GM WORLDWIDE ENGINEERING STANDARDS	Test Procedure	GMW14824

Body/Exhaust System, Carbon Monoxide Intrusion

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. To measure exhaust-induced Carbon Monoxide (CO) inside the passenger compartment and stowage areas of the vehicle under conditions of operation.

1.2 Applicability. Passenger cars, vans, sport utility vehicles and light-duty trucks.

1.3 Remarks. Not applicable.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW15470 (ID)

(ID) = This standard is limited to internal distribution within General Motors and shall not be distributed outside this company. Contact the GM Lead Engineer for further instructions.

2.3 Additional References.

- Knowledge Set 3406
- Owner's Manual
- Peer Review process

3 Resources

3.1 Facilities. GM Milford Proving Grounds (MPG) road system or equivalent. Indoor testing MPG Building 94 Dynamometer room or equivalent.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 Analyzer. Non-Dispersive Infrared Analyzer (NDIR) or equivalent and related equipment to determine CO concentrations. Data recording LabView program or equivalent (multi-channel interface to Laptop) to measure 30 minute Time Weighted Average (TWA) sampling.

Note: Maximum error of system to be ± 2% of reading when utilizing a 200 Parts per Million (ppm) scale.

3.2.2 Anemometer. Must be available at the test facility. Suitable for determining ambient wind speed in the range of 1.5 km/h to 20 km/h (1 mph to 12 mph), such as Kestrel Model 1000 Wind Meter or equivalent.

3.2.3 Wind Direction Indicator. Wind vane, windsock or other suitable means for determining wind direction.

3.2.4 Portable Fan Array. Fan array per Appendix A, Figure A1 and Figure A2 or equivalent.

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Note: All instrumentation is to be calibrated as required; record instrumentation details and date of calibration on CO Test Data Sheet, (see Appendix B, Datasheet B1, B2 or B3 as applicable), unless the information is otherwise preserved in the testing laboratory records.

3.2.5 CO Alarm System. Sample continuously during testing and alert high ambient levels (> 35 ppm) inside Test Cell.

3.3 Test Vehicle/Test Piece.

3.3.1 Test Vehicle. Full-scale vehicle. Entire vehicle, in particular the powertrain, including the Engine Control Module (ECM), Powertrain Control Module (PCM), etc., should be as representative of design intent as possible.

Note: Verify that all powertrain controls and calibrations are the most current version.

3.4 Test Time.

Calendar time:	3 days
Test hours:	24 hours
Coordination hours:	12 hours

3.5 Test Required Information. Information should be provided to identify whether test is to be development or validation.

3.6 Personnel/Skills. Experience and knowledge about facility/equipment operation and equipment safety.

4 Procedure

4.1 Preparation.

Note: If vehicle has more than one (1) powertrain combination, a request should be sent to the GM Powertrain (GMPT) Vehicle Systems Group one (1) month prior to Vehicle Program Initiation (VPI) for a math-based analysis to determine which combination has the greatest engine-out CO emissions. Once identified, this powertrain combination should be used for Analysis Development Validation (ADV) development testing. See Knowledge Set 3406 for reference on process.

4.1.1 Vehicle Preparation.

4.1.1.1 Check exhaust system for proper installation.

4.1.1.2 Check body seals for proper installation. Do not run CO tests without verifying vehicle is sealed at design intent. Full Vehicle Static Air Leakage (GMW15470) testing is critical in order to evaluate vehicle fidelity. All issues identified during these initial evaluation must be addressed and remedied prior to CO testing using current issue resolution processes.

4.1.1.3 Check that the heater, air conditioning and ventilation systems are functioning properly.

4.1.1.4 If power leads must be routed to a battery source, be sure that door or window sealing is not disturbed.

4.1.1.5. For vehicles with an “access” from the passenger compartment to the luggage compartment such as fold-down seats, pass-through, etc., the vehicle should be tested with the “access” in the open position.

4.1.1.6. Protective breathing apparatus and an audible CO alarm device must be available in case of unanticipated high CO levels in the passenger compartment.

