Compliance Test Report

Zeeland Generating Station
Title V Performance Tests

Simple Cycle Turbine EUGT1A
and
Combined Cycle Turbine EUGT2A

Zeeland Generating Station
425 Fairview Road
Zeeland, Michigan 49464

N6521

Test Dates: October 8 - 11, 2013

December 10, 2013
Work Order No. 6503259

Revision 0

Test Performed by the Consumers Energy Company
Equipment Performance Testing Section – Air Emissions Testing Body
Engineering Services Department

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1.0 INTRODUCTION

Consumers Energy Company (CECo), Equipment Performance Testing Section (EPTS) performed Title V or Renewable Operating Permit (ROP) performance testing at the Zeeland Generating Station (Zeeland), ORIS Code 55087, owned and operated by the Consumers Energy Company. Performance testing was conducted on one simple cycle and one combined cycle natural gas fired combustion turbine designated as EUGT1A (Unit 1A) and EUGT2A (Unit 2A), respectively. The facility is located at 425 Fairview Road in Zeeland, Michigan.

The testing was performed pursuant to Michigan Department of Environmental Quality (MDEQ) Renewable Operating Permit (ROP) Number MI-ROP-N6521-2009, which requires testing be conducted for one simple cycle and one combined cycle combustion turbine at least one year prior to expiration of the current ROP (i.e., by 12/29/2013). The testing must be conducted on one simple and one combined cycle turbine not tested during the prior ROP term for particulate matter (PM) with an aerodynamic size of ≤ 10 microns (PM_{10}), volatile organic compounds (VOC) and formaldehyde (CH_2O) concentrations and emissions at 70 and 100 percent operating load. The ROP was written in this manner to alleviate some test burden since each of the four turbines at the facility were tested during the prior ROP term, and as such, future ROP terms will feature testing on the simple and combined cycle turbines not tested during the previous ROP term (i.e., Units 1B and 2B will be testing during the next ROP term).

Zeeland is an affected source and each turbine is an affected unit under the Acid Rain Program and the Clean Air Interstate Rule (CAIR). As such, the facility maintains certified nitrogen oxides (NO_x) and oxygen (O_2) monitoring systems at the turbine outlet stacks following the periodic quality assurance (QA) requirements pursuant to 40CFR75.21(a)(1) and the periodic QA testing requirements for Natural Gas Flow Metering Systems in 40CFR75, Appendix D, Section 2. Certified continuous carbon monoxide (CO) monitors, subject to performance standards in Chapter 40 of the Code of Federal Regulations, Part 60 (40 CFR 60), Appendix F, are also maintained to demonstrate compliance with emission permit limits in MI-ROP-N6521-2009, consistent with Appendix 3.1 of the ROP.

A test notification containing a sampling protocol describing the Reference Methods employed during the test event, consistent with the listed approved methods in Appendix 5 of the

ROP, was submitted to the MDEQ offices on September 6, 2013. Please note that after submitting this test notification, Consumers Energy requested and received approval for a sampling protocol deviation, consisting of expanding the measurement scope of approved CH_2O Reference Method 320 Fourier transform infrared (FTIR) instrumentation to include VOC measurement. Therefore, Reference Method 25A was not used for VOC measurement during this test event. Further discussion of the Reference Methods employed during the test program is described further on in this report. Consumers Energy's Equipment Performance Testing Section (EPTS), a self-accredited Air Emission Testing Body (AETB), conducted the tests on October 8 – 11, 2013. The test program contact list is provided below.

