Consumers Energy

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Particulate Matter (PM) CEMS RRA and ROP PM Test Report

EU-KARN1 and EU-KARN2

Consumers Energy Company
D.E. Karn Plant
2742 North Weadock Highway
Essexville, Michigan 48732
SRN: B2840
FRS: 110000593171

Test Dates: September 25-28, 2017

November 14, 2017

Test Performed by the Consnmers Energy Company
Regulatory Compliance Testing Section – Air Emissions Testing Body
Laboratory Services
Work Order No. 29436194
Revision 0

EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted filterable particulate matter (PM) testing of the single dedicated exhausts of coal-fired boilers EU-KARN1 (Unit 1) and EU-KARN2 (Unit 2) operating at the D.E. Karn Generating Station in Essexville, Michigan. EU-KARN1 and EU-KARN2 are coal-fired electric utility steam generating units (EGUs) that turn turbines connected to an electricity producing generator. The testing was performed to ensure the continued validity of the PM CEMS correlation curve via a relative response audit (RRA) as required in 40 CFR Part 63, Subpart 63.10010(i)(2)(i) utilizing Procedure 2—Quality Assurance Requirements for Particulate Matter Continuous Emission Monitoring Systems at Stationary Sources (40 CFR Part 60 Appendix F). The criteria to pass an RRA described in Section 10.4(6) of Performance Specification 2 are listed below. Secondarily, the results were used to demonstrate compliance for PM limits in Michigan Department of Environmental Quality (MDEQ) Renewable Operating Permit (ROP) MI-ROP-B2840-2014a.

Triplicate minimum 120-minute PM test runs were conducted on EU-KARN1 on September 25, 26, and 27, 2017, one run per day. Triplicate minimum 120-minute PM test runs were conducted on EU-KARN2 on September 27, and 28, 2017. These PM test runs were conducted following the procedures in United States Environmental Protection Agency (USEPA) Reference Methods (RM) 1, 2, 3A, 4, 5, and 19 in 40 CFR 60, Appendix A. Each test run sampled a minimum of 60 dry standard cubic feet (dscf) in an attempt to ensure enough particulate was collected to permit an accurate weighing. There were no deviations from the approved stack test protocol or the associated USEPA Reference Methods. During testing, both units were operated at the maximum load achievable under normal operating conditions. The PM results are summarized below.

Summary of PM Test Results

EU-KARN1						
Parameter	**Units**	**Run**			**Average**	**ROP Emission Limit**
		1	**2**	**3**		
PM	lb/1,000lb @ 50% EA	0.0003	0.0004	0.0011	**0.0006**	**0.16**
EU-KARN2						
Parameter	**Units**	**Run**			**Average**	**ROP Emission Limit**
		1	**2**	**3**		
PM	lb/1,000lb @ 50% EA	0.0008	0.0007	0.0007	**0.0008**	**0.16**

Summary of PM RRA Results

EU-KARN1		
Procedure 2 Criteria	**10.4(6)(i)**	**PASS (All PM CEMS responses ≤ 67.60 mg/wacm)**
	10.4(6)(ii)	**PASS (All PM CEMS responses ≥ 0.05 & ≤ 67.60 mg/wacm)**
	10.4(6)(iii)	**PASS (All sets of PM CEMS and reference method measurements fall within ± 25% of the emissions limit on a graph of the correlation regression line)**
EU-KARN2		
Procedure 2 Criteria	**10.4(6)(i)**	**PASS (All PM CEMS responses ≤ 73.45 mg/wacm)**
	10.4(6)(ii)	**PASS (All PM CEMS responses ≥ 0.08 & ≤ 73.45 mg/wacm)**
	10.4(6)(iii)	**PASS (All sets of PM CEMS and reference method measurements fall within ± 25% of the emissions limit on a graph of the correlation regression line)**

The results of the testing indicate the 3-run average PM results are in compliance with applicable PM ROP limit and the PM CEMS met all criteria specified in Section 10.4(6) in Procedure 2 of 40 CFR 60 Appendix F.

Detailed results are presented in Table 1. Sample calculations and field data sheets are presented in Appendices A and B. Laboratory data is presented in Appendix C. Boiler operating data and supporting information are provided in Appendices D and E.

1.0 INTRODUCTION

Consumers Energy Regulatory Compliance Testing Section (RCTS) conducted filterable particulate matter (PM) testing of the single dedicated exhausts of coal-fired boilers EU-KARN1 (Unit 1) and EU-KARN2 (Unit 2) operating at the D.E. Karn Generating Station in Essexville, Michigan. EU-KARN1 and EU-KARN2 are coal-fired electric utility steam generating units (EGUs) that turn turbines connected to an electricity producing generator. The testing was performed to ensure the continued validity of the PM CEMS correlation curve via a relative response audit (RRA) as required in 40 CFR Part 63, Subpart 63.10010(i)(2)(i) utilizing Procedure 2—Quality Assurance Requirements for Particulate Matter Continuous Emission Monitoring Systems at Stationary Sources (40 CFR Part 60 Appendix F). Secondarily, the results were used to demonstrate compliance for PM limits in Michigan Department of Environmental Quality (MDEQ) Renewable Operating Permit (ROP) MI-ROP-B2840-2014a.

Notification to the EPA, as well as a courtesy notification to the MDEQ was sent August 26, 2017 informing the agencies of Consumers Energy's intention to perform this test program. The test protocol was approved by Mr. Jeremy Howe, Environmental Quality Analyst with MDEQ in his letter dated September 15, 2017.

The criteria to pass an RRA described in Section 10.4(6) of Performance Specification 2 are listed below. The results of the testing were also used to demonstrate compliance with the applicable emission limits summarized in Table 1-1.

- 10.4(6)(i): For all three test runs (data points), the PM CEMS response value can be no greater than the highest PM CEMS response value used to develop the correlation curve (Unit 1 = 67.60 milligram per wet actual cubic meter [mg/wacm]; Unit 2 = 73.45 mg/wacm).
- 10.4(6)(ii): For two of the three data points, the PM CEMS response value must lie within the PM CEMS output range used to develop the correlation curve (see above for the maximum PM CEMS responses; minimum responses were are as follows: Unit 1 = 0.05 mg/wacm; Unit 2 = 0.08 mg/wacm).
- 10.4(6)(iii): At least two of the three sets of PM CEMS and reference method measurements must fall within the area on a graph of the correlation regression line bounded by two parallel lines at ± 25% of the permit emission limit. (When assessing PM CEMS performance in relation to the "emissions limit", the MATS PM emission limit of

0.030 lb/mmBtu is used. The preceding MATS PM emission limit equates to 21.5 mg/wacm for Unit 1, and 18.7 mg/wacm for Unit 2 based upon the average of the reference method data collected during those runs used to establish the correlation curves.)

Please note that for both Units 1 and 2, errors were found within the initial correlation test reports dated September 24, 2015 and October 5, 2015, respectively, in regards to converting the MATS emission limit of 0.030 lb/mmBtu into units of the PM CEMS measurement (mg/wacm). The error consists of having used the average dry CO_2 concentration from the associated reference method testing; the average **wet** CO_2 concentration from the associated reference method testing should have been used for the conversion of the MATS emission limit into units of mg/wacm. This error results in the mg/wacm emission limit equivalents for Units 1 and 2 being revised from 24.8 and 21.8 mg/wacm, respectively, to 21.5 and 18.7 mg/wacm, respectively. Note that this error has no effect on the correlation curves themselves, and Consumers has verified that all of the PS-11 statistical criteria are still met.

There was also another error within the Unit 1 initial correlation test report in regards to the lowest PM CEMS response associated with the data set used to develop the correlation curve, as reported in the 2016 RRA test report. Specifically, in "Table 3, PS-11 Correlation Test Data", the PM CEMS response for Run 21 is listed as 0.47 mg/wacm. However, in the Appendix C CEMS data associated with each correlation test run, the PM CEMS response (see the column titled PM1 (MG/WACM)) for Run 21 is listed as 0.05 mg/wacm. Consumers Energy has reviewed the associated 1-minute CEMS data for Run 21 and verified that the correct PM CEMS response for Run 21 should be 0.047 mg/wacm (not the 0.47 mg/wacm listed in Table 3 of the initial correlation test report). Thus, the average Unit 1 PM CEMS responses observed during the RRA were all above the lowest PM CEMS response associated with the data set used to develop the initial correlation curve

Table 1-1.
PM Emission Limits

Parameter	Emission Limit	Units	Applicable Requirement
PM	0.16	lb/1,000lb @ 50% EA	MI-ROP-B2840-2014a, Section1, EU-KARN1 and EU-KARN2 Emission Limits

lb/1,000lb: pound per thousand pounds of actual stack gas
@ 50% EA: corrected to fifty percent excess air

The test runs for Unit 1 were conducted on September 25, 26, and 27, 2017 and the test runs for Unit 2 were conducted on September 27 and 28, 2017 following the procedures in United States Environmental Protection Agency (USEPA) Reference Methods (RM) 1, 2, 3A, 4, 5, and 19 in 40 CFR 60, Appendix A.

