



**AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM A
LANDFILL GAS FUELED INTERNAL COMBUSTION ENGINE
NORTHERN OAKS RECYCLING AND DISPOSAL FACILITY**

1.0 INTRODUCTION

Waste Management of Michigan, Inc. (WMI) operates one (1) Caterpillar (CAT®) Model No. G3520C gas-fired reciprocating internal combustion engine (RICE) electricity generator set at the Northern Oaks Recycling and Disposal Facility (RDF) in Harrison, Clare County, Michigan. The treated landfill gas (LFG) fueled RICE generator set is identified as emission unit EUIENGINE1 in Renewable Operating Permit (ROP) MI-ROP-N6010-2018, issued by the State of Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD).

Pursuant to the requirements of the federal *Standards of Performance for Stationary Spark Ignition Internal Combustion Engines* (40 CFR Part 60 Subpart JJJJ) §60.4243(a)(2)(ii), WMI is required to perform testing for specific regulated air pollutant emissions exhausted from the RICE within 180 days of startup and every 8,760 operating hours or three years, whichever comes first.

The performance testing for emission unit EUIENGINE1 was conducted on October 6, 2020 by Impact Compliance & Testing, Inc. (ICT), an environmental consulting and testing company based in Michigan. Blake Beddow and Jake Spry of ICT performed the test event. Rich Kunze of WMI assisted with process coordination and operating parameter data acquisition. EGLE-AQD representative Ms. Lindsey Wells was onsite to witness portions of the test event.

The compliance demonstration consisted of triplicate, one-hour test runs for the determination of nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOC, as non-methane hydrocarbons) mass emission rates. The exhaust gas sampling and analysis was performed using procedures specified in the Stack Test Protocol dated August 13, 2020, and the EGLE-AQD Test Plan Approval Letter dated September 15, 2020.

Impact Compliance & Testing, Inc.

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Report Certification

This test report was prepared by ICT based on field sampling data collected by ICT. Facility process data was collected and provided by WMI employees or representatives.

This test report has been reviewed by WMI representatives and approved for submittal to the EGLE-AQD.

I certify that the testing was conducted in accordance with the approved test plan unless otherwise specified in this report. I believe the information provided in this report and its attachments are true, accurate, and complete.

Report Prepared By:



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Environmental Consultant
Impact Compliance & Testing, Inc.

Reviewed By:



Tyler Wilson
Senior Project Manager
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2.0 SUMMARY OF RESULTS

Emission testing was performed on October 6, 2020 for one (1) LFG-fueled RICE-generator set (identified as EUCENGINE1) to determine exhaust gas concentrations of NOx, CO, and VOC. Exhaust gas velocity, moisture, oxygen (O₂) content, and carbon dioxide (CO₂) content measurements were performed for each test period to calculate pollutant mass emission rates.

The testing was performed while the RICE-generator set operated at normal base load conditions (i.e., within 10% of peak electricity output, 1,600 kW). Test results and applicable emission limits are provided in the following table. Data for each one-hour test period are presented in the summary table at the end of this report. The test results demonstrate compliance with emission limits specified in 40 CFR Part 60, Subpart JJJJ and MI-ROP-N6010-2018.

2.1 Summary of measured air pollutant emission rates and permitted limits

Pollutant	Results for EUCENGINE1 (g/bhp-hr)	Emission Limits (g/bhp-hr)
NOx	0.79	1.5 g/bhp-hr (ROP-N6010-2018) 2.0 g/bhp-hr (NSPS JJJJ)
CO	2.70	4.15 g/bhp-hr (ROP-N6010-2018) 5.0 g/bhp-hr (NSPS JJJJ)
VOC	0.10	1.0 g/bhp-hr (ROP-N6010-2018) 1.0 g/bhp-hr (NSPS JJJJ)

3.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

3.1 General Process Description

LFG is produced in the Northern Oaks RDF from the anaerobic decomposition of disposed waste materials. The LFG is collected from active landfill cells using a system of wells that are connected to a central header (gas collection system). The collected LFG is treated and used as fuel for the CAT® Model No. G3520C RICE-generator set that produces electricity for transfer to the local utility.

