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PM_{10}, VOCs, and HCHO ROP Test Report

EUGT2B

Consumers Energy Company
Zeeland Generating Station
425 Fairview Road
Zeeland, Michigan 49464
SRN: N6521

February 1, 2019

Test Dates: December 11-12, 2018

Test Performed by the Consumers Energy Company
Regulatory Compliance Testing Section
Air Emissions Testing Body
Laboratory Services Section
Work Order No. 6500411
Version No.: 0

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

EXECUTIVE SUMMARY

Consumers Energy Regulatory Compliance Testing Section (RCTS) personnel conducted filterable particulate matter (FPM), condensable particulate matter (CPM), volatile organic compounds (VOCs) and formaldehyde (HCHO) testing at the exhaust of gas turbine EUGT2B (Unit 2B) operating at the Zeeland Generating Station in Zeeland, Michigan. Unit 2B is a natural gas fired combined-cycle combustion turbine that generates electricity. The test program, performed December 11 and 12, 2018, was conducted to satisfy testing requirements in renewable operating permit (ROP) MI-ROP-B6521-2015a and reestablish lb/mmBtu emission factors to be used with heat input determinations to calculate mass emission rates as specified in Appendix 5 of the ROP.

Triplicate 120-minute FPM, CPM, and VOCs test runs and 60-minute HCHO test runs were conducted following the procedures in USEPA Reference Methods (RM) 1, 2, 4, 5, 18 and 19 in 40 CFR 60, Appendix A, RM 320 in 40 CFR 63, Appendix A and RM 202 in 40 CFR 51, Appendix M. One set of test runs was conducted with Unit 2B operating at 100% load, and another set of test runs was conducted at 70% load as required in the facility's air permit. There were no deviations from the approved stack test protocol or the USEPA Reference Methods therein. The Unit 2B PM less than 10 microns in diameter (PM_{10}), VOCs and HCHO results are summarized in the following table.

Table E-1
Executive Summary of Test Results

Parameter	Units	Run 1	Run 2	Run 3	Average	Emission Limit ROP
Unit 2B - 70% Load						
PM_{10}	lb/hr	3.77	2.92	3.35	**3.35**	**14.7**
	ton/yr	16.5	12.8	14.7	**14.7**	**64.4**
	lb/mmBtu	0.0023	0.0018	0.0021	**0.0021**	**N/A***
VOCs†	lb/hr	0.23	0.22	0.20	**0.22**	**16.8**
	ton/yr	1.0	1.0	0.9	**1.0**	**73.6**
	lb/mmBtu	1.4E-04	1.3E-04	1.2E-04	**1.3E-04**	**N/A***
HCHO‡	ton/yr	1.0	1.0	0.9	**1.0**	**2.35‡**
	lb/mmBtu	1.4E-04	1.3E-04	1.2E-04	**1.3E-04**	**N/A***
Unit 2B - 100% Load						
PM_{10}	lb/hr	3.32	4.34	7.08	**4.91**	**14.7**
	ton/yr	14.6	19.0	31.0	**21.5**	**64.4**
	lb/mmBtu	0.0016	0.0022	0.0036	**0.0025**	**N/A***
VOCs†	lb/hr	0.22	0.18	0.20	**0.20**	**16.8**
	ton/yr	1.0	0.8	0.9	**0.9**	**73.6**
	lb/mmBtu	1.1E-04	9.4E-05	1.0E-04	**1.0E-04**	**N/A***
HCHO‡	ton/yr	1.0	0.8	0.9	**0.9**	**2.35‡**
	lb/mmBtu	1.1E-04	9.4E-05	1.0E-04	**1.0E-04**	**N/A***

* : lb/mmBtu results are used in mass emission calculations with continuous heat input to evaluate compliance with the mass emission limits
† : VOCs mass emissions calculated as sum of mass emissions of VOCs detected
‡ : HCHO limit is applicable to all turbine operations, the presented limit is the permit limit divided by four

Although not consistent with the prescribed compliance methodology in the ROP, the Unit 2B PM, PM_{10}, VOC and HCHO emission results indicate compliance with the mass emission limits in the permit. The preceding tons per year values are extrapolated assuming continuous operation at the pounds per hour emission rates observed during the testing. The facility uses lb/mmBtu emission factors in conjunction with continuous heat input determinations to calculate mass emission rates, consistent with Appendix 5 of the ROP.

Detailed test results are presented in Appendix Tables 1 and 2. Sample calculations, field data sheets, and laboratory data are presented in Appendices A, B, and C. Operating data and supporting documentation are provided in Appendices D and E.

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1.0 INTRODUCTION

This report summarizes the results of compliance particulate matter (PM), PM less than 10 microns in diameter (PM_{10}), volatile organic compounds (VOCs), and formaldehyde (HCHO) testing conducted December 11 and 12, 2018 on EUGT2B (Unit 2B) operating at the Consumers Energy Zeeland Generating Station in Zeeland, Michigan.

This document was prepared using the Michigan Department of Environmental Quality (MDEQ) *Format for Submittal of Source Emission Test Plans and Reports* published in March of 2018. Please exercise due care if portions of this report are reproduced, as critical substantiating documentation and/or other information may be omitted or taken out of context.

1.1 Identification, Location, and Dates of Tests

Consumers Energy Regulatory Compliance Testing Section (RCTS) personnel conducted PM_{10} (as the sum of filterable and condensable PM), VOCs, and HCHO tests at the dedicated exhaust of natural gas-fired combustion turbine Unit 2B operating at the Zeeland Generating Station in Zeeland, Michigan on December 11 and 12, 2018.

A test protocol was submitted to the MDEQ on October 26, 2018 and subsequently approved by Mr. Jeremy Howe, Environmental Quality Analyst, in his letter dated November 21, 2018.

1.2 Purpose of Testing

The purpose of the test was to satisfy testing requirements in renewable operating permit (ROP) MI-ROP-B6521-2015a and reestablish lb/mmBtu emission factors to be used with heat input determinations to calculate mass emission rates as specified in Appendix 5 of the ROP. The applicable emission limits are presented in Table 1-1.

Table 1-1
Emission Limits

Parameter	Emission Limit	Units	Applicable Requirement
EUGT2A, EUGT2B			
PM	0.03	lb/mmBtu	MI-ROP-N6521-2015a, Section 1, FGCOMBINEDCYCLE Emission Limits
PM_{10}	14.7	lb/hr	
	64.4	ton/yr	
VOC	16.8	lb/hr	
	73.6	ton/yr	
HCHO†	9.4	ton/yr	MI-ROP-N6521-2015a, Section 1, FGSIMPLECYCLE Emission Limits & FGCOMBINEDCYCLE† Emission Limits

†: HCHO limit is applicable to all combustion turbine operations

The ROP requires that testing be performed for one simple cycle and one combined cycle unit not tested at the last test event at 100% and 70% load. Units 1A and 2A were tested in 2013. This report summarizes the testing of Unit 2B, as Unit 1B testing occurred November 27 and 28, 2018 with results previously submitted in a separate report.

1.3 Brief Description of Source

The Zeeland Generating Station operates four General Electric (GE) model 7FA natural gas fired combustion turbines.

1.4 Contact Information

Table 1-2 presents the names, addresses, and telephone numbers for contacts involved in this test program.

Table 1-2
Contact Information

Program Role	Contact	Address
EPA Regional Contact	Compliance Tracker, AE-18J 312-353-2000	Air Enforcement and Compliance Assurance U.S. Environmental Protection Agency–Region 5 77 W. Jackson Boulevard Chicago, Illinois 60604
Regulatory Agency Representative	Ms. Karen Kajiya-Mills Technical Programs Unit Manager 517-335-4874 Kajiya-Millsk@michigan.gov	Michigan Department of Environmental Quality Technical Programs Unit 525 W. Allegan, Constitution Hall, 2nd Floor S Lansing, Michigan 48933
Regulatory Agency Representative	Mr. Jeremy Howe Environmental Quality Analyst 231-878-6687 HoweJ1@michigan.gov	Michigan Department of Environmental Quality Air Quality Division 120 W. Chapin Street Cadillac, Michigan 49601
Test Facility	Mr. J. Homer Manning Environmental Health & Safety 616-237-4004 Homer.ManningIII@cmsenergy.com	Consumers Energy Company Zeeland Generating Station 425 Fairview Road Zeeland, Michigan 49464
Test Team Representative	Mr. Dillon King, QSTI Sr. Engineering Technical Analyst 989-891-5585 Dillon.King@cmsenergy.com	Consumers Energy Company D.E. Karn Power Plant 2742 North Weadock Highway, ESD Trailer #4 Essexville, Michigan 48732
Test Team Representative	Mr. Thomas Schmelter, QSTI Sr. Engineering Technical Analyst 616-738-3234 Thomas.Schmelter@cmsenergy.com	Consumers Energy Company L&D Training Center 17010 Croswell Street West Olive, Michigan 49460

2.0 SUMMARY OF RESULTS

2.1 Operating Data

The combined cycle combustion turbine fired natural gas during the test event. As noted in the test protocol, the achievable load for a combustion turbine varies with ambient conditions. Based upon weather conditions at the time of testing, the 100% load condition was run at the maximum achievable load condition and corresponded to approximately 170 gross megawatts (MWg). The reduced load testing was run at approximately 123 MWg, or 72% of the load achieved at the 100% load condition. Note that the preceding loads reflect electrical production for the combustion turbine only and do not account for the share of electrical production from the common steam turbine and electrical generator. When accounting for the additional electricity from the steam turbine and electrical generator, the 100% load condition test equated to approximately 258 MW, while the reduced load condition equated to approximately 196 MW.