1.1 CONTACT INFORMATION

Table 1-2 presents the EGU test program organization, major lines of communication, and names and phone numbers of responsible individuals.

Table 1-2.
Contact Information

Program Role	Contact	Address
EPA Regional Contact	Emission Collection and Monitoring Plan System (ECMPS)	U.S. EPA Region 5 77 W. Jackson Blvd. (AE-17J) Chicago, IL 60604
Regulatory Agency Representative	Ms. Karen Kajiya-Mills 517-335-4874 Technical Programs Unit Manager Kajiya-Millsk@michigan.gov	Michigan Department of Environmental Quality Technical Programs Unit 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
Responsible Official	Mr. Cresencio Hernandez III 989-891-3407 Karn Complex Production Mgr Cresencio.hernandezIII@cmsenergy.com	Consumers Energy Company D.E. Karn Power Plant 2555 North Weadock Highway Essexville, Michigan 48732
Test Facility	Mr. George Eurich 989-891-3317 Sr. Engineering Tech Analyst Lead George.Eurich@cmsenergy.com	Consumers Energy Company D.E. Karn Power Plant 2555 North Weadock Highway Essexville, Michigan 48732
Test Facility	Ms. Karen Gauld 989-891-3168 Senior Technician Karen.Gauld@cmsenergy.com	Consumers Energy Company D.E. Karn Power Plant 2555 North Weadock Highway Essexville, Michigan 48732
Test Team Representative	Mr. Dillon King, QSTI 989-891-5585 Engineering Technical Analyst Dillon.King@cmsenergy.com	Consumers Energy Company D.E. Karn Power Plant ESD Trailer #4 2742 North Weadock Highway Essexville, Michigan 48732
Test Team Representative	Mr. Brian Miska, QSTI 989-891-3415 Sr. Engineering Technical Analyst Brian.Miska@cmsenergy.com	Consumers Energy Company D.E. Karn Power Plant ESD Trailer #4 2742 North Weadock Highway Essexville, Michigan 48732

2.0 SUMMARY OF RESULTS

2.1 OPERATING DATA

During the performance tests, the boilers fired 100% western coal and were operated at maximum normal operating load conditions. Unit 1 testing was performed while the boiler was operating within the range of 252 MWg to 256 MWg (92.6-94.1% of the achievable capacity). Unit 2 testing was performed while the boiler was operated at 257 MWg (92.8% of achievable capacity).

Refer to Attachment D for detailed operating data, which was recorded in Eastern Standard Time. Note the time convention for the reference method (RM) testing was Eastern Daylight Savings Time (EDT); therefore, there is a one hour offset between the RM time stamps and continuous emissions monitoring system (CEMS)/process data time stamps.

2.2 APPLICABLE PERMIT INFORMATION

The D.E. Karn generating station has the State of Michigan Registration Number (SRN) B2840 and operates in accordance with air permit MI-ROP-B2840-2014a. The air permit incorporates federal regulations and reports under Federal Registry Service (FRS) identification number 110000593171. EU-KARN1 and EU-KARN2 are the emission unit source identifications in the permit and included in the FG-KARN12 flexible group. Incorporated within the permit are the applicable requirements of 40 CFR 63, Subpart UUUUU – National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-fired Electric Utility Steam Generating Units.

In addition to the state issued air permit, Consumers Energy operates Units 1 and 2 in accordance with the requirements in Consent Decree (CD), Civil Action No.: 14-13580, entered between Consumers Energy, the United States Environmental Protection Agency (EPA), and the United States Department of Justice (DOJ) on November 4, 2014.

2.3 RESULTS

The results of the testing on both EU-KARN1 and EU-KARN2 indicate the 3-run average PM results are in compliance with applicable limits and the PM CEMS met all criteria specified in Section 10.4(6) in Procedure 2 of 40 CFR 60 Appendix F. Refer to Table 2-1 for a summary of the PM results in comparison to emission limits. Refer to Table 2-2 and Figures 2-1 and 2-2 for summaries of the PM CEMS RRA tests.

Table 2-1.
Summary of PM Test Results

EU-KARN1						
Parameter	Units	Run			Average	ROP Emission Limit
		1	2	3		
PM	lb/1,000lb @ 50% EA	0.0003	0.0004	0.0011	**0.0006**	0.16
EU-KARN2						
Parameter	**Units**	**Run**			**Average**	**ROP Emission Limit**
		1	**2**	**3**		
PM	Lb/1,000lb @ 50% EA	0.0008	0.0007	0.0007	**0.0008**	**0.16**

lb/1,000lb: pound per thousand pounds of actual stack gas

@ 50% EA: corrected to fifty percent excess air

Table 2-2.
Summary of PM CEMS RRA Results

EU-KARN1				
Run	Parameter	Uuits	PM Concentration	
			RM Result	PM CEMS Response
1	PM	mg/wacm	0.269	0.220
2			0.343	0.300
3			0.999	0.440
Average			**0.537**	**0.320**
Procedure 2 Criteria				
10.4(6)(i)	**PASS (All PM CEMS responses ≤ 67.60 mg/wacm)**			
10.4(6)(ii)	**PASS (All PM CEMS responses ≥ 0.05 & ≤ 67.60 mg/wacm)**			
10.4(6)(iii)	**PASS (All sets of PM CEMS and reference method measurements fall within ± 25% of the emissions limit on a graph of the correlation regression line)**			
EU-KARN2				
Run	**Parameter**	**Units**	**PM Concentration**	
			RM Result	**PM CEMS Response**
1	PM	mg/wacm	0.725	0.750
2			0.653	0.790
3			0.662	0.730
Average			**0.680**	**0.757**
Procedure 2 Criteria				
10.4(6)(i)	**PASS (All PM CEMS responses ≤ 73.45 mg/wacm)**			
10.4(6)(ii)	**PASS (All PM CEMS responses ≥ 0.08 & ≤ 73.45 mg/wacm)**			
10.4(6)(iii)	**PASS (All sets of PM CEMS and reference method measurements fall within ± 25% of the emissions limit on a graph of the correlation regression line)**			

