



Global Engine Thermal Cycle (GETC) Test – Vendor Version

1 Scope

Note: Security. This document may be released to vendors that supply engine components to or test engines for General Motors. There is a GM Confidential version of this document which may not be released outside of General Motors.

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 determine the durability characteristics of the engine as a result of thermal cycling. Being an accelerated test, it does not duplicate customer usage, but intends to generate similar cumulative damage as would occur in the useful life of the vehicle.

1.2 Foreword. The operating parameters of this test have been related to the application of the engine being tested. General Motors will provide the specific information for each given engine. In general the test setup should allow the engine to experience similar conditions as in the vehicle. Modifications to the engine for the purpose of testing should be kept to a minimum.

1.3 Applicability. The procedure is written in generic terms to cover all internal combustion engines.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW16166 GMW16340

GMW16398 GMW16401

2.3 Additional References.

- Test Code Book (7th edition) "Vehicle Exhaust Backpressure Measurement Techniques"
- TP 1149 – Nitrogen Leak Check (See also L-6A2-6)
- TP 1272 – Engine Checkout (Durability Break-in)
- TP 3707 – Cranking Compression test
- TP 3708 – Cylinder Leakage test

3 Resources

3.1 Facilities. Major Facility - Engineering Test Laboratory; Minor Facility - Dynamometer Test Cell.

3.2 Equipment.

3.2.1 Dynamometer. Suitably rated for the speed range and torque output of the engine to be tested. Motoring capability at 2000 ($\pm$ 50) rpm is required. **Note:** Some motoring dynamometers may be damaged by sustained high speed/high load tests such as Global Engine Thermal Cycle (GETC). The 2000 rpm motoring requirement can be accommodated by driving an absorbing dynamometer with an electric motor. The motor can drive the dynamometer from the back and can be engaged/disengaged with a clutch. There is a clutch unit produced by

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Eaton which has an air bladder that has proven to be effective and durable ("Airflex"). **Note:** If using an electric motor with an absorbing dynamometer, then the command speed value to the dynamometer must be higher than the actual motoring speed to prevent the dynamometer from trying to apply "load" to the electric motor.

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. **Note:** Improper shaft selection could lead to reduced shaft life and false failure modes caused by incorrect vibration conditions, e.g., elevated high-speed crankshaft torsionals or low speed propshaft "rattles".

3.2.3 Transmission. Connect one to the engine only if requested by the Test Engineer. (Document whether or not a transmission is used.) If used, it should be locked in a specific gear to prevent shifting and allow the dynamometer to control engine speed according to the dynamometer controller. The torque converter should also be locked in order to have engine speed equal dynamometer speed. Inertia weights are not required.

3.2.4 Throttle actuator. With linkage, used for automatic throttle control.

Note: This system may need to accommodate electronic throttle control systems.

3.2.5 Dynamometer Controller. To manage engine speed, engine load and pedal per Table A2, Appendix A: GETC Steps and Figures A12 and A13: GETC Plots.

3.2.6 Coolant Cooling System. It must incorporate the following features:

- A closed system with vehicle equivalent flow restrictions. The minimum coolant hose inner diameter (ID) in the "hot" (except the "thermostat" valve by-pass hose) or "cool" loops must be no smaller than the engine-in/out hoses to/from the radiator.
- A sight glass to visually monitor coolant condition.
- A pinned-open thermostat. See 3.3.8.
- Production equivalent by-pass loops (e.g., heater, oil cooler, internal, etc.)

Note: Do not use the heater core. This volume of coolant is being eliminated to speed up the "closed thermostat" heat-up rate. This test specifies to run low flow through the "Hot Loop" during the "closed thermostat" steps, and this low flow operation reduces the natural heat-up rate.