TEST PROGRAM CONTACT LIST

Responsible Party	Address	Contact
Facility Tested	Zeeland Generating Station 425 Fairview Road Zeeland, Michigan 49464	Mr. J. Homer Manning Environmental Health & Safety Specialist 616-237-4004 homer.manning@cmsenergy.com
Consumers Energy Corporate Environmental Contact	Consumers Energy Company 1945 W Parnall Road Jackson, Michigan 4921	Mr. Jason Prentice Senior Engineer II 517-788-1467 jason.prentice@cmsenergy.com
Consumers Energy EPTS Test Representative	Consumers Energy Company 17000 Croswell Street West Olive, Michigan 49460	Mr. Joe Mason, QSTI Senior Technical Analyst 616-738-3385 joe.mason@cmsenergy.com
Contracted FTIR Testing	Prism Analytical Technologies, Inc. 2625 Denison Mount Pleasant, MI 48858	Ms. Lindsey Wells Chemist/FTIR Specialist 989-772-5088
Regulatory Agency	Michigan Department of Environmental Quality Technical Programs Unit Constitution Hall, 2nd Floor N Tower 525 W. Allegan, Lansing, Michigan 48933-1502	Mr. David Patterson 517-241-7469 pattersond2@michigan.gov
		Ms. April Lazzaro 616-356-0248 lazzaroa@michigan.gov

2.0 SUMMARY AND DISCUSSION

The primary goal of the test program was to reestablish lb/mmBtu emission factors which will be used along with continuous heat input determinations to calculate mass emissions rates, consistent with Appendix 5 of MI-ROP-N6521-2009. The preceding calculations will then be used to assess compliance with the applicable mass emission limits which are based on a daily average and/or 12-month rolling total basis. The following tables present a summary of the test results, including extrapolated tons per year values assuming continuous operation at the lbs/hr emission rates observed during testing. Sample calculations and comprehensive test results are contained in Appendices A and B, respectively.

SUMMARY OF UNIT 1A SIMPLE CYCLE TURBINE ROP TEST RESULTS

Parameter and Units	70% Load	100% Load	ROP Limit
Date	10/11/2013	10/10/2013	-----
Unit Load, MW gross	114.8	160.5	-----
PM_{10} Tot., lb/mmBtu	3.63E-03	3.81E-03	-----
PM_{10} Tot., lbs/hr	4.67	6.10	10.8
PM_{10} Tot., tons/yr	20.5	26.7	47.3
CH_2O, lb/mmBtu [1]	1.90E-04	1.91E-04	-----
CH_2O, tons/yr [1]	1.07	1.34	2.35 [2]
VOCs as Propane, lb/mmBtu [1]	7.56E-04	7.59E-04	-----
VOCs as Propane, lbs/hr [1]	0.90	1.12	5.8
VOCs as Propane, tons/yr [1]	3.93	4.92	25.4

[1] Formaldehyde and other speciated VOCs were not detected during any of the test runs. These emission rates are based upon ½ of the associated FTIR instrument wet-basis detection limits (CH_2O = 0.2 ppm; VOCs = 0.5 ppm).

[2] The formaldehyde emission limit for Zeeland Generating Station is 9.4 tons per 12-month rolling time period for all four units combined. For illustrative purposes, the formaldehyde emission limit for a single unit has been presented as ¼ of the facility total.

SUMMARY OF UNIT 2A COMBINED CYCLE ROP TEST RESULTS

Parameter and Units	70% Load	100% Load	ROP Limit
Date	10/08/2013	10/09/2013	-----
Unit Load, MW gross [1]	CT = 117.7 CT+ST = 185.7	CT = 170.4 CT+ST = 255.2	-----
PM_{10} Tot., lb/mmBtu	4.47E-03	3.06E-03	0.03
PM_{10} Tot., lbs/hr	6.41	5.79	14.7
PM_{10} Tot., tons/yr	28.1	25.4	64.4
CH_2O, lb/mmBtu [2]	1.86E-04	1.85E-04	-----
CH_2O, tons/yr [2]	1.17	1.53	2.35 [3]
VOCs as Propane, lb/mmBtu [2]	7.39E-04	7.35E-04	-----
VOCs as Propane, lbs/hr [2]	0.98	1.28	16.8
VOCs as Propane, tons/yr [2]	4.29	5.61	73.6

[1] The Unit 2A combustion turbine serves a dedicated electrical generator (CT) and, via the associated Heat Recovery Steam Generator (HRSG), also supplies steam in conjunction with Unit 2B to a common steam turbine and associated electrical generator (ST). The CT+ST electrical output is based upon apportionment of the common steam turbine electrical output per Question 17.2 of the EPA's Part 75 Emissions Monitoring Policy Manual.