Figure 2-1. EU-KARN1
PM CEMS 10.4(6)(iii) Assessment

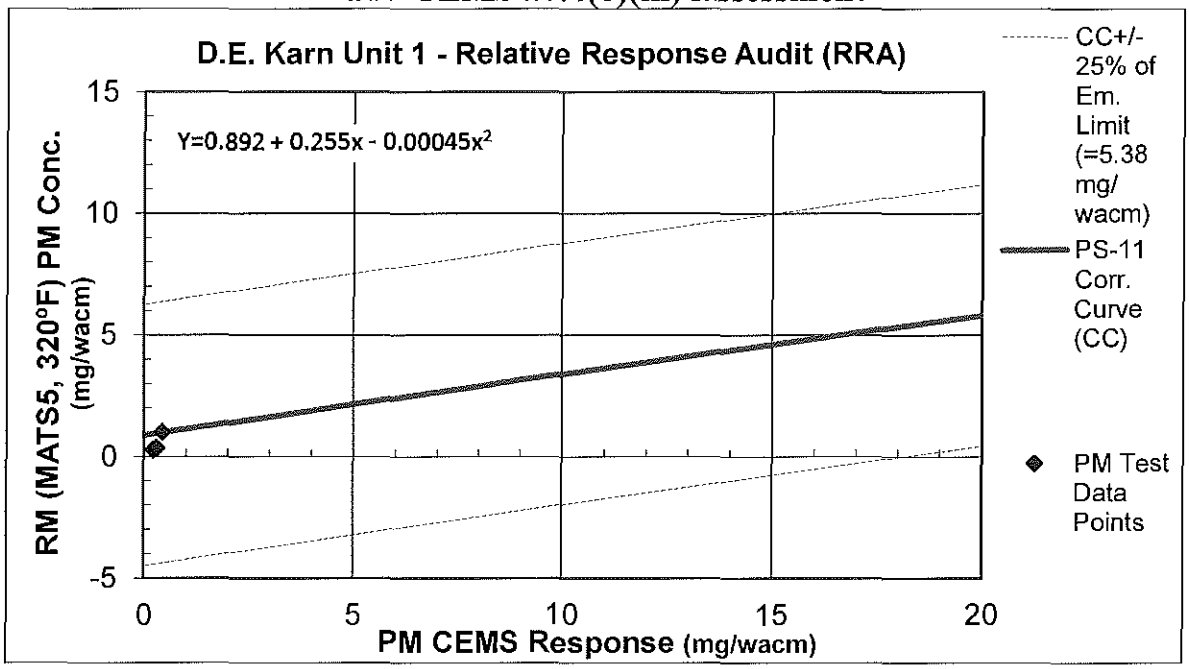
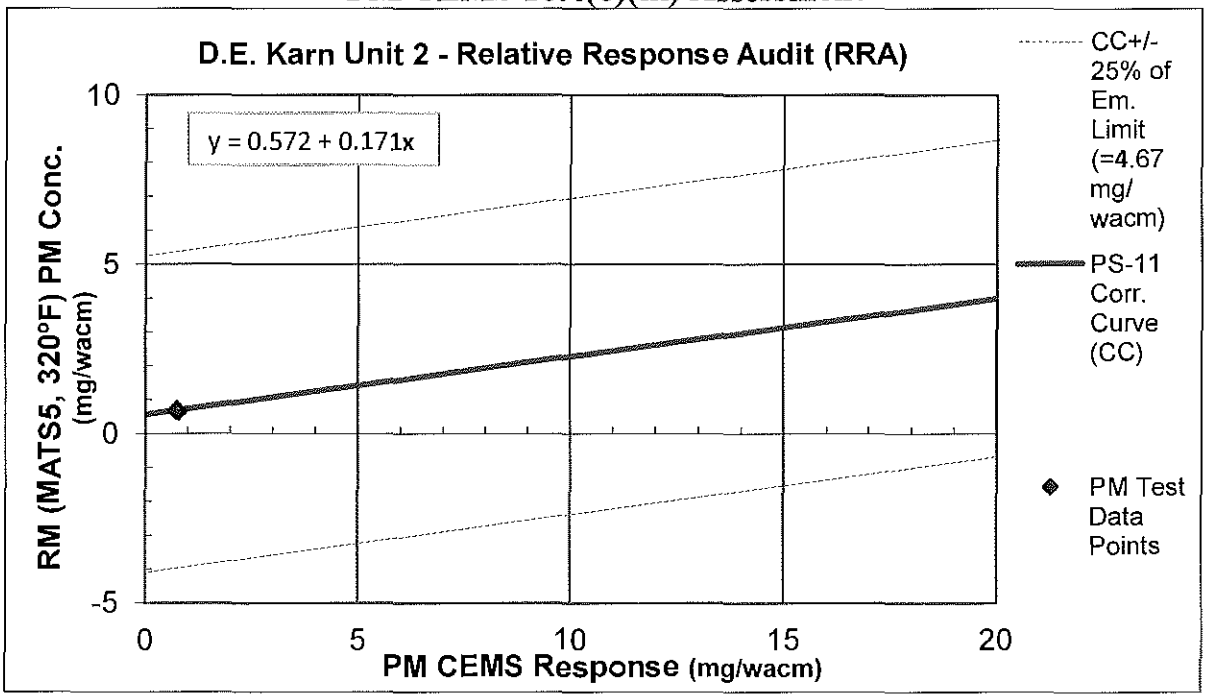


Figure 2-2. EU-KARN2
PM CEMS 10.4(6)(iii) Assessment



Detailed results for EU-KARN1 are presented in Table 1; results for EU-KARN2 are presented in Table 2. Sample calculations and field data sheets are presented in Appendices A and B. Laboratory data is presented in Appendix C. Boiler operating data and supporting information are provided in Appendices D and E.

3.0 SOURCE DESCRIPTION

EU-KARN1 and EU-KARN2 are coal-fired EGUs that turn turbines connected to electricity producing generators.

3.1 PROCESS

EU-KARN1 is a dry bottom tangential coal fired boiler with fuel oil startup capabilities and supplemental co-firing for flame stabilization and mill outages. EU-KARN2 is a dry bottom wall coal fired boiler also with fuel oil startup capabilities and supplemental co-firing for flame stabilization and mill outages.

The steam is used to turn an engine turbine that is connected to an electricity producing generator. The electricity is routed through the transmission and distribution system to consumers.

3.2 PROCESS FLOW

The flue gas generated through coal combustion is controlled by multiple pollution control devices for each unit. Both EU-KARN1 and EU-KARN2 have a Selective Catalytic Reduction (SCR) system for the control of nitrogen oxides (NOx), and EU-KARN2 also has low NOx burners for additional control of nitrogen oxides (NOx). Further, both units are equipped with pulse jet fabric filter (PJFF) baghouses for Particulate Matter (PM) control and Spray Dryer Absorbers (SDAs) for the control of sulfur dioxide (SO2) and other acid gases. Each unit is also equipped with Activated Carbon Injection (ACI) for the control of mercury (used on an as needed basis to comply with the applicable MATS mercury emission limit).

3.3 MATERIALS PROCESSED

The normal fuel utilized in Units 1 and 2 is 100% western subbituminous coal. The boilers are classified as coal-fired units not firing low rank virgin coal as described in Table 2 to Subpart UUUUU. For this test, both units were burning 100% western subbituminous coal.

3.4 RATED CAPACITY

Unit 1 has a nominally rated heat input capacity of 2,500 million BTU per hour and can generate a gross electrical output of approximately 272 megawatts (MWg). Unit 2 has a nominally rated heat input capacity of 2,540 million BTU per hour and can generate a gross electrical output of approximately 277 megawatts (MWg). The boilers operate in a continuous manner in order to meet the electrical demands of Midcontinent Independent System Operator, Inc. (MISO) and Consumers Energy customers. Both units are considered baseload units because they are designed to operate 24 hours a day, 365 days a year.

3.5 PROCESS INSTRUMENTATION

The process was continuously monitored by boiler operators, environmental technicians, and data acquisition systems during testing. One-minute data for the following parameters were collected during each PM test runs: PM (mg/wacm), load (MWg), CO_2 concentration (vol-%, Wet), and opacity (%). Please note that the 1-minute opacity data for Unit 1 is marked as invalid, but the opacity monitor was in control during the test periods; the invalid status of the opacity data is due to the values having been slightly below zero and the data acquisition and handling system subsequently flooring the opacity values at 0%. Due to the various instrumentation systems, the sampling times were correlated to instrumentation times. The control equipment process instrumentation and reference method data is recorded on Eastern Daylight Time (EDT), whereas, the continuous emissions monitoring systems records data on Eastern Standard Time (EST). During the test program, EDT was one hour later than EST. (i.e., 8:00 am EDT = 7:00 am EST). Refer to Appendix D for operating data.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

Consumers Energy RCTS tested for PM emissions using the USEPA test methods presented in Table 4-1. The sampling and analytical procedures associated with each parameter are described in the following sections.

Table 4-1.
Test Methods

Parameter	USEPA	
	Method	Title
Sampling location	1	Sample and Velocity Traverses for Stationary Sources
Traverse points	2	Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
Molecular weight (O_2 and CO_2)	3A	Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)
Moisture	4	Determination of Moisture Content in Stack Gases
Filterable particulate matter	MATS5	Determination of Particulate Matter Emissions from Stationary Sources (320±25°F rather than 248±25°F)
Pollutant emission rate	19	Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates

4.1 Description of Sampling Train and Field Procedures

The test matrix presented in Tables 4-2 and 4-3 summarize the sampling and analytical methods performed for the specified parameters during this test programs.

