



Diesel Fuel Injector Coking Test Procedure

1 Scope

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 used to assess the robustness of diesel fuel injectors with respect to nozzle coking. Extended exposure to high temperatures and high Exhaust Gas Recirculation (EGR) flow rates can cause injector nozzles to coke, resulting in reduced fuel flow rates.

1.2 Foreword. The Coking Cycle is a repeating, steady-state test composed of high speed/load operating points alternating with part throttle operating points. The use of a Zn doped fuel is optional, but is recommended.

Before installation into the engine each test injector should be flow tested at the supplier. After the test is complete the injectors must be carefully handled so that the coking deposits are not disturbed. Each injector should then be flow tested again, at the supplier, to determine the change in flow characteristics due to coking deposits. The flow decrease due to coking should not exceed 5%.

1.3 Applicability. This test was developed for direct injection diesel applications, and may not be appropriate for other applications.

1.4 Security. Except as noted here, none of the text, procedures, tables, or numbers in this document may be released outside General Motors. If a company outside General Motors is to conduct testing based on this procedure, the following information **may** be released:

- The required content of the test (how many hours/cycles, the speeds, the temperatures, etc.,) or a separate document which gives this information.
- The test reliability (and associated confidence) to be demonstrated on the test.
- Recommendations for continued testing for failure and for analysis of the results.
- Requirements for reporting the test results to GM.

Information about how the test reliability was determined **may not** be released. For example, background on how the test inputs were selected (such as the customer severity being represented) or the field reliability that corresponds to the required test reliability, **may not** be released. Information about how the life goal, speeds, or temperatures were determined **may not** be released.

2 References

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

2.1 External Standards/Specifications.

SAE J1349

2.2 GM Standards/Specifications.

None

2.3 Additional References.

- Subsystem Technical Specifications (SSTS)
- Vehicle Technical Specifications (VTS)

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Originating Department: North American Engineering Standards

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Note: This data may change during an engine program or from model year to model year. Make sure the data is kept current.

3 Resources

3.1 Facilities. Major Facility: Engineering Test Laboratory.

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 Propshaft. 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 Pedal Position Actuator. Used for automatic pedal control.

3.2.4 Dynamometer Controller. To manage engine speed, engine load/pedal position per the test cycle.

3.2.5 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 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 whole system should have new oil. The oil in the cooling system should be replaced at the regularly scheduled engine oil changes, per Section 4.4.

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. Diesel Particulate Filter (DPF) regenerations and other operating modes can impact the test results, so a full vehicle exhaust system is not recommended.

3.2.9 Fuel Delivery System. Capable of maintaining production (intent) vehicle pressure and flow. A fuel flow meter is required to measure actual fuel consumption during the test. A heat exchanger is required to cool the return fuel to the fuel supply temperature specification in 4.2.2.3. If the test fuel is doped with a Zn additive (optional), the fuel supply system should be separated from the conventional supply system to avoid contamination of the conventional supply system. See Figure A3 for further details.

3.2.10 Instrumentation. As needed to measure the parameters found in Section 5.1.

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 Sections 5.1 and 5.1.2.1).

3.2.12 Intake Air Condition. Provisions for maintaining the intake air specifications in 4.2.1.

3.2.13 Fuel Sample Valve. An extraction valve in the injector return loop is required to sample the test fuel per 4.3.5. See Figure A3 for a detailed schematic of the extraction location.

3.3 Test Vehicle/Test Piece.

3.3.1 Engine. All pre-durability measurements prescribed by the Design/Release Engineer(s) must be made and recorded in the Engine Build Room (unless plant built). The engine should be broke-in prior to beginning any test cycle tuning/slaving, and a power run (using SAE J1349, or similar) should be completed after the engine break-in. The oil and oil filter should be changed following the break-in and power run procedures.

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3.3.2 Short-Belt Accessory Drive System. Full accessory drive system is not required.

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 absolutely 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., biodiesel, etc.) After the test injectors are qualified with the new engine, per 4.3.5, it is strongly recommended that the test fuel be switched to a Zn doped fuel. If a doped fuel is used it should be carefully mixed to achieve a Zn level of 3 ppm on a mass basis (3 mg of Zn per kg of fuel). Shell Helix Ultra 5W-30, purchased from the German market, is recommended because of its stringent Zn quantity control of 1 to 1.25%.

3.3.5 Induction Hardware. Use production (intent) hardware with a complete induction system.

3.3.6 Thermostat. Use a pinned open thermostat.

3.3.7 Exhaust. Use production (intent) exhaust manifold(s). DPF regenerations and other operating modes can impact the test results, so a full vehicle exhaust system is not recommended.