- A system to apply 27.5 kPa (4 psi) of pressure to the coolant system at the coolant-in position. This should be done via a bladder tank to prevent sudden drops of pressure when cooling (a result of running a "packed" system) and to prevent shop air from entering the cooling system (via a regulator).
- A proportional three-way valve to enable precise control of the cool-down rate. For this test the maximum cool-down rate must not exceed the maximum (closed thermostat) heat-up rate by more than 0.2 °C/s.
- A ball valve to simulate the thermostat operation. There should also be a bypass line around this valve, with a manual valve in the line, to set a low flow rate during "closed" thermostat operation. An option to the above is to use a 2-way proportional valve instead. See Figure A7, Appendix A.
- A large heat exchanger to enable the large cool-downs required by this test. Coolant heat exchangers (plate and frame) used in traditional dynamometer testing have a heat transfer area of approximately 1.0 m² (10.8 ft²). For the GETC test the heat exchanger should have a heat transfer area of 2.3 m² (24.8 ft²) or larger. Shell and tube heat exchangers need to be approximately 2.5 times larger than plate and frame units. **Note:** Spiral type heat exchangers have been shown to be very restrictive to coolant flow and should not be used.
- Cold cooling water. The GETC test lowers the coolant-out down to 23 °C. Typical cool-down rates (based on maximum heat-up rates) are 0.75 to 1.50 °C/s. Even if a slow cool-down rate is allowed at the end of the cool-down (for example 0.15 °C/s when coolant-out < 28 °C), the following temperatures are required to get down to 23 °C coolant-out: the coolant-in must be approximately 9 °C less than coolant-out and the cooling water must be approximately 5 °C less than coolant-in. Therefore the maximum cooling water temperature is 23 – 9 – 5 = 9 °C (48 °F).

Typically "city" water or process water gets much warmer in the summer than it is in the winter. For example, in the Detroit, Michigan area the "city" water is as low as 2 °C (36 °F) in the winter but as high as 24 °C (75 °F) in late summer. Due to the high "city" or process water temperatures in the summer, most test locations will require a chiller to provide the cooling "water" for this test.

There are two types of chillers used for the thermal cycle tests: "regular" and "deep". **Note:** Chiller power is typically rated at approximately 10 °C and the actual cooling power drops considerably as the temperature

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setting is lowered (approximately 25% drop in power per 6 °C drop in temperature). "Regular" chillers have a minimum setting of -1 °C (30 °F) and should be no smaller than 20 ton/70.27 kilowatts/240 000 Btu/hour. "Deep" chillers have a minimum setting of -32 °C (-25 °F) and should be no smaller than 30 ton/105.42 kilowatts/360 000 Btu/hour. The typical chiller settings during GETC are 4 to 8 °C (40 to 46 °F) for a "regular" unit and -18 °C (0 °F, the maximum setting) for a "deep" unit.

It is also recommended to use a 380 to 570 L reservoir in conjunction with the chillers. The cooling water flow path should be from chiller out → heat exchanger → reservoir → chiller in.

The cooling water flow rate should be 76 L/minute (20.1 gal/minute.) or higher.

- j. Test cells which can run either the GETC or Global Deep Thermal Shock (GDTS) must have some additional equipment. Because of lower cooling power at their operating temperatures, a pre-cool step is used in the setups that have the "deep" chillers. While cooling, the reservoir temperature climbs, and the chiller must be able to bring this back down as the engine is heating up. The higher the power rating of the chiller the more quickly it can cool-down the reservoir. The problem with the GETC is that heat-up times are too short to allow recovery (maximum setting of these chillers is 0 °F). The heat exchanger from 3.2.6 (h) is used with city or process water for the pre-cool step.

A second, larger heat exchanger is used with the chiller water. This heat exchanger should have a heat transfer area of 4.8 m² (52 ft²) or larger (this value is for plate and frame style exchangers, shell and tube units need to be approximately 2.5 times larger).

An external coolant pump is also part of this setup. This pump is not used for the GETC test but is included in the combined GETC/GDTS setup because it is required for the GDTS test.

3.2.7 Oil Cooling System. It must incorporate the following features:

- Vehicle equivalent flow restrictions. Internal engine oil flow is not to be disrupted.
- 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.

Warning: Oil cooling system must be replaced or carefully flushed/back-flushed following an engine failure.

3.2.8 Temperature Controllers. To maintain oil and coolant temperatures/heat-up and cool-down rates per sections 4.2.2 (d) thru (g), (j) and (k).

3.2.9 Exhaust System. Capable of providing vehicle equivalent backpressure. See 4.1.1 (c). If a production intent exhaust system is used, which has to be modified due to cell limitations, the backpressure has to meet design targets.

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

Warning: Excess fuel temperature can cause flow problems (vapor lock).

