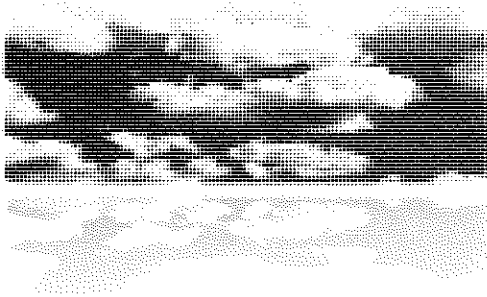


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AIR QUALITY DIVISION

CleanAir Engineering  
500 W. Wood Street  
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www.cleanair.com



REPORT ON COMPLIANCE  
TESTING

Detroit Refinery  
FCCU Regenerator Stack

Marathon Petroleum Company LP  
1300 South Fort Street  
Detroit, MI 48217  
Client Reference No. 4101379616

CleanAir Project No. 13488-1  
A2LA ISO 17025 Certificate No. 4342.01  
A2LA / STAC Certificate No. 4342.02  
Revision 1, Final Report  
April 12, 2018

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**1. PROJECT OVERVIEW****AIR QUALITY DIVISION****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 4.

**Table 1-1:  
Summary of NSFPM, CPM, and Total PM<sub>10</sub> Results (5F/202)**

| <b>FCCU Regenerator Stack</b>                   |                 | <b>NSFPM Rate<br/>(lb/Mlb coke)</b> | <b>CPM Rate<br/>(lb/Mlb coke)</b> | <b>Total PM<sub>10</sub> Rate<br/>(lb/Mlb coke)</b> |            |
|---|-----------------|-------------------------------------|-----------------------------------|---|------------|
| <b>Test Dates: 2/13-14/18</b>                   |                 |                                     |                                   |   |            |
| <b>Coke Burn Rate (lb/hr)</b>                   | <b>24,383</b>   | Run 1                               | 0.3                               | 0.6   | 0.9        |
| <b>FCC Rate (bpd)</b>                           | <b>40,997</b>   | Run 2                               | 0.4                               | 0.6   | 0.9        |
| <b>Aqueous NH<sub>3</sub> Injection (lb/hr)</b> | <b>32.1</b>     | Run 3                               | 0.3                               | 0.7   | 1.0        |
| <b>ESP Operation</b>                            | <b>Both/LPR</b> | <b>Average</b>                      | <b>0.3</b>                        | <b>0.6</b>  | <b>0.9</b> |
|   |                 | <b>Limit</b>                        | <b>0.8</b>                        |   | <b>1.1</b> |

Note: Average includes 3 runs for all parameters.

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**Table 1-2:  
Summary of NH<sub>3</sub> Results (CTM-027)**

| <b>FCCU Regenerator Stack</b>                   |                 | <b>NH<sub>3</sub> Conc.<br/>(ppmdv)</b> | <b>NH<sub>3</sub> Slip<br/>(lb/hr)</b> | <b>NH<sub>3</sub> Slip<br/>(lb/Mlb coke)</b> |             |
|---|-----------------|---|--|--|-------------|
| <b>Test Dates: 2/13-14/18</b>                   |                 |   |  |  |             |
| <b>Coke Burn Rate (lb/hr)</b>                   | <b>24,383</b>   | Run 1                                   | 15                                     | 3.2  | 0.13        |
| <b>FCC Rate (bpd)</b>                           | <b>40,997</b>   | Run 2                                   | 13                                     | 2.8  | 0.11        |
| <b>Aqueous NH<sub>3</sub> Injection (lb/hr)</b> | <b>32.1</b>     | Run 3                                   | 16                                     | 3.3  | 0.14        |
| <b>ESP Operation</b>                            | <b>Both/LPR</b> | <b>Average</b>                          | <b>15</b>                              | <b>3.1</b>                                   | <b>0.13</b> |

Note: Average includes 3 runs for all parameters.

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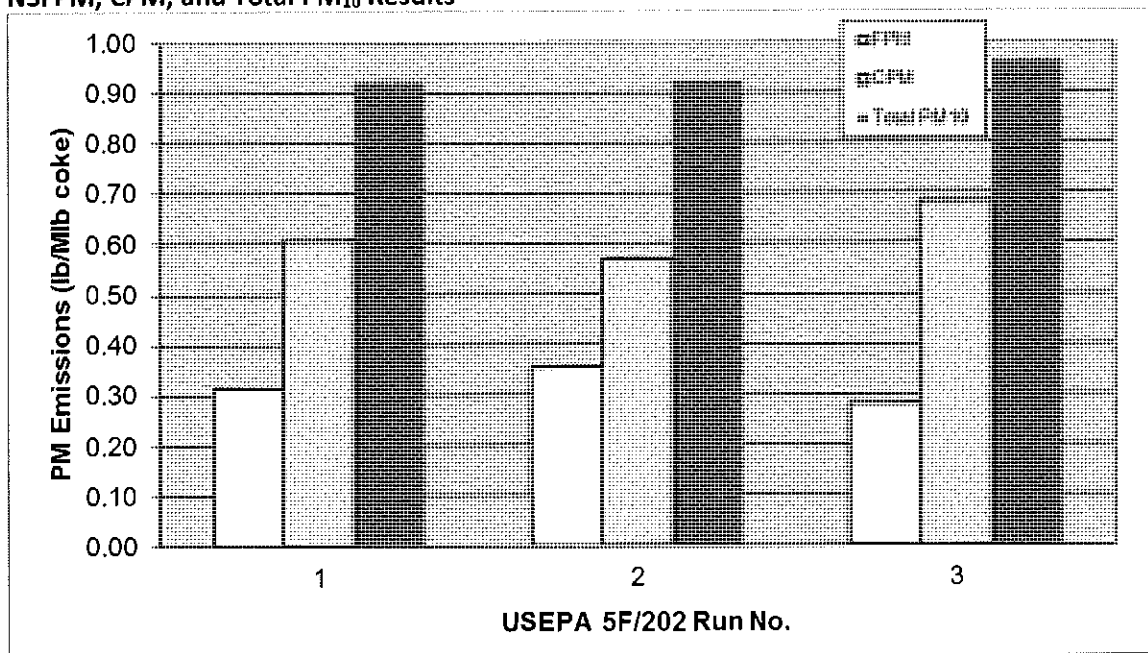
**Table 1-3:**  
**Summary of H<sub>2</sub>SO<sub>4</sub> and VOC Results (Draft ASTM CCM & 18/25A)**