3.2 Rated Capacities, Type and Quantity of Raw Materials Used

The CAT® G3520C engine is a spark ignition, lean-burn, RICE fueled with treated LFG. The RICE-generator set has an engine power rating of 2,233 hp at 100% load and a generator power rating of 1,600 kW. The CAT® G3520C RICE was tested while operating at baseload conditions, within 10% of the maximum electricity generation rate of 1,600 kW. Fuel

consumption is regulated to maintain the required heat input rate to support engine operations and is dependent on the fuel heat value (methane content).

3.3 Emission Control System Description

The CAT® G3520C RICE uses an electronic air-to-fuel ratio (AFR) controller to fire lean fuel mixtures and produce low combustion by-product emissions. Emissions from the combustion of LFG are released to the ambient air through a stack connected to the RICE exhaust manifold and noise control system (noise muffler). The unit is not equipped with an add-on emission control device. Air pollutant emissions are minimized by treating the recovered LFG used as fuel and operation of the AFR controller.

3.4 Sampling Locations (USEPA Method 1)

The exhaust stack sampling ports for the Model G3520C RICE satisfied the USEPA Method 1 criteria for a representative sample location. The inner diameter of the engine exhaust stack is 15.5 inches at the sampling location. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 36 inches (2.3 duct diameters) downstream and 67 inches (4.3 duct diameters) upstream from any flow disturbance.

Velocity pressure traverse locations for the sampling points were determined in accordance with USEPA Method 1 for the engine exhaust.

Figure 1 presents the emission test sampling and measurement location.

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A Stack Test Protocol for the compliance testing was prepared by ICT and reviewed by the EGLE-AQD. This section provides a summary of the sampling and analytical procedures that were used during the test and presented in the Stack Test Protocol.

Appendix A provides a copy of the EGLE-AQD Approval Letter.

4.1 Exhaust Gas Velocity and Flowrate Determination (USEPA Method 2)

RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 once for each 60-minute test period. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube. The Pitot tube and connective tubing were leak-checked to verify the integrity of the measurement system.

Exhaust gas velocity pressure and temperature were measured once for each one-hour sampling period (at or near the beginning of that particular sampling period) in accordance with USEPA Method 2.

4.2 Exhaust Gas Molecular Weight Determination (USEPA Method 3A)

CO₂ and O₂ content in the RICE exhaust was measured continuously throughout each one-hour test period in accordance with USEPA Method 3A. The CO₂ content of the exhaust was monitored using a Servomex Model 4900 single beam single wavelength (SBSW) infrared gas analyzer. The O₂ content of the exhaust was monitored using a Servomex Model 4900 gas analyzer that utilizes a paramagnetic sensor.

During each one-hour sampling period, a continuous sample of the RICE exhaust gas stream was extracted from the stack using a stainless-steel probe connected to a Teflon® heated sample line. The sampled gas was conditioned by removing moisture prior to being introduced to the analyzer; therefore, measurement of O₂ and CO₂ concentrations correspond to standard dry gas conditions. The instruments were calibrated using appropriate calibration gases to determine accuracy and system bias (described in Section 5.0 of this document).

Figure 2 presents a diagram of the instrumental analyzer sampling train.

4.3 Exhaust Gas Moisture Content Determinations (Method 4)

Moisture content of the RICE exhaust gas was determined in accordance with USEPA Method 4 using a chilled impinger sampling train. Exhaust gas moisture content measurements were performed concurrently with the instrumental analyzer sampling periods. At the conclusion of each sampling period the moisture gain in the impingers was determined gravimetrically by weighing each impinger to determine net weight gain.

Figure 3 presents a schematic of the moisture sampling train.

4.4 NO_x and CO Concentration Measurements (USEPA Method 7E and 10)

NO_x and CO pollutant concentrations in the RICE exhaust were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42C chemiluminescence NO-NO₂-NO_x analyzer and a California Analytics / Fuji Model ZRF non-dispersive infrared (NDIR) CO analyzer.

Three (3) one-hour sampling periods were performed for the RICE exhaust test event. Throughout each one-hour test period, a continuous sample of the engine exhaust gas was extracted from the stack using the Teflon® heated sample line and gas conditioning system described in Section 4.2 of this document, and delivered to the instrumental analyzers. Instrument response for each analyzer was recorded on a data logging system that monitored the analog output of the instrumental analyzers continuously and logged data as one-minute averages. Prior to, and at the conclusion of each test, the instruments were calibrated using appropriate upscale calibration and zero gas to determine analyzer calibration error and system bias.