3.2.11 Instrumentation. As needed to measure the parameters found in 5.1.

3.2.12 Shut down devices. For engine safety to respond to conditions in 6.2.

3.2.13 Flight recorder. Must be capable of holding at least 30 seconds of data before a shutdown and 5 seconds of data after.

Should be capable of holding one hour of data. Specifically:

- 10 samples/second for last 3 minutes
- 1 sample/second for last 10 minutes
- 1 sample/minute for last 60 minutes.
- Track for 2 minutes after limit condition at 1 sample/second.
- Computer should hold 2 sets of this and should ask operator if he or she wants to restart after limit shutdown without saving data.

3.2.14 Automatic data acquisition equipment. Must be capable of a 10 Hz minimum raw signal sample rate and able to average raw signal values into data for recording. See 5.1.

3.2.15 Intake Air Condition. Provisions for maintaining the intake air temperature at 16 to 38 °C (60 to 100 °F) and pressure of 95 to 105 kPa (28 to 31 inches Hg). See 4.2.1.

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3.2.16 Exhaust Manifold Cooling. Traditionally, large fans have been used for exhaust manifold cooling. Trying to cool shielded exhaust manifolds with these fans has resulted in cool-down times ranging from 200 to 320 seconds. The cool-down times for the coolant and head metal are typically only 130 to 180 seconds. This added test time (20 to 190 seconds/cycle) will add 48 to 454 hours per 8600 cycle test. Testing has shown that high air velocity/head pressure (not high cubic feet per minute (cfm)) result in turbulent flow that is required for effective cooling of shielded exhaust manifolds. The minimum requirements of the blower are 2.0 kPa (8.0 inches of water) static pressure and 236 L/s (500 cfm). Blowers which are "radial blade, high pressure, direct drive blowers" can meet these requirements.

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). Clearances are to be within production (intent) specifications. Use multi-spindle tools for assembly as early in the development process as possible.

For hand built engines. Document the head(s) and block flatness at the interface. Head bolt assembly torques have to be measured and recorded. It is recommended also to measure the head bolt tension (this requires special ground fasteners).

Mark all fasteners and the adjacent head material to check for head bolt rotation during test.

3.3.2 Complete Accessory Drive System. This is optional. The use of brackets that bridge major castings is recommended.

3.3.3 Active Emissions Equipment. Production (intent) system, including: Positive Crankcase Ventilation (PCV) system (without oil catch jars), Air Injection Reaction (AIR) system (engine mounted hardware), functioning Exhaust Gas Recirculation (EGR) system, pre-catalyst oxygen sensors, etc. **Note:** Some products have had over-temperature problems in dynamometer test cells with heated O₂ sensors; if using non-heated sensors as a replacement, there must be supporting vehicle temperature data. See 4.1.1 (p). The use of under-floor catalytic converter(s) is optional, though exhaust manifold-integral converters are required. See 3.3.4. Document whether or not converters are used. If catalytic converters are used, the catalyst should be active. Any other emissions systems which mount on the engine or affect its operation should be included.

3.3.4 Exhaust. Use production (intent) exhaust manifold(s). For exhaust manifolds that include a catalytic converter as a welded assembly or have close-coupled bolted-on catalytic converters, GETC should be run with an active/loaded catalytic converter. Any manifold or converter support brackets should also be installed. GETC must run with the exhaust manifold heat shields installed. Shields should be removed for inspection and thermocouple installations.

Measure the length of the exhaust manifold(s) (front to rear at the manifold to head interface) at the beginning of test and at inspection points, there may also be other critical dimensions to monitor as well (to be specified by the Test Engineer). For hand built engines, it is recommended to also document the head(s) and exhaust manifold(s) flatness at the interface. Bolt assembly torques have to be measured and recorded.

On a front wheel drive application a cross-over pipe or a cross-under pipe is used to connect the two banks of cylinders together and then go to a downpipe. These cross-over or under pipes are treated with the same life goal as the manifolds and must be included in the GETC setup.

For all applications, including close coupled welded, close coupled bolted, or under floor converters, the exhaust pipe assembly, which often contains the flexible coupling, should be installed. This front pipe should be supported with its production type hanger, or a hanger as similar to production as possible. This will provide proper "mechanical" support and loading to the system, in addition to the "thermal" loading. The intent is to have a somewhat representative load at the manifold takedown, a near-zero load.

