Draft Test Method for UL 2201 Task Group for Determining CO Emission Rate of Portable Generators[1]

1. Purpose

This document provides test methods to determine the carbon monoxide (CO) emission rate of a portable generator. The appropriate method is determined by the impact of a reduced oxygen environment on the engine's CO emission rate. Test methods and requirements for documentation are also provided to make this determination.

2. Scope

The following requirements apply to spark-ignited, engine-driven portable generators with rated continuous power up to, and including, 15 kilowatts (kW).

3. Determining the Oxygen Dependence of a Portable Generator's CO Emission Rate

3.1 A portable generator is oxygen-independent if the conditions in Sections 3.1.1, 3.1.2, and 3.1.3 are satisfied. Its modal CO emission rates must be determined using one of the two test methods specified in Section 5. The generator's weighted CO emission rate and its power-specific weighted CO emission rate are then determined using the calculations provided in Section 7. The power-specific weighted CO emission rate must meet the performance requirement specified in Section 8.

3.1.1 The manufacturer of either the engine's fuel control system or the generator must provide documentation demonstrating that the fuel control system maintains an air-to-fuel equivalence ratio (λ) of 1 ± 0.05 λ, while operating in closed loop, when tested to one of the methods specified in Section 4. A fuel control system that meets this performance requirement is considered to be an oxygen-independent fuel control system.

3.1.2 The manufacturer of either the generator's engine or the generator must provide documentation stating the maximum power the engine can deliver while operating in closed loop. This power limit is the maximum load that can be applied continuously to the engine when used in a portable generator.

3.1.3 The generator manufacturer must provide documentation stating that the generator assembly is designed to prevent continuous engine operation above the power limit specified by the engine manufacturer for closed-loop operation. Open-loop engine operation must only occur during engine warm-up and transient conditions. This documentation must include the size and efficiency of the alternator and the size and performance characteristics of the generator's circuit breaker.

3.2 A portable generator that does not satisfy the conditions stated in Section 3.1 is oxygen dependent. Its modal CO emission rates must be determined using the test method specified in Section 6. The generator's weighted CO emission rate and its power-specific weighted CO

[1] This draft test method was prepared by the CPSC staff, and has not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

emission rate are then determined using the calculations provided in Section 7. The power-specific weighted CO emission rate must meet the performance requirement specified in Section 8.

4. Test Method to Determine the Oxygen Dependence of the Fuel Control System

The fuel control system manufacturer can choose one of two test methods to evaluate the relationship of λ to the engine intake oxygen concentration. The results of either test will determine if the fuel control system is oxygen dependent.

Note to Task Group: Due to concerns expressed about using a small test chamber in the test method in Section 4.1 in laboratory facilities not configured with an exhaust hood, CPSC staff is proposing an alternative test method in Section 4.2. This alternative test method uses an intake oxygen dilution system, rather than recirculating exhaust, to reduce the oxygen in the intake air to 16.0%. Since this system is under development, the test equipment and procedures are not yet fully defined.

4.1 Chamber Test Method

4.1.1 Test Equipment

4.1.1.1 Test Chamber: The test chamber is a single-zone enclosure capable of reducing oxygen passively to 16 percent oxygen by volume within 2 to 10 minutes by recirculating the exhaust emissions from the test engine within the chamber. Forced ventilation and temperature management are not required. Mixing is naturally driven by the test engine exhaust flow, creating oxygen reduction at the engine intake that is consistent and repeatable. Small variable diameter ports may be used to aid with ventilation adjustments to control the rate of oxygen depletion. For an example of engine displacement versus chamber volume, a nominally 3.5 cubic meter chamber with a nominally 700 cubic centimeter (cc) four-stroke, two cylinder engine is capable of reducing oxygen to 16 percent by volume between 1.5 and 5 minutes, depending on load.

4.1.1.2 Dynamometer: Engine power is measured using an absorption dynamometer at a minimum sample frequency of 1 hertz (Hz).