4.5 VOC Concentration Measurements (USEPA Method 25A and ALT-096)

VOC emission rate was determined by measuring the nonmethane hydrocarbon (NMHC) concentration in the RICE exhaust gas. NMHC pollutant concentration was determined using a Thermo Environmental Instruments (TEI) Model 55i Methane / Nonmethane hydrocarbon analyzer. The TEI 55i analyzer contains an internal gas chromatograph column that separates methane from non-methane components. The concentration of NMHC in the sampled gas stream, after separation from methane, is determined relative to a propane standard using a flame ionization detector in accordance with USEPA Method 25A. The TEI 55-series analyzer has been approved by the USEPA for measuring VOC relative to 40 CFR Part 60 Subpart JJJJ compliance test demonstrations (Alternative Test Method 096 or ALT-096).

Samples of the exhaust gas were delivered directly to the instrumental analyzer using the Teflon® heated sample line to prevent condensation. The sample to the NHMC analyzer was not conditioned to remove moisture. Therefore, VOC measurements correspond to standard conditions with no moisture correction (wet basis).

The instrumental analyzer was calibrated using certified propane concentrations in hydrocarbon-free air to demonstrate detector linearity and determine calibration drift and zero drift error.

5.0 QA/QC ACTIVITIES

5.1 Flow Measurement

Prior to arriving onsite, the instruments used during the source test to measure exhaust gas properties and velocity (barometer, pyrometer, scale, and Pitot tube) were calibrated to specifications in the sampling methods.

The absence of cyclonic flow for each sampling location was verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each of the velocity traverse points with the planes of the face openings of the Pitot tube perpendicular to the stack cross-sectional plane. The Pitot tube was then rotated to determine the null angle (rotational angle as measured from the perpendicular, or reference, position at which the differential pressure is equal to zero).

5.2 NO_x Converter Efficiency Test

The NO₂ – NO conversion efficiency of the TEI Model 42C instrumental analyzer was verified prior to the commencement of the performance tests. The instrument analyzer NO₂ – NO converter uses a catalyst at high temperatures to convert the NO₂ to NO for measurement. A USEPA Protocol 1 certified NO₂ calibration gas was used to verify the efficiency of the NO₂ – NO converter.

The NO₂ – NO conversion efficiency test satisfied the USEPA Method 7E criteria (the calculated NO₂ – NO conversion efficiency is greater than 90%).

5.3 Calibration Gas Divider Field Validation

A STEC Model SGD-710C 10-step gas divider was used to obtain appropriate calibration span gases. The ten-step STEC gas divider was NIST certified (within the last 12 months) with a primary flow standard in accordance with Method 205. When cut with an appropriate zero gas, the ten-step STEC gas divider delivered calibration gas values ranging from 0% to 100% (in 10% step increments) of the USEPA Protocol 1 calibration gas that was introduced into the system. The field evaluation procedures presented in Section 3.2 of Method 205 were followed prior to use of gas divider. The field evaluation yielded no errors greater than 2% of the triplicate measured average and no errors greater than 2% from the expected values.

5.4 Sampling System Response Time Determination

The response time of the sampling system was determined prior to the compliance test program by introducing upscale gas and zero gas, in series, into the sampling system using a tee connection at the base of the sample probe. The elapsed time for the analyzer to display a reading of 95% of the expected concentration was determined using a stopwatch.

Sampling periods did not commence until the sampling probe had been in place for at least twice the system response time.

5.5 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NO_x, CO, O₂, and CO₂ have had an interference response test performed prior to their use in the field, pursuant to the interference response test procedures specified in USEPA Method 7E. The appropriate interference test gases (i.e. gases that would be encountered in the exhaust gas stream) were introduced into each analyzer, separately and as a mixture with the analyte that each analyzer is designed to measure. All of the analyzers exhibited a composite deviation of less than 2.5% of the span for all measured interferent gases. No major analytical components of the analyzers have been replaced since performing the original interference tests.

5.6 Instrument Calibration and System Bias Checks

At the beginning of each field test day, initial three-point instrument calibrations were performed for the NO_x, CO, CO₂, and O₂ analyzers by injecting calibration gas directly into the inlet sample port for each instrument. System bias checks were performed prior to and at the conclusion of each sampling period by introducing the upscale calibration gas and zero gas into the sampling system (at the base of the stainless steel sampling probe prior to the particulate filter and Teflon® heated sample line) and determining the instrument response against the initial instrument calibration readings.