It is preferred that the exhaust manifolds be installed with production equipment to provide the intended production clamp load. New fasteners (studs, nuts, and bolts) should be used when manifolds are removed or serviced.

The exhaust fasteners should be marked for location at the beginning of test and monitored for loosening. The bolts should never be tightened during test to re-align with the original marks, as this will change the clamp load on the manifold. Do not use anti-seize on fasteners unless this has been/will be released for production.

The service procedure should be used if the production assembly equipment is not available.

If service procedure is not known, it is recommended that the exhaust manifold fasteners be brought up to torque using a "three pass" procedure in the following sequence:

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- a. Clean out the bolt holes using the appropriate sized tap or thread chaser if the exhaust manifold bolts use a locking "patch".
- b. Determine the appropriate bolt sequence torque to achieve the same clamp load distribution as the production installation equipment. Lab tests have shown that a "three pass" torque sequence such as the one shown on Figure A1, Appendix A will achieve an evenly distributed clamp load. In the example a production bolt torque of 25 Nm would be achieved by tightening to 15, 20; then 25 N·m in the sequence shown. **Be sure to consult the appropriate fastener engineer** to determine the tightening sequence for new manifold designs.

3.3.5 Ignition System. Active Electronic Spark Control (ESC) should be used, but only if it works properly in the test cell environment. (Document whether or not ESC is used.) Production (intent) spark plugs are recommended, but "colder" plugs may be used if the ESC system does not function properly or if inlet air > 38 °C (100 °F), due to facility limitations. (Document which spark plugs are used.) The spark plugs to be set at production (intent) gap.

3.3.6 Production Engine Control Module (ECM)/Powertrain Control Module (PCM)/Vehicle Control Module (VCM). Software and calibration for electronically-managed engine controls. The spark, fuel, and emissions calibrations are to be the same as vehicle or at least latest level during a development program with active timers, etc. Document all changes made to the calibration – changes are to be kept to a minimum. 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. It is required to modify the electrical system (wiring harness) on engines using electronic throttle control in order to disconnect fuel injectors and ignition system during motoring hence all diagnostic functions for those components have to be disabled in the calibration. Make sure that the ECM does not enable "limp home" mode or emergency reaction by motoring with power on ECM and disconnected components. **Note:** Engine parameters such as Air/Fuel Ratio (A/F), exhaust gas temperatures and spark need to be observed very carefully during the test since any malfunction on injectors and ignition system will not be detected in this case.

3.3.7 Engine Fluids. Factory fill (production intent for model year of system being tested) engine oil.

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 permitted since they may hide design or quality flaws.

Primary vehicle specified fuel type (e.g., ethanol, Liquefied Petroleum Gas (LPG), Compressed Natural Gas (CNG), gasoline, diesel) is recommended.

Note: For gasoline engines, fuel with a higher octane number may be used if the ESC system is not working properly, is not yet calibrated, or if the inlet air temperature > 38 °C (100 °F), due to facility limitations. (Document which fuel is used.) The appropriate spark for customer recommended fuel should be used even if higher octane fuel is used.

3.3.8 Thermostat. In order to have total control over the coolant flow in the cool-down phase, a pinned open thermostat has to be used. Pin open thermostat to a level equal to maximum thermostat opening (per drawing) to provide a proper flow restriction. To simulate the closed thermostat condition use a cut-off valve in the "hot loop", see 3.2.6 (g). Make sure that the valve opens at the temperature specified as the nominal production thermostat "start to open" temperature.

Note: Use the temperature of the coolant in the heater loop as the feedback to open this valve. If the engine uses an inlet thermostat then open the valve at 6 °C (10 °F) above the nominal production thermostat "start to open" temperature.

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

3.4 Test Time.

Calendar time:	Varies days
Test hours:	Varies hours
Coordination hours:	Varies hours

3.4.1 Engine Test Time. The life goal for the engine (except the exhaust manifolds) is 8600 cycles.

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3.4.2 Exhaust Test Time. The exhaust test bogies for success are shorter than the engine and will be provided by General Motors.

3.5 Test Required Information. To be provided by General Motors.

3.6 Personnel/Skills. Not applicable.

4 Procedure

4.1 Preparation.

4.1.1 Sample Preparation.

- a. Mount the engine with associated test material from 3.3.2, 3.3.3, and 3.3.8 on the dynamometer test stand. Engine mounting that yields vibration levels representative of the actual vehicle environment is recommended since hard mounting causes high vibration levels, which may lead to false failures of brackets, baffles, etc.