[2] Formaldehyde and other speciated VOCs were not detected during any of the test runs. These emission rates are based upon ½ of the associated FTIR instrument wet-basis detection limits (CH_2O = 0.2 ppm; VOCs = 0.5 ppm).

[3] The formaldehyde emission limit for Zeeland Generating Station is 9.4 tons per 12-month rolling time period for all four units combined. For illustrative purposes, the formaldehyde emission limit for a single unit has been presented as ¼ of the facility total.

3.0 SOURCE DESCRIPTION

Per the associated 40 CFR Part 75 Monitoring Plans, the Unit 1A and 1B simple cycle turbines operating at the Zeeland Generating Station are rated at 2,205 mmBtu/hour maximum heat input with an Upper and Lower Bound Range of Operation at 190 megawatts (MW) and 17 MW, respectively. The Unit 2A and 2B combined-cycle turbines are rated at 2,323 mmBtu/hour maximum heat input with an Upper and Lower Bound Range of Operation at 265 MW and 17 MW, respectively.

The preceding unit ratings are maximum expected values based upon the range of possible ambient conditions experienced at the facility. The achievable heat input and electrical output are heavily influenced by ambient conditions at the time of testing. For the 100% load condition tests, the turbines were operated at the maximum achievable capacity during the test periods. For the 70% load condition tests, vendor curves relating electrical output to ambient conditions were used to calculate maximum expected output for the forecasted ambient conditions during the test period, after which the turbines were operated at these target output levels. Lastly, it should be noted that for combined-cycle Unit 2A, duct firing was not employed during the tests as such was not required to achieve full capacity. Duct firing is primarily employed during warm weather periods when turbine output is limited due to ambient conditions.

Air pollution control is achieved on each turbine through the use of Dry Low NO_x Burners. Additionally, Units 2A & 2B use selective catalytic reduction (SCR) for additional NO_x reduction. Dedicated dry extractive NO_x, O_2 and CO CEMS are installed on each turbine exhaust to monitor emissions on a continuous basis. Figures 1 and 2 provide a general schematic of each unit.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

The following Test Methods and Parameters were performed in accordance with FGSIMPLECYCLE, Condition V.2 and FGCOMBINEDCYCLE, Condition V.2 as written in Zeeland's ROP. The specifications indicate that one turbine within each flexible group will be tested to 1) demonstrate compliance with the applicable simple and combined cycle turbine PM_{10} and VOC lbs/hour emission limits, 2) demonstrate compliance with the combined cycle turbine filterable PM emission limit of 0.03 lb/mmBtu, and 3) establish PM_{10}, VOC and CH_2O lb/mmBtu emission factors to be used in accordance with the procedures in Appendix 5 of the ROP to calculate ongoing mass emission rates (relative to demonstrating compliance with the 12-month rolling mass emission limits). Triplicate test runs of varying durations were performed at each of two load conditions (70 percent of base or maximum load, and 100% base load) using the following Reference Methods.

4.1 Traverse Points

The sampling location and number of traverse points were selected according to U.S. EPA Reference Method 1, *"Sample and Velocity Traverses for Stationary Sources"*. The cross-sectional inside diameter of each exhaust stack was measured. Based upon this value and after evaluating the duct for upstream and downstream flow disturbances, traverse points were selected for the test procedure. Utilizing the four test ports installed at each sample location, six traverse points per port were located and marked on the applicable sample probe, for a total of twenty-four traverse points. The procedure described in Section 11.4 of Method 1 was also employed to ensure the absence of cyclonic flow at the test site. This procedure, known as the Nulling Technique, was employed by positioning the S-type Pitot tube at each traverse point in the duct so that the face openings were perpendicular to the stack cross-sectional plane or at the "0° reference" point. Differential pressure (Δ P) measurements were noted at each traverse point. If an observed Δ P value was not zero, rotating or "yawing" the Pitot tube up to 90° was performed to obtain a null reading. For a test site to be considered non-cyclonic, the average yaw angle obtained from the complete duct traverse must be less than 20 degrees. The yaw angles determined at the Unit 1A and 2A test locations were 5.4° and 3.2°, respectively, and are therefore considered non-cyclonic. A traverse point location schematic is shown in Figures 1 and 2.

