



Exhaust Gas Recirculation (EGR) Cooler Fouling Test Procedure

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. This test is primarily run to evaluate the cooler fouling effects of extended cooled Exhaust Gas Recirculation (EGR) operation. This test is comprised primarily of repeating steady-state operating points to accelerate cooler fouling.

1.2 Applicability. The procedure is written in generic terms to cover all internal combustion engines that include EGR coolers.

1.3 Remarks. The largest portion of the test is spent in the Fouling Cycle (Figure A1 and Figure A2 in Appendix A). This test was designed for light-duty gasoline/diesel applications, and may not be appropriate for some commercial or heavy-duty applications such as delivery, shuttle, and extended Power Take Off (PTO) use, etc. Operating at low speed/light load conditions typically requires cooled EGR, this may vary depending upon the engine operating mode, e.g., Gasoline Particulate Filter (GPF) or Diesel Particulate Filter (DPF) regeneration, Selective Catalyst Reduction (SCR) warm-up, etc. which results in exhaust contaminant accumulation on the internal EGR cooler fins. This accumulation restricts flow, and reduces the effectiveness of the cooler. The test includes 550 Fouling Cycles (distributed throughout the test) which may give an indication of the cooler fouling trends for the engine. This portion of the test provides elevated EGR contaminants, high EGR flows, and low EGR temperatures; all of which are significant contributors to cooler fouling. There are Regeneration Points (Figure A3 in Appendix A) positioned throughout the test, which provide a reasonable amount of EGR cooler regeneration for light-duty applications. Likewise, there are Idle, Engine Warm Up, Engine Cool Down and Soak cycles (Figure A3 in Appendix A) dispersed throughout the test which provide steady state operating points for consistent data acquisition between the Fouling Cycles.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

None

2.3 Additional References. The following data may change during an engine program or from model year to model year so confirm with the GM Design Release Engineer (DRE):

- Accessory belt(s) production (intent) tension (adjustable systems)
- Air filter housing in-vehicle installation position
- Base engine nominal production (intent) timing
- Engine in-vehicle installation angle

3 Resources

3.1 Facilities. Major Facility: Engineering Test Laboratory.

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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 Dynamometer. Suitably rated for the speed range and torque output of the test conditions. Motoring capability is not required.

3.2.2 Driveshaft. Suitably matched to inertia and torque output of the engine, inertia of the dynamometer being used, and the maximum speed of the test.

3.2.3 Throttle Actuator. With linkage used for automatic throttle control.

3.2.4 Dynamometer Controller. To manage engine speed, engine load/pedal position per Figure A3 in Appendix A.

3.2.5 Engine Coolant Cooling System. It must incorporate the following features:

- A closed system with vehicle equivalent flow restriction.
- A sight glass to visually monitor coolant condition.
- Production equivalent by-pass loops, e.g., heater, oil cooler, internal, etc.
- Other vehicle equivalent features, e.g., overflow/pressure bottle, etc.
- Cooling system components should have proper relative orientations to allow appropriate air purging, etc.
- The maximum system pressure is to be equal to vehicle radiator cap relief pressure.

Note: External pressurization of the coolant system is not appropriate unless the design of the system prevents the attainment of minimum vehicle pressure levels at equivalent engine speed/ coolant temperature conditions.

3.2.6 Engine Oil Cooling System. With vehicle equivalent flow restrictions. Internal engine oil flow is not to be disrupted. The quantity of oil in the oil cooler should be kept to a minimum so that the oil quality degradation rate will not be affected. All test sites must duplicate the oil cooling method used at the design test site for a given family of engines. At Start of Test (SOT) or fluid change, the entire system should have new oil.

Note: Oil cooling may not be necessary, depending on the application.

3.2.7 Temperature Controllers. To maintain oil, coolant, and fuel temperatures per 4.2.2.1 thru 4.2.2.3.

3.2.8 Exhaust System. Capable of providing vehicle equivalent backpressure. See 3.3.7.

3.2.9 Fuel Delivery System. Capable of maintaining production (intent) vehicle pressure and flow.

3.2.10 Instrumentation. As needed to measure the parameters found in 5.3.1.

3.2.11 Automatic Data Acquisition Equipment. Must be capable of a 1 Hz minimum raw signal sample rate and be able to average raw signal values into data for recording. See 5.3.1 and Figure A2 in Appendix A.