At the beginning of each test day, appropriate high-range, mid-range, and low-range span gases followed by a zero gas were introduced to the NMHC analyzer, in series at a tee connection, which is installed between the sample probe and the particulate filter, through a

poppet check valve. After each one-hour test period, mid-range and zero gases were re-introduced in series at the tee connection in the sampling system to check against the method's performance specifications for calibration drift and zero drift error.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of CO₂, O₂, NO_x, and CO in nitrogen and zeroed using hydrocarbon free nitrogen. The NMHC (VOC) instrument was calibrated with USEPA Protocol 1 certified concentrations of propane in air and zeroed using hydrocarbon-free air. A STEC Model SGD-710C ten-step gas divider was used to obtain intermediate calibration gas concentrations as needed.

5.7 Determination of Exhaust Gas Stratification

A stratification test for the RICE exhaust stack gas was performed as part of the first test period. The stainless-steel sample probe was positioned at sample points correlating to 16.7, 50.0 (centroid), and 83.3% of the stack diameter. Pollutant concentration data were recorded at each sample point for a minimum of twice the maximum system response time.

The recorded data for the RICE exhaust stack gas indicate that the measured CO, NO_x, CO₂, and O₂ concentrations did not vary by more than 5% of the mean across the stack diameter. Therefore, the stack gas was considered to be unstratified and the compliance test sampling was performed at a single sampling location within the engine exhaust stack.

5.8 Meter Box Calibrations

The dry gas meter sampling console used for moisture testing was calibrated prior to and after the testing program. This calibration uses the critical orifice calibration technique presented in USEPA Method 5. The metering console calibration exhibited no data outside the acceptable ranges presented in USEPA Method 5.

The digital pyrometer in the metering console was calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Appendix E presents test equipment quality assurance data (NO₂ – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas certifications, interference test results, meter box calibration records, and field equipment calibration records).

6.0 TEST RESULTS AND DISCUSSION

6.1 Purpose and Objectives of the Tests

Renewable Operating Permit No. MI-ROP-N6010-2018 and 40 CFR 60.4243(b)(2)(ii) [40 CFR Part 60 Subpart JJJJ] specify that owners and operators of new stationary spark-ignited engines with a power rating greater than 500 horsepower must conduct an initial performance test and conduct subsequent performance testing every 8,760 hours of engine operation or 3 years, whichever comes first, thereafter to demonstrate compliance.

The recorded engine hours at the beginning of Test No. 1 for EUIENGINE1 were 28,436 and are within 8,760 operating hours of those recorded during the previous test event on October 16, 2019.

6.2 Operating Conditions During the Compliance Test

The LFG-fueled RICE was operated at an average electricity generation rate of slightly over 1,600 kW during the compliance test periods.

Engine output (bhp) cannot be measured directly. Therefore, it is calculated based on the recorded electricity output, the generator efficiency (96.1%), and the unit conversion factor for kW to horsepower (0.7457 kW/hp). The following equation was used to calculate average engine horsepower for each test period based on a linear relationship between engine output and electricity generator output:

$$\text{Engine output (bhp)} = \text{Electricity output (kW)} / (0.961) / (0.7457 \text{ kW/hp})$$

In addition to electricity generation rate, the following process operating data were monitored and recorded during each test run at 15-minute intervals:

- LFG fuel flow rate to EUIENGINE1 (scfm)
- LFG fuel flow to Leachate Evaporator (scfm)
- LFG fuel flow to Flare (scfm)
- LFG methane content (%)
- RICE inlet pressure (psi)

Fuel flow data were recorded using the permanently installed fuel flow meters operated by WMI. LFG methane content was measured and recorded by the on-site gas chromatograph.

Appendix B provides process data collected during the compliance test periods.

6.3 Air Pollutant Sampling Results

The LFG-fueled RICE exhaust was monitored for three (3) one-hour test periods, during which the NO_x, CO, VOC, O₂, and CO₂ concentrations were measured using instrumental analyzers. The measured pollutant concentrations were adjusted based on instrument calibrations performed prior to and following each test period (drift and bias corrected pursuant to equations in specified in the USEPA reference test methods).

Exhaust gas moisture content was determined by gravimetric analysis of the weight gain in chilled impingers in accordance with USEPA Method 4. Exhaust gas velocity was measured once for each one-hour test period. The calculated exhaust gas volumetric flowrate was used to calculate NO_x, CO, and VOC mass emission rates based on the measured pollutant concentrations (parts per million by volume (ppmv)).