| Source                         |               | Sampling Method | Average Emission | Permit Limit <sup>1</sup> |
|--------------------------------|---------------|-----------------|------------------|---------------------------|
| Constituent (Units)            |               |                 |                  |                           |
| <u>FCCU Regenerator Stack</u>  |               |                 |                  |                           |
| H <sub>2</sub> SO <sub>4</sub> | (lb/Mlb coke) | Draft ASTM CCM  | 0.034            | N/A                       |
| H <sub>2</sub> SO <sub>4</sub> | (ppmdv)       | Draft ASTM CCM  | 0.69             | N/A                       |
| VOC                            | (Ton/yr)      | USEPA 25A / 18  | 8.5              | 21                        |
| VOC                            | (lb/Mlb coke) | USEPA 25A / 18  | 0.080            | N/A                       |

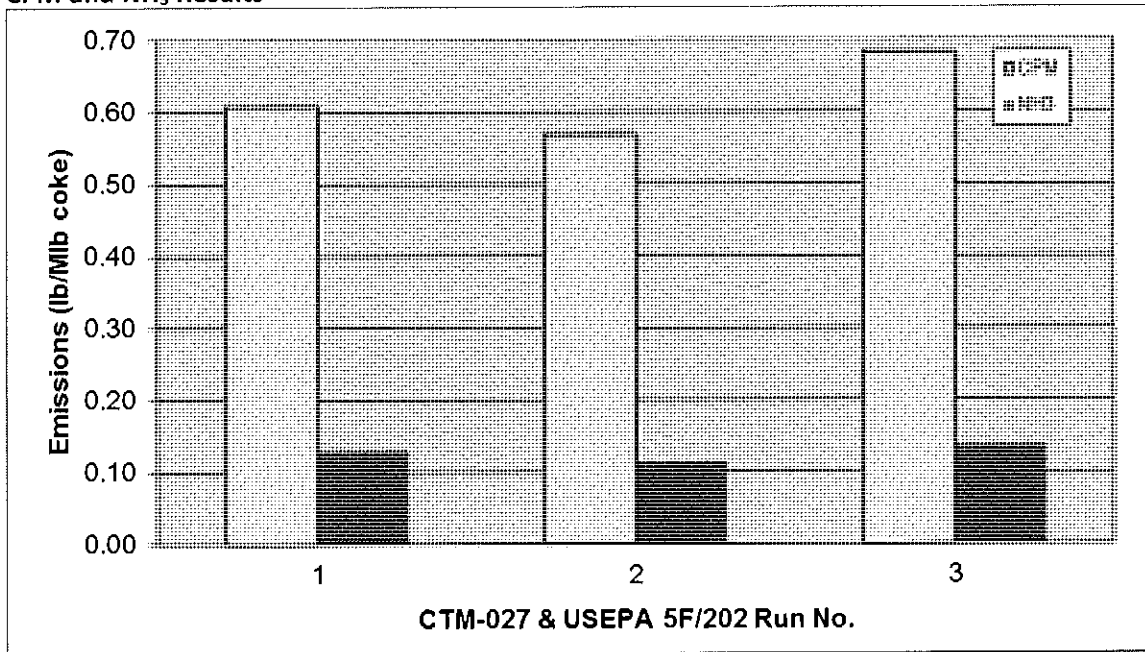
<sup>1</sup> Permit limit obtained from MDEQ Permit No. MI-ROP-A9831-2012c.

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**Figure 1-1:**  
**NSFPM, CPM, and Total PM<sub>10</sub> Results**



**Figure 1-2:  
 CPM and NH<sub>3</sub> 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 ( $\mu\text{m}$ ) in diameter (Total PM<sub>10</sub>), assumed equivalent to the sum of the following constituents:
  - NSFPM
  - condensable particulate matter (CPM)
- ammonia (NH<sub>3</sub>)
- sulfuric acid (H<sub>2</sub>SO<sub>4</sub>)
- volatile organic compounds (VOCs), assumed equivalent to total hydrocarbons (THCs) minus the following constituents:
  - methane (CH<sub>4</sub>)
  - ethane (C<sub>2</sub>H<sub>6</sub>)
- flue gas composition (e.g., O<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>O)
- flue gas flow rate
- flue gas velocity decay (wall-effects)