3.2.12 Intake Air Condition. Provisions for maintaining the intake air temperature at 20 °C to 30 °C (68 °F to 86 °F) and pressure of 95 kPa to 105 kPa (28 in Hg to 31 in Hg). See also 4.2.

3.2.13 Emissions Measurement Equipment (Optional).

3.2.14 Independent EGR Cooler Coolant Cooling System (if relevant). If the test application incorporates and independent EGR cooler coolant loop, the test setup must incorporate the following features:

- A closed system with vehicle equivalent flow restriction.
- A sight glass to visually monitor coolant condition.
- Production equivalent by-pass loops, e.g., heater, oil cooler, internal, etc.
- Other vehicle equivalent features, e.g., overflow/pressure bottle, etc.
- Cooling system components should have proper relative orientations to allow appropriate air purging, etc.
- The maximum system pressure is to be defined by the appropriate GM DRE/Product Management Team (PMT).

Note: External pressurization of the coolant system is not appropriate unless the design of the system prevents the attainment of minimum vehicle pressure levels at equivalent engine speed/ coolant temperature conditions.

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3.3 Test Vehicle/Test Piece.

3.3.1 Engine. All pre-durability measurements prescribed by the GM DREs must be made and recorded during the engine build (unless a plant built). The engine should be broke-in prior to beginning the cycle tuning. The EGR cooler should be replaced after the test script is proven to be correct during cycle tuning.

3.3.2 Short-Belt Accessory Drive System. Full accessory drive system is not required however, the Fouling Cycle engine loads need to be controlled to ensure the severity of the test. If Brake Mean Effective Pressure (BMEP) BMEP1 and BMEP2 (Figure A1 and Figure A2 in Appendix A) were chosen using data from an engine with a full accessory drive, this hardware may be required on the test engine.

3.3.3 Production Engine Control Module (ECM). Hardware and software/calibration for electronically managed engine controls may be required. The engine calibrations are to be the same as used in the vehicle or at least the latest available level during a development program. Calibration changes should only be made if necessary. Changes should be documented. Non-engine codes, e.g., transmission, Vehicle Anti-Theft System (VATS), etc. may need to be masked and routines that affect engine performance for non-engine related reasons, e.g., torque management, traction control, etc. should be disabled.

3.3.4 Engine Fluids. Factory fill production (intent), for model year of system being tested, engine oil should be used. Use factory source coolant at the as released mix (typically 50/50) for the model year of the system being tested. The use of coolant supplement pellets is not recommended since they may hide design/quality flaws. Primary vehicle specified fuel type should be used. If the test is to be run more than once, alternative fuels can be used, e.g., ethanol/biodiesel based fuels, etc.

3.3.5 Induction Hardware. Production (intent) with complete induction system.

3.3.6 Thermostat. Use a pinned open thermostat.

3.3.7 Exhaust. Use production (intent) exhaust manifold(s). Downstream, e.g., muffler, converter, SCR, DPF, etc. hardware is not required however, the Test Engineer should use discretion when deciding what downstream exhaust hardware should be included.

3.3.8 Ignition System (Gas Engine). Use the production (intent) system. Production (intent) spark plugs are required. The spark plugs should be set at production (intent) gap.

3.4 Test Time. Times shown are estimates due to cycle tuning.

Calendar time: 15 d

Test time: 300 h

Coordination time: 8 h

3.5 Test Required Information. The New European Driving Cycle (NEDC) and Extra Urban Driving Cycle (EUDC) should be driven in the vehicle that would be considered the most severe for the application. The speed and Accelerator Pedal Position (APP) traces should be used to program the dynamometer to run those test portions. Ideally, a 1 Hz trace should be used to program the dynamometer.

Engineering discretion should be used to choose speed/torque SPEED1/BMEP1 and SPEED2/BMEP2 (Figure A1 and Figure A2 in Appendix A) of the Fouling Cycle, since proper selection of these points is critical to the severity of the test. All points in the Fouling Cycle may be unique for each application however, the speed and/or load transition (ramp) time (Figure A1 and Figure A2 in Appendix A) is typically 2 s to 3 s. SPEED1/BMEP1 should be the speed and load at which the EGR unburned hydro-carbon content is the highest. SPEED2/BMEP2 should be the speed and load at which the exhaust soot content is the highest. Care should be taken to ensure that there is significant EGR flow at both SPEED1/BMEP1 and SPEED2/BMEP2. The test will yield poor results if there is little or no EGR flow during these points. SPED3/BMEP3 is defined as the mean of SPEED1/BMEP1 and SPEED2/BMEP2.