Document the type of mounting system used. It is also desirable to mount the engine so the crankshaft is parallel (within $\pm 0.5^\circ$) but not in-line with the axis of the dynamometer shaft to eliminate unrepresentative second order torsional vibrations induced by propshaft universal joints.

Note: Put the propshaft at the proper angle per the specifications of the supplier.

- b. Connect transmission to the engine only if requested by the Test Engineer. See 3.2.3. (Document whether or not a transmission is used.)
- c. Connect the exhaust system to the engine. The backpressure should be set to the vehicle equivalent level (select the lowest backpressure application) per the appropriate Test 1 procedure (transient or steady state) in the Test Code Book (7th edition, "Vehicle Exhaust Backpressure Measurement Techniques"). Avoid making the dynamometer exhaust system too heavy or too rigid for the engine exhaust parts as this may lead to false failures.
Note: If measurement technique differs from vehicle to dynamometer (e.g., kiel to static), any offsets must be accounted for.
- d. Connect the air filter housing to the engine. It should contain a new air filter element. The induction system should be at the same orientation as the vehicle.
- e. Connect the fuel lines to the engine. The fuel delivery system should be adjusted to maintain the production (intent) vehicle pressure.
- f. Connect the ignition (per 3.3.5) and the engine control (per 3.3.6) systems to the engine.
- g. Connect the throttle linkage to the engine. Adjust it if necessary to obtain closed throttle and wide open throttle (WOT) conditions.
- h. Connect the coolant (per 3.2.6) and the oil (per 3.2.7) cooling systems to the engine.
- i. Fill the coolant cooling system with fresh factory-fill coolant per 3.3.6. **Note:** Make sure the system is full of coolant without trapped air pockets; the complicated cooling system will make the fill more difficult. To check how thoroughly the system has been filled with coolant, apply air pressure to the expansion tank, if the coolant level in the tank drops then there is air trapped somewhere in the cooling system.
- j. Install a new production (intent) oil filter.
- k. If necessary, calibrate the dipstick per the Test Engineer's instructions. (**Note:** GMW16401 is available).
WARNING: May need to re-calibrate dipstick for applications which are at an angle in the vehicle but at 0° in dynamometer cell.
- l. 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 "FULL" mark).
- m. 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.
- n. If adjustable, then tension the accessory belt(s) per the production (intent) specification. If not adjustable, then the production (intent) tensioner(s) should be used.

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- o. If accessory loading is requested by the Test Engineer, then make the necessary connections to accomplish this. (Document whether or not accessories are loaded.)
- p. 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 Facilities Preparation.

- a. Program dynamometer controller to run the GETC schedule per Figures A12 and A13: GETC Plots and Table A2, Appendix A. See also 4.2.2.
- b. Set the oil and coolant temperature controllers to maintain temperatures per 4.2.2 (d) thru (g). **Note:** The control point for the coolant temperature controller will be the coolant-in location. This position provides the best control of the temperature.
- c. Connect the instrumentation to measure the parameters found in Section 5.
- d. Set the engine safety shut down limits per 6.2.
- e. Set the sample rates for the flight recorder and data acquisition equipment.

4.1.3 Instrument Calibration. Perform all pre-test calibrations on load cells and other required instrumentation.

4.2 Conditions.

4.2.1 Environmental Conditions.

- **(A)** Intake Air Temperature: 16 to 38 °C (60 to 100 °F).
- **(B)** Intake Air Pressure: 95 to 105 kPa (28 to 31 inches 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.

The following speed point descriptions relate to the waveform shown in Figures A12 and A13: GETC Plots and described in Table A2, Appendix A.

- a. Motoring Speed (speed A): Use 2000 ($\pm$ 50) rpm. **Note:** If using an electric motor with an absorbing dynamometer then the command speed value to the dynamometer must be higher than the actual motoring speed to prevent the dynamometer from trying to apply "load" to the electric motor.
- b. Speed B: To be provided by General Motors.
- c. Speed C: To be provided by General Motors.
- d. Coolant temperature: the coolant-out temperature will range from 23 to 115 °C.
- e. Oil temperature: the oil-in temperature (at the gallery) will range from 23 to 115 °C. The peak oil sump temperature may exceed 115 °C and the minimum oil sump value is not typically as low as 23 °C.
- f. Coolant heat-up rate:

There are two main factors that affect the rate of heat-up of the coolant: the amount of power that the engine is producing and the volume of coolant being heated up. In the GETC test the fastest possible heat-up rate from the vehicle is achieved. This keeps the test severity high while keeping the length of test to a minimum.