Table 6.1 presents measured exhaust gas conditions and calculated air pollutant emission rates for each one-hour test period.

Appendix C provides computer calculated and field data sheets for the RICE test periods.

Appendix D provides raw instrumental analyzer response data for each test period.

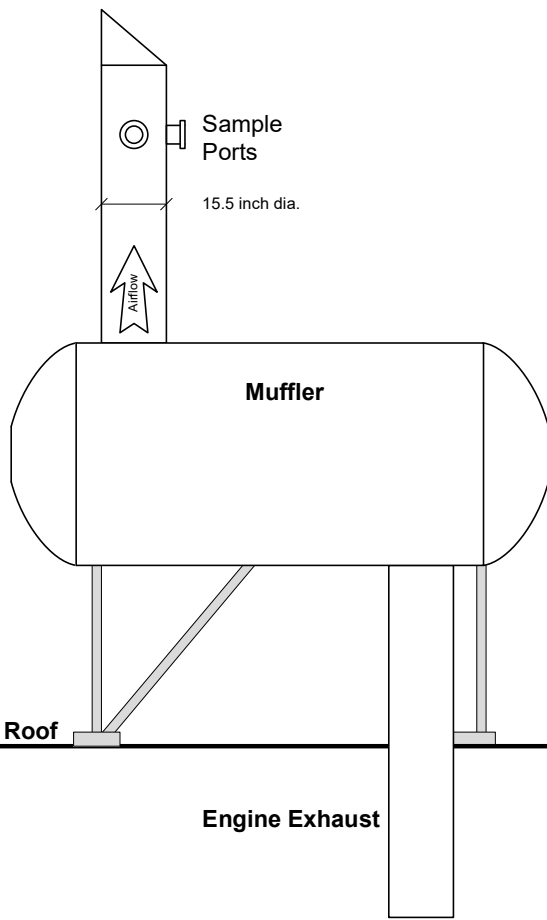
6.4 Variations from Normal Sampling Procedures or Operating Conditions

The compliance tests for all pollutants were performed in accordance with the Stack Test Protocol dated August 13, 2020, the EGLE-AQD Test Plan Approval Letter dated September 15, 2020, and the specified USEPA test methods.

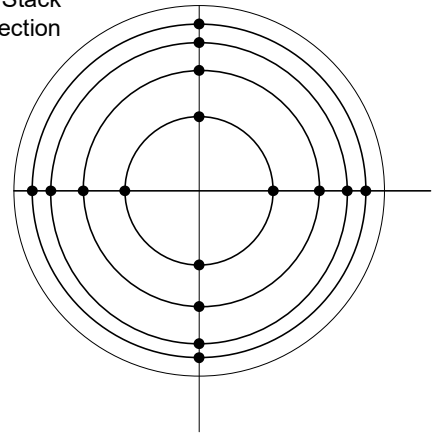
Instrument calibrations and sampling period results satisfy the quality assurance verifications required by USEPA Methods 3A, 7E, 10, and ALT-096. No variations from the normal operating conditions of the RICE occurred during the testing program.

Table 6.1 Measured exhaust gas conditions and air pollutant emission rates for the CAT® G3520C LFG-fueled engine, EUIENGINE1

