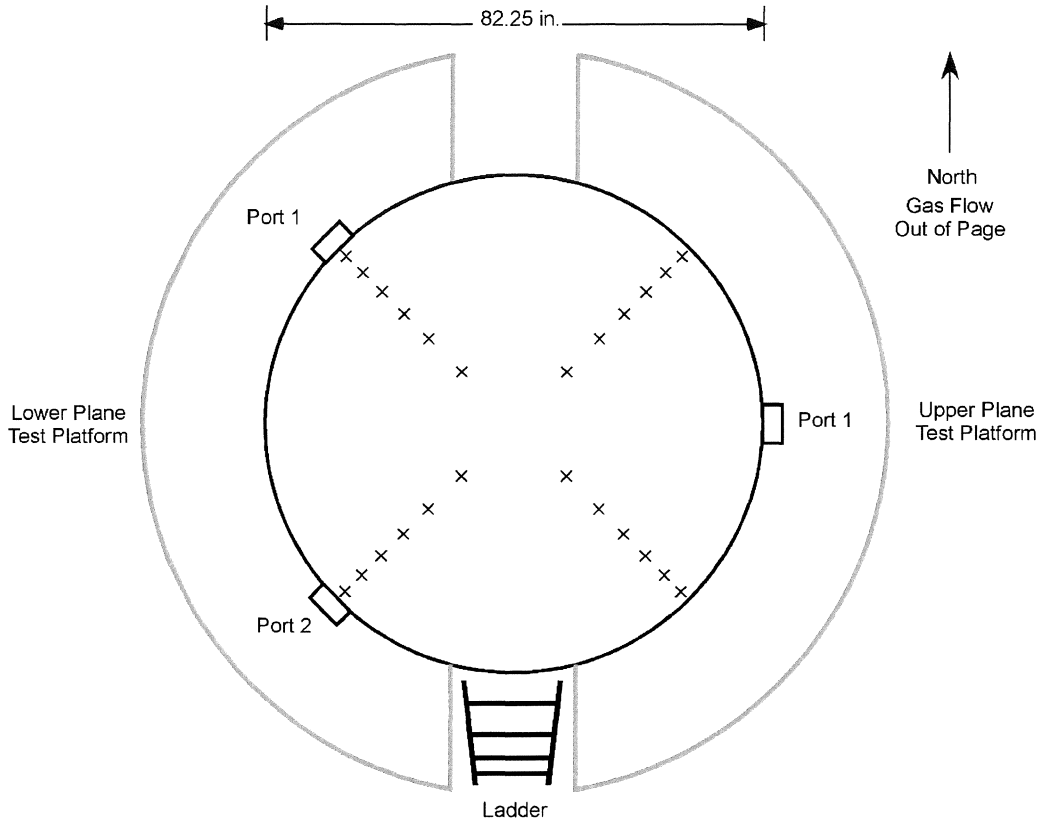
Run No.		1	2	3	Average
Date (2019)		Mar 14	Mar 14	Mar 14	
Start Time (approx.)		11:33	12:59	14:21	
Stop Time (approx.)		12:33	13:59	15:21	
Process Conditions					
R _P	Coke burn rate (Mlb/hr)	20.3	20.3	20.2	20.0
P ₁	FCC charge rate (bpd)	41,001	41,004	40,992	40,999
P ₂	NH ₃ Injection (lb/hr)	6.0	6.0	6.1	6.0
Cap	Capacity factor (hours/year)	8,760	8,760	8,760	
Gas Conditions					
O ₂	Oxygen (dry volume %)	2.0	2.0	2.1	2.0
CO ₂	Carbon dioxide (dry volume %)	16.5	16.5	16.5	16.5
B _w	Actual water vapor in gas (% by volume) ¹	10.8	10.2	13.7	11.6
THC Results					
C _{sd}	Concentration (ppmdv as C ₃ H ₈)	0.627	0.626	0.685	0.646
C _{sd}	Concentration (lb/dscf)	7.17E-08	7.16E-08	7.84E-08	7.39E-08
E _{lb/hr}	Emission Rate (lb/hr)	0.288	0.292	0.303	0.29
E _{T/yr}	Emission Rate (Ton/yr)	1.26	1.28	1.33	1.29
E _{Rp}	Emission Rate - Production-based (lb/Mlb)	0.0142	0.0144	0.0150	0.0145
VOC Results²					
C _{sd}	Concentration (ppmdv as C ₃ H ₈)	0.627	0.626	0.685	0.646
C _{sd}	Concentration (lb/dscf)	7.17E-08	7.16E-08	7.84E-08	7.39E-08
E _{lb/hr}	Emission Rate (lb/hr)	0.288	0.292	0.303	0.2944
E _{T/yr}	Emission Rate (Ton/yr)	1.26	1.28	1.33	1.29
E _{Rp}	Emission Rate - Production-based (lb/Mlb)	0.0142	0.0144	0.0150	0.0145

¹ Moisture data used for ppmw v to ppmdv correction obtained from nearly-concurrent CTM-013 runs.

² VOC is reported as THC since all THC results were less than the limit for VOC.

End of Section

**Figure 3-1:
 FCCU Regenerator Stack Sample Point Layout (EPA Methods 2F, 5F/202, & CTM-027)**



Note: Ports on the lower plane were used for these points.

Traverse Point	% of Stack Diameter	Port to Point Distance (inches)
1	97.9	80.5
2	93.3	76.7
3	88.2	72.5
4	82.3	67.7
5	75.0	61.7
6	64.4	53.0
7	35.6	29.3
8	25.0	20.6
9	17.7	14.6
10	11.8	9.7
11	6.7	5.5
12	2.1	1.7

Duct diameters upstream from flow disturbance (A): 2.2

Limit: 0.5

Duct diameters downstream from flow disturbance (B): 3.4

Limit: 2.0