## Schedule

Testing was performed on February 13 and 14, 2018. 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 2 / 2H            | Velocity Decay   | 02/13/18 | 10:35      | 10:50    |
| 1          | FCCU Regenerator Stack | USEPA Method 2F                | 3-D Velocity & Flow Rate   | 02/13/18 | 14:29      | 14:40    |
| 1          | FCCU Regenerator Stack | USEPA Method 5F/202            | NSFPM/CPM  | 02/13/18 | 15:25      | 16:37    |
| 1          | FCCU Regenerator Stack | CTM-027                        | Ammonia  | 02/13/18 | 15:25      | 16:37    |
| 2          | FCCU Regenerator Stack | USEPA Method 2F                | 3-D Velocity & Flow Rate   | 02/13/18 | 17:03      | 17:14    |
| 2          | FCCU Regenerator Stack | USEPA Method 5F/202            | NSFPM/CPM  | 02/13/18 | 17:55      | 19:07    |
| 2          | FCCU Regenerator Stack | CTM-027                        | Ammonia  | 02/13/18 | 17:58      | 19:06    |
| 3          | FCCU Regenerator Stack | USEPA Method 2F                | 3-D Velocity & Flow Rate   | 02/13/18 | 19:27      | 19:36    |
| 4          | FCCU Regenerator Stack | USEPA Method 2F                | 3-D Velocity & Flow Rate   | 02/14/18 | 7:40       | 07:48    |
| 3          | FCCU Regenerator Stack | USEPA Method 5F/202            | NSFPM/CPM  | 02/14/18 | 08:20      | 09:30    |
| 3          | FCCU Regenerator Stack | CTM-027                        | Ammonia  | 02/14/18 | 08:20      | 09:30    |
| 5          | FCCU Regenerator Stack | USEPA Method 2F                | Cyclonic Flow  | 02/14/18 | 09:50      | 09:57    |
| 0          | FCCU Regenerator Stack | CTM-013 (mod) / Draft ASTM CCM | H <sub>2</sub> SO <sub>4</sub>   | 02/14/18 | 11:55      | 13:09    |
| 6          | FCCU Regenerator Stack | USEPA Method 2F                | 3-D Velocity & Flow Rate   | 02/14/18 | 13:13      | 13:26    |
| 1          | FCCU Regenerator Stack | CTM-013 (mod) / Draft ASTM CCM | H <sub>2</sub> SO <sub>4</sub>   | 02/14/18 | 13:37      | 14:37    |
| 1          | FCCU Regenerator Stack | 3A / 18 / 25A                  | O <sub>2</sub> / CO <sub>2</sub> / CH <sub>4</sub> / C <sub>2</sub> H <sub>6</sub> / THC | 02/14/18 | 13:39      | 14:41    |
| 7          | FCCU Regenerator Stack | USEPA Method 2F                | 3-D Velocity & Flow Rate   | 02/14/18 | 16:01      | 16:10    |
| 2          | FCCU Regenerator Stack | CTM-013 (mod) / Draft ASTM CCM | H <sub>2</sub> SO <sub>4</sub>   | 02/14/18 | 16:00      | 17:00    |
| 2          | FCCU Regenerator Stack | 3A / 18 / 25A                  | O <sub>2</sub> / CO <sub>2</sub> / CH <sub>4</sub> / C <sub>2</sub> H <sub>6</sub> / THC | 02/14/18 | 16:22      | 17:23    |
| 8          | FCCU Regenerator Stack | USEPA Method 2F                | 3-D Velocity & Flow Rate   | 02/14/18 | 17:27      | 17:34    |
| 3          | FCCU Regenerator Stack | CTM-013 (mod) / Draft ASTM CCM | H <sub>2</sub> SO <sub>4</sub>   | 02/14/18 | 17:25      | 18:25    |
| 3          | FCCU Regenerator Stack | 3A / 18 / 25A                  | O <sub>2</sub> / CO <sub>2</sub> / CH <sub>4</sub> / C <sub>2</sub> H <sub>6</sub> / THC | 02/14/18 | 17:39      | 18:39    |

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## Discussion

### *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*

Three (3) 60-minute Method 5F/202 test runs were performed on February 13 and 14.

For this test program, PM emission rate is assumed equivalent to NSFPM emission rate and PM<sub>10</sub> 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.

*NH<sub>3</sub> Testing*

Three (3) 60-minute CTM-027 test runs were performed on February 13 and 14. Each test run was performed concurrently with Method 5F/202 testing.

The integrated gas sample (IGS) bag from CTM-027 Run 1 became compromised following testing and was unable to be analyzed for O<sub>2</sub> and CO<sub>2</sub>. Instead, the O<sub>2</sub> and CO<sub>2</sub> results from the concurrently operated Method 5F/202 test run were used for resultant calculations.

*H<sub>2</sub>SO<sub>4</sub> 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 H<sub>2</sub>SO<sub>4</sub>-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.

Following the conditioning run on February 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) approximately 60-minute Method 18 IGS collections for CH<sub>4</sub> and C<sub>2</sub>H<sub>6</sub>.

VOC emission rate is normally equivalent to THC emission rate, minus CH<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> emission rate (units of lb/hr, Ton/yr, or lb/Mlb coke for all constituents). For CH<sub>4</sub> and C<sub>2</sub>H<sub>6</sub>, a result less than the limit of quantitation 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 measured during the run, as determined by EPA Method 2 without the WAF correction 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 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.

NH<sub>3</sub> injection rates shown in Tables 2-1 and 2-2 are the aqueous NH<sub>3</sub> (11FC2032) multiplied by a factor of 0.2.

---

*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:  
NSFPM, CPM, and Total PM<sub>10</sub> (5F/202)**

| Run No.  | 1        | 2        | 3        | Average  |
|--|----------|----------|----------|----------|
| Date (2018)  | Feb 13   | Feb 13   | Feb 14   |          |
| Start Time (approx)  | 15:25    | 17:55    | 08:20    |          |
| Stop Time (approx)   | 16:37    | 19:07    | 09:30    |          |
| <b>Process Conditions</b>  |          |          |          |          |
| R <sub>P</sub> Production rate (Mb coke/hr)                      | 24.4     | 24.3     | 24.5     | 24.4     |
| P <sub>1</sub> FCC charge rate (bpd)                             | 41,001   | 40,990   | 41,000   | 40,997   |
| P <sub>2</sub> Ammonia Injection (lb/hr)                         | 6.4      | 6.4      | 6.4      | 6.4      |
| P <sub>3</sub> ESP Operation                                     | Both/LPR | Both/LPR | Both/LPR |          |
| Cap Capacity factor (hours/year)                                 | 8,760    | 8,760    | 8,760    | 8,760    |
| <b>Gas Conditions</b>  |          |          |          |          |
| O <sub>2</sub> Oxygen (dry volume %)                             | 2.9      | 5.3      | 4.5      | 4.2      |
| CO <sub>2</sub> Carbon dioxide (dry volume %)                    | 15.2     | 15.4     | 14.1     | 14.9     |
| T <sub>s</sub> Sample temperature (°F)                           | 496      | 496      | 496      | 496      |
| B <sub>w</sub> Actual water vapor in gas (% by volume)           | 8.9      | 8.5      | 8.9      | 8.8      |
| <b>Gas Flow Rate<sup>1</sup></b>                                 |          |          |          |          |
| Q <sub>a</sub> Volumetric flow rate, actual (acfm)               | 155,000  | 154,000  | 153,000  | 154,000  |
| Q <sub>s</sub> Volumetric flow rate, standard (scfm)             | 85,500   | 85,000   | 83,700   | 84,700   |
| Q <sub>std</sub> Volumetric flow rate, dry standard (dscfm)      | 78,000   | 77,800   | 76,200   | 77,300   |
| <b>Sampling Data</b>   |          |          |          |          |
| V <sub>metd</sub> Volume metered, standard (dscf)                | 41.34    | 42.24    | 40.87    | 41.48    |
| %I Isokinetic sampling (%) <sup>2</sup>                          | 101.2    | 101.2    | 102.7    | 101.7    |
| <b>Laboratory Data</b>   |          |          |          |          |
| m <sub>n</sub> Total NSFPM (g)                                   | 0.03075  | 0.03542  | 0.02789  |          |
| m <sub>CPM</sub> Total CPM (g)                                   | 0.05937  | 0.05675  | 0.06772  |          |
| <b>NSFPM Results</b>   |          |          |          |          |
| C <sub>sd</sub> Particulate Concentration (lb/dscf)              | 1.64E-06 | 1.85E-06 | 1.50E-06 | 1.66E-06 |
| E <sub>lb/hr</sub> Particulate Rate (lb/hr)                      | 7.67     | 8.63     | 6.88     | 7.73     |
| E <sub>T/yr</sub> Particulate Rate (Ton/yr)                      | 33.6     | 37.8     | 30.2     | 33.9     |
| E <sub>Rp</sub> Particulate Rate - Production-based (lb/Mb coke) | 0.315    | 0.355    | 0.282    | 0.317    |
| <b>CPM Results</b>   |          |          |          |          |
| C <sub>sd</sub> Particulate Concentration (lb/dscf)              | 3.17E-06 | 2.96E-06 | 3.65E-06 | 3.26E-06 |
| E <sub>lb/hr</sub> Particulate Rate (lb/hr)                      | 14.8     | 13.8     | 16.7     | 15.1     |
| E <sub>T/yr</sub> Particulate Rate (Ton/yr)                      | 64.9     | 60.6     | 73.2     | 66.2     |
| E <sub>Rp</sub> Particulate Rate - Production-based (lb/Mb coke) | 0.608    | 0.568    | 0.684    | 0.620    |
| <b>Total Particulate (as PM<sub>10</sub>) Results</b>            |          |          |          |          |
| C <sub>sd</sub> Particulate Concentration (lb/dscf)              | 4.81E-06 | 4.81E-06 | 5.16E-06 | 4.93E-06 |
| E <sub>lb/hr</sub> Particulate Rate (lb/hr)                      | 22.5     | 22.5     | 23.6     | 22.8     |
| E <sub>T/yr</sub> Particulate Rate (Ton/yr)                      | 98.5     | 98.4     | 103      | 100      |
| E <sub>Rp</sub> Particulate Rate - Production-based (lb/Mb coke) | 0.923    | 0.922    | 0.965    | 0.937    |