4.2 Velocity

The stack gas velocity and temperature were determined using U.S. EPA Reference Method 2, "*Determination of Stack Gas Temperature and Velocity (Type S Pitot Tube)*" using an S-type Pitot tube with an attached thermocouple probe. The Pitot tube was connected to an inclined water column manometer, leak checked at a minimum of five inches of water and then zeroed. The stack gas temperature was measured using a K-type thermocouple. Measurements were taken at each traverse point throughout the PM_{10} testing and if ambient temperature fluctuations were observed, the manometer was re-zeroed.

4.3 Molecular Weight

Oxygen (O_2) and CO concentration data was obtained from the Zeeland certified CEMS operating continuously at each turbine exhaust. The CEMS data was appropriately correlated for determining emission rates and/or exhaust gas molecular weight, in conjunction with carbon dioxide (CO_2) data obtained by Prism Analytical Technologies, Inc. (Pati) in conjunction with the PM_{10} tests using 40 CFR Part 63, Test Method 320, *Measurement of Vapor Phase Organic and Inorganic Emissions by Extractive Fourier Transform Infrared (FTIR) Spectroscopy.*

4.4 Moisture Content

Exhaust gas moisture content was determined using U.S. EPA Method 4 *"Determination of Moisture Content in Stack Gases"* in conjunction with U.S. EPA Methods 5 and 202. The exhaust gas was withdrawn from the stack into Method 202 glassware components placed in an ice bath to assure condensation of the flue gas stream moisture. The amount of water vapor collected was measured and used to calculate the percent stack gas moisture. A detailed discussion of the glassware components is contained in Section 4.2.

4.1 Filterable PM

Filterable PM was collected utilizing 40 CFR Part 60, U.S. EPA Method 5, *Determination of Particulate Matter Emissions from Stationary Sources.* A minimum of 100 dry standard cubic feet (dscf) of sample volume was drawn through either stainless or Inconel steel nozzles, a heated stainless or an unheated Inconel steel probe, a glass cyclone bypass and a heated glass filter holder containing an 83 millimeter (mm) quartz glass fiber filter followed by a Teflon frit filter support. After each run, filterable PM collected in the nozzle and probe was rinsed into an appropriately labeled sample bottle using acetone and a brush. After recovering the quartz FPM filter into a Petri dish, the cyclone bypass and front half filter holder was recovered with acetone rinses into the same sample bottle. At the laboratory, Method 5 gravimetric analytical procedures were used to analyze the filters and rinses.

4.2 Condensable PM

Condensable PM_{10} (CPM) was collected in conjunction with U.S. EPA Method 5 using 40 CFR Part 51, EPA Method 202, *Dry Impinger Method for Determining Condensable particulate Emissions from Stationary Sources* using clean, baked glassware consisting of a glass coil type condenser, a dropout impinger and a modified Greenburg-Smith (GS) impinger with an open tube tip, a CPM filter holder containing a Teflon filter, one impinger containing 100 mL of water and one impinger containing silica gel for moisture collection. The CPM filter temperature was maintained between 68 and 85° F throughout each test run using a water recirculation pump attached to the condenser. The metering console attached to the PM_{10} apparatus was maintained and controlled by an EPTS operator during the test event.

Upon test completion, each impinger was weighed for the purpose of determining exhaust gas moisture content, after which the condenser, dropout impinger and GS impinger followed by the CPM filter housing was re-assembled. An ultra-high purity nitrogen source was then connected to the condenser inlet and the apparatus was purged at a rate equal to the calibrated meter box orifice or approximately 14 liters per minute for a minimum of one hour to remove any dissolved sulfur dioxide gases from the condensed impinger water. During the purge, the condenser recirculation pump remained in service and the CPM filter exit temperature was monitored to ensure the impinger contents did not evaporate.

After the purge, the dropout impinger and GS impinger condensate was transferred to a clean sample bottle labeled as 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 rinse). The liquid levels on the bottles were marked. The CPM filter was removed prior to the water and organic rinses and placed in a clean Petri dish identified as Container #3.