Refer to Attachment D for detailed operating data, which was recorded in Eastern Standard Time (EST).

2.2 Applicable Permit Information

The Zeeland generating station is identified by State Registration Number (SRN) N6521 and operates in accordance with renewable operating permit (ROP) MI-ROP-N6521-2015a. The permit incorporates federal regulations and reports under Federal Registry Service (FRS) Id: 110012534551. EUGT1A and EUGT1B are included in the flexible group FGSIMPLECYCLE. EUGT2A and EUGT2B are included in the FG COMBINEDCYCLE flexible group.

2.3 Results

The Unit 2B PM less than 10 microns in diameter (PM_{10}), VOCs and HCHO results are summarized in Table 2-1 below.

Table 2-1
Summary of Test Results

Parameter	Units	Run 1	Run 2	Run 3	Average	Emission Limit ROP
Unit 2B - 70% Load						
PM_{10}	lb/hr	3.77	2.92	3.35	**3.35**	**14.7**
	ton/yr	16.5	12.8	14.7	**14.7**	**64.4**
	lb/mmBtu	0.0023	0.0018	0.0021	**0.0021**	**N/A***
VOCs†	lb/hr	0.23	0.22	0.20	**0.22**	**16.8**
	ton/yr	1.0	1.0	0.9	**1.0**	**73.6**
	lb/mmBtu	1.4E-04	1.3E-04	1.2E-04	**1.3E-04**	**N/A***
HCHO‡	ton/yr	1.0	1.0	0.9	**1.0**	**2.35‡**
	lb/mmBtu	1.4E-04	1.3E-04	1.2E-04	**1.3E-04**	**N/A***
Unit 2B - 100% Load						
PM_{10}	lb/hr	3.32	4.34	7.08	**4.91**	**14.7**
	ton/yr	14.6	19.0	31.0	**21.5**	**64.4**
	lb/mmBtu	0.0016	0.0022	0.0036	**0.0025**	**N/A***
VOCs†	lb/hr	0.22	0.18	0.20	**0.20**	**16.8**
	ton/yr	1.0	0.8	0.9	**0.9**	**73.6**
	lb/mmBtu	1.1E-04	9.4E-05	1.0E-04	**1.0E-04**	**N/A***
HCHO‡	ton/yr	1.0	0.8	0.9	**0.9**	**2.35‡**
	lb/mmBtu	1.1E-04	9.4E-05	1.0E-04	**1.0E-04**	**N/A***

* : lb/mmBtu results are used in mass emission calculations with continuous heat input to evaluate compliance with the mass emission limits

† : VOCs mass emissions calculated as sum of mass emissions of VOCs detected

‡ : HCHO limit is applicable to all turbine operations, the presented limit is the permit limit divided by four

Although not consistent with the prescribed compliance methodology in the ROP, the Unit 2B PM, PM_{10}, VOC and HCHO emission results indicate compliance with the mass emission limits in the permit. PM_{10} was determined as the sum of filterable and condensable PM. The preceding tons per year values are extrapolated assuming continuous operation at the pounds per hour emission rates observed during the testing. The facility uses lb/mmBtu emission factors in conjunction with continuous heat input determinations to calculate mass emission rates, consistent with Appendix 5 of the ROP.

Detailed test results are presented in Appendix Tables 1 and 2. Sample calculations, field data sheets, and laboratory data are presented in Appendices A, B, and C. Operating data and supporting documentation are provided in Appendices D and E.

3.0 SOURCE DESCRIPTION

EUGT2B is a combined-cycle natural gas fired combustion turbine directly coupled to an electricity producing generator. Steam generated in the associated Heat Recovery Steam Generator (HRSG) is then fed to a common steam extraction turbine and electrical generator shared with EUGT2A.

3.1 PROCESS

The Zeeland Generating Station operates four General Electric (GE) model 7FA natural gas fired combustion turbines. Units 1A and 1B are simple cycle units rated at 2,205 mmBtu/hr heat input, with an Upper Bound Range of Operation (UBRO) at 190 megawatts (MW) and a Lower Bound Range of Operation (LBRO) at 17 MW. Units 2A and 2B are combined-cycle units rated at 2,323 mmBtu/hr heat input, with an UBRO at approximately 303 MW and an LBRO at 17 MW.

3.2 PROCESS FLOW

Air pollution control is achieved on all four combustion turbines through the use of Dry Low NOx Burners. The combined cycle units are also equipped with selective catalytic reduction (SCR) systems for controlling NOx.

3.3 MATERIALS PROCESSED

Natural gas is combusted in the turbine producing heat that is used for electricity generation.

3.4 RATED CAPACITY

Units 1A and 1B are rated at 2,205 mmBtu/hr heat input, with an UBRO at 190 MW and a LBRO at 17 MW. Units 2A and 2B are rated at 2,323 mmBtu/hr heat input, with an UBRO at 303 (Unit 2A) and 305 (Unit 2B) MW and an LBRO at 17 MW.

Testing was performed on one combined-cycle unit (Unit 2B, as 2A was tested during the most recent test event in 2013) at 100% and 70% load as required in MI-ROP-N6521-2015a.

3.5 PROCESS INSTRUMENTATION

Operators, environmental technicians, and data acquisition systems continuously monitored the process during testing. One-minute data for the following parameters were collected during each FPM, CPM, VOCs, and HCHO test run:

- total heat input (mmBtu/hr)
- gross electricity output (MWg) [for the combustion turbine only]
- turbine and duct burner gas flow (hundred scfh)
- ammonia injection rate (lb/hr)
- oxygen (%)
- nitrogen oxides (ppmv at 15% O_2, lb/mmBtu)
- carbon monoxide (ppmv, lb/mmBtu)

Due to the various instrumentation systems, the sampling times were correlated to instrumentation times. Refer to Appendix D for operating data.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

RCTS personnel tested for FPM, CPM, VOCs and HCHO 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	Method	USEPA 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)
Moisture	4	Determination of Moisture Content in Stack Gases
Filterable Particulate Matter*	5	Determination of Particulate Matter Emissions from Stationary Sources
Formaldehyde	18	Measurement of Gaseous Organic Compound Emissions by Gas Chromatography (FTIR)
Emission Rate	19	Determination of Sulfur Dioxide Removal Efficiency and Particulate Matter, Sulfur Dioxide, and Nitrogen Oxide Emission Rates
Condensable Particulate Matter*	202	Dry Impinger Method for Determining Condensable Particulate Emissions From Stationary Sources
Molecular Weight (CO_2 and O_2†)	320	Vapor Phase Organic and Inorganic Emissions by Extractive FTIR
Volatile Organic Compounds		

†: O_2 values will be determined from certified CEMS measurements
*: Methods 5 and 202 will be conducted in conjunction to measure PM_{10}

4.1 DESCRIPTION OF SAMPLING TRAIN AND FIELD PROCEDURES

The test matrix presented as Table 4-2 summarizes the sampling and analytical methods performed as specified in this test program.