4.1.1.3 Gas and Environmental Measurement Systems: Oxygen concentration and temperature are measured at the engine intake with a minimum sample frequency of 1 Hz. λ is measured in the exhaust stream with a minimum sample frequency of 60 Hz.

4.1.2 Test Procedures

4.1.3 Start the engine and warm to operating temperature using recommendations in 40 C.F.R. § 1065.510, allowing sufficient ventilation to maintain normal ambient oxygen levels at the engine intake.

4.1.4 Shut down the engine and adjust the test chamber as needed to reduce oxygen to 16 percent oxygen by volume within 2 to 10 minutes of starting the test engine.

4.1.5 Start the engine, achieve design engine speed, and apply 50 percent of the engine's rated load within 10 seconds of starting.

4.1.6 Operate the test until the oxygen concentration is reduced to 16 percent oxygen by volume or the engine stops running.

4.1.7 Repeat the test two times.

4.1.8 Perform the calculation procedure specified in Section 4.3.

4.2 Intake Oxygen Dilution Test Method

4.2.1 Test Equipment

4.2.1.1 Dilution Tunnel: The dilution tunnel is a tube connected to the engine intake that is long enough to provide a well-mixed combination of air and bottled nitrogen. The tunnel is large enough in diameter to provide unimpeded flow of the mixture into the intake. Nitrogen for dilution is injected at the far end from the engine intake. Oxygen is measured near the intake to verify the concentration provided to the engine.

4.2.1.2 Nitrogen Injection System: The nitrogen injection system is capable of providing a variable volume of nitrogen to the intake of the engine to reduce the intake oxygen concentration to 16 percent oxygen by volume while the engine is at operating speed. A control system may be used that references the intake oxygen measurement and properly adjusts the nitrogen injection.

4.2.1.3 Dynamometer: Engine power is measured using an absorption dynamometer at a minimum sample frequency of 1 hertz (Hz).

4.2.1.4 Gas and Environmental Measurement Systems: Oxygen concentration is measured at the engine intake with a minimum sample frequency of 1 Hz. λ is measured in the exhaust stream with a minimum sample frequency of 60 Hz.

4.2.2 Test Procedures

4.2.2.1 Start the engine and warm to operating temperature using recommendations in 40 C.F.R. § 1065.510 with undiluted air.

4.2.2.2 Apply 50 percent of the engine's rated load and begin recording the oxygen concentration and λ.

4.2.2.3 Reduce the intake oxygen concentration by introducing the nitrogen stream. Reduce oxygen steadily to 16 percent oxygen by volume, measured at the engine intake, over a period of 5 to 10 minutes or until the engine shuts down.

4.2.2.4 Repeat this test two times.

4.2.2.5 Perform the calculation procedure specified in Section 4.3.

4.3 Calculation Procedure

For each test, calculate the 5-second running mean λ for the test duration after the load is applied. To be oxygen independent, the fuel control system must maintain a mean λ of 1 ± 0.05 λ for all oxygen concentrations down to 16 percent or until the engine shuts down, for all three tests.

5. Test Method to Determine the Modal CO emission Rates of an Oxygen Independent Portable Generator

An oxygen independent portable generator is a portable generator that meets the conditions specified in Section 3.1 To determine the modal CO emission rates of an oxygen-independent portable generator, the generator manufacturer may estimate or determine through testing the CO rates when each of six discrete loads are applied.

5.1 Estimation Method: Estimate the generator's modal CO emission rates at each of six discrete loads described in section 5.1.1 in ambient oxygen. Calculate the generator's weighted CO emission rate and power-specific weighted CO emission rate using the equations specified in Section 7.

