Excel Engineering Carbon Monoxide (CO) and Nitrous Oxides (NO_x) Emissions Test Report

Prepared for:

Excel Testing & Engineering, LLC

IMPACT COMPLIANCE & TESTING

Report Certification

Excel Engineering CO and NOx Emissions Test Report

Excel Testing & Engineering, Inc.
Van Buren Township, MI

This Test Report was prepared by Impact Compliance & Testing, Inc. based on field sampling data collected by Impact Compliance & Testing, Inc. Facility process data were collected and provided by Excel Testing & Engineering, LLC employees or representatives. This test report has been reviewed by Excel Testing & Engineering, LLC 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:

Blake Beddow
Sr. Project Manager
Impact Compliance & Testing, Inc.

I certify that the facility operating conditions were in compliance with permit requirements or were at the maximum routine operating conditions for the facility. Based on information and belief formed after reasonable inquiry, the statements and information in this report are true, accurate and complete.

Responsible Official Certification:

William A. Schmidt June 26, 2024

William Schmidt
General Manager
Excel Testing & Engineering, LLC

Table of Contents

APPENDICES

List of Tables

1.0 Introduction

AIR EMISSION TEST REPORT

FOR THE

VERIFICATION OF

CARBON MONOXIDE

AND NITROGEN OXIDES EMISSIONS

FROM ENGINE DYNAMOMETER TEST CELLS

Excel Testing & Engineering, LLC. (Excel Engineering) State Registration Number (SRN) N6962 retained Impact Compliance & Testing, Inc. (ICT) to conduct a testing program for the determination of carbon monoxide (CO) and nitrogen oxides (NO_x) emissions from the exhaust of one (1) compression ignited (CI) internal combustion (IC) diesel fueled engine and one (1) spark ignited (SI) IC gasoline fueled engine at the Excel Engineering facility located at 9059 Samuel Barton Drive, Van Buren Township, Wayne County, Michigan.

Testing was conducted on a diesel fueled CI-IC engine operated in EU-TESTCELL-01 and on a gasoline fueled SI-IC engine operated in EU-TESTCELL-02, following the provisions specified in Michigan Department of Environment, Great Lakes, and Energy-Air Quality Division (EGLE-AQD) Permit to Install (PTI) No. 370-08D. Condition V.1. for Flexible Group FG-TESTCELLS of the PTI requires Excel Engineering to verify CO and NO_x emission rates and applicable emission factors from a representative engine in FG-TESTCELLS.

The compliance testing was performed by ICT, a Michigan-based environmental consulting and testing company. ICT representatives Blake Beddow and Andrew Eisenberg performed the field sampling and measurements on May 7, 2024.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan that was reviewed and approved by the EGLE-AQD in the April 26, 2024, Test Plan Approval Letter. EGLE-AQD representative Mr. Andrew Riley observed portions of the testing project. Appendix 1 contains a copy of the Test Plan Approval Letter.

Questions regarding this emission test report should be directed to:

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2.0 Summary of Test Results

Performance testing for the exhaust of EU-TESTCELL-01 and EU-TESTCELL-02 verified the NO_x and CO emission rates to be used in emissions calculations for CI and SI fuels.

The exhausts from EU-TESTCELL-01 and EU-TESTCELL-02 were each monitored for three (3) one-hour test periods during which the CO, NO_x, oxygen (O_2), and carbon dioxide (CO_2) exhaust gas concentrations were measured using instrumental analyzers. Exhaust gas moisture content was determined by water weight gain in chilled impingers. Velocity pressure measurements were performed once for each test using a Pitot tube for exhaust gas velocity determination. The testing was performed while the IC engines operated at normal/maximum, representative operating conditions, as a worst-case scenario, as discussed with EGLE-AQD representatives. A summary of the measured CO and NO_x emission rates for Excel Engineering are presented in Table 2.1.