Table 4-2
Test Matrix

Date (2018)	Run	Sample Type	Load (%)	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	Comment
Dec. 11	1	PM_{10} and VOCs	70	9:05	11:19	120	Isokinetic sampling from 24 traverse points collected 3.137 dscm sample volume
	1	HCHO	70	9:41	10:41	60	Single point, 1,199.7 milliliter sample volume
	2	PM_{10} and VOCs	70	11:50	14:00	120	Isokinetic sampling from 24 traverse points collected 3.165 dscm sample volume

Table 4-2
Test Matrix

Date (2018)	Run	Sample Type	Load (%)	Start Time (EDT)	Stop Time (EDT)	Test Duration (min)	Comment
Dec. 11	2	HCHO	70	12:24	13:24	60	Single point, 1,199.7 milliliter sample volume
	3	PM_{10} and VOCs	70	14:20	16:30	120	Isokinetic sampling from 24 traverse points collected 3.234 dscm sample volume
	3	HCHO	70	15:10	16:10	60	Single point, 1,199.7 milliliter sample volume
Dec. 12	1	PM_{10} and VOCs	100	8:30	10:39	120	Isokinetic sampling from 24 traverse points collected 3.487 dscm sample volume
	1	HCHO	100	8:45	9:45	60	Single point, 1,199.7 milliliter sample volume
	2	PM_{10} and VOCs	100	11:00	13:09	120	Isokinetic sampling from 24 traverse points collected 3.305 dscm sample volume
	2	HCHO	100	13:46	14:46	60	Single point, 1,199.7 milliliter sample volume
	3	PM_{10} and VOCs	100	13:25	15:33	120	Isokinetic sampling from 24 traverse points collected 3.347 dscm sample volume
	3	HCHO	100	14:50	15:50	60	Single point, 1,199.7 milliliter sample volume

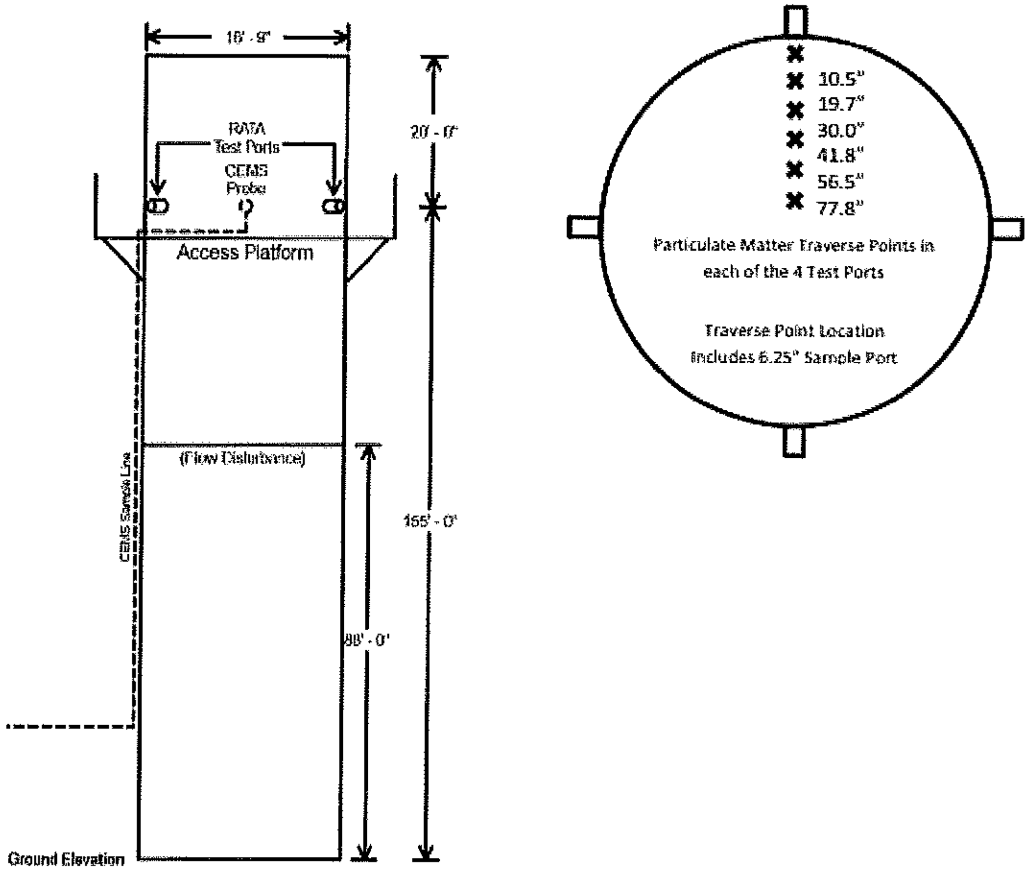
4.1.1 Sample Location and Traverse Points (USEPA Method 1)

The number and location of traverse points for measuring exhaust gas velocity and volumetric airflow 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 approximately 16.75 feet diameter stack. Refer to Figure 4-1 for a drawing showing the traverse points and upstream and downstream disturbances. The sampling ports are situated:

- Approximately 67 feet or 4 duct diameters downstream of a flow disturbance, and
- Approximately 20 feet or 1.2 duct diameters upstream of the stack exit.

The sample ports are 6-inches in diameter and extend 6.25 inches beyond the stack wall. The area of the exhaust duct was calculated and the cross-sectional area divided into a number of equal areas based on distances to air flow disturbances. Flue gas was sampled for five minutes at each of the six traverse points from the four sample ports for a total of 24 sample points and 120 minutes.

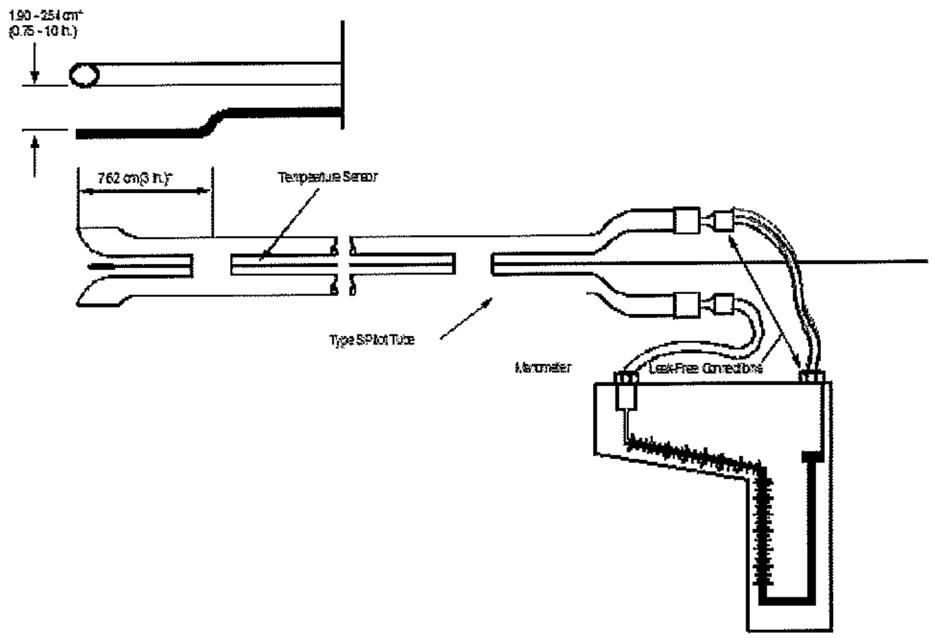
Figure 4-1. Unit 2B Sampling Location and Test Port/Traverse Point Detail



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 4-2 for the Method 2 Pitot tube, thermocouple, and inclined oil-filled manometer configuration.

Figure 4-2. Method 2 Sample Apparatus



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 1B exhaust on December 10, 2018 was 5.1°, thus meeting the less than 20° requirement. Since no ductwork and/or stack configuration changes are expected to occur in the future, the null angle information is considered reliable and additional cyclonic flow verification will not be performed. The cyclonic flow testing data is presented in Appendix B.

4.1.3 Molecular Weight (Certified CEMS and USEPA Method 320)

The exhaust gas composition and molecular weight was calculated using O_2 measurements from the certified CEMS during the testing and CO_2 measurements obtained from the FTIR following the sampling and analytical procedures of USEPA Method 320, *Vapor Phase Organic and Inorganic Emissions by Extractive FTIR.* The flue gas oxygen and carbon dioxide concentrations are required to calculate molecular weight, flue gas velocity, and emissions in lb/mmBtu, lb/hr, and ton/yr. Refer to Section 4.1.8 for sampling and analytical procedures of USEPA Method 320.