4.1.1.7 Mount a CO probe at both the front and rear seat occupant breath levels at the centerline of the vehicle. If vehicle has additional seating positions, a probe should also be mounted at the breath level of the rearward-most seating position at the centerline of the vehicle. If the vehicle has a rear stowage compartment, an additional probe is to be located in the compartment. For additional probe locations, mount one probe at the most rearward cushion at a location 25 mm (1.0 in) forward of the seat back at the centerline of the vehicle and 50 mm (2.0 in) above the cushion. Additional probes may also be located on the floor footwell of the rearward-most seat. Probes are to be located 50 mm (2.0 in) above the floor at the center of each occupant fore/aft foot location.

4.1.2 Trailer Towing Test Preparation.

Note: Refer to Owner’s Manual or other available information relative to suitability of vehicle to tow a trailer.

4.1.2.1 Couple to the vehicle, a U-Haul type plywood sided trailer according to the towing information as specified in the Owner’s Manual. If the Owner’s Manual is not available, obtain the towing capacity information from the requestor or other personnel responsible for information of this nature, i.e., Validation Department.

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Select a trailer size as shown in Table 1.

Table 1: Trailer Capacities and Sizes

Towing Capacity	Trailer Width	Model
< 907 kg (2000 lb)	1.2 m (4.0 ft)	Light Vehicle (LV) trailer
> 907 kg (2000 lb)	1.8 m (6.0 ft)	Recreational Vehicle (RV) trailer

Note: Ballast trailer to maximum towing capacity of vehicle as specified in Owner's Manual.

Note: If an actual U-Haul trailer is not available, a trailer with the exact physical dimensions and performance characteristics may be substituted.

4.2 Conditions – Moving Vehicle, Methods, Tests.

4.2.1 Environmental Conditions. Tests should not be run if the road surface is wet or if the wind speed exceeds an average of 13 km/h (8 mph) with a peak wind velocity of 20 km/h (12 mph). Conduct tests only on dry roads.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.2.1 Test Conditions for Moving Vehicle.

4.2.2.1.1 Unless otherwise specified, conduct the tests with the vehicle configured as follows:

a. Place a strip of 50 mm (2.0 in) wide tape on the driver's window with the bottom of the tape at beltline height. Lower the driver's window to the point that the top of the tape is level with the outer beltline molding.
b. All other windows are closed.
c. All outside air and air conditioning controls are set in the "off" position or any other position that will minimize the entry of outside air.

Note: The intent of testing with the preceding conditions is to obtain a high negative body pressure. However, for new design vehicles, higher negative body pressure may be obtained under different conditions such as all windows closed and sunroof open, etc. This should be investigated by the test engineer with additional testing conducted accordingly.

4.2.2.1.2 All tests should be conducted with the engine a normal operating temperature.

4.2.2.1.3 Purge the test vehicle of accumulated CO before and after each test conducted.

4.2.2.1.4 Determine the ambient CO level at the start of each test day, mid-day and at the end of the day. When utilizing the MPG Circular Test Track, an air sample is to be obtained at each quadrant of the track to arrive at an average value.

4.2.3 Moving Vehicle – "Baseline" Test.

4.2.3.1 For vehicles WITHOUT a trailering option, measure the CO concentrations per the following instructions:

a. **Conditioning Lap:** Drive one (1) complete lap of the MPG Circular Test Track without recording any measurements, according to the following steps "b" thru "e".
b. Accelerate from 65 km/h (40 mph) at Wide Open Throttle (WOT) to 130 km/h (80 mph).

Note: If the vehicle cannot attain 130 km/h (80 mph), substitute the maximum speed attainable within 1.6 km (1 mi) of vehicle operation.

c. Coast down, in gear, to 65 km/h (40 mph).
d. Drive at 65 km/h (40 mph) for 0.5 km (0.3 mi).
e. Repeat this cycle four (4) times or until the test vehicle has completed one (1) full lap of the MPG Circular Test Track.
f. **Test Lap:** Begin to collect or record a continuous sampling of the CO concentration within the vehicle using the appropriate CO measuring equipment while driving according to steps "b" thru "e".

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4.2.3.2 For vehicle WITH a trailering option, measure the CO concentrations per the following instructions:

a. **Conditioning Lap:** Drive one (1) complete lap of the MPG Circular Test Track at 110 km/h (70 mph) constant speed in the recommended gear range, according to the Owner's Manual for pulling a trailer at this speed, without recording any measurements.