Table 4-2.
EU-KARN1 Test Matrix

Date	Run	Sample Type	Start Time (DST)	Stop Time (DST)	Test Duration (min)	EPA Test Method	Comment
9/25/2017	1	PM	14:15	16:30	120	MATS5	24 traverse points; isokinetic sampling; 120 minute test duration; minimum sample volume of 60 dscf
9/26/2017	2	PM	07:55	10:40	120	MATS5	
9/27/2017	3	PM	8:12	10:21	120	MATS5	

Table 4-3.
EU-KARN2 Test Matrix

Date	Run	Sample Type	Start Time (DST)	Stop Time (DST)	Test Duration (min)	EPA Test Method	Comment
9/27/2017	1	PM	12:30	14:42	120	MATS5	24 traverse points; isokinetic sampling; 120 minute test duration; minimum sample volume of 60 dscf
9/27/2017	2	PM	15:10	17:27	120	MATS5	
9/28/2017	3	PM	8:05	10:21	120	MATS5	

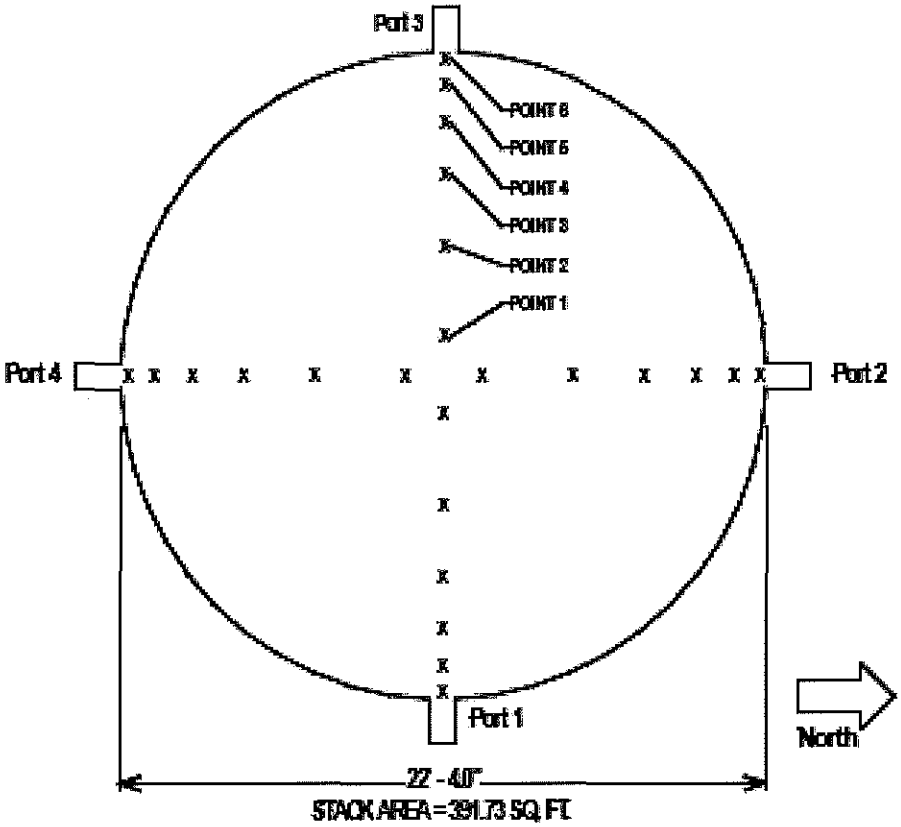
4.1.1 Sample Location and Traverse Points (USEPA Method 1)

The number and location of traverse points for determining particulate concentrations and exhaust gas velocity/ volumetric air-flow was determined in accordance with USEPA Method 1, *Sample and Velocity Traverses for Stationary Sources.* Four test ports are located in the horizontal plane of the stacks dividing the cross-section into a number of equal areas based on the existing air flow disturbances. The Unit 1 stack diameter is 22 feet 4 inches; Unit 2 has a stack diameter of 18 feet. The ports are situated:

- Approximately 70 feet downstream of the breechings entering the exhaust stack, and
- Approximately 200 feet upstream of the exhaust stack exit.

The sample ports are 6-inches in diameter and extend 24 inches beyond the stack wall. Flue gas was sampled for five minutes at six traverse points from each of the four sample ports, for a total of 24 sample points and 120 minutes. Drawings of the Unit 1 and Unit 2 traverse points are presented as Figures 4-1 and 4-2, while a drawing of the Units 1 and 2 Test Port Locations is presented as Figure 4-3.

Figure 4-1. Unit 1 Duct Cross Section and Test Port/Traverse Point Detail



PARTICULATE EMISSION TEST POINT LOCATIONS

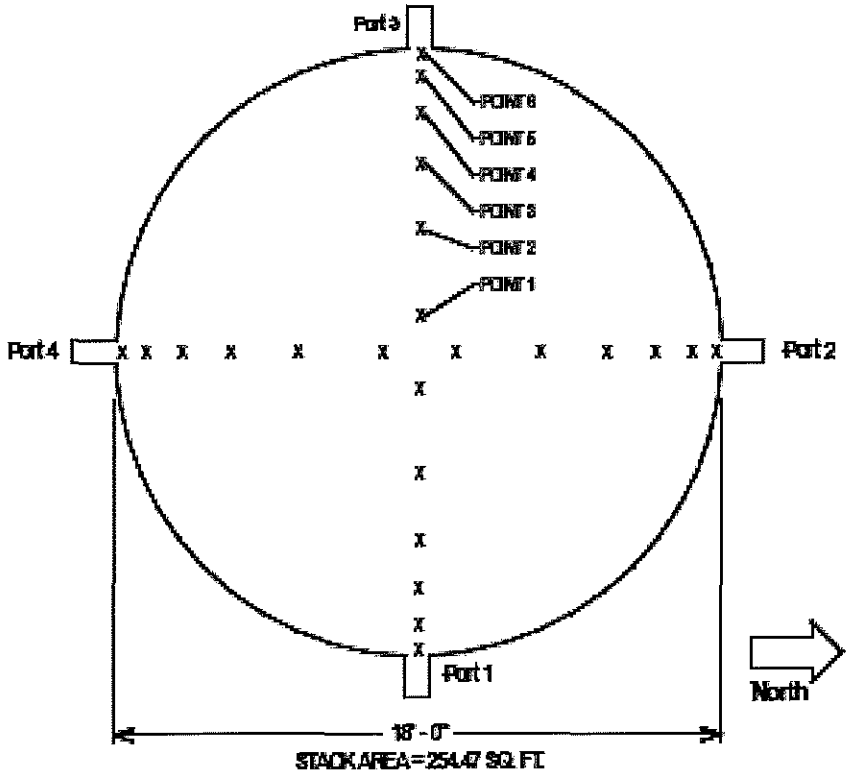
Note: Test Port Length = 24" from inside stack wall to outside flange.

DISTANCES FROM INSIDE STACK WALL

Point 1	96.27"
Point 2	66.90"
Point 3	47.37"
Point 4	31.58"
Point 5	17.93"
Point 6	5.62"

Figure 4-2. Unit 2 Duct Cross Section and Test Port/Traverse Point Detail

D E KARN UNIT 2 PARTICULATE EMISSION TEST POINT LOCATIONS



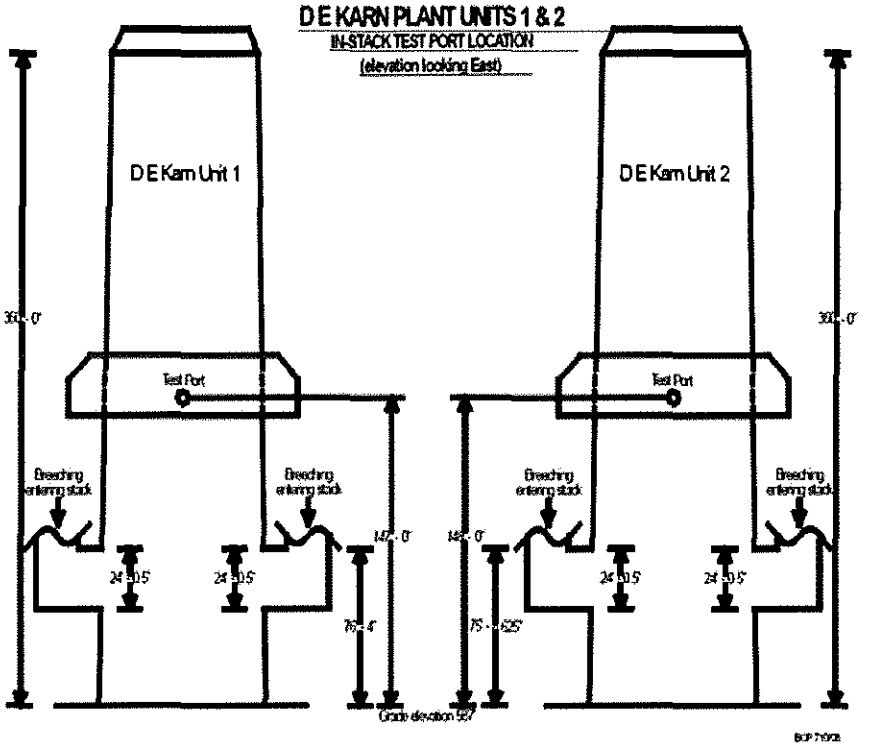
PARTICULATE EMISSION TEST POINT LOCATIONS

Note: Test Port Length = 14" from inside stack wall to outside flange.