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 and 202 sample apparatus. Flue gas was drawn through a series of impingers immersed in an ice bath to condense and remove water from the sample. 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 Filterable Particulate Matter (USEPA Method 5)

Filterable particulate matter samples were collected isokinetically in conjunction with RM 202 following USEPA Method 5, *Determination of Particulate Matter Emissions from Stationary Sources* procedures.

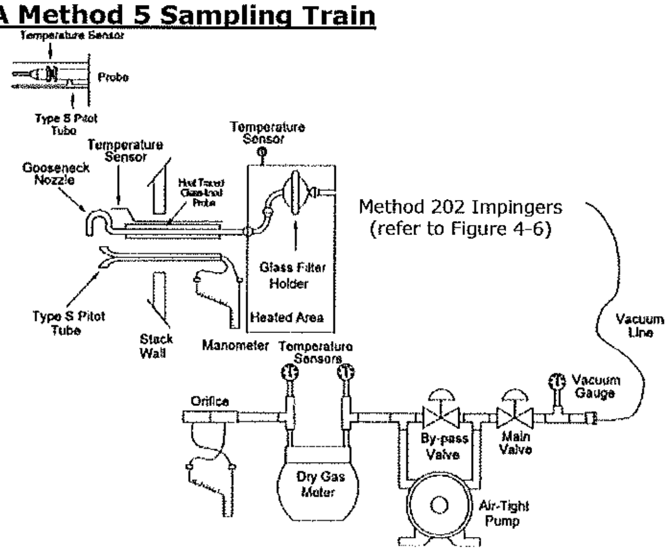
The flue gas is collected using a specifically sized nozzle, probe, quartz-fiber filter, and a series of impingers configured as shown in Method 5/202 Table 4-3. The FPM is collected on the filter and water vapor and/or CPM is collected in the impingers. Figure 4-3 depicts the USEPA Method 5 sample apparatus.

Before testing, a preliminary velocity traverse was performed and/or representative flow data from previous measurements was reviewed to calculate an ideal nozzle size that allowed isokinetic sampling to be performed. A pre-cleaned nozzle that had an inner diameter approximating the calculated value was measured with calipers across three cross-sectional chords, rinsed and brushed with 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 PM sample train was leak-checked by capping the nozzle opening and applying a vacuum of approximately 15 inches of mercury. The dry-gas meter was monitored for approximately 1 minute to verify a sample apparatus leak rate of less than 0.02 cubic feet per minute (cfm). The sample probe was inserted into the sampling port to begin sampling.

Ice was placed around the impingers and the probe, and filter temperatures were allowed to stabilize to a temperature of 248±25°F before sampling, as applicable. After the desired operating conditions were coordinated with the facility, testing was initiated. Stack and sample apparatus parameters (e.g., flue velocity, temperature) were monitored to ensure isokinetic sample rates were within 100±10% for the duration of the test.

Figure 4-3. USEPA Method 5 Sampling Train



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

The filter was recovered from the filter housing, 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 was triple rinsed with acetone and collected in pre-cleaned sample containers, sealed with Teflon tape, and labeled as "FPM Container 2." The flue gas moisture condensed in the impingers was weighed on an electronic scale to determine flue gas moisture content, after which the impingers were recovered following Method 202 CPM requirements (see Section 4.1.6). Refer to Figure 4-4 for the USEPA Method 5 sample recovery scheme.

The sample containers, including blanks, were transported to the RCTS laboratory for analysis. The sample analysis followed USEPA Method 5 procedures as summarized in the sample recovery scheme presented in Figure 4-5.

Figure 4-4. USEPA Method 5 Sample Recovery Scheme

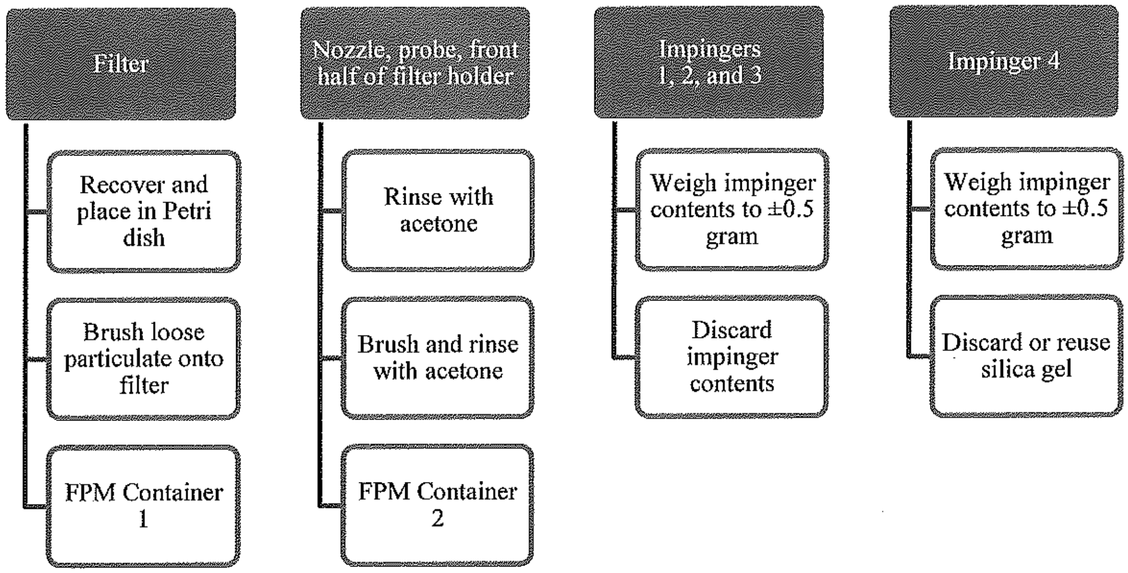
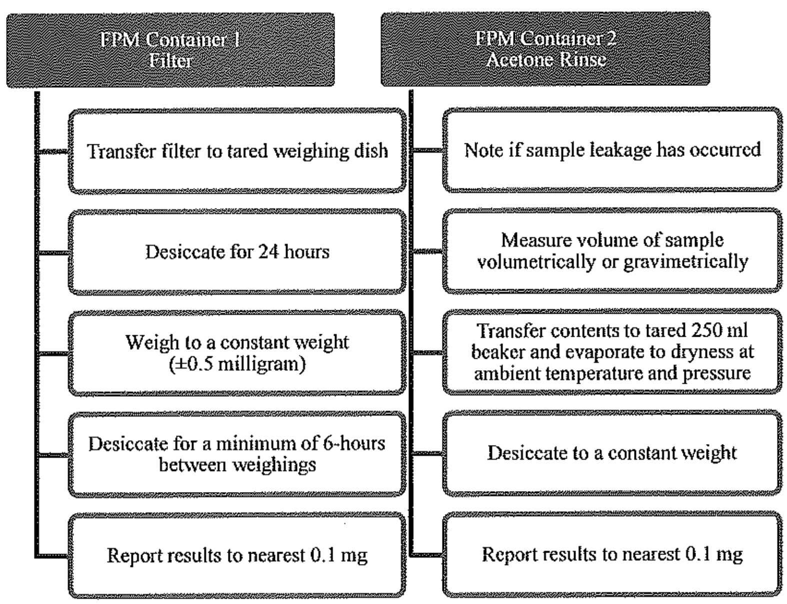


Figure 4-5. USEPA Method 5 Analytical Scheme



4.1.6 Condensable Particulate Matter (USEPA Method 202)

Condensable particulate matter was collected isokinetically in conjunction with USEPA Method 5 using 40 CFR Part 51, EPA Method 202, *Dry Impinger Method for Determining Condensable Particulate Emissions from Stationary Sources.* The Method 202 sample apparatus uses clean, baked glassware comprised of a glass coil type condenser, a dropout impinger, a modified Greenburg-Smith (GS) impinger with an open tube tip, a CPM filter holder containing a Teflon filter, one impinger containing approximately 100 milliliters of water and one impinger containing silica gel. During each CPM run, temperature controlled water recirculated in the coil condenser jacket maintained the CPM filter temperature below 85°F. Refer to Figure 4-6 for a drawing of the Method 202 sample apparatus and Table 4-3 which describes the Method 5/202 impinger configuration.