5.0 QUALITY ASSURANCE PROCEDURES

The objective of a Quality Assurance (QA) program is to produce data that are complete, representative, and of known precision and accuracy. Within the ROP test program, completeness can be defined as the percentage of the required field measurements and associated documentation achieved. Representativeness, defined as the "when," "how," and "how many" measurements taken, is typically specified within the regulations or permit governing the source to be tested as well as the Test Protocol submitted to the regulatory agency prior to the test event. As noted previously, the ROP required testing at 70% and 100% loads, with three test runs being conducted at each load condition. Precision and accuracy are measures of data quality and exist by design within each of the U.S. EPA reference test methods and procedures incorporated during the test program.

The Pitot tubes and thermocouples used to measure the exhaust gas volumetric flow were calibrated according to procedures outlined in the *Quality Assurance Handbook for Air Pollution Measurement Systems:* Volume III, Stationary Source-Specific Methods, Method 2, Type S Pitot Tube Inspection, and the *Alternative Method 2 Thermocouple Calibration Procedure* (ALT-011). ALT-011 describes the inherent accuracy and precision of the thermocouple within ±1.3°F in the range of -32°F and 2500°F and states that a system that performs accurately at one temperature is expected to behave similarly at other temperatures. Therefore, the two-point calibration described in Method 2 may be replaced with a single point calibration procedure that verifies a thermocouple system is operating within ± 1.0 percent of the absolute measured temperature, while taking into account the presence of disconnected wire junctions, other loose connections or a potential mis-calibrated temperature display.

The metering console and associated pump used in association with U.S. EPA Methods 5 and 202 was calibrated prior to the test program against a dry gas meter calibration standard as described in Method 5, § 16.1. Upon completion of the test, the metering console was then verified to be within 5 percent of the meter console calibration factor (Y_{qa}), as described in and using the procedures in *ALT-009, Alternative Method 5 Post-Test Calibration.*

Prism Analytical Technologies, Inc. (PATI) was contracted by EPTS to perform Method 320 sampling for various chemical species, including carbon dioxide, formaldehyde, total VOCs and methane, ethane and acetaldehyde. The PATI report presented as Appendix B describes the various QA activities conducted in accordance with Method 320.

6.0 DISCUSSION OF TEST RESULTS

As required, the ROP performance testing successfully reestablished lb/mmBtu emission factors for PM_{10}, VOCs and formaldehyde for each of Units 1A and 2A when operating at 70% and 100% load. Although the mass emission rates observed during testing cannot be used directly to assess compliance with the associated ROP mass emission limits (due to differences in averaging periods), extrapolation of the emission test data across the appropriate averaging periods indicates that Units 1A and 2A are compliant with the associated ROP mass emission limits.

Detailed test results are presented in Appendix A, including presentation of the PM test results as filterable, condensable and total values. In the case of Unit 2A, the average filterable PM_{10} emission rate was 6.7E-07 lb/mmBtu at 70% load and 3.2E-06 lb/mmBtu at 100% load. Both of the preceding average emission rates are far less than the applicable ROP emission limit of 3.0E-02 lb/mmBtu.

Per Appendix 5 of the ROP, the higher of the observed lb/mmBtu VOC and formaldehyde emission factors at 70% and 100% loads for Units 1A and 2A will be used in conjunction with heat input determinations to calculate mass emissions. For PM_{10}, Zeeland Generating Station intends to submit a letter to the MDEQ-AQD Grand Rapids District Office regarding derivation of new lb/mmBtu versus heat input correlation curves and corresponding linear equations.

It should be noted that formaldehyde, VOCs and speciated organics as measured via Method 320 were all non-detect, with the associated detection levels noted within the PATI test report contained within Appendix B. For purposes of presenting the formaldehyde and VOC concentrations and emission rate results, concentrations equal to one half of the applicable detection limits have been utilized. EPTS believes that use of ½ of the detection level is a reasonable approach based on the concept that the actual concentration is between zero and the stated detection level.

With the following exceptions as noted below and in Section 1.0, all of the criteria specified in the applicable Reference Methods, Performance Specifications and the agency-approved Test Protocol were followed. All hard copy and/or electronic field data was fully completed in the field and upon return to the home office, verified for data precision and accuracy, further ensuring the appropriate Reference Method quality measures were met.