Average includes 3 runs.

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<sup>1</sup> Gas flow rates obtained from concurrent or bracketing Method 2F test runs combined with the WAF determined by Method 2H.

<sup>2</sup> Sample flow rates as determined by EPA Method 2 were used to calculate isokinetic sampling conditions.



**Table 2-2:  
NH<sub>3</sub> (CTM-027)**

| Run No.   | 1        | 2        | 3        | Average  |
|---|----------|----------|----------|----------|
| Date (2018)   | Feb 13   | Feb 13   | Feb 14   |          |
| Start Time (approx.)  | 15:25    | 17:58    | 08:20    |          |
| Stop Time (approx.)   | 16:37    | 19:06    | 09:30    |          |
| <b>Process Conditions</b>                                     |          |          |          |          |
| R <sub>p</sub> Production rate - (Mlb coke/hr)                | 24.4     | 24.3     | 24.5     | 24.4     |
| P <sub>1</sub> FCC charge rate - (bpd)                        | 41,001   | 40,990   | 41,000   | 40,997   |
| P <sub>2</sub> Ammonia Injection - (lb/hr)                    | 6.4      | 6.4      | 6.4      | 6.4      |
| P <sub>3</sub> ESP Operation                                  | Both/LPR | Both/LPR | Both/LPR |          |
| Cap Capacity factor (hours/year)                              | 8,760    | 8,760    | 8,760    | 8,760    |
| <b>Gas Conditions</b>   |          |          |          |          |
| O <sub>2</sub> Oxygen (dry volume %)                          | 2.9      | 3.0      | 2.7      | 2.9      |
| CO <sub>2</sub> Carbon dioxide (dry volume %)                 | 15.2     | 15.2     | 15.8     | 15.4     |
| T <sub>s</sub> Sample temperature (°F)                        | 491      | 493      | 489      | 491      |
| B <sub>w</sub> Actual water vapor in gas (% by volume)        | 9.62     | 9.72     | 9.04     | 9.46     |
| <b>Gas Flow Rate<sup>1</sup></b>                              |          |          |          |          |
| Q <sub>a</sub> Volumetric flow rate, actual (acfm)            | 155,000  | 154,000  | 153,000  | 154,000  |
| Q <sub>s</sub> Volumetric flow rate, standard (scfm)          | 85,500   | 85,000   | 83,700   | 84,700   |
| Q <sub>std</sub> Volumetric flow rate, dry standard (dscfm)   | 78,000   | 77,800   | 76,200   | 77,300   |
| <b>Sampling Data</b>  |          |          |          |          |
| V <sub>mstd</sub> Volume metered, standard (dscf)             | 37.13    | 38.07    | 41.08    | 38.76    |
| %I Isokinetic sampling (%) <sup>2</sup>                       | 102.8961 | 98.5647  | 105.2206 | 102.2271 |
| <b>Laboratory Data</b>  |          |          |          |          |
| m <sub>n</sub> Total NH <sub>3</sub> collected (mg)           | 11.43256 | 10.20477 | 13.49298 |          |
| <b>Ammonia (NH<sub>3</sub>) Results</b>                       |          |          |          |          |
| C <sub>sd</sub> Ammonia Concentration (lb/dscf)               | 6.79E-07 | 5.91E-07 | 7.24E-07 | 6.65E-07 |
| C <sub>sd</sub> Ammonia Concentration (ppmdv)                 | 15.4     | 13.4     | 16.4     | 15.0     |
| E <sub>lb/hr</sub> Ammonia Rate (lb/hr)                       | 3.18     | 2.76     | 3.31     | 3.08     |
| E <sub>T/yr</sub> Ammonia Rate (Ton/yr)                       | 13.9     | 12.1     | 14.5     | 13.5     |
| E <sub>Rp</sub> Ammonia Rate - Production-based (lb/Mlb coke) | 0.130    | 0.113    | 0.136    | 0.126    |

Average includes 3 runs.