Figure 4-6. USEPA Method 202 Sampling Train

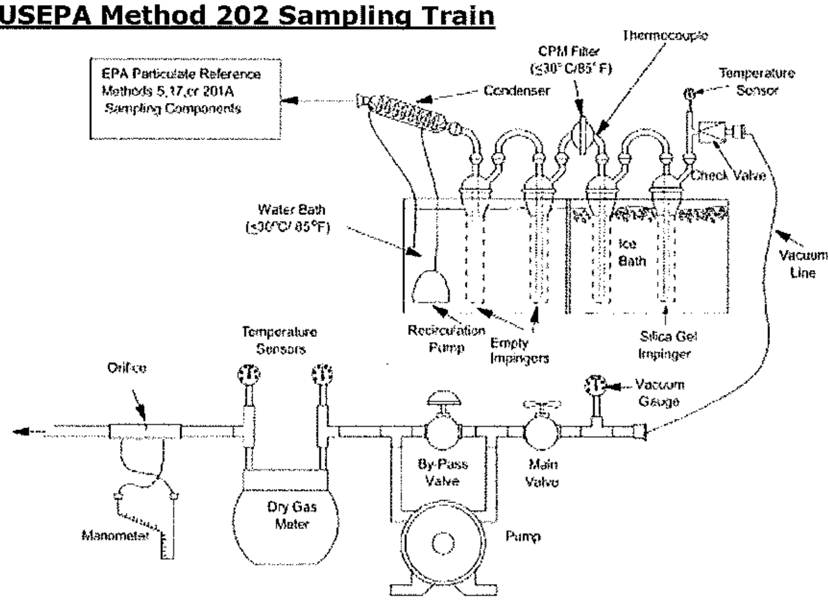


Table 4-3 Method 5/202 Impinger Configuration

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

Upon test completion, each impinger was weighed to determine flue gas moisture content. The condenser, dropout and back-up impingers, and the CPM filter housing were then re-assembled and purged with Ultra-high purity nitrogen at a rate of approximately 14 liters per minute for a minimum of one hour to remove dissolved sulfur dioxide (SO_2) gases from the impinger water. During the purge, water continued to recirculate in the condenser jacket to maintain the CPM filter exit temperature and the impingers were observed to ensure the contents did not evaporate.

After the nitrogen purge, the condensate collected in the dropout and back-up impingers were transferred to a clean sample bottle labeled as CPM Container #1, Aqueous Liquid Impinger. The back half of the Method 5 filter bell, condenser, impingers and connecting glassware were then rinsed twice with deionized, ultra-filtered water into the same container. The water rinses were followed by an acetone rinse and duplicate hexane rinses into a separate sample bottle identified as CPM Container #2 (organic rinses). The CPM filter was removed prior to the water and organic rinses and placed in a clean Petri dish identified as CPM Container #3. Liquid levels on the sample bottles were marked and the samples were sealed and transported to Maxxam Analytics laboratory in Mississauga, Ontario for analysis.

4.1.7 Formaldehyde (USEPA Method 18)

Formaldehyde concentrations were determined using USEPA Method 18, Measurement of Gaseous Organic Compound Emissions by Gas Chromatography via adsorbent tube sampling and analysis. The target organic compound (formaldehyde) was separated by gas chromatography and quantified by the FTIR onsite. Sampling, analytical and calibration procedures followed USEPA Method 18 specifications for adsorbent tube sampling.

A recovery study was performed utilizing two identical trains. One of the sampling trains was designated the spiked train and the other the unspiked train. Formaldehyde was spiked (at 40% to 60% of the expected catch) onto the adsorbent tube in the spiked train prior to sampling. The two trains were sampled simultaneously and the fraction of the spiked compound recovered (R) was calculated in accordance with USEPA Method 18. A complete recovery study will consist of three runs. For the adsorbent tube sampling and analytical procedure to be acceptable, R (in this case the average of three runs) must be ≥0.70 and ≤1.30. The calculated R value was 1.067 for the 100% load condition and 0.980 for the 70% load condition. Refer to the laboratory report in Appendix C for detailed data and calibrations.

4.1.8 VOCs and Carbon Dioxide (USEPA Method 320)

VOCs and CO2 were measured using the sampling and analytical procedures of USEPA Method 320, Vapor Phase Organic and Inorganic Emissions by Extractive FTIR. Exhaust gas was extracted through a heated stainless steel probe and heated Teflon® sample line prior to being introduced to the FTIR. The stainless steel probe and Teflon® sample line were maintained at approximately 375°F.

Prior to testing a calibration transfer standard (CTS) was used to ensure suitable agreement between the sample and reference spectra. Following the CTS, a spike gas and tracer gas was introduced to the sample line at a constant flowrate of ≤10% of the total sample flow. The system passed the QA spike when the average spike concentration was within 0.7 to 1.3 times the expected concentration.

Data was validated and corrected per specifications outlined in USEPA Method 301. A total of 120 minutes of reference spectra data was collected for each run. Following each run, another CTS spectrum was recorded and compared to the pre-test CTS. The pre-test and post-test CTS are required to be within ±5% of the mean value for the run to be valid.

An on-site minimum detectable concentration (MDC) analysis was performed for the target analytes using procedures outlined in ASTM D 6348 A2.3. The MDC was calculated as three times the standard deviation of the concentrations from ten representative background spectra taken during the MDC analysis.

The VOCs tested for with the FTIR were acetylene, propane, propylene, butane, acetaldehyde, ethylene and methanol. Total VOC mass and lb/mmBtu emission rates were calculated as the sum of the mass and lb/mmBtu emission rates of any VOCs present above the detection limit plus the mass and lb/mmBtu emission rate of formaldehyde (from M18). No VOCs were detected above the minimum detection limit (0.5 ppmv) and each such VOC was assigned a value of zero consistent with guidance from the MDEQ-AQD. It should be noted that there was a minor sampling system contaminant/interferent that required bias corrections to be applied to butane concentration data.

4.1.9 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_{10}, VOC and formaldehyde emission rates in units of lb/mmBtu. Measured oxygen concentrations from the certified CEMS and F factors (ratios of combustion gas volumes to heat inputs) were used to calculate emission rates using equation 19-1 from the method; refer to Appendix A for sample calculations.

5.0 TEST RESULTS AND DISCUSSION

The test results obtained as required by MDEQ ROP MI-ROP-N6521-2015a on December 11 and 12, 2018 indicate the average of the three runs performed on Unit 2B for PM_{10}, VOCs and HCHO measured less than the emission limits in Table 1-1 at both load conditions (again, stack testing is not the compliance method; the lb/mmBtu emission factors will be used in conjunction with heat input determinations to calculate mass emissions based upon the proper averaging periods). Therefore, Unit 2B is in compliance with the mass emission limits in the ROP. Refer to Section 2.3 for a summary of the test results.

5.1 Tabulation of Results

Table 2-1 in Section 2 of this report summarizes the results and Appendix Tables 1 and 2 contain detailed tabulation of results, process operating conditions, and exhaust gas conditions.

5.2 Significance of Results

The Unit 2B PM_{10}, VOCs and HCHO results indicate ongoing compliance with the mass emission limits present in MDEQ ROP MI-ROP-N6521-2015a.

5.3 Variations from Sampling or Operating Conditions

There were no significant sampling or variations encountered during the test program. It should be noted that the 2nd and 3rd Method 18 test runs for HCHO at 100% load did not occur concurrently with the PM/VOCs test runs. Additional process data sheets are included in Appendix D to accompany these runs.

5.4 Process or Control Equipment Upset Conditions

The turbine and associated control equipment were operating under routine conditions and no upsets were encountered during testing.

5.5 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 equipment is a continuous process to ensure compliance with regulatory emission limits.

5.6 Re-Test Discussion

Based on the results of this test program, a re-test is not required.

5.7 Results of Audit Samples

Audit samples are not required for the reference methods utilized during this test program and are not available from USEPA Stationary Source Audit Sample Program providers. A list of QA/QC Procedures is listed below in Table 5-1.