5.1.1 Using the alternator size and efficiency data, circuit breaker size, and the modal CO rates obtained from the engine's exhaust emission test* required by the U.S. Environmental Protection Agency (EPA) for certification to 40 C.F.R. § 1054, make reasonable estimations of the CO emission rates when the engine is installed in the generator and operating with each of the following six discrete loads on the generator:

1. Generator mode 1 power: 100 percent of the generator's continuous power rating
2. Generator mode 2 power: 75 percent of the generator's continuous power rating
3. Generator mode 3 power: 50 percent of the generator's continuous power rating
4. Generator mode 4 power: 25 percent of the generator's continuous power rating
5. Generator mode 5 power: 10 percent of the generator's continuous power rating
6. Generator mode 6 power: no load applied

* Note: The EPA allows engine manufacturers to group engines with similar configurations into a single engine family, and the engine configuration in that family, which is expected but not necessarily known to have the highest hydrocarbon and oxides of nitrogen (HC+NOx) emission rate, is to be used for certification of the entire family to 40 C.F.R. § 1054. Notably, the engine in the generator may not be the same as the engine on which the certification test was performed.

5.1.2 Perform the calculation procedure in Section 7, using the modal CO emission rates estimated in Section 5.1.1, to determine the generator's weighted CO emission rate and power-specific weighted CO emission rate.

5.2 Measurement method: Determine the generator's modal CO emission rates at each of six loads in ambient oxygen.

5.2.1 Test Equipment

5.2.1.1 Load bank and power meter: An AC electric resistor load bank is used to simulate steady electric loads on the generator. The load bank is capable of adjustment to within 5 percent of each required load condition. A power meter is used to measure the actual electrical load delivered by the generator with an accuracy of 5 percent.

5.2.1.2 Fuel and lubricants: Fuel and lubricants for this test must meet manufacturer's specifications for the generator being tested.

5.2.1.3 Emission measurement system: A constant volume sampling (CVS) or raw gaseous emission measurement system must meet the requirements of 40 C.F.R. § 1065.

5.2.2 Test Procedures

5.2.2.1 Establish and maintain intake air temperature of 20 °C ± 10 °C and relative humidity of 50 percent ± 15 percent RH.

5.2.2.2 Connect the load bank to the generator's receptacle.

5.2.2.3 Start the generator and warm to operating temperature using recommendations in 40 C.F.R. § 1065.510.

5.2.2.4 With the generator still running, adjust the load bank to apply the first load listed in Section 5.1.1.

5.2.2.5 After at least 5 minutes of stable operation with the prescribed load applied, sample emissions for at least 1 minute using the emission measurement system, then stop emission sampling. Record the mean CO emission values for that load, then adjust the load bank to apply the next load listed in Section 5.1.1.

5.2.2.6 Repeat step 5.2.2.5 for all six loads.

5.2.2.7 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.

5.2.2.8 Perform the calculation procedure in Section 7, using the modal CO emission rates determined in Section 5.2.2.7, to determine the generator's weighted CO emission rate and power-specific weighted CO emission rate.

6. Test Method to Determine the Modal CO emission Rates of an Oxygen Dependent Portable Generator.

An oxygen-dependent portable generator is a portable generator that does not meet the conditions specified in Section 3.1. To determine the CO emission rate of an oxygen-dependent portable generator, determine the generator's modal CO emission rates at six discrete generator loads with reduced engine intake oxygen between 17.0 percent and 17.5 percent oxygen by volume.

Note to Task Group: This test method is provided in the event it is found that the relationship of a generator's peak CO emission rate at reduced oxygen relative to the CO emission rate at ambient is not consistent among a variety of portable generator sizes (discussed within the Task Group as a "common factor" for the increase in CO emission rate). For this test, CPSC staff proposes to use the intake oxygen dilution system described in Section 4.2 to reduce the oxygen in the intake. This will allow manufacturers to use their current exhaust emission measurement equipment to determine CO emission rates instead of the NIST proposed chamber test method. The intake oxygen dilution system is under development; therefore, the test equipment and procedures are not yet fully defined.

6.1 Test Equipment

6.1.1 Load bank and power meter: An AC electric resistor load bank is used to simulate steady electric loads on the generator. The load bank is capable of adjustment to within 5 percent of each required load condition. A power meter is used to measure the actual electrical load delivered by the generator with an accuracy of 5 percent.