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<sup>1</sup> Gas flow rates obtained from concurrent or bracketing Method 2F test runs combined with the WAF determined by Method 2H.<sup>2</sup> Sample flow rates as determined by EPA Method 2 were used to calculate isokinetic sampling conditions.

**Table 2-3:  
H<sub>2</sub>SO<sub>4</sub> (Draft ASTM CCM)**

| Run No.  | 1        | 2        | 3        | Average         |
|--|----------|----------|----------|-----------------|
| Date (2018)  | Feb 14   | Feb 14   | Feb 14   |                 |
| Start Time (approx.)   | 13:37    | 16:00    | 17:25    |                 |
| Stop Time (approx.)  | 14:37    | 17:00    | 18:25    |                 |
| <b>Process Conditions</b>  |          |          |          |                 |
| R <sub>p</sub> Coke burn rate (lb/hr)  | 24.2     | 24.2     | 24.1     | <b>24.2</b>     |
| P <sub>1</sub> FCC charge rate (bpd)   | 40,996   | 40,983   | 40,997   | <b>40,992</b>   |
| P <sub>2</sub> NH3 Injection (lb/hr)   | 6.42     | 6.31     | 6.24     | <b>6.33</b>     |
| Cap Capacity factor (hours/year)   | 8,760    | 8,760    | 8,760    | <b>8,760</b>    |
| <b>Gas Conditions</b>  |          |          |          |                 |
| O <sub>2</sub> Oxygen (dry volume %)   | 2.8      | 3.1      | 2.8      | <b>2.9</b>      |
| CO <sub>2</sub> Carbon dioxide (dry volume %)  | 14.7     | 15.0     | 15.3     | <b>15.0</b>     |
| T <sub>s</sub> Sample temperature (°F)   | 494      | 496      | 495      | <b>495</b>      |
| B <sub>w</sub> Actual water vapor in gas (% by volume)                               | 11.4     | 9.9      | 10.8     | <b>10.7</b>     |
| <b>Gas Flow Rate<sup>1</sup></b>   |          |          |          |                 |
| Q <sub>a</sub> Volumetric flow rate, actual (acfm)                                   | 161,000  | 158,000  | 156,000  | <b>158,000</b>  |
| Q <sub>s</sub> Volumetric flow rate, standard (scfm)                                 | 87,600   | 85,600   | 84,800   | <b>86,000</b>   |
| Q <sub>std</sub> Volumetric flow rate, dry standard (dscfm)                          | 77,600   | 77,100   | 75,600   | <b>76,800</b>   |
| <b>Sampling Data</b>   |          |          |          |                 |
| V <sub>mstd</sub> Volume metered, standard (dscf)                                    | 27.15    | 27.12    | 27.03    | <b>27.10</b>    |
| <b>Laboratory Data (Ion Chromatography)</b>  |          |          |          |                 |
| m <sub>n</sub> Total H <sub>2</sub> SO <sub>4</sub> collected (mg)                   | 3.3837   | 0.8252   | 2.2918   |                 |
| <b>Sulfuric Acid Vapor (H<sub>2</sub>SO<sub>4</sub>) Results</b>                     |          |          |          |                 |
| C <sub>sd</sub> H <sub>2</sub> SO <sub>4</sub> Concentration (lb/dscf)               | 2.75E-07 | 6.71E-08 | 1.87E-07 | <b>1.76E-07</b> |
| C <sub>sd</sub> H <sub>2</sub> SO <sub>4</sub> Concentration (ppm <sub>dv</sub> )    | 1.08     | 0.264    | 0.735    | <b>0.693</b>    |
| E <sub>T/yr</sub> H <sub>2</sub> SO <sub>4</sub> Rate (Ton/yr)                       | 5.61     | 1.36     | 3.72     | <b>3.56</b>     |
| E <sub>Rp</sub> H <sub>2</sub> SO <sub>4</sub> Rate - Production-based (lb/Mlb coke) | 0.0530   | 0.0128   | 0.0353   | <b>0.0337</b>   |

Average includes 3 runs.

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<sup>1</sup> Gas flow rates obtained from concurrent Method 2F test runs combined with the WAF determined by Method 2H