Table 5-1
QA/QC Procedures

QA/QC Activity	Purpose	Procedure	Frequency	Acceptance Criteria
M1: Sampling Location	Evaluates if the sampling location is suitable for sampling	Measure distance from ports to downstream and upstream flow disturbances	Pre-test	≥2 diameters downstream; ≥0.5 diameter upstream.
M1: Duct diameter/ dimensions	Verifies area of stack is accurately measured	Review as-built drawings and field measurement	Pre-test	Field measurement agreement with as-built drawings
M1: Cyclonic flow evaluation	Evaluate the sampling location for cyclonic flow	Measure null angles	Pre-test	≤20°
M2: Pitot tube calibration and standardization	Verifies construction and alignment of Pitot tube	Inspect Pitot tube, assign coefficient value	Pre-test and after each field use	Method 2 alignment and dimension requirements
M2: Pitot tube leak check	Verify leak free sampling systems	Apply minimum pressure of 3.0 inches of H_2O to Pitot tube	Pre-test and Post-test	±0.01 in H_2O for 15 seconds at minimum 3.0 in H_2O velocity head
M4: Field balance calibration	Verify moisture measurement accuracy	Use Class 6 weight to check balance accuracy	Daily before use	The field balance must measure the weight within ±0.5 gram of the certified mass
M4: Impinger temperature	Ensures collection of condensed water	Maintain last impinger temperature ≤68°F	Throughout test	Last impinger temperature must be ≤68°F
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: Apparatus Temperature	Prevents condensation within sample apparatus	Set probe & filter heat controllers to 248±25°F	Verify prior to and during each run	Apparatus temperature must be 248±25°F
M5: sample rate	Ensure representative sample collection	Calculate isokinetic sample rate	During and post-test	100±10% isokinetic rate
M5: Sample volume	Ensure minimum required sample volumes collected	Record pre- and post-test dry gas meter volume reading	Post test	PM: ≥100 dscf

Table 5-1
QA/QC Procedures

QA/QC Activity	Purpose	Procedure	Frequency	Acceptance Criteria
M5/202: Post-test leak check	Evaluate if system leaks biased the sample	Cap sample train; monitor DGM	Post-test	≤0.020 cfm
M5/202: post-test meter audit	Evaluates sample volume accuracy	DGM pre- and post-test; compare calibration factors (Y and Yqa)	Pre-test Post-test	±5%
M5: Apparatus Temperature	Ensures purge of acid gases in glass probe liner and Teflon filter	Set probe & filter heat controllers to ≥248°F	Verify prior to and during each run	Apparatus temperature must be ≥223°F and ≤273°F
M202: impinger temperature	Ensure collection of condensate	Maintain CPM filter temperature below 85°F	Throughout test	CPM filter temperature must be ≥65°F and ≤85°F
M18: Analyzer calibration	Develop calibration curve, evaluates operation of analyzers	Calibration gases introduces directly into analyzers	Pre-test Post-test	pre- and post- test average response factors ±5% of mean value
M18: Recovery study	Verify the acceptability of the sampling technique for the target compound(s)	Average recovery from three spiked adsorption tubes; correct all field measurements based on the average recovery	Field sample runs not validated without successful field recovery test	Average recovery between 0.7 and 1.3
M320: Sampling system leak check	Verify leak free sampling system	Cap sampling system, monitor flowrate	Pre-test	≤200 mL/min
M320: Analytical system leak check	Verify leak free analytical system	Cap analytical system, monitor pressure	Pre-test	≤4.0% of the FTIR system volume
M320: QA Spike	Evaluates operation of analyzer	Calibration gases introduced into sampling system at ≤10.0% of sampling rate	Pre-test Post-test	average spiked concentration 0.7 to 1.3 times the expected concentration

5.8 Calibration Sheets

Calibration sheets, including dry gas meter, gas protocol sheets, and analyzer quality control and assurance checks are presented in Appendix E.

5.9 Sample Calculations

Sample calculations and formulas used to compute emissions data are presented in Appendix A.

5.10 Field Data Sheets

Field data sheets are presented in Appendix B.

5.11 Laboratory Quality Assurance / Quality Control Procedures

The method specific quality assurance and quality control procedures in each method employed during this test program were followed, without deviation. Refer to Appendix C for the laboratory data sheets.

5.11.1 QA/QC Blanks

Reagent and media blanks were analyzed for the parameters of interest. The results of the blanks analysis are presented in the Table 5-2. Laboratory QA/QC and blank results data are contained in Appendix C.

Table 5-2
QA/QC Blanks

Sample Identification	Result	Comment
Method 5 Acetone Blank	1.4 mg	Sample volume was 200 milliliters Acetone blank corrections were applied
Method 5 Filter Blank	0.0 mg	Reporting limit is 0.1 milligrams
Method 202 DI H_2O Blank	<0.5 mg	Sample weight was 200 grams Result is for inorganic condensable
Method 202 Acetone Blank	<1.0 mg	Sample weight was 160 grams Result is for organic condensable
Method 202 Hexane Blank	<1.0 mg	Sample weight was 150 grams Result is for organic condensable
Method 202 Field Train Recovery Blank	1.9 mg inorganic 1.1 mg organic	Maximum blank correction of 2.0 mg applied to results

Appendix Table

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Table 1 - Unit 2B 70% Load PM Emission Test Results

Facility and Source Information	Units	Run 1	Run 2	Run 3	Average
Customer:		Zeeland Generating Station			
Source:		Unit 2B - 70% Load			
Work Order:		6500411			
Date:		12/11/2018	12/11/2018	12/11/2018	
Load:	MWg	122.8	122.6	122.8	122.7
Stack Diameter	inches	201.0	201.0	201.0	
Cross-sectional Area of Stack, A	ft^2	220.35	220.35	220.35	
Source Pollutant Test Data	**Units**	**Run 1**	**Run 2**	**Run 3**	**Average**
Barometric Pressure, P_{bar}	inches of Hg	29.25	29.25	29.40	29.30
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	-1.00	-0.70	-1.00	-0.90
Nozzle Diameter, D_n	inches	0.240	0.240	0.240	0.240
Run Start Time	hr:mm	9:05	11:50	14:20	
Run Stop Time	hr:mm	11:19	14:00	16:30	
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	408.04	521.62	642.25	523.97
Dry Gas Meter Final Volume	ft^3	521.00	636.88	760.01	639.30
Average Pressure Difference across the Orifice Meter, ΔH	inches of H_2O	2.87	3.09	3.06	3.01
Average Dry Gas Meter Temperature, T_m	°F	69.5	75.8	78.4	74.6
Average Square Root Velocity Head, √Δp	√inches H_2O	1.0761	1.1115	1.1037	1.0971
Stack Gas Temperature, $T_{s(abavg)}$	°F	217.5	217.7	219.5	218.2
Source Moisture Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Volume of Water Vapor Condensed in Silica Gel, $V_{wsg(std)}$	scf	1.2	1.6	1.7	1.5
Total Volume of Water Vapor Condensed, $V_{w(std)}$	scf	8.659	9.187	8.968	8.938
Volume of Gas Sample as Measured by the Dry Gas Meter, V_m	dcf	112.959	115.256	117.760	115.325
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscf	110.759	111.743	114.188	112.230
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscm	3.137	3.165	3.234	3.178
Moisture Content of Stack Gas, B_{ws}	% H_2O	7.25	7.60	7.28	7.38
Gas Analysis Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Carbon Dioxide, %CO_2	%, dry	4.2	4.2	4.2	4.2
Oxygen, %O_2	%, dry	13.4	13.4	13.5	13.4
Nitrogen, %N	%, dry	82.4	82.4	82.3	82.4
Dry Molecular Weight, M_d	lb/lb-mole	29.21	29.21	29.21	29.21
Wet Molecular Weight, M_s	lb/lb-mole	28.40	28.36	28.40	28.38
Fuel F-Factor, F_d:	dscf/mmBtu	8,710	8,710	8,710	8,710
Gas Volumetric Flow Rate Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Average Stack Gas Velocity, v_s	ft/s	69.9	72.2	71.6	71.2
Stack Gas Volumetric Flow Rate, Q	acfm	923,878	954,716	946,575	941,723
Stack Gas Standard Volumetric Flow Rate, Q_s	scfm	702,118	725,879	720,937	716,312
Stack Gas Dry Standard Volumetric Flow Rate, Q_{sd}	dscfm	651,207	670,734	668,440	663,460
Percent of Isokinetic Sampling, I	%	99.5	97.4	99.9	98.9
Gas Concentrations and Emission Rates		**Run 1**	**Run 2**	**Run 3**	**Average**
Mass of Filterable PM Collected, m_n	mg	0.76	1.68	1.04	1.16
Filterable PM Concentration, c_s	gr/dscf	0.00011	0.00023	0.00014	0.00016
Filterable PM Mass Emission Rate, E	lb/hr	0.59	1.33	0.80	0.91
Filterable PM, lb/mmBtu, E	lb/mmBtu	0.0004	0.0008	0.0005	0.0006
Filterable PM, tpy [Assumes 8,760 Hrs/Yr Operation]	tpy	2.6	5.8	3.5	4.0
Mass of Organic CPM, m_o	mg	1.0	1.4	1.9	1.4
Mass of Inorganic Condensable PM, m_i	mg	5.1	2.6	3.4	3.7
Mass of Total CPM in Field Train Recovery Blank Correction, m_{fb}	mg	2.0	2.0	2.0	2.0
Mass of Total Condensable PM, m_{cpm}	mg	4.1	2.0	3.3	3.1
Condensable PM Concentration	gr/dscf	0.00057	0.00028	0.00045	0.00043
Condensable PM Mass Emission Rate	lb/hr	3.18	1.58	2.55	2.44
Condensable PM Mass Emission Rate	lb/mmBtu	0.0020	0.0010	0.0016	0.0015
Condensable PM Mass Emission Rate [Assumes 8,760 Hrs/Yr Operation]	tpy	13.9	6.9	11.2	10.7
Mass of Filterable and Condensable PM (PM_{10})	mg	4.9	3.7	4.3	4.3
PM_{10} Concentration	gr/dscf	0.00068	0.00051	0.00058	0.00059
PM_{10} Mass Emission Rate	lb/hr	3.77	2.92	3.35	3.35
PM_{10} Mass Emission Rate	lb/mmBtu	0.0023	0.0018	0.0021	0.0021
PM_{10} Mass Emission Rate [Assumes 8,760 Hrs/Yr Op.]	tpy	16.5	12.8	14.7	14.7