DISTANCES FROM INSIDE STACK WALL

Point 1	76.90"
Point 2	54.00"
Point 3	38.23"
Point 4	25.49"
Point 5	14.40"
Point 6	4.54"

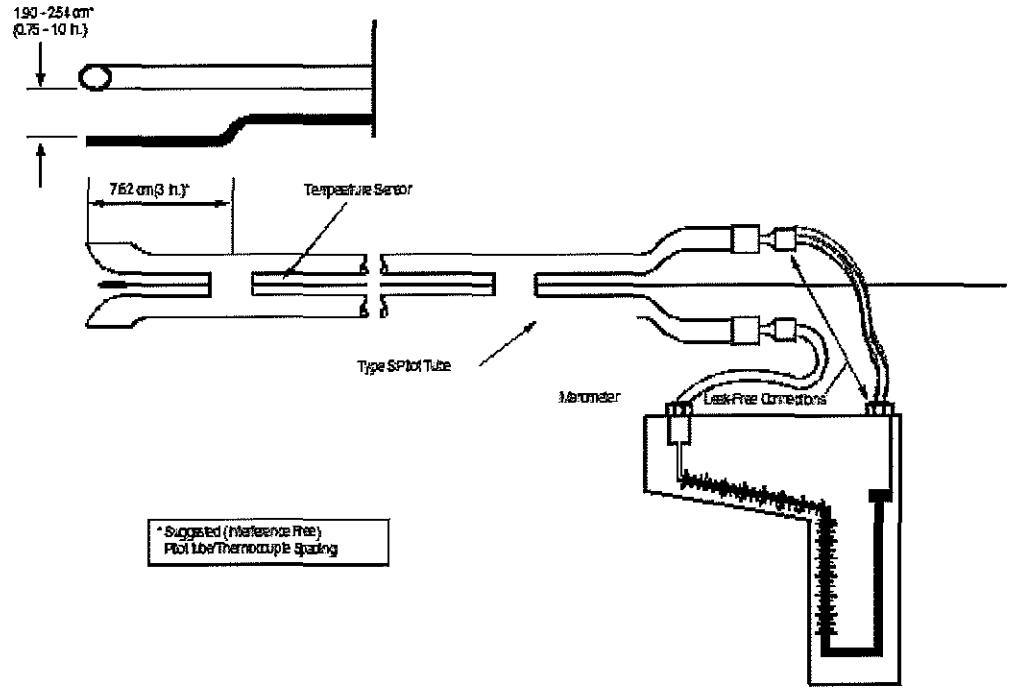
Figure 4-3. Units 1 and 2 Test Port Locations



4.1.2 Velocity and Temperature (USEPA Method 2)

The exhaust gas velocity and temperature were measured using USEPA Method 2, *Determination of Stack Gas Temperature and Velocity (Type S Pitot Tube)*. The pressure differential (ΔP) across the positive impact and negative static openings of the Pitot tube inserted in the exhaust duct at each traverse point were measured using an "S Type" (Stauscheibe or reverse type) Pitot tube connected to an appropriately sized oil filled inclined manometer. Exhaust gas temperatures were measured using a nickel-chromium/nickel-alumel "Type K" thermocouple and a temperature indicator. Refer to Figure 4-4 for the Method 2 Pitot tube, thermocouple, and inclined oil-filled manometer configuration.

Figure 4-4. Method 2 Sample Apparatus



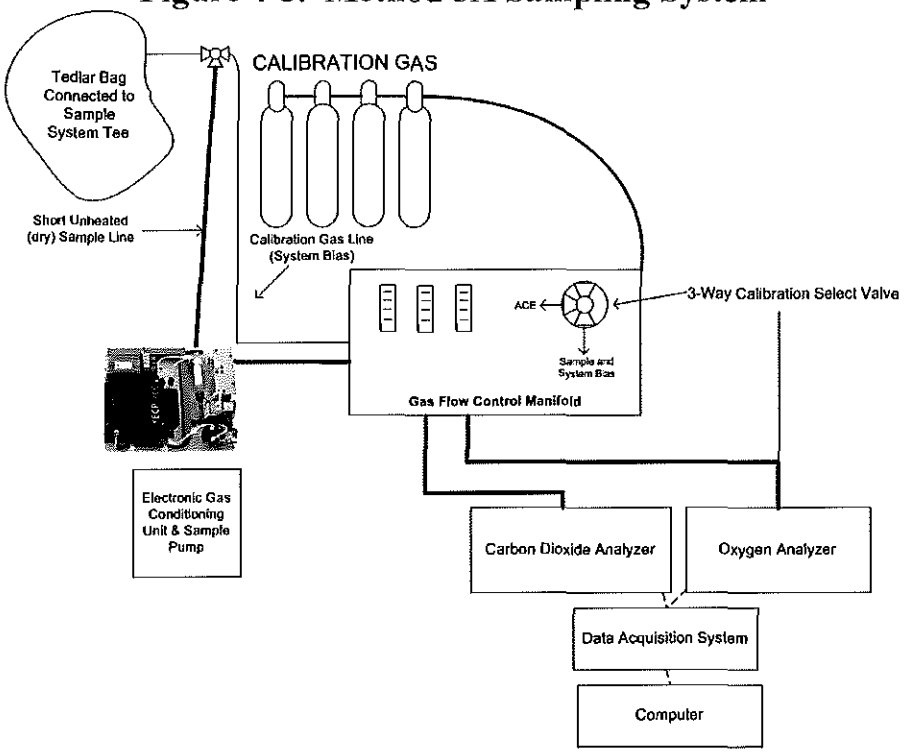
Appendix B of this report includes cyclonic flow test data as verification of the absence of cyclonic flow at the sample location. Method 1, § 11.4.2 states "if the average (null angle) is greater than 20°, the overall flow condition in the stack is unacceptable, and alternative methodology…must be used." The average null yaw angle measured at the Unit 1 exhaust on September 25, 2017, was observed to be 2.625°, thus meeting the less than 20° requirement. The average null yaw angle measured at the Unit 2 exhaust on October 20, 2005, was observed to be 2.917°, also meeting the less than 20° requirement. Since the cyclonic flow test was performed on Unit 2, there have been no changes to the stack within 2 stack diameters upstream, or within one half stack diameter downstream of the sample port location.

4.1.3 Molecular Weight (USEPA Method 3A)

The exhaust gas composition and molecular weight was measured using the sampling and analytical procedures of USEPA Method 3A, *Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure).* The flue gas oxygen and carbon dioxide concentrations were used to calculate molecular weight, flue gas velocity, emissions in lb/mmBtu, and/or lb/1,000 lbs corrected to 50% excess air.

Flue gas was extracted from the stack through a heated stainless steel lined probe and Teflon® sample line into a flexible sample bag. The sample was withdrawn from the flexible bag and conveyed through a gas conditioning system to remove water content before entering paramagnetic and infrared gas analyzers that measure oxygen and carbon dioxide concentrations. Figure 4-5 depicts the Method 3A sampling system.

Figure 4-5. Method 3A Sampling System



Prior to sampling flue gas, the analyzers were calibrated by performing a calibration error test where zero-, mid-, and high-level calibration gases are introduced to the back of the analyzers. The calibration error check was performed to evaluate if the analyzers response was within ±2.0% of the calibration gas span. A system-bias and drift test was performed where the zero- and mid- or high- calibration gases are introduced at the inlet to the gas conditioner to measure the ability of the system to respond to within ±5.0 percent of span.

In lieu of performing a stratification test, the flexible bag samples were collected throughout the particulate matter tests at each of the 24 traverse points.

At the conclusion of the bag sample analysis, an additional system bias check was performed to evaluate the drift from the pre- and post-test system bias checks. The system-bias checks

evaluated if the analyzers drift is within the allowable criterion of ±3.0% of span from pre- to post-test system bias checks. The measured oxygen and carbon dioxide concentrations were corrected for analyzer drift. Refer to Appendix E for analyzer calibration supporting documentation.