**Table 2-4:  
THC, CH<sub>4</sub>, C<sub>2</sub>H<sub>6</sub>, and VOC Emissions (USEPA 25A/18)**

| Run No.  | 1         | 2         | 3         | Average   |
|--|-----------|-----------|-----------|-----------|
| Date (2018)  | Feb 14    | Feb 14    | Feb 14    |           |
| Start Time (approx.)   | 13:39     | 16:22     | 17:39     |           |
| Stop Time (approx.)  | 14:41     | 17:23     | 18:39     |           |
| <b>Process Conditions</b>  |           |           |           |           |
| R <sub>P</sub> Coke burn rate (Mb/hr)                                    | 24.2      | 24.2      | 24.2      | 24.2      |
| P <sub>1</sub> FCC charge rate (bpd)                                     | 40,999    | 40,986    | 41,001    | 40,995    |
| P <sub>2</sub> NH <sub>3</sub> injection (lb/hr)                         | 6.4       | 6.3       | 6.2       | 6.3       |
| Cap Capacity factor (hours/year)   | 8,760     | 8,760     | 8,760     | 8,760     |
| <b>Gas Conditions</b>  |           |           |           |           |
| O <sub>2</sub> Oxygen (dry volume %)                                     | 1.7       | 1.9       | 1.7       | 1.8       |
| CO <sub>2</sub> Carbon dioxide (dry volume %)                            | 16.9      | 16.9      | 16.9      | 16.9      |
| B <sub>w</sub> Actual water vapor in gas (% by volume) <sup>1</sup>      | 11.4      | 9.9       | 10.8      | 10.7      |
| <b>Gas Flow Rate<sup>2</sup></b>   |           |           |           |           |
| Q <sub>a</sub> Volumetric flow rate, actual (acfm)                       | 161,000   | 158,000   | 156,000   | 158,000   |
| Q <sub>s</sub> Volumetric flow rate, standard (scfm)                     | 87,600    | 85,600    | 84,800    | 86,000    |
| Q <sub>std</sub> Volumetric flow rate, dry standard (dscfm)              | 77,600    | 77,100    | 75,600    | 76,800    |
| <b>THC Results</b>   |           |           |           |           |
| C <sub>std</sub> Concentration (ppmdv as C <sub>3</sub> H <sub>8</sub> ) | 4.44      | 3.08      | 3.49      | 3.67      |
| C <sub>std</sub> Concentration (lb/dscf)                                 | 5.08E-07  | 3.53E-07  | 3.99E-07  | 4.20E-07  |
| E <sub>lb/hr</sub> Emission Rate (lb/hr)                                 | 2.37      | 1.63      | 1.81      | 1.94      |
| E <sub>T/yr</sub> Emission Rate (Ton/yr)                                 | 10.37     | 7.15      | 7.93      | 8.48      |
| E <sub>Rp</sub> Emission Rate - Production-based (lb/Mlb coke)           | 0.0979    | 0.0676    | 0.0749    | 0.0801    |
| <b>Methane Results</b>   |           |           |           |           |
| C <sub>std</sub> Concentration (ppmdv)                                   | <0.490    | 0.530     | <0.490    | <0.503    |
| C <sub>std</sub> Concentration (lb/dscf)                                 | <2.04E-08 | 2.21E-08  | <2.04E-08 | <2.10E-08 |
| E <sub>lb/hr</sub> Emission Rate (lb/hr)                                 | <0.0950   | 0.10      | <0.0926   | <0.0966   |
| E <sub>T/yr</sub> Emission Rate (Ton/yr)                                 | <0.416    | 0.447     | <0.406    | <0.423    |
| E <sub>Rp</sub> Emission Rate - Production-based (lb/Mlb coke)           | <0.00393  | 0.0042    | <0.00383  | <0.00399  |
| <b>Ethane Results</b>  |           |           |           |           |
| C <sub>std</sub> Concentration (ppmdv)                                   | <0.200    | <0.200    | <0.200    | <0.200    |
| C <sub>std</sub> Concentration (lb/dscf)                                 | <1.56E-08 | <1.56E-08 | <1.56E-08 | <1.56E-08 |
| E <sub>lb/hr</sub> Emission Rate (lb/hr)                                 | <0.0727   | <0.0722   | <0.0708   | <0.0719   |
| E <sub>T/yr</sub> Emission Rate (Ton/yr)                                 | <0.318    | <0.316    | <0.310    | <0.315    |
| E <sub>Rp</sub> Emission Rate - Production-based (lb/Mlb coke)           | <0.00301  | <0.00299  | <0.00293  | <0.00297  |
| <b>VOC Results</b>   |           |           |           |           |
| E <sub>lb/hr</sub> Emission Rate (lb/hr)                                 | 2.37      | 1.63      | 1.81      | 1.94      |
| E <sub>T/yr</sub> Emission Rate (Ton/yr)                                 | 10.37     | 7.15      | 7.93      | 8.48      |
| E <sub>Rp</sub> Emission Rate - Production-based (lb/Mlb coke)           | 0.0979    | 0.0676    | 0.0749    | 0.0801    |

Average includes 3 runs.

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<sup>1</sup> Moisture data used for ppmv to ppmdv correction obtained from nearly-concurrent Draft ASTM CCM runs.<sup>2</sup> Gas flow rates obtained from concurrent Method 2F test runs combined with the WAF determined by Method 2H.

For methane and ethane, "&lt;" indicates a measured response below the analytical detection limit determined by the laboratory.

For all calculated averages, "&lt;" values are treated as the entire value of the detection limit.

End of Section

### 3. DESCRIPTION OF INSTALLATION

#### Process Description

MPC's facility in Detroit, Michigan, produces refined petroleum products from crude oil. MPC must continue to demonstrate that select process units are in compliance with permitted emission limits.

The Fluid Catalytic Cracking Unit (EU11-FCCU-S1) utilizes a primary reactor, a distillation column and a catalyst regeneration unit to continuously generate light hydrocarbon products from heavy oil feeds. The FCCU is equipped with an ESP with two (2) bays and variable aqueous NH<sub>3</sub> injection to control emissions. Emissions are vented to the atmosphere via the FCCU Regenerator Stack (SVFCCU).

The testing described in this document was performed at the FCCU Regenerator Stack.

#### Test Location

EPA Methods 1 and 2H specifications determined the sample point locations. Table 3-1 presents the sampling information for the test location. The figures shown on pages 12 and 13 represent the layout of the test location.