Table 2.1 Summary of measured CO and NO_x emission rates for the diesel fueled CI-IC engine and the gasoline fueled SI-IC engine

Test ID	Diesel Fueled CI Engine CO Emission Rate (lb/1000 gal)	Diesel Fueled CI Engine NO_x Emission Rate (lb/1000 gal)	Gasoline Fueled SI Engine CO Emission Rate (lb/1000 gal)	Gasoline Fueled SI Engine NOx Emission Rate (lb/1000 gal)
Test No. 1	45.8	126	824	274
Test No. 2	44.1	118	767	257
Test No. 3	40.7	121	726	242
Average	**43.5**	**121**	**773**	**257.6**
Permit Limit	*94.0*	*164*	*1,725*	*279*

3.0 Source and Sampling Location Description

3.1 General Process Description

Excel Engineering operates twelve (12) engine dynamometer test cells at its Van Buren Township facility (identified as Flexible Group FG-TESTCELLS). Each cell has the capacity to test engines using either CI fuels (e.g., diesel, biodiesel, kerosene) or SI fuels (gasoline, ethanol, methanol, CNG). The engine exhaust manifolds are connected to the test cell exhaust system and engine exhaust gases are released to the atmosphere through vertical exhaust stacks. Each test cell has a dedicated exhaust system and vertical exhaust stack.

3.2 Rated Capacities, Type and Quantity of Raw Materials Used

During the performance testing a:

- 15L, 485 horsepower (hp), Inline-6 (6-cylinder) diesel engine was operated in EU-TESTCELL-01.
- 6.2L, 455 horsepower (hp), Inline-8 (8-cylinder) gasoline engine was operated in EU-TESTCELL-02.

These engines are representative of the typical size and power of engines operated at Excel Engineering. Table 3.1 presents a summary of the specifications for the engines that were included in the testing program.

Table 3.1 Specifications for engines included in the testing program

Test Cell	Fuel	Engine Size / Displacement	Engine Power	No. of Cylinders
EU-TESTCELL-01	Diesel	15 Liters	485 hp	6
EU-TESTCELL-02	Gasoline	6.2 Liters	455 hp	8

3.3 Emission Control System Description

The IC engines are permitted to operate with and without catalytic converters. The permitted emission rates are based on operation without catalytic control; therefore, during the performance testing the IC engines were operated without catalysts

3.4 Process Operating Conditions During the Compliance Testing

During the compliance testing program the CI-IC engine was operated at an average engine speed of 1,800 revolutions per minute (rpm) and average engine torque of 2,353 Newton-meters (Nm). The average diesel fuel use rate was 29.2 gallons per hour (gph).

During the compliance testing program the SI-IC engine was operated at an average engine speed of 4,000 rpm and average engine torque of 356 Nm. The average gasoline fuel use rate was 14.6 gph.

Appendix 2 provides operating records for the CI and SI IC engines.

4.0 Sampling and Analytical Procedures

A Test Plan for the compliance testing was prepared by Excel Engineering and 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 Test Plan.

4.1 Sampling Locations (USEPA Method 1)

The sampling location for the vertical EU-TESTCELL-01 (diesel fueled IC engine) exhaust stack satisfied the USEPA Method 1 criteria for a representative sample location. The inner diameter of the stack is 6.50 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provided a sampling location 15.25 inches (2.34 duct diameters) downstream and 44.0 inches (6.77 duct diameters) upstream from any flow disturbance.

The sampling location for vertical EU-TESTCELL-02 (gasoline fueled IC engine) exhaust stack satisfied the USEPA Method 1 criteria for a representative sample location. The inner diameter of the stack is 6.50 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provided a sampling location 15.0 inches (2.31 duct diameters) downstream and 31.75 inches (4.88 duct diameters) upstream from any flow disturbance.

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

Appendix 3 provides diagrams of the performance test sampling locations.

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

Exhaust gas velocity pressure and temperature were measured at the sampling locations once for each one-hour sampling period in accordance with USEPA Method 2. A Standard 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 on-site, prior to the test event, to verify the integrity of the measurement system.