4.1.4 Moisture Content (USEPA Method 4)

The exhaust gas moisture content was measured using USEPA Method 4, *Determination of Moisture in Stack Gases* in conjunction with the Method 5 sample apparatus. Sampled gas was drawn through a series of impingers immersed in an ice bath to condense and remove water from the flue gas. The amount of water condensed and collected in the impingers was measured gravimetrically and used to calculate the exhaust gas moisture content.

4.1.5 Particulate Matter (USEPA MATS Method 5)

Filterable particulate matter samples were collected isokinetically by withdrawing a sample of the flue gas through a nozzle, heated probe, and filter following the procedures of USEPA Method 5 (RM5), *Determination of Particulate Matter Emissions from Stationary Sources.* USEPA Method 5 measures filterable particulate matter (aka PM, FPM) collected on a filter heated to 248±25°F, but in accordance with §63.10010(i)(1), the filter was instead heated to 320±25°F.

The RM5 sampling apparatus was setup and operated in accordance with the method. The flue gas was passed through a nozzle, heated probe, quartz-fiber filter, and into a series of impingers with the configuration presented in Table 4-3. The filter collects filterable particulate matter while the impingers collect water vapor. Figure 4-6 depicts the USEPA Method 5 sampling train.

Table 4-3.
Method 5 Impinger Configuration

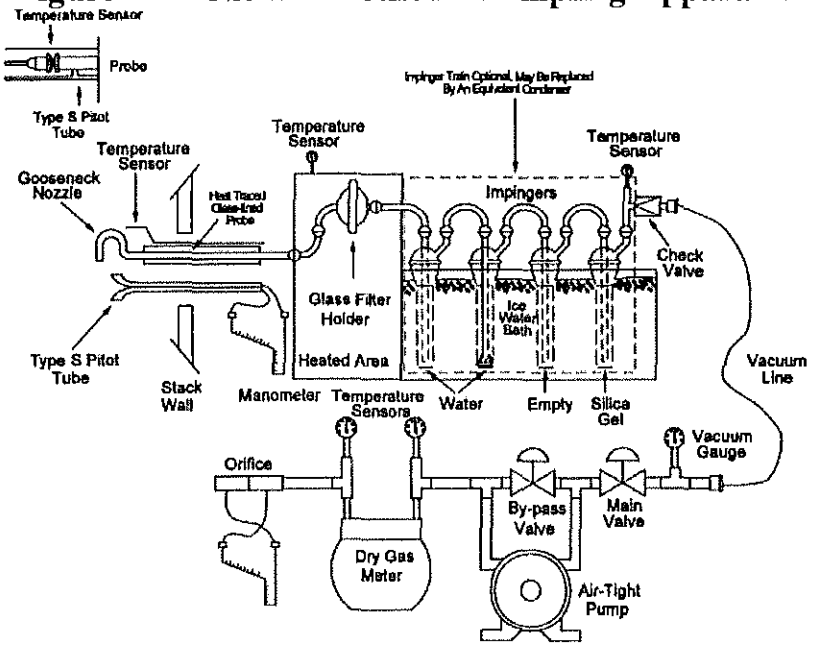
Impinger Order (Upstream to Downstream)	Impinger Type	Impinger Contents	Amount (gram)
1	Modified	Water	100
2	Greenburg-Smith	Water	100
3	Modified	Empty	0
4	Modified	Silica gel desiccant	~200-300

Prior to testing, representative velocity head and temperature data were reviewed to calculate an ideal nozzle diameter that would allow isokinetic sampling to be performed. The diameter of the selected nozzle was measured with calipers across three cross-sectional chords and used to calculate its cross-sectional area. Prior to testing the nozzle was rinsed and brushed with deionized water and acetone, and connected to the sample probe.

The impact and static pressure openings of the Pitot tube were leak-checked at or above a velocity head of 3.0 inches of water for a minimum of 15 seconds. The sampling train was leak-checked by capping the nozzle and applying a vacuum of approximately 15 inches of mercury. The dry-gas meter was monitored for approximately 1 minute to verify the sample train leak rate was less than 0.02 cubic foot per minute (cfm). The sample probe was then inserted into the sampling port to begin sampling.

Ice and water were placed around the impingers and the probe and filter temperature were allowed to stabilize to 320±25°F. After the desired operating conditions were coordinated with the facility, testing was initiated. Stack and sampling apparatus parameters (e.g., flue gas velocity head, filter temperature) were monitored to calculate and sample at the isokinetic rate within 100±10% for the duration of the test. Refer to Appendix B for field data sheets.

Figure 4-6. USEPA Method 5 Sampling Apparatus



At the conclusion of a test run and post-test leak check, the sampling apparatus was disassembled and the impingers and filter housing were transported to the recovery area.

The filter was recovered from the filter housing and placed in a Petri dish, sealed with Teflon tape, and labeled as "FPM Container 1." The nozzle, probe liner, and the front half of the filter housing were triple rinsed with acetone to collect particulate matter. The acetone rinses were collected in pre-cleaned sample containers, sealed with Teflon tape, and labeled as "FPM Container 2." The weight of liquid collected in each impinger, including the silica gel impinger, was measured using an electronic scale; these weights were used to calculate the moisture content of the sampled flue gas. The contents of the impingers were discarded. Refer to Figure 4-7 for the USEPA Method 5 sample recovery scheme.

The sample containers, including a filter and acetone blank were transported to the laboratory for analysis. The sample analysis followed USEPA Method 5 procedures as summarized in the analytical scheme presented in Figure 4-8. Refer to Appendix C for laboratory data sheets.

Figure 4-7. USEPA Method 5 Sample Recovery Scheme

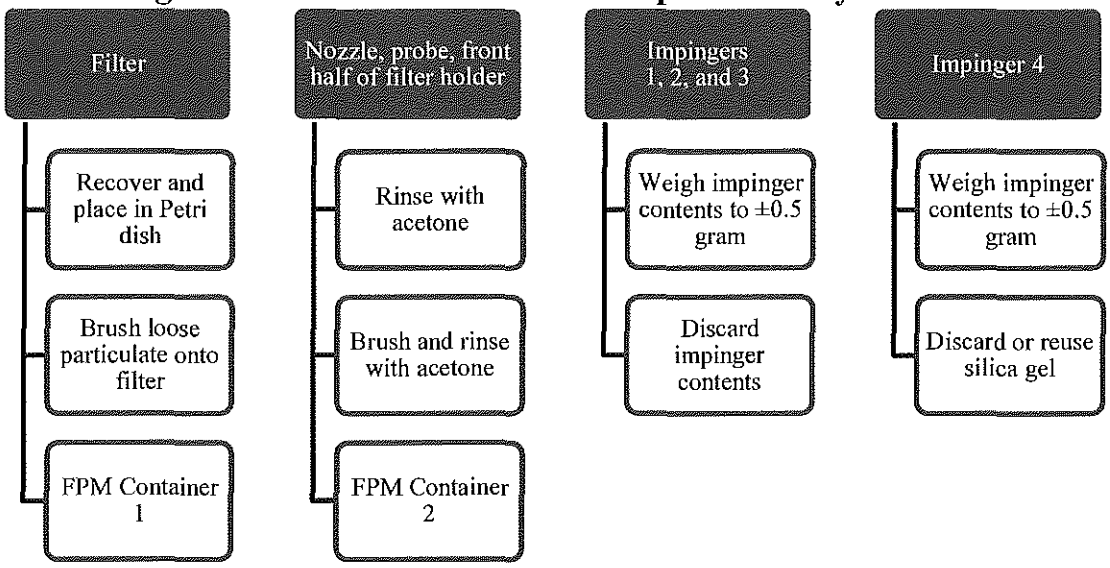
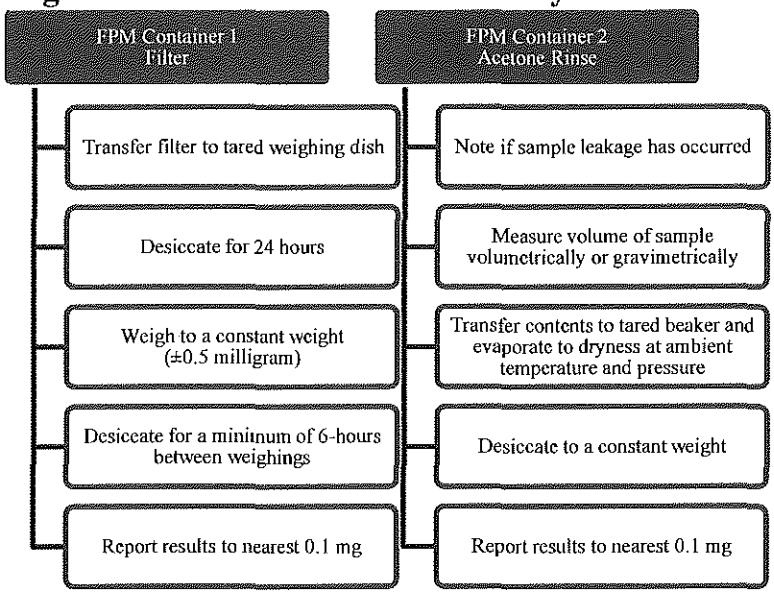