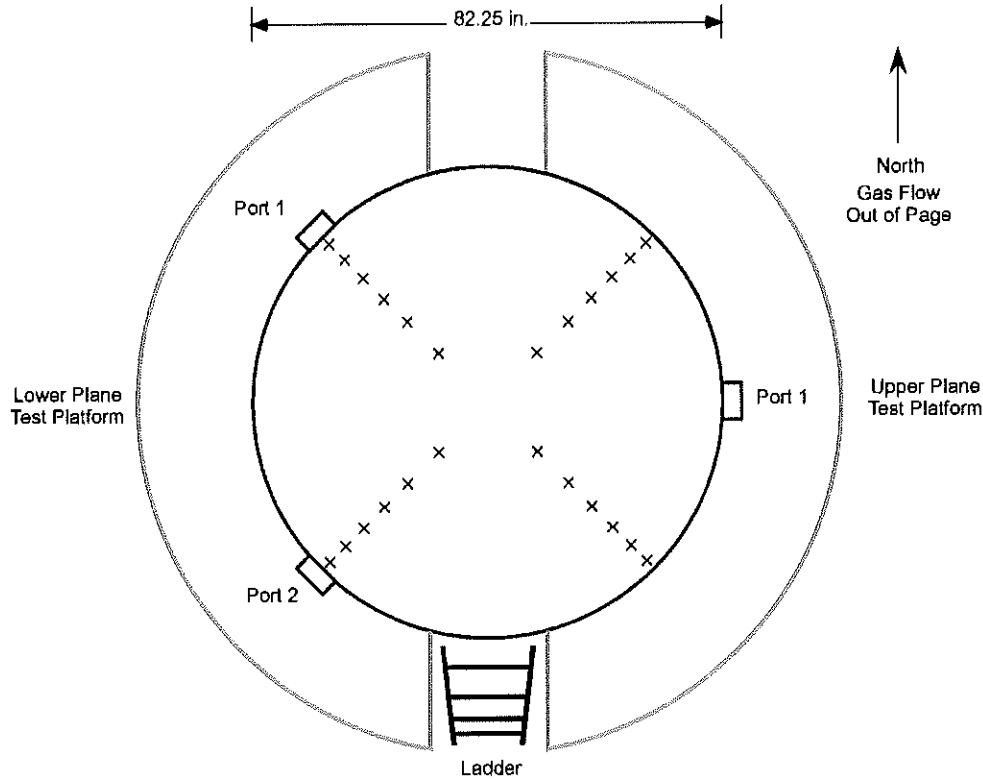
**Table 3-1:  
Sampling Information**

| Source   | Method              | Run No. | Ports | Points per Port | Minutes per Point | Total Minutes | Figure           |
|--|---------------------|---------|-------|-----------------|-------------------|---------------|------------------|
| <b>FCCU Regenerator Stack</b>  |                     |         |       |                 |                   |               |                  |
| Flow Rate  | USEPA 2F            | 1-8     | 2     | 12              | varied            | varied        | 3-1              |
| Velocity Decay   | USEPA 2H            | 1       | 2     | 6               | varied            | varied        | 3-2              |
| NSFPM/CPM  | USEPA 5F / 202      | 1-3     | 2     | 12              | 2.5               | 60            | 3-1              |
| NH <sub>3</sub>  | USEPA CTM-027       | 1-3     | 2     | 12              | 2.5               | 60            | 3-1              |
| H <sub>2</sub> SO <sub>4</sub>   | Draft ASTM CCM      | 1-3     | 1     | 1               | 60                | 60            | N/A <sup>1</sup> |
| O <sub>2</sub> /CO <sub>2</sub> /CH <sub>4</sub> /C <sub>2</sub> H <sub>6</sub> /THC | USEPA 3A / 18 / 25A | 1-3     | 1     | 1               | 60                | 60            | N/A <sup>1</sup> |

<sup>1</sup> Sampling occurred at a single point near the center of duct.

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**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                             |

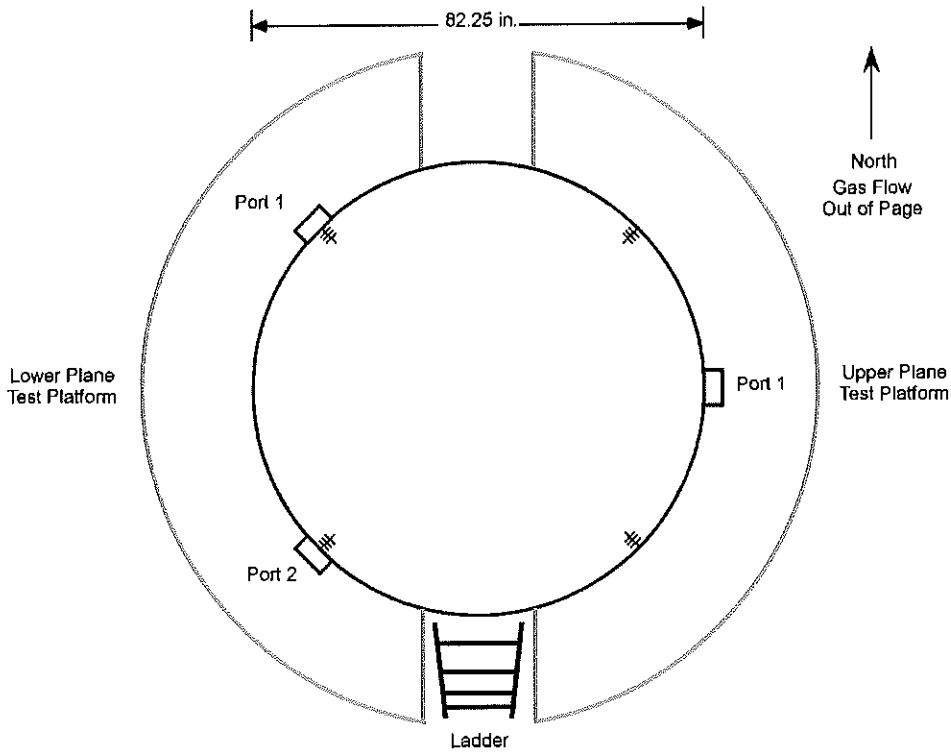
Duct diameters upstream from flow disturbance (A): 2.2

Limit: 0.5

Duct diameters downstream from flow disturbance (B): 3.4

Limit: 2.0

**Figure 3-2:  
 FCCU Regenerator Stack Sample Point Layout (EPA Method 2H)**



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

| Traverse Point | Port to Point Distance (inches) |
|----------------|---------------------------------|
| 1              | 81.25                           |
| 2              | 80.25                           |
| 3              | 79.25                           |
| 4              | 3.0                             |
| 5              | 2.0                             |
| 6              | 1.0                             |

Duct diameters upstream from flow disturbance (A): 2.2      Limit: 0.5  
 Duct diameters downstream from flow disturbance (B): 3.4      Limit: 2.0

End of Section

## 4. METHODOLOGY

### Procedures and Regulations

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The test program sampling measurements followed procedures and regulations outlined by the United States Environmental Protection Agency (USEPA) and the Michigan 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 2F  | "Determination of Stack Gas Velocity and Volumetric Flow Rate with Three-Dimensional Probes"                                       |
| Method 2H  | "Determination of Stack Gas Velocity Taking into Account Velocity Decay near the Stack Wall"                                       |
| 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 5F  | "Determination of Nonsulfate Particulate Matter Emissions from Stationary Sources"   |
| 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 51, Appendix M

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

#### Conditional Test Methods

|         |  |
|---------|--|
| CTM-027 | "Procedure for Collection and Analysis of Ammonia in 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

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#### USEPA Method 5F/202

PM and PM<sub>10</sub> emissions were determined using EPA Method 5F/202.

- For this test program, PM is assumed equivalent to NSFPM. Per 40 CFR Subpart Ja §60.104a, EPA Method 5F is permitted for measuring front-half PM emissions from FCCUs.
- PM<sub>10</sub> is equivalent to the sum of filterable particulate matter less than 10 micrometers (µm) in diameter (FPM<sub>10</sub>) and (CPM). The Method 5F/202 sample train yields a front-half, non-sulfate FPM result and a back-half, CPM result. The total non-sulfate PM result (NSFPM plus CPM) from Method 5F/202 can be used as a worst-case estimation of Total PM<sub>10</sub> since Method 5F will collect all NSFPM present in the flue gas (regardless of particle size).