Test No.	1	2	3	Test Avg.
Test Date	10/6/2020	10/6/2020	10/6/2020	
Test Period (24-hr clock)	0700-0800	0822-0927	0949-1049	
Generator output (kW)	1,614	1,615	1,617	1,615
Engine horsepower (bhp)	2,253	2,254	2,256	2,254
Engine inlet pressure (psi)	43.2	43.1	43.4	43.3
Engine fuel use (scfm)	521	520	523	521
LFG methane content (%)	52.8	52.9	52.8	52.8
LFG heat content (Btu/scf)	480	481	480	480
Fuel to flare (scfm)	138	132	132	134
Fuel to leachate evap. (scfm)	0	0	0	0
Exhaust gas composition				
CO ₂ content (% vol)	11.3	11.3	11.3	11.3
O ₂ content (% vol)	8.09	8.17	8.00	8.09
Moisture (% vol)	11.5	10.7	14.4	12.2
Exhaust gas flowrate				
Exhaust temperature (°F)	868	870	868	869
Flowrate, std. conditions (scfm)	4,556	4,443	4,536	4,512
Flowrate, dry basis (dscfm)	4,032	3,970	3,882	3,961
Nitrogen oxides emission rates				
NO _x conc. (ppmvd)	141	135	137	138
NO _x emissions (lb/hr NO ₂)	4.09	3.84	3.80	3.91
NO _x emissions (g/bhp-hr)	0.82	0.77	0.76	0.79
NO _x permit limit (g/bhp-hr)	-	-	-	1.5
Carbon monoxide emission rates				
CO conc. (ppmvd)	775	771	780	775
CO emissions (lb/hr)	13.6	13.4	13.2	13.4
CO emissions (g/bhp-hr)	2.75	2.69	2.66	2.70
CO permit limit (g/bhp-hr)	-	-	-	4.15
VOC/NMHC emission rates				
VOC conc. (ppmv C ₃)	15.8	15.7	15.6	15.7
VOC emissions (lb/hr)	0.50	0.48	0.49	0.49
VOC emissions (g/bhp-hr)	0.10	0.10	0.10	0.10
VOC permit limit (g/bhp-hr)	-	-	-	1.0



Exhaust Stack
Cross-Section



Velocity sample locations
(as measured from stack wall)

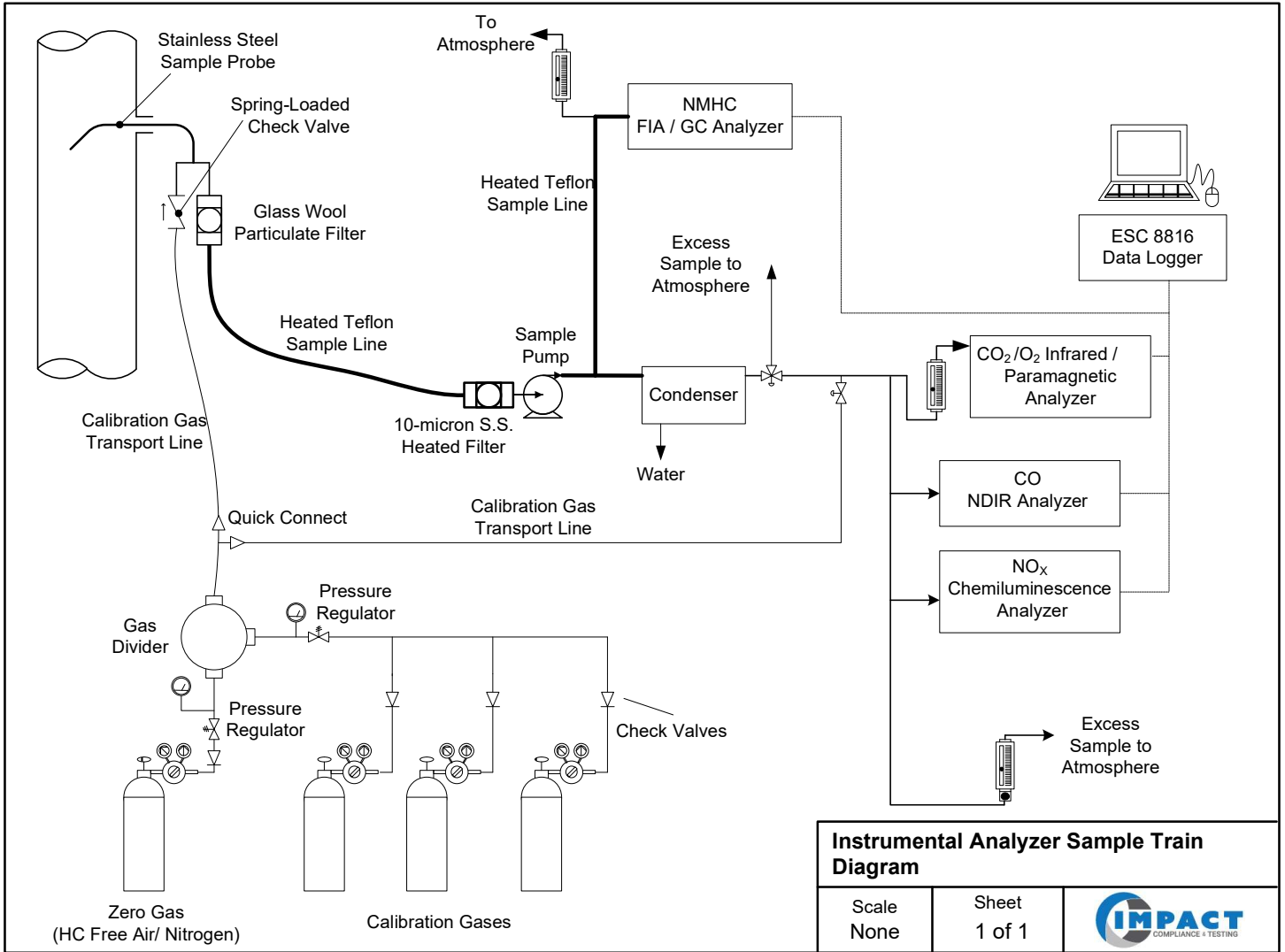
1	0.5"
2	1.6"
3	3.0"
4	5.0"
5	10.5"
6	12.5"
7	13.9"
8	15.0"