Figure 4-8. USEPA Method 5 Analytical Scheme



4.1.6 Emission Rates (USEPA Method 19)

USEPA Method 19, *Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates*, was used to calculate PM emission rates in units of lb/mmBtu. Measured carbon dioxide concentrations and F factors (ratios of combustion gas volumes to heat inputs) were used to calculate emission rates using equation 19-6 from the method. Figure 4-9 presents the equation used to calculate lb/mmBtu emission rate:

Figure 4-9. USEPA Method 19 Equation 19-6

$$E = C_d F_c \frac{100}{\%CO_{2d}}$$

Where:

E	=	Pollutant emission rate (lb/mmBtu)
C_d	=	Pollutant concentration, dry basis (lb/dscf)
F_c	=	Volumes of combustion components per unit of heat content 1,840 scf CO_2/mmBtu for subbituminous coal from 40 CFR 75, Appendix F, Table 1
$\%CO_{2d}$	=	Concentration of carbon dioxide on a dry basis (%, dry)

The Units 1 and 2 CEMS utilize the fuel factor provisions in 40 CFR Part 75, Appendix F, Section 3.3.6.5 whereby the worst case fuel factor for any of the fuels combusted in the unit is used to calculate lb/mmBtu emission rates. Refer to Appendix A for sample calculations.

5.0 TEST RESULTS AND DISCUSSION

This testing was performed to ensure the continued validity of the PM CEMS correlation curves via a relative response audit (RRA) as required in 40 CFR Part 63, Subpart 63.10010(i)(2)(i) utilizing Procedure 2—Quality Assurance Requirements for Particulate Matter Continuous Emission Monitoring Systems at Stationary Sources (40 CFR Part 60 Appendix F). Secondarily, the results were used to demonstrate compliance for PM limits in Michigan Department of Environmental Quality (MDEQ) Renewable Operating Permit (ROP) MI-ROP-B2840-2014a.

The results of the testing indicate the 3-run average PM results for both EU-KARN1 and EU-KARN2 are in compliance with applicable limits and the PM CEMS met all criteria specified in Section 10.4(6) in Procedure 2 of 40 CFR 60 Appendix F.

5.1 VARIATIONS AND UPSET CONDITIONS

No sampling procedure or results affecting boiler operating condition variations were encountered during the test program. The process and control equipment were operating under routine conditions and no upsets were encountered.

On September 26th, the second day of testing on Unit 1, RCTS was contacted by the source representative and informed that due to the extreme demand for electricity expected that day, further testing would need to be postponed to September 27 on both Units 1 and 2. This delay split the triplicate test runs required for Unit 1 into three separate days, and postponed the anticipated testing start date on Unit 2 from September 26 to September 27.

5.2 AIR POLLUTION CONTROL DEVICE MAINTENANCE

No significant pollution control device maintenance occurred during the three months prior to the test. Optimization of the air pollution control devices is a continuous process to ensure compliance with regulatory emission limits.

5.3 Field Quality Assurance / Quality Control Procedures

The USEPA reference methods performed state reliable results are obtained by persons equipped with a thorough knowledge of the techniques associated with each method. Factors with the potential to cause measurement errors are minimized by implementing quality control (QC) and assurance (QA) programs into the applicable components of field testing. QA/QC components were included in this test program. Table 5-1 summarizes the primary field quality assurance and quality control activities that were performed. Refer to Appendix E for supporting documentation.

Table 5-1.
Quality Control Procedures

QC Specification	Purpose	Procedure	Frequency	Acceptance Criteria
M1: Sampling Location	Evaluate if the sampling location is suitable for sampling	Measure distance from ports to downstream and upstream disturbance	Pre-test	≤2 diameters downstream; ≤0.5 diameter upstream.
M1: Duct diameter	Verify area of stack is accurately measured	Review as-built drawings and field measurement	Pre-test	Field measurement agreement with as-built drawings
M3A: Calibration gas standards	Ensure accurate calibration standards	Traceability protocol of calibration gases	Pre-test	Calibration gas uncertainty ≤2.0%
M3A: Calibration Error	Evaluates operation of analyzers	Calibration gases introduces directly into analyzers	Pre-test	±2% of the calibration span
M3A: System Bias and Analyzer Drift	Evaluates ability of sampling system to delivery stack gas to analyzers	Cal gases introduced at inlet of sampling system and into analyzers	Pre-test and Post-test	±5% of the analyzer calibratiou span for bias and ±3% of analyzer calibration span for drift
M5: nozzle diameter measurements	Verify nozzle diameter used to calculate sample rate	Measure inner diameter across three cross-sectional chords	Pre-test	3 measurements agree within ±0.004 inch
M5: sample rate	Ensure representative sample collection	Calculate isokinetic sample rate	During and post-test	100±10% isokinetic rate
M5: sample volume	Ensure sufficient sample volume is collected	Record pre- and post-test dry gas meter volume reading	Post test	≥ 60 dscf target in an attempt to ensure enough particulate was collected to permit an accurate weighing

Table 5-1.
Quality Control Procedures

QC Specification	Purpose	Procedure	Frequency	Acceptance Criteria
M5: post-test leak check	Evaluate if the sample was affected by system leak	Cap sample train; monitor dry gas meter	Post-test	≤0.020 cfm
M5: post-test meter audits	Evaluates accurate measurement equipment for sample volume	DGM pre- and post-test; compare calibration factors (Y and Y_{qa})	Pre-test Post-test	±5 %

5.4 Laboratory Quality Assurance / Quality Control Procedures

Laboratory quality assurance and quality control procedures were performed in accordance with USEPA Method 5. Specific QA/QC procedures include evaluation of reagent and filter blanks, laboratory conditions, and the application of blank corrections. Refer to Appendix C for the laboratory data sheets.

5.4.1 QA/QC Blanks

Reagent and media blanks were analyzed for the parameters of interest. The results of the blanks are presented in the Table 5-2.

Table 5-2.
QA/QC Blanks

Sample Identification	Result	Comment
Method 5 Acetone Field Blank	1.5 mg	Sample volume was 150 milliliters. Acetone blank corrections of ~0.30-40 mg were applied.
Method 5 Laboratory Filter Blank	0.0 mg	Reporting limit is 0.1 milligrams.

5.4.2 Audit Samples

Audit Samples were not required for this test program.

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Table 1 - Particulate Matter Results