In the GETC test, operating at near peak power conditions with a simulated closed thermostat operation duplicates this heat-up rate. **Note:** This test specifies to run low flow through the "Hot Loop" during the "closed thermostat" steps (to minimize a large drop in temperature/excessive cool-down rate that occurs when the thermostat valve is opened), and this low flow operation reduces the natural heat-up rate. For this reason the heater core (and its volume of coolant) is being eliminated to speed up the "closed thermostat" heat-up rate. See 3.2.6 (d).

It is natural for the heat-up rate to drop once the thermostat valve opens. If it drops too much it will cause excessively long heat-up times. There are two problems that could cause this:

- Too much coolant in the "Hot Loop". It should contain less than 3.0 liters.
- Coolant being allowed to flow to the heat exchanger. This should not occur until the coolant is very close to the 115 °C maximum value.

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The heat up rate for the GETC should be calculated as follows:

$$\frac{T_{by-pass} \text{ at end of Step 6} - T_{by-pass} \text{ at start of Step 4}}{\text{Time at end of Step 6} - \text{Time at start of Step 4}}$$

g. Oil heat-up rate:

There are three main factors which effect the rate of heat-up of the oil: the engine speed, the engine and coolant temperatures, and the volume of oil being heated up. In the GETC test, the heat-up is run at high speed and the engine and coolant are heated up at maximum rates possible in the vehicle. See 4.2.2 (f). The cooling water should not be allowed to flow to the heat exchanger until the oil-in temperature is very close to its 125 °C maximum value.

h. Head metal hot acclimation:

Steps 8 thru 11 will serve this purpose.

i. Exhaust manifold hot acclimation:

The exhaust manifold skin temperatures must achieve at least 95% of their acclimation values at the high speed, 115 °C coolant-out condition. The exhaust gas and exhaust skin temperatures are affected by the A/F ratio and spark values. The A/F and spark values change in response to component protection timers/models and coolant temperature. There are significant calibration differences from one type of engine to another. This leads to a wide range of exhaust manifold heat-up times. Some engines achieve the exhaust trip value during Step 6 while others require 30 seconds after Step 7 to make it. The shorter coolant heat-up times provided by the 3-way valve also help to shorten the exhaust heat-up times. **Note:** For engines that hit their exhaust trip value(s) early it is acceptable to achieve temperatures in excess of the trip point.

The GETC test has an option to eliminate the exhaust heat-up and cool-down requirements. This can represent a time saving to run the test. To exercise this option the time for Steps 8 and 17 are set to 0. Modifying the GETC in this way would be for cases in which exhaust manifold testing (at least for the current level of parts) is complete. **The decision to make this change must be done in conjunction with the exhaust manifold Design/Release Engineer and the Validation Manager/Total Validation Engineer.** **Note:** Even when running the test this way any exhaust parts which fail at less than the exhaust system life goal, see 3.4.2, must be documented with a proper incident report (e.g., Problem Resolution Tracking System (PRTS+), etc.)

j. Coolant cool-down rate:

For the GETC test the maximum instantaneous rate of cool-down should equal the maximum rate of heat-up. The rate of cool-down is much faster than in the vehicle, but it is felt that as long as this rate is not faster than the fastest rate of temperature change possible in the vehicle (i.e., during heat-up) then no false failure modes will be generated.

In the GETC test a proportional three-way valve enables precise control of the cool-down rate. For this test the maximum instantaneous cool-down rate must not exceed the maximum (closed thermostat) heat-up rate by more than 0.2 °C/s. See 3.2.6 (f) and 4.2.2 (f). The maximum heat-up rate will be provided by General Motors.