The absence of cyclonic flow for both sampling locations was verified using the S-type Pitot tube and oil manometer. The Pitot tube was positioned at selected 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)

4.3 Exhaust Gas Molecular Weight Determination (USEPA Methods 3A and 4)

CO_2 and O_2 content in both exhaust gas streams was measured continuously throughout each one-hour test period in accordance with USEPA Method 3A. The exhaust gas CO_2 content was monitored using a M&C GenTwo single beam single wavelength (SBSW) infrared gas analyzer. The exhaust gas O_2 content was monitored using a M&C GenTwo gas analyzer that uses a paramagnetic sensor.

During each one-hour pollutant sampling period, a continuous sample of the 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 O_2 and CO_2 concentrations correspond to standard dry gas conditions. The instrument was calibrated using appropriate calibration gases to determine accuracy and system bias (described in Section 4.5.1 of this document).

Moisture content of the exhaust gas was determined in accordance with the USEPA Method 4 chilled impinger method. During each pollutant sampling period, a gas sample was extracted at a constant rate from the source using a non-heated, stainless steel sample probe followed by chilled impingers containing DI water, where moisture was removed from the sample stream. At the conclusion of each sampling period, the moisture gain in the impingers was determined gravimetrically.

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

NO_X and CO pollutant concentrations in both exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 42i High Level chemiluminescence NO_X analyzer and an M&C GenTwo NDIR CO analyzer.

Three (3) one-hour sampling periods were performed for each test cell exhaust. 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 4.3 of this document, and delivered to the instrumental analyzers. Instrument response for each analyzer was recorded on an ESC Model 8864 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 (described in Section 4.6 of this document).

4.5 Instrumental Analyzer Quality Assurance Verification

4.5.1 Instrument Calibration and System Bias Checks

At the beginning of the testing program for each IC engine, initial three-point instrument calibrations were performed by injecting calibration gas directly into the inlet sample port for each instrument. System bias checks were preformed prior to and at the conclusion of each sampling period by introducing the appropriate 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 verifying the instrument response against the initial instrument calibration readings.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of CO_2, O_2, NO_x and CO and zeroed using nitrogen. A STEC Model SGD-710C 10-step gas divider was used to obtain intermediate calibration gas concentrations as needed.

4.5.2 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.

The M&C GenTwo NDIR CO analyzer exhibited the longest system response time at 47 seconds. Results of the response time determinations were recorded on field data sheets. For each test period, test data were collected once the sample probe was in position for at least twice the maximum system response time.

4.5.3 NO_x Converter Test

The NO_2 – NO conversion efficiency of the Model 42i analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO_2 was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO_2 – NO converter uses a catalyst at high temperatures to convert the NO_2 to NO for measurement. The conversion efficiency of the analyzer is deemed acceptable if the measured NO_X concentration is at least 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_X concentration was greater than 90% of the expected value as required by Method 7E).

4.5.4 Gas Divider Certification (USEPA Method 205)

A STEC Model SGD-710C 10-step gas divider was used to obtain appropriate calibration span gases. The five-step 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.

4.5.5 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NOx, CO, O_2, and CO_2 have had an interference response test preformed 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 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.

4.5.6 Meter Box Calibrations

The Nutech Model 2010 sampling console, which was used to extract a measured amount of exhaust gas from the stack for moisture determinations, was calibrated prior to and after the testing program. This calibration uses the critical orifice calibration technique presented in USEPA Method 5.

Appendix 4 presents test equipment quality assurance data (NO_2 – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas and gas divider certifications, interference test results, meter box calibration records, stratification checks, cyclonic flow determinations sheets, Pitot tube, scale, and barometer calibration records).

5.0Test Results and Discussion

5.1 Operating Conditions During the Compliance Test

During the compliance testing program the CI-IC engine in EU-TESTCELL-01 was operated at an average engine speed of 1,800 rpm and average engine torque of 2,353 Nm. The average diesel fuel use rate was 29.2 gph.