3.6 Personnel/Skills. Person familiar with EGR testing on an engine dynamometer.

4 Procedure

4.1 Preparation.

4.1.1 Sample Preparation.

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4.1.1.1 Mount the engine with associated test material from 3.3 in the dynamometer test cell. Use production (intent) mounts if possible. Mount engine at the same installation angle as in the vehicle.

4.1.1.2 Connect the exhaust system to the engine. If downstream exhaust hardware is not used, set exhaust back pressure to approximate vehicle back pressure.

4.1.1.3 Place the air filter housing in-vehicle installation position relative to the engine and connect it to the engine. It should contain a new air filter element

4.1.1.4 Connect the fuel lines to the engine.

4.1.1.5 Connect the ignition (per 3.3.8) and the engine control (per 3.3.3) systems to the engine.

4.1.1.6 Connect the throttle linkage to the engine.

4.1.1.7 Connect the coolant (per 3.2.5) and oil (per 3.2.6) conditioning systems.

4.1.1.8 Fill the coolant cooling system with fresh factory-fill coolant (per 3.3.4).

Note: Make sure the system is full of coolant without trapped air pockets.

4.1.1.9 Install a new production (intent) oil filter.

4.1.1.10 If necessary, calibrate the dipstick per the Test Engineer instructions.

4.1.1.11 Fill the engine with factory fill oil to the "FULL" mark (top of operating range). Recheck the oil level after running the engine for a couple of minutes. Adjust if necessary to achieve the "FULL" mark.

4.1.1.12 If the engine has base timing which is adjustable, then:

a. Verify the timing mark is at zero (0) when piston number one (1) is at Top Dead Center (TDC). If not, document, then correct.

b. Set the timing to the base engine nominal production (intent) timing.

4.1.1.13 If adjustable, tension the accessory belt(s) per the production (intent) specification. If not adjustable, then the production (intent) tensioner(s) should be used.

4.1.1.14 Connect the instrumentation to measure the parameters found in 5.3.1.

4.1.1.15 Auxiliary cooling, e.g., with blowers, fans, etc. should only be used if it can be demonstrated that component temperatures in the dynamometer environment exceed the maximum temperatures found in the vehicle. Document any parts being cooled or insulated.

4.1.2 Instrument Calibration. Calibrate all instrumentation as required prior to start of test.

4.2 Conditions.

4.2.1 Environmental Conditions. No specific requirements (could even be run outside), although ambient temperature range should not exceed 10 °C to 40 °C. Care should be taken to ensure that the environmental conditions do not cause the engine to run with excessive compensations, e.g., cold ambient temperatures can cause some applications to bypass the EGR cooler, that reduce the severity of the test.

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 Engine Coolant Temperature Conditions. This temperature should be controlled to 5 °C warmer than the minimum thermostat "start to open" temperature ± 5 °C, unless otherwise specified by the Test Engineer.

4.2.2.2 Engine Oil Temperature Conditions. The oil sump temperature should be measured. This temperature should be controlled to 90 °C ± 5 °C unless otherwise specified by the Test Engineer.

4.2.2.3 Independent EGR Cooler Coolant Conditions (if relevant). The EGR cooler coolant loop temperature set point is application specific, and should be supplied by the Test Engineer.

4.3 Instructions.

4.3.1 Engine Break-In. The engine should be broke-in using the procedures provided by the Test Engineer.

4.3.2 Cycle Tuning. Run any portion of the test, as required, to ensure that the test script will properly function once the engine is put on test.

4.3.3 Replace the EGR cooler, so that a new cooler is used at the start of test. Include all instrumentation as required by 5.3.1. It is recommended that the test EGR cooler should be analyzed (flow tested, weighed, etc.) by the Supplier prior to testing. After testing, the same analysis should be repeated to determine the cooler performance degradation.

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