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Table 2 - Unit 2B 70% Load VOC Emission Test Results

Facility and Source Information	Units	Run 1	Run 2	Run 3	Average
Customer:		Zeeland Generating Station			
Source:		Unit 2B - 70% Load			
Work Order:		6500411			
Date:		12/11/2018	12/11/2018	12/11/2018	
Load:	MWg	122.8	122.6	122.8	122.7
Stack Diameter	inches	201.0	201.0	201.0	
Cross-sectional Area of Stack, A	ft^2	220.35	220.35	220.35	
Source Pollutant Test Data	**Units**	**Run 1**	**Run 2**	**Run 3**	**Average**
Barometric Pressure, P_{bar}	inches of Hg	29.25	29.25	29.40	29.30
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	-1.00	-0.70	-1.00	-0.90
Nozzle Diameter, D_n	inches	0.240	0.240	0.240	0.240
Run Start Time	hr:mm	9:05	11:50	14:20	
Run Stop Time	hr:mm	11:19	14:00	16:30	
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	408.04	521.62	642.25	523.97
Dry Gas Meter Final Volume	ft^3	521.00	636.88	760.01	639.30
Average Pressure Difference across the Orifice Meter, ΔH	inches of H_2O	2.87	3.09	3.06	3.01
Average Dry Gas Meter Temperature, T_m	°F	69.5	75.8	78.4	74.6
Average Square Root Velocity Head, $\sqrt{\Delta p}$	$\sqrt{\text{inches } H_2O}$	1.0761	1.1115	1.1037	1.0971
Stack Gas Temperature, $T_{s(abavg)}$	°F	217.5	217.7	219.5	218.2
Source Moisture Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Volume of Water Vapor Condensed in Silica Gel, $V_{wsg(std)}$	scf	1.2	1.6	1.7	1.5
Total Volume of Water Vapor Condensed, $V_{w(std)}$	scf	8.659	9.187	8.968	8.938
Volume of Gas Sample as Measured by the Dry Gas Meter, V_m	dcf	112.959	115.256	117.760	115.325
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscf	110.759	111.743	114.188	112.230
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscm	3.137	3.165	3.234	3.178
Moisture Content of Stack Gas, B_{ws}	% H_2O	7.25	7.60	7.28	7.38
Gas Analysis Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Carbon Dioxide, $\%CO_2$	%, dry	4.2	4.2	4.2	4.2
Oxygen, $\%O_2$	%, dry	13.4	13.4	13.5	13.4
Nitrogen, %N	%, dry	82.4	82.4	82.3	82.4
Dry Molecular Weight, M_d	lb/lb-mole	29.21	29.21	29.21	29.21
Wet Molecular Weight, M_s	lb/lb-mole	28.40	28.36	28.40	28.38
Fuel F-Factor, F_d:	dscf/mmBtu	8,710	8,710	8,710	8,710
Gas Volumetric Flow Rate Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Average Stack Gas Velocity, v_s	ft/s	69.9	72.2	71.6	71.2
Stack Gas Volumetric Flow Rate, Q	acfm	923,878	954,716	946,575	941,723
Stack Gas Standard Volumetric Flow Rate, Q_s	scfm	702,118	725,879	720,937	716,312
Stack Gas Dry Standard Volumetric Flow Rate, Q_{sd}	dscfm	651,207	670,734	668,440	663,460
Percent of Isokinetic Sampling, I	%	99.5	97.4	99.9	98.9
Gas Concentrations and Emission Rates		**Run 1**	**Run 2**	**Run 3**	**Average**
Formaldehyde Concentration	ppmvd	0.076	0.071	0.065	0.071
Formaldehyde Molecular Weight	g/mole	30.031	30.031	30.031	30.031
Formaldehyde lb/scf Coversion Factor	lb/scf	7.799E-08	7.799E-08	7.799E-08	7.799E-08
Formaldehyde Mass Emission Rate	lb/hr	0.23	0.22	0.20	0.22
Formaldehyde Mass Emission Rate	lb/mmBtu	0.0001	0.0001	0.0001	0.0001
Formaldehyde Mass Emission Rate [Assumes 8,760 Hrs/Yr Operation]	tpy	1.0	1.0	0.9	1.0
Acetylene Concentration	ppmvd	ND	ND	ND	0
Propane Concentration	ppmvd	ND	ND	ND	0
Butane Concentration	ppmvd	ND	ND	ND	0
Propylene Concentration	ppmvd	ND	ND	ND	0
Acetaldehyde Concentration	ppmvd	ND	ND	ND	0
Ethylene Concentration	ppmvd	ND	ND	ND	0
Methanol Concentration	ppmvd	ND	ND	ND	0
Total VOC Mass Emission Rate	lb/hr	0.23	0.22	0.20	0.22
Total VOC Mass Emission Rate	lb/mmBtu	0.0001	0.0001	0.0001	0.0001
Total VOC Mass Emission Rate [Assumes 8,760 Hrs/Yr Operation]	tpy	1.0	1.0	0.9	1.0

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Table 3 - Unit 2B 100% Load PM Emission Test Results