Note: If the vehicle cannot attain 110 km/h (70 mph), substitute the maximum speed attainable within 1.6 km (1 mi) of vehicle operation.

b. **Test Lap:** Begin to collect or record a continuous sampling of the CO concentrations within the vehicle using the appropriate CO measuring equipment while driving 110 km/h (70 mph) for one (1) complete lap of the MPG Circular Test Track.
c. **Conditioning Lap:** Drive one (1) complete lap of the MPG Circular Test Track without recording any measurements, according to the following steps "d" thru "g":
d. Attain a speed of 65 km/h (40 mph) and then accelerate at WOT to 110 km/h (70 km/h)
e. Coast down, in gear, to 65 km/h (40 mph).
f. Drive at 65 km/h (40 mph) for 0.5 km (0.3 mi).
g. Repeat this cycle four (4) times or until the test vehicle has completed one (1) full lap of the MPG Circular Test Track.
h. **Test Lap:** Begin to collect or record a continuous sampling of the CO concentrations within the vehicle using the appropriate CO measuring equipment while driving according to steps "d" thru "g".

4.2.3.3 Moving Vehicle – "Baseline" – Optional Rear Compartment Test. Per engineering direction, additional testing may be conducted utilizing one (1) of the following configurations:

- For a passenger type vehicle with a deck lid, arrange deck lid in an open position so that a 50 mm (2.0 in) gap exists between the deck lid and the deck lid seal at the centerline of the vehicle.
- For vehicles with rear doors (vans, etc.), arrange both rear doors in an open position so that a 50 mm (2.0 in) gap exists between the doors at the centerline of the vehicle.
- For vehicles with functional rear glass, arrange glass to maximum open position as dictated by the detent lever. If glass does not incorporate a detent lever, open glass so that a 50 mm (2.0 in) gap exists between the glass and the glass seal.
- For vehicles equipped with sliding rear windows or mid-gates, configure windows/mid-gates to maximum open position.

Note: Use Peer Review process to discuss new vehicle designs and to establish CO development test strategies.

If Owner's Manual does not specify a configuration for the ventilation system during the preceding test conditions, configure ventilation system to outside air, high blower setting. All windows should be closed.

4.2.3.3.1 With the vehicle configured according to engineering direction, measure the CO concentrations per the following instructions:

a. **Conditioning Lap:** Drive one (1) complete lap of the MPG Circular Test Track without recording any measurements, according to the following steps "b" thru "e":
b. Accelerate from 65 km/h (40 mph) at WOT to 130 km/h (80 mph).

Note: If the vehicle cannot attain 130 km/h (80 mph), substitute the maximum speed attainable within 1.6 km (0.3 mi) of vehicle operation.

c. Coast down, in gear, to 65 km/h (40 mph).
d. Drive at 65 km/h (40 mph) for 0.5 km (0.3 mi).
e. Repeat this cycle four (4) times or until the test vehicle has completed one (1) full lap of the MPG Circular Test Track.
f. **Test Lap:** Begin to collect or record a continuous sampling of the CO concentrations within the vehicle using the appropriate CO measuring equipment while driving according to steps "b" thru "e".

4.2.4 Moving Vehicle "Engine Non-Design Mode" Test. Modify the engine exhaust system as follows: drill an 8.7 mm ($^{11}/_{32}$ in) diameter hole in the exhaust manifold (tap hole for an M10 x 1 (⅛ in) pipe plug for later repair of test vehicle, see Appendix A, Figure A5). Locate hole in exhaust system at a point which is closest to the cowl cover ventilation air inlet. Record hole location on Appendix B, Data Sheet B1 or B2 as applicable (see "Engine Non-Design Mode Hole Location").

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4.2.4.1 For vehicles WITHOUT a trailering option, measure the CO concentrations per the following instructions:

a. **Conditioning Lap:** Drive one (1) complete lap of the MPG Circular Test Track without recording any measurements, according to the following steps “b” thru “e”:
b. Accelerate from 65 km/h (40 mph) at WOT to 130 km/h (80 mph).