The front-half (Method 5F portion) of the sampling train consisted of a glass nozzle, glass liner, and filter holder heated to 320°F, and a quartz fiber filter heated to 320°F. Flue gas samples were extracted isokinetically; nozzle and probe liner recoveries were performed using de-ionized water (DI H<sub>2</sub>O) as the recovery solvent.

The back-half (Method 202 portion) of the sampling train is designed to mimic ambient conditions and collect only the particles that would truly form CPM in the atmosphere by minimizing the sulfur dioxide (SO<sub>2</sub>) and nitrogen oxide (NO<sub>x</sub>) interferences observed with earlier versions of the method, in which flue gas was bubbled through cold water, and SO<sub>2</sub> and NO<sub>x</sub> were absorbed and partially oxidized before they could be purged out with nitrogen (N<sub>2</sub>).

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 (2) 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 5F requirements. 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<sub>2</sub> at a rate of 14 liters per minute (lpm) for one (1) 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 in Palatine, Illinois, for gravimetric analysis. Method 202 samples were maintained at a temperature < 85°F during transport to the laboratory.

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<sub>2</sub>SO<sub>4</sub>, 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.

## USEPA CTM-027

NH<sub>3</sub> emissions were determined using a CTM-027 and an isokinetic, multi-point sample train. The sampling system consisted of a glass nozzle, in-stack quartz filter, glass-lined heated probe, impinger train (for NH<sub>3</sub> collection and H<sub>2</sub>O removal and measurement), and a dry gas meter. The NH<sub>3</sub>-collecting impingers were charged with 0.1 N H<sub>2</sub>SO<sub>4</sub> solution.

The filter temperature, as noted on the raw data sheets, is actually the heated area between the probe outlet and impinger inlet of the sampling train. The actual filter was in-stack at stack temperature.

The sampling system traversed all of the Method 1 points during each run. A minimum volume of 0.9 dry standard cubic meters (dscm), or 31.8 dry standard cubic feet (dscf), were sampled during each 60-minute run.

The sample train was recovered per CTM-027 requirements. The front-half assembly (components prior to the in-stack filter) was not recovered or analyzed, as gaseous NH<sub>3</sub> passed through without reacting or changing state. The three (3) NH<sub>3</sub>-collecting impingers were recovered separately per CTM-027 requirements. The back-half of the sample train prior to Impinger 1 (heated probe and connecting glassware) was rinsed into Impinger 1.

Samples were brought back to CleanAir Analytical Services in Palatine, Illinois, for ion chromatography (IC) analysis.

## Draft ASTM Controlled Condensation Method

H<sub>2</sub>SO<sub>4</sub> emissions were determined referencing the Draft ASTM Controlled Condensation Method (CCM).

A gas sample was extracted from the source at a constant flow rate using a quartz-lined probe maintained at a temperature of 650°F ± 25°F (depending on the required probe length) and a quartz fiber filter (to remove particulate matter) maintained at the same temperature as the probe. 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) is located at the condenser outlet for the collection of residual SAM not collected by the condenser. The condenser temperature is regulated by a water jacket and the SAM filter is 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<sub>2</sub> into the H<sub>2</sub>SO<sub>4</sub>-collecting fraction of the sample train).

After exiting the SAM filter, the sample gas then continued through a series of four (4) glass knock-out jars; two (2) containing water, one (1) empty and one (1) containing silica gel for residual moisture removal. The exit temperature from the knock-out jar set is maintained below 68°F. The sample gas then flowed into a dry gas meter, where the collected sample gas volume is determined by means of a calibrated, dry gas meter or an orifice-based flow meter.

The H<sub>2</sub>SO<sub>4</sub>-collecting portion of the sample train (condenser and SAM filter) was recovered into a single fraction using DI H<sub>2</sub>O as the recovery/extraction solvent; any H<sub>2</sub>SO<sub>4</sub> disassociates into sulfate ion (SO<sub>4</sub><sup>2-</sup>) and was stabilized in the H<sub>2</sub>O matrix until analysis.

Samples and blanks were returned to CleanAir Analytical Services in Palatine, Illinois, for IC analysis.

## USEPA Methods 3A, 18, and 25A

Oxygen (O<sub>2</sub>) and carbon dioxide (CO<sub>2</sub>) emissions were determined using a paramagnetic/NDIR analyzer per EPA Method 3A. VOC emissions were determined using EPA Method 25A to quantify THC emissions and EPA Method 18 to quantify CH<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> emissions. VOC emissions are equivalent to THC emissions, minus CH<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> 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 approximately 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<sub>3</sub>H<sub>8</sub>) 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<sub>2</sub>/CO<sub>2</sub> analyzers which measured concentration on a dry basis (units of %dv or ppm<sub>dv</sub>).
- 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<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> are insoluble in water. Each bag was filled over a period of approximately one hour for each test run.

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 during calibration error checks. 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.

Analysis for  $CH_4$  and  $C_2H_6$  was performed off-site by CleanAir Analytical Services using gas chromatography (GC). Since moisture was removed from the sample prior to collection and GC analysis, the concentration results were on a dry basis. At least three (3) sample injections were analyzed for each run.

GC calibration was performed by generating a calibration curve from triplicate injections of three (3) 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.

## General Considerations

A traditional verification of the absence of cyclonic flow following Method 1 specifications was not performed. However, absence of cyclonic flow was demonstrated by measuring the resultant angle of flow during each Method 2F flow traverse, which yielded a resultant angle of flow less than  $20^\circ$  in all instances. Data is included in Appendix G of this report.

$H_2O$  data used for moisture correction of concentration data was obtained (when required) for Method 5F/202, CTM-027, and Draft ASTM CCM by Method 4 measurements incorporated into the sampling and recovery procedures. For Method 3A/18/25A,  $H_2O$  data was obtained from most concurrently-operated Draft ASTM CCM sample trains.

$O_2$ ,  $CO_2$ , and  $H_2O$  data used for Methods 2H and 2F flow calculations were obtained from the most concurrently-operated Method 5F/202 sample trains.

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*End of Section*