During the compliance testing program the SI-IC engine EU-TESTCELL-02 was operated at an average engine speed of 4,000 rpm and average engine torque of 356 Nm. The average gasoline fuel use rate was 14.6 gph.

5.2 Air pollutant Sampling Results

5.2.1 Diesel Fueled CI-IC Engine Test Results

The gas stream exhausted from the engine operated in EU-TESTCELL-01 (diesel fueled IC engine) was sampled for three (3) separate one-hour test periods during the compliance testing performed May 7, 2024. Instrumental analyzers were used to measure concentrations of NO_x, CO, O_2, and CO_2 in the exhaust. Moisture content was determined by gravimetric weight gain in chilled impingers and velocity pressure measurements were performed once for each sampling period using a Pitot tube for exhaust gas velocity determination.

The average measured NO_X and CO concentrations in the exhaust gas were 539 and 318 parts per million by volume, dry basis (ppmvd), respectively. This results in calculated emission rates of 121 pounds of NO_x per 1,000 gallons of fuel combusted (lb/1,000 gal) and 43.5 lb CO/1,000 gal based on the measured average exhaust gas volumetric flowrate of 917 dry standard cubic feet per minute (dscfm) and average diesel fuel use rate of 29.2 gph. The average moisture content of the exhaust gas was 11.4% and the average O_2 and CO_2 concentrations of the exhaust gas were 5.18 and 12.0%, respectively.

Tables 5.1 presents measured exhaust gas conditions and pollutant emission rates for the diesel fueled CI-IC engine operated in EU-TESTCELL-01.

5.2.2 Gasoline Fueled SI-IC Engine Test Results

The gas stream exhausted from the engine operated in EU-TESTCELL-02 (gasoline fueled IC engine) was sampled for three (3) separate one-hour test periods during the compliance testing performed May 7, 2024. Instrumental analyzers were used to measure concentrations of NO_x, CO, O_2, and CO_2 in the exhaust. Moisture content was determined by gravimetric weight gain in chilled impingers and velocity pressure measurements were performed once for each sampling period using a Pitot tube for exhaust gas velocity determination.

The average measured NO_X and CO concentrations in the exhaust gas were 2,052 and 10,092 ppmvd, respectively. This results in calculated emission rates of 258 lb NO_x/1,000 gal and 773 lb CO/1,000 gal based on the measured average exhaust gas volumetric flowrate of 256 dscfm and average gasoline fuel use rate of 14.6 gph. The average moisture content of the exhaust gas was 13.4% and the average O_2 and CO_2 concentrations of the exhaust gas were 1.41% and 13.7%, respectively.

Table 5.2 presents measured exhaust gas conditions and pollutant emission rates for the gasoline fueled SI-IC engine operated in EU-TESTCELL-02.

Appendix 5 provides field data and calculations for the diesel fueled CI-IC and gasoline fueled SI-IC engine exhaust gas streams.

Appendix 6 provides raw instrumental analyzer response data for each test period.

5.3 Emission Compliance Determination

For CI fuels, PTI No. 370-08D specifies NO_x and CO emission factors of 164 and 94.0 lb/1,000 gal, respectively. For SI fuels, PTI No. 370-08D specifies NO_x and CO emission factors of 279 and 1,725 lb/1,000 gal, respectively. The permit indicates that Excel Engineering shall use the permitted emission factors until test-derived emission factors are available.

For FGFACILITY, PTI No. 370-08D specifies annual NO_x and CO emission limits of 22.8 and 71.7 tons per year (tpy), respectively. Excel Engineering will use the emission factors determined during this emissions test program to determine compliance with the permitted annual emission limits.