Note: If the vehicle cannot attain 130 km/h (80 mph), substitute the maximum speed attainable within 1.6 km (0.3 mi) of vehicle operation.

c. Coast down, in gear, to 65 km/h (40 mph).
d. Drive at 65 km/h (40 mph) for 0.5 km (0.3 mi).
e. Repeat this cycle four (4) times or until the test vehicle has completed one (1) full lap of the MPG Circular Test Track.
f. **Test Lap:** Begin to collect or record a continuous sampling of the CO concentrations within the vehicle using the appropriate CO measuring equipment while driving according to steps “b” thru “e”.

4.2.4.2 For vehicles WITH a trailering option, measure the CO concentrations per the following instructions:

a. **Conditioning Lap:** Drive one (1) complete lap of the MPG Circular Test Track at 110 km/h (70 mph) constant speed in the recommended gear range, according to the Owner’s Manual for pulling a trailer at this speed, without recording any measurements.

Note: If the vehicle cannot attain 110 km/h (70 mph), substitute the maximum speed attainable within 1.6 km (1 mi) of vehicle operation.

b. **Test Lap:** Begin to collect or record a continuous sampling of the CO concentrations within the vehicle using the appropriate CO measuring equipment while driving 110 km/h (70 mph) for one (1) complete lap of the MPG Circular Test Track.
c. **Conditioning Lap:** Drive one (1) complete lap of the MPG Circular Test Track without recording any measurements, according to the following steps “d” thru “g”:
d. Attain a speed of 65 km/h (40 mph) and then accelerate at WOT to 110 km/h (70 km/h)
e. Coast down, in gear, to 65 km/h (40 mph).
f. Drive at 65 km/h (40 mph) for 0.5 km (0.3 mi).
g. Repeat this cycle four (4) times or until the test vehicle has completed one (1) full lap of the MPG Circular Test Track.
h. **Test Lap:** Begin to collect or record a continuous sampling of the CO concentrations within the vehicle using the appropriate CO measuring equipment while driving according to steps “d” thru “g”.

4.2.4.3 Thread Pipe Plug into Exhaust Manifold Hole to Repair Test Vehicle. See Appendix A, Figure A5.

4.2.5 Moving Vehicle “Muffler Non-Design Mode” Test. Modify the exhaust muffler(s) as follows:

a. For vehicles with a fore/aft mounted muffler, drill a 25 mm (1.0 in) diameter hole on the front vertical surface of the muffler (see Appendix A, Figure A6 for later repair of test vehicle). Record hole location on Appendix B, Data Sheet B1 or B2 as applicable (see “Muffler Non-Design Mode Hole Location”).
b. For vehicles with a lateral mounted muffler, drill a 25 mm (1.0 in) diameter hole in one face of the muffler (see Appendix A, Figure A6 for later repair of test vehicle). Conduct test as specified in 4.2.5.1 or 4.2.5.2, as applicable. After restoring muffler to its original integrity (see 4.2.5.3), drill a 25 mm (1.0 in) diameter hole in the opposite face of the muffler (see Appendix A, Figure A6 for later repair of test vehicle). Repeat Test.
c. For vehicles with dual mufflers, repeat (a) or (b) according to the orientation of the mufflers. Test each muffler separately.

Note: Be sure to drill hole(s) in the exhaust muffler and not the exhaust resonator.

4.2.5.1 For vehicles WITHOUT a trailering option, measure the CO concentrations per the following instructions:

a. **Conditioning Lap:** Drive one (1) complete lap of the MPG Circular Test Track without recording any measurements, according to the following steps “b” thru “e”:
b. Accelerate from 65 km/h (40 mph) at WOT to 130 km/h (80 mph).

Note: If vehicle cannot attain 130 km/h (80 mph), substitute the maximum speed attainable within 1.6 km (1 mi) of vehicle operation.

c. Coast down, in gear, to 65 km/h (40 mph).
d. Drive at 65 km/h (40 mph) for 0.5 km (0.3 mi).