The test protocol dated 09/06/2013 stated that the anticipated sampling time for each PM_{10} emission test run would be 2.5 hours, with an anticipated minimum sample volume of 100 dry standard cubic feet (DSCF). When conducting the field tests, it was observed that the available nozzles would result in sampling volumes either much lower or much greater than 100 DSCF based upon a run time of 2.5 hours. Thus, this issue was discussed with Mr. David Patterson of the MDEQ-AQD while in the field, and he agreed that the run times could be adjusted as necessary to result in a target PM_{10} sample volume of at least 100 DSCF. While actual PM_{10} run times were between approximately 1.6 and 2.5 hours in duration, a minimum of 100 DSCF of sample gas was collected during each test run.

During the first PM run at Unit 2A on October 8, the monorail support installed by EPTS suddenly came loose. A monorail is used at each test port to support the Method 5/202 apparatus at the sample platform, thus allowing for a complete duct traverse during each test. When the support slipped, the weight of the Method 5/202 sample apparatus generated downward momentum and the apparatus came to a stop at the end of the monorail, while slightly bending the sample probe in the process. The test was stopped instantaneously and steps were taken to repair the issue. During this repair, Mr. David Patterson of the MDEQ-AQD was informed of the stoppage, and EPTS received his approval to continue the test run after recovering the PM captured in the damaged probe up to that point in the test, and resuming the test with a new probe.

The MDEQ-AQD's test protocol acceptance letter dated 09/16/2013 stated "Acetaldehyde **and nitric oxide** will be used for FTIR analyte spiking. **NOx and CO will be monitored via FTIR for internal use. [Emphasis added]**". Via e-mail on December 9, 2013, Mr. David Patterson of the MDED-AQD confirmed that the use of nitric oxide for FTIR analyte spiking and collecting NO_x and CO data via Method 320 were not necessary and stemmed from a misunderstanding between the MDEQ-AQD and PATI regarding the specific chemical species to be evaluated via Method 320.

Quality Assurance data, including calibrations of the metering console, thermocouple and Pitot tubes used in the test program and laboratory chain of custody forms are in Appendices E and F.