Facility and Source Information	Units	Run 1	Run 2	Run 3	Average
Customer:		Zeeland Generating Station			
Source:		Unit 2B - 100% Load			
Work Order:		6500411			
Date:		12/12/2018	12/12/2018	12/12/2018	
Load:	MWg	171.2	169.1	168.0	169.4
Stack Diameter	inches	201.0	201.0	201.0	
Cross-sectional Area of Stack, A	ft^2	220.35	220.35	220.35	
Source Pollutant Test Data	**Units**	**Run 1**	**Run 2**	**Run 3**	**Average**
Barometric Pressure, P_{bar}	inches of Hg	29.10	29.10	29.05	29.08
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	-1.00	-1.00	-1.00	-1.00
Nozzle Diameter, D_n	inches	0.219	0.219	0.219	0.219
Run Start Time	hr:mm	8:30	11:00	13:25	
Run Stop Time	hr:mm	10:39	13:09	15:33	
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	761.26	889.10	12.13	554.16
Dry Gas Meter Final Volume	ft^3	888.16	1011.25	135.94	678.45
Average Pressure Difference across the Orifice Meter, ΔH	inches of H_2O	3.48	3.30	3.36	3.38
Average Dry Gas Meter Temperature, T_m	°F	73.2	81.3	80.8	78.4
Average Square Root Velocity Head, √Δp	√inches H_2O	1.4353	1.3837	1.3957	1.4049
Stack Gas Temperature, $T_{s(abavg)}$	°F	229.1	227.9	227.8	228.3
Source Moisture Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Volume of Water Vapor Condensed, $V_{wc(std)}$	scf	8.2	7.8	7.5	7.8
Volume of Water Vapor Condensed in Silica Gel, $V_{wsg(std)}$	scf	1.4	1.4	1.7	1.5
Total Volume of Water Vapor Condensed, $V_{w(std)}$	scf	9.630	9.175	9.185	9.330
Volume of Gas Sample as Measured by the Dry Gas Meter, V_m	dcf	126.905	122.150	123.810	124.288
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscf	123.128	116.688	118.189	119.335
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscm	3.487	3.305	3.347	3.380
Moisture Content of Stack Gas, B_{ws}	% H_2O	7.25	7.29	7.21	7.25
Gas Analysis Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Carbon Dioxide, $\%CO_2$	%, dry	4.0	4.1	4.1	4.1
Oxygen, $\%O_2$	%, dry	13.5	13.8	13.8	13.7
Nitrogen, %N	%, dry	82.5	82.1	82.1	82.2
Dry Molecular Weight, M_d	lb/lb-mole	29.18	29.21	29.21	29.20
Wet Molecular Weight, M_s	lb/lb-mole	28.37	28.39	28.40	28.39
Fuel F-Factor, F_d	dscf/mmBtu	8,710	8,710	8,710	8,710
Gas Volumetric Flow Rate Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Average Stack Gas Velocity, v_s	ft/s	94.3	90.8	91.6	92.2
Stack Gas Volumetric Flow Rate, Q	acfm	1,246,600	1,200,302	1,211,458	1,219,453
Stack Gas Standard Volumetric Flow Rate, Q_s	scfm	926,663	893,761	900,623	907,016
Stack Gas Dry Standard Volumetric Flow Rate, Q_{sd}	dscfm	859,442	828,606	835,680	841,243
Percent of Isokinetic Sampling, I	%	100.6	98.9	99.3	99.6
Gas Concentrations and Emission Rates		**Run 1**	**Run 2**	**Run 3**	**Average**
Mass of Filterable PM Collected, m_n	mg	1.91	2.33	4.79	3.01
Filterable PM Concentration, c_s	gr/dscf	0.00024	0.00031	0.00062	0.00039
Filterable PM Mass Emission Rate, E	lb/hr	1.76	2.18	4.47	2.80
Filterable PM, lb/mmBtu, E	lb/mmBtu	0.0008	0.0011	0.0023	0.0014
Filterable PM, tpy [Assumes 8,760 Hrs/Yr Operation]	tpy	7.7	9.6	19.6	12.3
Mass of Organic CPM, m_o	mg	<1.0	1.6	2.2	1.6
Mass of Inorganic Condensable PM, m_i	mg	2.7	2.7	2.6	2.7
Mass of Total CPM in Field Train Recovery Blank Correction, m_{fb}	mg	2.0	2.0	2.0	2.0
Mass of Total Condensable PM, m_{cpm}	mg	1.7	2.3	2.8	2.3
Condensable PM Concentration	gr/dscf	0.00021	0.00030	0.00036	0.00029
Condensable PM Mass Emission Rate	lb/hr	1.57	2.16	2.61	2.11
Condensable PM Mass Emission Rate	lb/mmBtu	0.0007	0.0011	0.0013	0.0011
Condensable PM Mass Emission Rate [Assumes 8,760 Hrs/Yr Operation]	tpy	6.9	9.4	11.4	9.2
Mass of Filterable and Condensable PM (PM_{10})	mg	3.6	4.6	7.6	5.3
PM_{10} Concentration	gr/dscf	0.00045	0.00061	0.00099	0.00068
PM_{10} Mass Emission Rate	lb/hr	3.32	4.34	7.08	4.91
PM_{10} Mass Emission Rate	lb/mmBtu	0.0016	0.0022	0.0036	0.0025
PM_{10} Mass Emission Rate [Assumes 8,760 Hrs/Yr Op.]	tpy	14.6	19.0	31.0	21.5

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Table 4 - Unit 2B 100% Load VOC Emission Test Results

Facility and Source Information	Units	Run 1	Run 2	Run 3	Average
Customer:		Zeeland Generating Station			
Source:		Unit 2B - 100% Load			
Work Order:		6500411			
Date:		12/12/2018	12/12/2018	12/12/2018	
Load:	MWg	171.2	169.1	168.0	169.4
Stack Diameter	inches	201.0	201.0	201.0	
Cross-sectional Area of Stack, A	ft^2	220.35	220.35	220.35	
Source Pollutant Test Data	**Units**	**Run 1**	**Run 2**	**Run 3**	**Average**
Barometric Pressure, P_{bar}	inches of Hg	29.10	29.10	29.05	29.08
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	-1.00	-1.00	-1.00	-1.00
Nozzle Diameter, D_n	inches	0.219	0.219	0.219	0.219
Run Start Time	hr:mm	8:30	11:00	13:25	
Run Stop Time	hr:mm	10:39	13:09	15:33	
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	761.26	889.10	12.13	554.16
Dry Gas Meter Final Volume	ft^3	888.16	1011.25	135.94	678.45
Average Pressure Difference across the Orifice Meter, ΔH	inches of H_2O	3.48	3.30	3.36	3.38
Average Dry Gas Meter Temperature, T_m	°F	73.2	81.3	80.8	78.4
Average Square Root Velocity Head, √Δp	√inches H_2O	1.4353	1.3837	1.3957	1.4049
Stack Gas Temperature, $T_{s(abavg)}$	°F	229.1	227.9	227.8	228.3
Source Moisture Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Volume of Water Vapor Condensed, $V_{wc(std)}$	scf	8.2	7.8	7.5	7.8
Volume of Water Vapor Condensed in Silica Gel, $V_{wsg(std)}$	scf	1.4	1.4	1.7	1.5
Total Volume of Water Vapor Condensed, $V_{w(std)}$	scf	9.630	9.175	9.185	9.330
Volume of Gas Sample as Measured by the Dry Gas Meter, V_m	dcf	126.905	122.150	123.810	124.288
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscf	123.128	116.688	118.189	119.335
Volume of Gas Sample Measured by the Dry Gas Meter corrected to STP, $V_{m(std)}$	dscm	3.487	3.305	3.347	3.380
Moisture Content of Stack Gas, B_{ws}	% H_2O	7.25	7.29	7.21	7.25
Gas Analysis Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Carbon Dioxide, $\%CO_2$	%, dry	4.0	4.1	4.1	4.1
Oxygen, $\%O_2$	%, dry	13.5	13.8	13.8	13.7
Nitrogen, %N	%, dry	82.5	82.1	82.1	82.2
Dry Molecular Weight, M_d	lb/lb-mole	29.18	29.21	29.21	29.20
Wet Molecular Weight, M_s	lb/lb-mole	28.37	28.39	28.40	28.39
Fuel F-Factor, F_d:	dscf/mmBtu	8,710	8,710	8,710	8,710
Gas Volumetric Flow Rate Data		**Run 1**	**Run 2**	**Run 3**	**Average**
Average Stack Gas Velocity, v_s	ft/s	94.3	90.8	91.6	92.2
Stack Gas Volumetric Flow Rate, Q	acfm	1,246,600	1,200,302	1,211,458	1,219,453
Stack Gas Standard Volumetric Flow Rate, Q_s	scfm	926,663	893,761	900,623	907,016
Stack Gas Dry Standard Volumetric Flow Rate, Q_{sd}	dscfm	859,442	828,606	835,680	841,243
Percent of Isokinetic Sampling, I	%	100.6	98.9	99.3	99.6
Gas Concentrations and Emission Rates		**Run 1**	**Run 2**	**Run 3**	**Average**
Formaldehyde Concentration	ppmvd	0.055	0.047	0.051	0.051
Formaldehyde Molecular Weight	g/mole	30.031	30.031	30.031	30.031
Formaldehyde lb/scf Coversion Factor	lb/scf	7.799E-08	7.799E-08	7.799E-08	7.799E-08
Formaldehyde Mass Emission Rate	lb/hr	0.22	0.18	0.20	0.20
Formaldehyde Mass Emission Rate	lb/mmBtu	0.0001	0.0001	0.0001	0.0001
Formaldehyde Mass Emission Rate [Assumes 8,760 Hrs/Yr Operation]	tpy	1.0	0.8	0.9	0.9
Acetylene Concentration	ppmvd	ND	ND	ND	0
Propane Concentration	ppmvd	ND	ND	ND	0
Butane Concentration	ppmvd	ND	ND	ND	0
Propylene Concentration	ppmvd	ND	ND	ND	0
Acetaldehyde Concentration	ppmvd	ND	ND	ND	0
Ethylene Concentration	ppmvd	ND	ND	ND	0
Methanol Concentration	ppmvd	ND	ND	ND	0
Total VOC Mass Emission Rate	lb/hr	0.22	0.18	0.20	0.20
Total VOC Mass Emission Rate	lb/mmBtu	0.0001	0.0001	0.0001	0.0001
Total VOC Mass Emission Rate [Assumes 8,760 Hrs/Yr Operation]	tpy	1.0	0.8	0.9	0.9