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e. Repeat this cycle four (4) times or until the test vehicle has completed one (1) full lap of the MPG Circular Test Track.
f. **Test Lap:** Begin to collect or record a continuous sampling of the CO concentrations within the vehicle using the appropriate CO measuring equipment while driving according to step “b” thru “e”.

4.2.5.2 For vehicles WITH a trailering option, measure the CO concentration per the following instructions:

a. **Conditioning Lap:** Drive one (1) complete lap of the MPG Circular Test Track at 110 km/h (70 mph) constant speed in the recommended gear range, according to the Owner’s Manual for pulling a trailer at this speed, without recording any measurements.

Note: If the vehicle cannot attain 110 km/h (70 mph), substitute the maximum vehicle speed attainable within 1.6 km (1.0 mi) of vehicle operation.

b. **Test Lap:** Begin to collect or record a continuous sampling of the CO concentrations within the vehicle using the appropriate CO measuring equipment while driving 110 km/h (70 mph) for one (1) complete lap of the MPG Circular Test Track.
c. **Conditioning Lap:** Drive one (1) complete lap of the MPG Circular Test Track without recording any measurements, according to the following steps “d” thru “g”:
d. Attain a speed of 65 km (40 mph) and then accelerate at WOT to 110 km/h (70 mph).
e. Coast down, in gear, to 65 km/h (40 mph).
f. Drive at 65 km/h (40 mph) for 0.5 km (0.3 mi).
g. Repeat this cycle four (4) times or until the test vehicle has completed one (1) full lap of the MPG Circular Test Track.
h. **Test Lap:** Begin to collect or record a continuous sampling of the CO concentrations within the vehicle using the appropriate CO measuring equipment while driving according to steps “d” thru “g”.

4.2.5.3 Thread Pipe Plug(s) into Exhaust Muffler Hole(s) to Repair Test Vehicle.

4.3 Instructions.

4.3.1 Indoor Test Cell. When available, a test cell that maintains a unidirectional wind speed of 8.05 km/h ± 1.6 km/h (5 mph ± 1 mph) without artificially elevating the ambient CO levels within the test cell is preferred. Position the fan array approximately 4 m to 5 m (13 ft to 16 ft) in front of the vehicle such that the collective fan direction sand speeds produce a steady state wind over the vehicle hood surface and directly in front of the vehicle (see Appendix A, Figure A3 and Figure A4). These tests may be conducted in an outside environment if they meet the conditions listed in 4.3.2.

4.3.2 Outside Environmental Conditions. Test are not to be performed when the road surface is wet. Select a test site in an open area with a wind speed from 3 km/h to 12 km/h (2 mph to 8 mph).

4.3.3 Vehicle Preparation. For all idle testing, all windows are to be closed. Remove the pipe plug from the exhaust manifold (see 4.2.4.3). Vehicle engine must be at operating temperature and vehicle interior CO levels must be a 0 ppm prior to any testing.

Note: If testing is conducted outside, engine warm-up and interior CO evacuation may be accomplished by driving on a suitable test track. If testing is conducted inside, idling the vehicle until the engine is warm is permissible as long as the interior CO levels remain at 0 ppm.

4.3.4 Facing into the Wind.

4.3.4.1 With the vehicle facing into the wind, set the heater and/or air conditioner control lever and duct outlet controls to permit the maximum volume of outside air into the vehicle.

4.3.4.2 Record CO concentration at each probe location with the blower control set in the high airflow position. Test duration is 30 minutes. Record the average CO concentration on the CO Data Sheet as applicable per the following: Appendix B, Data Sheet B1 for Six (6) Channel Recorder, Appendix B, Data Sheet B2 for Eight (8) Channel Recorder and Appendix B, Data Sheet B3 for Development Testing. Use Appendix B, Data Sheet B4 to attach any photographic documentation of issues as required.

4.3.4.3 Repeat 4.3.4.2 except with the blower control set in the low air flow position. Test duration is 30 minutes. Record the CO concentration on the CO Data Sheet as applicable per the following: Appendix B, Data Sheet B1 for Six (6) Channel Recorder, Appendix B, Data Sheet B2 for Eight (8) Channel Recorder and Appendix B, Data Sheet B3 for Development Testing. Use Appendix B, Data Sheet B4 to attach any photographic documentation of issues as required.

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