Facility and Source Information	Units	Run 1	Run 2	Run 3	Average
Customer:		D. E. Karn			
Source:		Unit 1			
Work Order:		26815610			
Date:		9/25/2017	9/26/2017	9/27/2017	
Unit Load:	MW_g	252	256	252	253
Stack Diameter	inches	268.0	268.0	268.0	
Cross-sectional Area of Stack, A	ft^2	391.74	391.74	391.74	
Source Pollutant Test Data	**Units**	**Run 1**	**Run 2**	**Run 3**	**Average**
Barometric Pressure, P_{bar}	inches of Hg	29.41	29.32	29.30	29.34
Dry Gas Meter Calibration Factor, Y	dimensionless	0.999	0.999	0.999	0.999
Pitot Tube Coefficient, C_p	dimensionless	0.84	0.84	0.84	0.84
Stack Static Pressure, P_g	inches of H_2O	-0.50	-0.50	-0.50	-0.50
Nozzle Diameter, D_n	inches	0.317	0.317	0.317	0.317
Run Start Time	hr:mm	14:15	7:55	8:12	
Run Stop Time	hr:mm	16:30	10:40	10:21	
Duration of Sample, θ	minutes	120	120	120	120
Dry Gas Meter Leak Rate, L_p	cfm	0.000	0.005	0.000	0.002
Dry Gas Meter Start Volume	ft^3	297.94	398.41	501.77	399.37
Dry Gas Meter Final Volume	ft^3	397.88	501.20	601.86	500.31
Average Pressure Difference across the Orifice Meter, ΔH	inches of H_2O	2.28	2.30	2.30	2.29
Average Dry Gas Meter Temperature, T_m	°F	97.1	89.3	78.3	88.3
Average Square Root Velocity Head, √Δp	√inches H_2O	0.5791	0.5936	0.5930	0.5886
Stack Gas Temperature, $T_{s(ts avg)}$	°F	236.3	233.4	237.5	235.7
Source Moisture Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Volume of Water Vapor Condensed in Silica Gel, $V_{wsg(std)}$	scf	1.2	1.3	1.0	1.2
Total Volume of Water Vapor Condensed, $V_{w(std)}$	scf	17.052	17.401	16.017	16.823
Volume of Gas Sample as Measured by the Dry Gas Meter, V_m	dcf	99.948	102.786	100.084	100.939
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscf	93.503	97.244	96.553	95.767
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscm	2.648	2.754	2.734	2.71
Moisture Content of Stack Gas, B_{ws}	% H_2O	15.42	15.18	14.23	14.94
Gas Analysis Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Carbon Dioxide, %CO_2	%, dry	13.1	13.7	13.4	13.4
Oxygen, %O_2	%, dry	6.4	6.0	6.8	6.4
Nitrogen, %N	%, dry	80.5	80.4	79.8	80.2
Dry Molecular Weight, M_d	lb/lb-mole	30.36	30.43	30.41	30.40
Wet Molecular Weight, M_s	lb/lb-mole	28.45	28.54	28.65	28.55
Percent Excess Air, %EA	%	42.68	39.00	47.26	42.98
Fuel F-Factor, F_o:	dimensionless	1.106	1.092	1.055	1.084
Fuel F-Factor, F_c:	scf/mmBtu	1,840	1,840	1,840	1,840
Gas Volumetric Flow Rate Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Average Stack Gas Velocity, v_s	ft/s	38.0	38.8	38.8	38.5
Stack Gas Volumetric Flow Rate, Q	acfm	892,263	912,593	912,892	905,916
Stack Gas Standard Volumetric Flow Rate, Q_s	scfm	664,202	680,102	675,921	673,408
Stack Gas Dry Standard Volumetric Flow Rate, Q_{sd}	dscfm	561,757	576,876	579,748	572,794
Percent of Isokinetic Sampling, I	%	99.2	100.5	99.3	99.6
Gas Concentrations and Emission Rates		**Run 1**	**Run 2**	**Run 3**	**Average**
Mass of Filterable PM Collected, m_n	mg	1.13	1.49	4.30	2.31
Filterable PM Concentration, c_s	gr/dscf	0.00019	0.00024	0.00069	0.00037
Filterable PM Concentration at Stack Conditions, $c_{s@stack\ conditions}$	mg/wacm	0.269	0.343	0.999	0.537
Filterable PM Concentration, C_s [Actual Conditions, Wet Basis]	lb/1,000 lbs	0.0003	0.0004	0.0011	0.0006
Filterable PM Concentration, C_{s50} [Actual Conditions, Wet Basis]	lb/1,000 lbs @ 50% EA	0.0003	0.0004	0.0011	0.0006
Filterable PM Mass Emission Rate, E	lb/hr	0.90	1.17	3.41	1.82
Filterable PM, lb/mmBtu, E	lb/mmBtu	0.0004	0.0005	0.0013	0.0007
Filterable PM, tpy [Assumes 8,760 Hrs/Yr Operation]	tpy	3.93	5.12	14.93	7.99

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Table 1 - Particulate Matter Results

Facility and Source Information	Units	Run 1	Run 2	Run 3	Average
Customer:		D. E. Karn			
Source:		Unit 2			
Work Order:		26815610			
Date:		9/27/2017	9/27/2017	9/28/2017	
Unit Load:	MW_g	257	257	257	257
Stack Diameter	inches	216.0	216.0	216.0	
Cross-sectional Area of Stack, A	ft^2	254.47	254.47	254.47	
Source Pollutant Test Data	**Units**	**Run 1**	**Run 2**	**Run 3**	**Average**
Barometric Pressure, P_{bar}	inches of Hg	29.32	29.31	29.46	29.36
Dry Gas Meter Calibration Factor, Y	dimensionless	0.999	0.999	0.999	0.999
Pitot Tube Coefficient, C_p	dimensionless	0.84	0.84	0.84	0.84
Stack Static Pressure, P_g	inches of H_2O	-0.50	-0.50	-0.50	-0.50
Nozzle Diameter, D_n	inches	0.240	0.240	0.240	0.240
Run Start Time	hr:mm	12:30	15:10	8:05	
Run Stop Time	hr:mm	14:42	17:27	10:21	
Duration of Sample, θ	minutes	120	120	120	120
Dry Gas Meter Leak Rate, L_p	cfm	0.000	0.000	0.000	0.000
Dry Gas Meter Start Volume	ft^3	602.48	701.20	804.58	702.75
Dry Gas Meter Final Volume	ft^3	700.70	802.69	901.17	801.52
Average Pressure Difference across the Orifice Meter, ΔH	inches of H_2O	2.17	2.29	2.15	2.21
Average Dry Gas Meter Temperature, T_m	°F	81.7	87.6	75.3	81.5
Average Square Root Velocity Head, √Δp	√inches H_2O	0.9505	0.9742	0.9489	0.9578
Stack Gas Temperature, $T_{s(absavg)}$	°F	205.0	206.7	199.8	203.8
Source Moisture Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Volume of Water Vapor Condensed in Silica Gel, $V_{wsg(std)}$	scf	1.2	1.0	1.0	1.1
Total Volume of Water Vapor Condensed, $V_{w(std)}$	scf	16.481	15.585	16.224	16.097
Volume of Gas Sample as Measured by the Dry Gas Meter, V_m	dcf	98.215	101.488	96.596	98.766
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscf	94.185	96.269	94.195	94.883
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscm	2.667	2.726	2.668	2.69
Moisture Content of Stack Gas, B_{ws}	% H_2O	14.89	13.93	14.69	14.51
Gas Analysis Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Carbon Dioxide, %CO_2	%, dry	12.7	12.6	12.9	12.7
Oxygen, %O_2	%, dry	7.4	7.5	7.3	7.4
Nitrogen, %N	%, dry	80.0	80.0	79.8	79.9
Dry Molecular Weight, M_d	lb/lb-mole	30.32	30.31	30.36	30.33
Wet Molecular Weight, M_s	lb/lb-mole	28.49	28.59	28.54	28.54
Percent Excess Air, %EA	%	53.53	54.65	53.03	53.74
Fuel F-Factor, F_o:	dimensionless	1.069	1.070	1.054	1.065
Fuel F-Factor, F_c:	scf/mmBtu	1,840	1,840	1,840	1,840
Gas Volumetric Flow Rate Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Average Stack Gas Velocity, v_s	ft/s	60.9	62.4	60.4	61.3
Stack Gas Volumetric Flow Rate, Q	acfm	930,482	953,279	922,142	935,301
Stack Gas Standard Volumetric Flow Rate, Q_s	scfm	723,066	738,630	725,740	729,145
Stack Gas Dry Standard Volumetric Flow Rate, Q_{sd}	dscfm	615,381	635,712	619,104	623,399
Percent of Isokinetic Sampling, I	%	103.4	102.3	102.8	102.8
Gas Concentrations and Emission Rates		**Run 1**	**Run 2**	**Run 3**	**Average**
Mass of Filterable PM Collected, m_n	mg	2.92	2.67	2.63	2.74
Filterable PM Concentration, c_s	gr/dscf	0.00048	0.00043	0.00043	0.00045
Filterable PM Concentration at Stack Conditions, $c_{s@stack\ conditions}$	mg/wacm	0.725	0.653	0.662	0.680
Filterable PM Concentration, C_s [Actual Conditions, Wet Basis]	lb/1,000 lbs	0.0008	0.0007	0.0007	0.0007
Filterable PM Concentration, C_{s50} [Actual Conditions, Wet Basis]	lb/1,000 lbs @ 50% EA	0.0008	0.0007	0.0007	0.0008
Filterable PM Mass Emission Rate, E	lb/hr	2.52	2.33	2.28	2.38
Filterable PM, lb/mmBtu, E	lb/mmBtu	0.0010	0.0009	0.0009	0.0009
Filterable PM, tpy [Assumes 8,760 Hrs/Yr Operation]	tpy	11.04	10.19	10.00	10.41