5.4 Variations from Normal Sampling Procedures or Operating Conditions

The testing for all pollutants was performed in accordance with the approved Test Plan. The CI-IC and SI-IC engines operated near maximum output and no variations from the normal operating conditions of the engines occurred during the test periods

Table 5.1 Measured exhaust gas conditions and air pollutant emission rates for the diesel fueled compression-ignited IC engine operated in EU-TESTCELL-01

Test No. Test date Test period (24-hr clock)	1 5/7/2024 906-1006	2 5/7/2024 1028-1128	3 5/7/2024 1148-1248	Three-Test Average
Diesel fuel use rate (kg/h)	93.9	93.9	94.0	93.9
Diesel fuel use rate (gph)[1]	29.2	29.2	29.2	29.2
Engine speed (rpm)	1,800	1,800	1,800	1,800
Engine torque (Nm)	2,352	2,351	2,357	2,353
Exhaust gas composition				
CO_2 content (% vol)	10.8	11.96	11.95	11.57
O_2 content (% vol)	5.15	5.18	5.22	5.18
Moisture (% vol)	11.6	11.0	11.5	11.4
Exhaust gas flowrate (dscfm)	955	898	900	917
Carbon monoxide emission rates				
CO conc. (ppmvd)	321	329	303	318
CO emissions (lb/hr)	1.34	1.29	1.19	1.27
CO emissions (lb/1,000 gal) †	45.8	44.1	40.7	43.5
Permit Limit (lb/1,000 gal)	-	-	-	*94.0*
Nitrogen Oxides emission rates				
NO_x conc. (ppmvd)	536	534	546	539
NO_x emissions (lb/hr)	3.67	3.43	3.53	3.54
NO_x emissions (lb/1,000 gal) †	126	118	121	121
Permit Limit (lb/1,000 gal)	-	-	-	164

1. Fuel use Conversion was based on a diesel "2D" fuel density of 849 kg/m³.

$$\text{gal/hr} = \frac{(F_r \text{ kg/hr}) / (849 \text{ kg/m}^3)}{(0.001) / (3.7854)}$$

Where:

F_r = Fuel use rate (kg/hr), as recorded
849 kg/m^3 = 2D Diesel Fuel Density
0.001 = Conversion factor, 0.001 m^3 per liter
3.7854 Conversion factor, 3.7854 liters per gallon

Table 5.2 Measured exhaust gas conditions and air pollutant emission rates for the gasoline fueled spark-ignited IC engine operated in EU-TESTCELL-02

Test No. Test date Test period (24-hr clock)	1 5/6/2024 1356-1456	2 5/6/2024 1518-1618	3 5/6/2024 1638-1738	Three-Test Average
Gasoline fuel use rate (kg/hr)	39.6	39.7	39.5	39.6
Gasoline fuel use rate (gph)	14.6	14.7	14.6	14.6
Engine speed (rpm)	4,002	3,998	4,001	4,000
Engine torque (Nm)	356	357	356	356
Exhaust gas composition				
CO_2 content (% vol)	13.7	13.7	13.7	13.7
O_2 content (% vol)	1.50	1.37	1.37	1.41
Moisture (% vol)	14.4	11.6	14.2	13.4
Exhaust gas flowrate (dscfm)	273	256	240	256
Carbon monoxide emission rates				
CO conc. (ppmvd)	10,108	10,069	10,100	10,092
CO emissions (lb/hr)	12.1	11.3	10.6	11.6
CO emissions (lb/1,000 gal)[1]	824	767	726	773
Permit Limit	-	-	-	1,725
Nitrogen Oxides emission rates				
NO_x conc. (ppmvd)	2,049	2,055	2,053	2,052
NO_x emissions (lb/hr)	4.01	3.77	3.53	3.77
NO_x emissions (lb/1,000 gal) [1]	274	257	242	258
Permit Limit (lb/1,000 gal)	-	-	-	279

1. Fuel use Conversion was based on a gasoline fuel density of 715 kg/m^3.

$$\text{gal/hr} = \frac{(F_r\ \text{kg/hr}) / (715\ \text{kg/m}^3)}{(0.001) / (3.7854)}$$

Where:

F_r = Fuel use rate (kg/hr), as recorded
715 kg/m^3 = Gasoline Fuel Density
0.001 = Conversion factor, 0.001 m^3 per liter
3.7854 Conversion factor, 3.7854 liters per gallon