Figure 1
Unit 1A stack schematic and traverse point locations

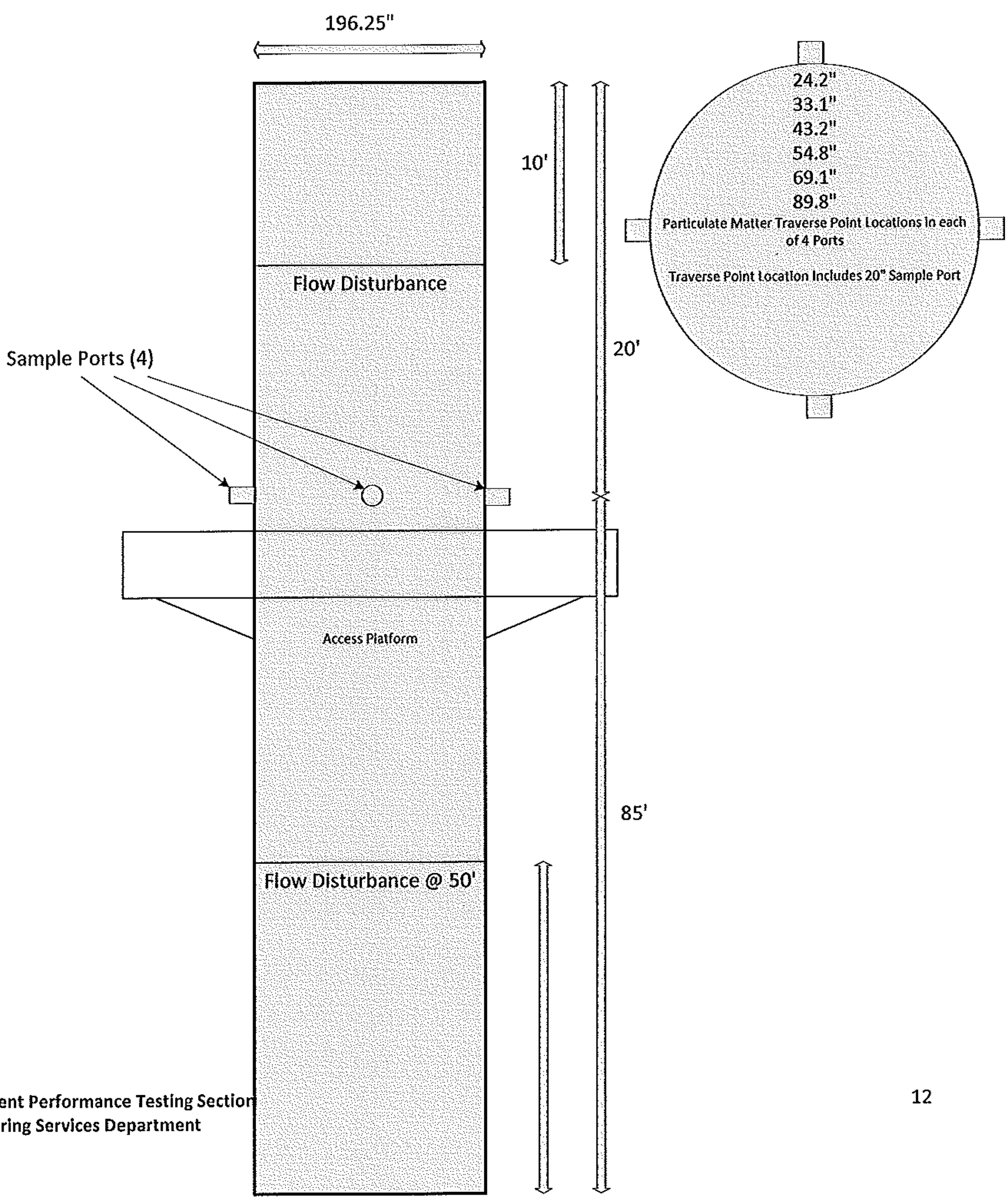

Figure 2.
Unit 2A stack schematic and traverse point locations