3.3.8 Injector Nozzle Thermocouples (optional). Injector nozzles with embedded thermocouples should be ordered from the supplier in advance of the test, if a nozzle temperature assessment is to be made. The thermocoupled injector(s) should be placed in the hottest cylinder(s).

3.4 Test Time.

Calendar time: 3 to 5 days

Test hours: 48 to 88 hours (see 4.3.7)

Coordination hours: Varies hours

Note: Calendar time represents an estimated value, and does not include setup, engine break-in, and test slaving.

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. Not applicable.

4 Procedure

4.1 Preparation.

4.1.1 Sample Preparation.

4.1.1.1 Mount the engine with associated test material from Section 3.3 in the dyno test cell. Use production (intent) mounts if possible. Mount engine using the appropriate vehicle installation angles.

4.1.1.2 Connect the exhaust system to the engine. Set exhaust back pressure to approximate vehicle back pressure.

4.1.1.3 Connect the air filter housing to the engine. It should contain a new air filter element. The induction system should be orientated the same way as found in the vehicle.

4.1.1.4 Rinse/purge the facility fuel lines with the test fuel prior to connecting the fuel lines to the engine. Change all facility fuel filters if they have been exposed to a fuel that is different from the test fuel. Change the engine fuel system and filter if they have been exposed to fuel that is different from the test fuel. Repeat this step every time the test fuel is changed.

4.1.1.5 Connect the pedal position actuator to the engine.

4.1.1.6 Connect the coolant and oil conditioning systems per 3.2.5 and 3.2.6.

4.1.1.7 Fill the coolant cooling system with fresh factory-fill coolant per 3.3.4.

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Note: Vacuum-fill and/or make sure the system is full of coolant without trapped air pockets.

4.1.1.8 If necessary, calibrate the dipstick per the Test Engineer's instructions.

4.1.1.9 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.

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

1. Verify the timing mark is at 0 when piston No. 1 is at top dead center (TDC) (if not, document; then correct) and,
2. Set the base timing to the nominal production (intent) specification.

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

4.1.1.12 Connect the instrumentation to measure the parameters found in 5.1.1.

4.1.1.13 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.

4.2.1.1 Intake Air Temperature. 16 to 38 °C (60 to 100 °F).

4.2.1.2 Intake Air Pressure. 95 to 105 kPa (28 to 31 in. Hg).

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.

Consult the fuel injector supplier to make sure that the testing described in this procedure meets their program requirements for an assessment of nozzle coking. The test engine speeds and loads are defined in the Appendix, Section A1.

4.2.2.1 Coolant Temperature Conditions. The coolant temperature should be measured near the thermostat as coolant is exiting the engine. This temperature must be controlled to 95 ± 5 °C unless otherwise specified by the Test Engineer.

4.2.2.2 Oil Temperature Conditions. The oil sump temperature should be measured. If it is controllable, the temperature should be controlled to 110 ± 5 °C unless otherwise specified by the Test Engineer.

4.2.2.3 Fuel Temperature Conditions. The fuel supply temperature must be controlled to 40 ± 5 °C.

4.3 Instructions.

4.3.1 Break the engine in using the test procedures supplied by the Test Engineer. Complete a power run (SAE J1349, or other) to determine if the engine is producing representative power. Complete a full load engine blow-by assessment.

4.3.2 Run the Coking Cycle schedule to make sure the cycle will properly function once the engine is put on test (slave the test). Verify that all engine parameters are controlled to the test specifications.

4.3.3 Change the oil and filter using the Oil Drain and Weigh Procedure. The total oil consumed while the test injectors are installed must be calculated. Analyze a sample of the oil used during break-in to discover any abnormalities.

4.3.4 Install a new set of injectors, making sure that each injector was flow tested by the suppliers test rig. The pre-test flow measurements are needed for the coking assessment. Input any/all quantity adjustment factors (e.g., injection quantity adjustment) into the calibration, as necessary, to accurately represent engine operation in a vehicle. Use a paint pen to mark each injector with the cylinder number it is installed in.

4.3.5 Complete a power run (SAE J1349, or other) **without** the Zn doped fuel to qualify the engine with the test injectors.

4.3.6 At the beginning and end of each complete test, and at the beginning and end of each barrel of fuel used, a fuel sample ≥ 100 mL must be taken. The fuel sample must be extracted from the injector return flow, to ensure that the fuel has gone through the compression and heating stages. The samples should be held until after the nozzle investigation is complete, so that the fuel composition can be scrutinized.

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