6.1.2 Fuel and lubricants: Fuel and lubricants for this test must meet manufacturer's specifications for the generator being tested.

6.1.3 Emission measurement system: Emission measurement system: A constant volume sampling (CVS) or raw gaseous emission measurement system must meet the requirements of 40 C.F.R. § 1065.

6.1.4 Dilution Tunnel: The dilution tunnel is a tube connected to the engine intake that is long enough to provide a well-mixed combination of air and bottled nitrogen. The tunnel is large enough in diameter to provide unimpeded flow of the mixture into the intake. Nitrogen for dilution is injected at the far end from the engine intake. Oxygen is measured near the intake to verify the concentration provided to the engine.

6.1.5 Nitrogen Injection System: The nitrogen injection system is capable of providing a variable volume of nitrogen to the intake of the engine to reduce the intake oxygen concentration to 16 percent oxygen by volume while the engine is at operating speed. A control system may be used that references the intake oxygen measurement and properly adjusts the nitrogen injection.

6.2 Test Procedures

6.2.1 Start the engine and warm to operating temperature using recommendations in 40 C.F.R. § 1065.510 with undiluted air.

6.2.2 With the generator still running, adjust the load bank to apply the first load listed in Section 5.1.1.

6.2.3 Reduce oxygen steadily at the engine intake by introducing the nitrogen stream until the oxygen concentration, measured at the engine intake, is between 17.0 percent and 17.5 percent by volume.

6.2.4 While maintaining the oxygen concentration between 17.0 percent and 17.5 percent by volume, sample emissions for at least 1 minute with the prescribed load applied then stop emission sampling. Record the mean CO emission values for that load.

6.2.5 Shut down the engine and repeat this test for each load listed in Section 5.1.1.

6.2.6 Determine the modal CO emission rate at each of the 6 loads using calculations consistent with those provided in 40 C.F.R. § 1065.

6.3 Perform the calculation procedure in Section 7, using the modal CO emission rates determined in Section 6.2.6, to determine the generator's weighted CO emission rate and power-specific weighted CO emission rate.

7. Calculation Procedure to Determine the Generator's Weighted CO Emission Rate and Power-Specific Weighted CO Emission Rate

Calculate the generator's weighted CO emission rate using the following equation:

$$\dot{m}_w = 0.09 \times \dot{m}_1 + 0.20 \times \dot{m}_2 + 0.29 \times \dot{m}_3 + 0.30 \times \dot{m}_4 + 0.07 \times \dot{m}_5 + 0.05 \times \dot{m}_6$$

where,

$$\dot{m}_w = Weighted\ CO\ Emission\ Rate, gram\ per\ hour\ \left(\frac{g}{hr}\right)$$
$$\dot{m}_1 = CO\ Emission\ Rate\ at\ mode\ 1\ (\frac{g}{hr})$$
$$\dot{m}_2 = CO\ Emission\ Rate\ at\ mode\ 2\ (\frac{g}{hr})$$
$$\dot{m}_3 = CO\ Emission\ Rate\ at\ mode\ 3\ (\frac{g}{hr})$$
$$\dot{m}_4 = CO\ Emission\ Rate\ at\ mode\ 4\ (\frac{g}{hr})$$
$$\dot{m}_5 = CO\ Emission\ Rate\ at\ mode\ 5\ (\frac{g}{hr})$$
$$\dot{m}_6 = CO\ Emission\ Rate\ at\ mode\ 6\ (\frac{g}{hr})$$

Calculate the generator's power-specific weighted CO emission rate by dividing the generator's weighted CO emission rate by its rated continuous power, as specified by the generator manufacturer.

8. Performance Requirement

Spark-ignited engine-driven portable generators with rated continuous power up to, and including, 15 kW must have a power-specific weighted CO emission rate less than or equal to ___ g/hr per kW of the generator's rated continuous power.