Northern Oaks RDF
Exhaust Sample Location, CAT G3520

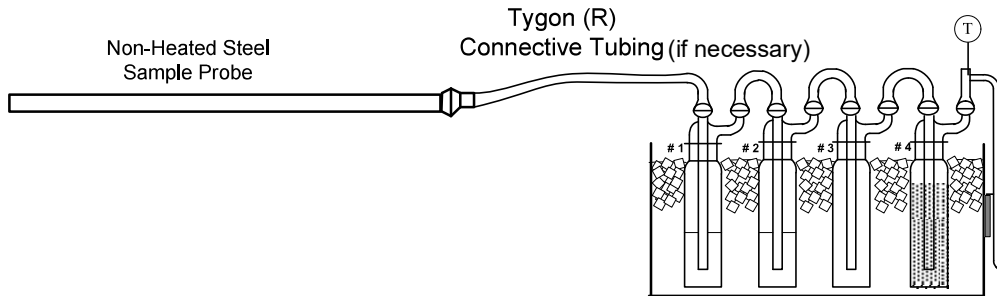
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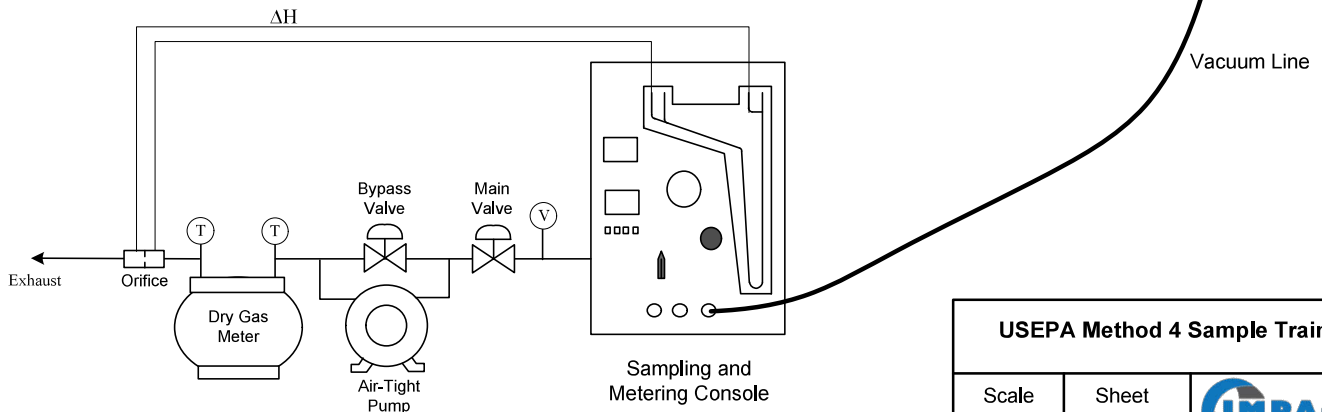
Instrumental Analyzer Sample Train Diagram		
Scale None	Sheet 1 of 1	



Impinger Contents (indicate Standard or Modified)

- Impinger # 1: 100 mL DI Water (std)
- Impinger # 2: 100 mL DI Water (mod)
- Impinger # 3: Empty (std)
- Impinger # 4: Dried silica gel (mod)

Ⓥ = Vacuum Gauge
 Ⓣ = Temperature Measurement



USEPA Method 4 Sample Train		
Scale None	Sheet 1 of 1	