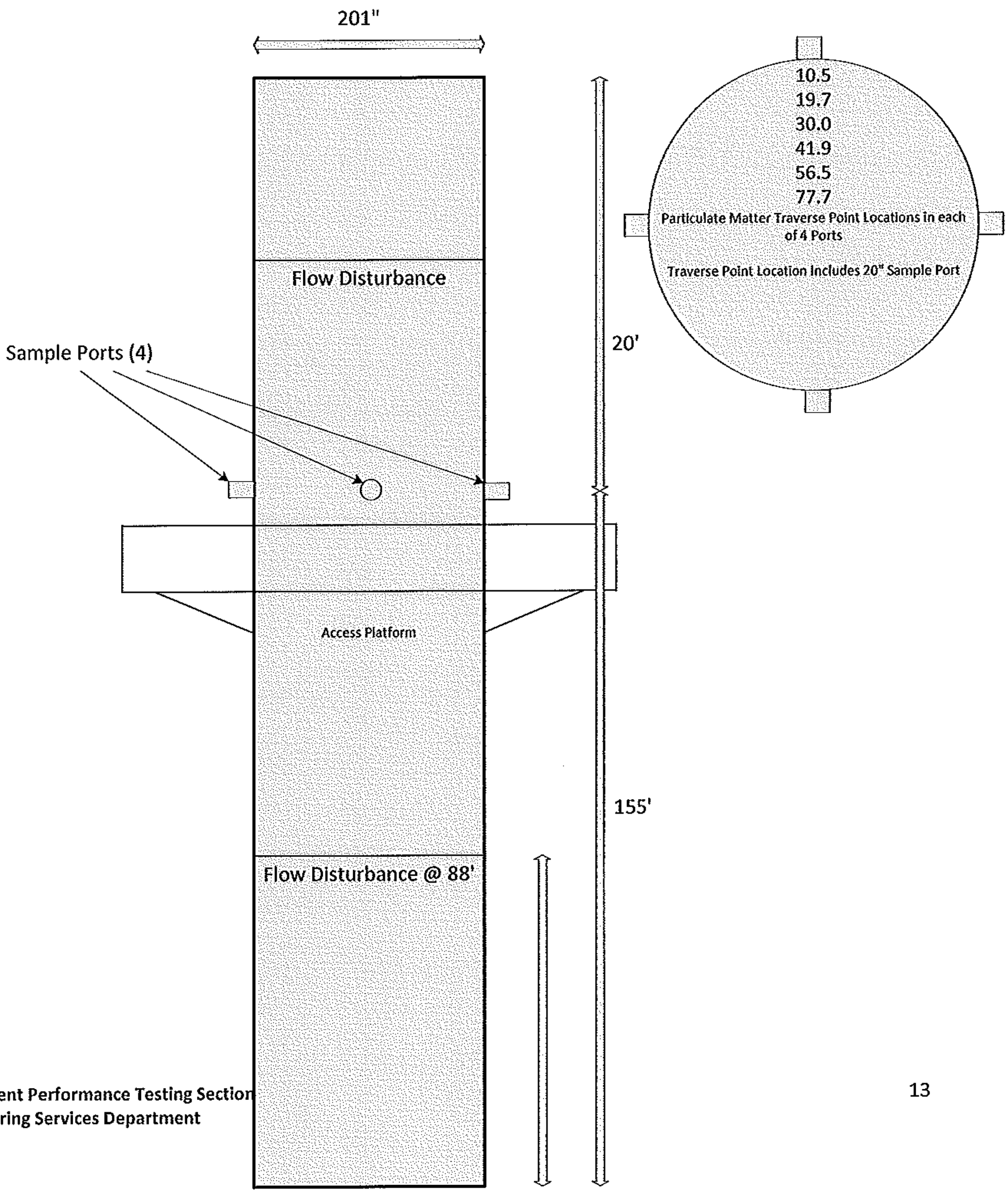

FIGURE 3
Method 5 Sample
Apparatus

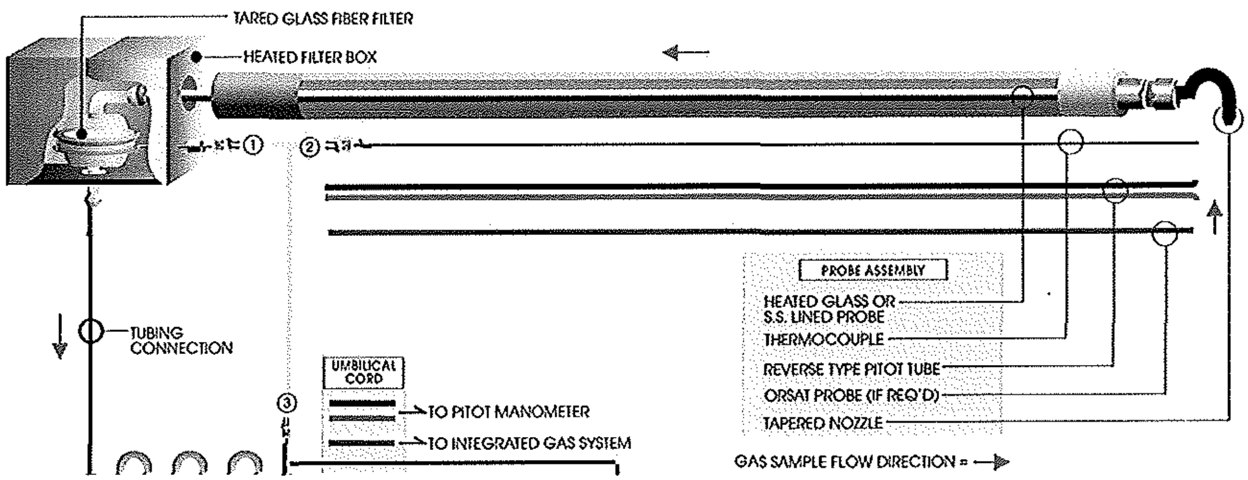

FIGURE 4
Method 202 Sample Apparatus