The cool-down rate for the GETC should be calculated as follows:

$$\frac{100\text{ °C} - 40\text{ °C}}{(\text{Time at } T_{clnt\ in} = 100\text{ °C}) - (\text{Time at } T_{clnt\ in} = 40\text{ °C})}$$

k. Oil cool-down rate:

Oil cooling is no longer required for this test. Oil cooling was eliminated since colder oil increases the amount of fuel in the oil.

l. Head metal cool acclimation:

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Some engines were studied to predict the cool acclimation time. The main variable was found to be the coolant cool-down time (to 23 °C). If the cool-down time is 80 seconds or less the acclimation time is 45 seconds. If the cool-down time is more than 190 seconds then the acclimation time is 0. Step 16 includes these values and a formula for cool-down times between 80 and 190 seconds. The cool acclimation times are longer than the hot acclimation times primarily due to the lower coolant flow rates at 2000 rpm versus high speed.

m. Exhaust manifold cool acclimation:

The exhaust manifold skin temperatures must get down to 125 °C. See 4.2.2 (i) for details on an option to eliminate the exhaust heat-up and cool-down requirements.

4.3 Instructions.

- a. If engine conditioning/equipment checkout is required, use schedule No. 1272 (1 hour maximum).
Note: Conditioning hours do not count as test hours.
- b. Conduct zero cycle checks per 4.3.1.
- c. Oil Consumption to be monitored on schedule. Perform oil “drain and weighs” (weigh out and weigh in) at the same interval with oil changes. Calculate the oil consumption after each “drain and weigh”.
- d. Whenever stopping a GETC engine mid-test (e.g., for checks, for the weekend, etc.) try to do this during Step No.1, this will allow a consistent restart condition. If an engine has been down for an extended period of time: 1) verify oil level is ok, 2) bar engine over by hand, 3) start the engine and run at moderate speed and load to verify engine is still operating properly, 4) check for leaks. Whenever restarting a GETC test, motor the engine at 2000 rpm and cool it down to duplicate the engine temperature conditions at the start of Step 1.
- e. Put engine on test per Figures A12 and A13: GETC Plots and Table A2, Appendix A. See also 4.2.2.
- f. Record engine data per section 5. **Note:** At SOT record 2 cycles of engine test data at least at 1 sample/2 seconds (0.5 Hz). Evaluate the data to make sure that the engine speed follows the cycle shape in Figures A12 and A13: GETC Plots and that the cool-down rate does not exceed the maximum heat-up rate. This data set has to be stored as a baseline to compare to if engine parameters deviate over test time. Plot the data per the instructions found in Table A1, Appendix A: GETC Plotting Requirements.
- g. Approximately every 10 cycles visually check the coolant sight glass for the presence of coolant aeration. If aeration is noted then shut the engine down and determine the root cause (too much water in coolant, coolant pressure/level too low, failed head gasket, cracked bore, etc.)
- h. Check oil level at least every 4 hours. Add oil only if the level is at or below the “ADD” (bottom of operating range) mark; only add oil in 1.0 L (quart) increments. This will allow the oil level to operate in the same range as in the field. **Note:** Even though 0.5 L (quart) containers are readily available in some markets, 1 L (quart) additions will be utilized as worst case. Record the amount of any oil added per the oil consumption monitoring instructions. Check oil level more often if the use is more than 1 L (quart) per 4 hours.
Note: Adjust the add amount if quantity between FULL and ADD marks does not equal 1.0 L (quart).
- i. At least twice per (8 hour) shift (and whenever the test is stopped) inspect the engine for oil and coolant leaks, loose fasteners and cracks in brackets, braces, wires, hoses, exhaust manifolds and engine exterior. Also, check dynamometer cell safeties /limits prior to restarting engine. Record any occurrences in the data sheets and repair or replace as necessary. (Document all part changes in the Part Change Summary sheet.)
- j. Perform checks and maintenance per sections 4.3.1 and 4.3.2.

4.3.1 Periodic checks. The following minimum number of periodic checks are to be made during the test. (Test Engineer may require additional checks.)

- a. Every 4 hours:
 - Oil level. See 4.3 (g).
 - General visual inspection. See 4.3 (h).
- b. After engine conditioning (Test No. 1272) and every 100 cycles:
 - Inspect the exhaust components (unless they are not being tested). It is important to know within a few cycles when the manifold actually failed to allow accurate Weibull projections of manifold fatigue life.

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The manifold should be visually checked for discoloration, flaking, cracks, bolt loosening, and leaking (blackish soot deposits) at each inspection point. The manifolds should be allowed to cool to approximately room temperature and the engine should be motored at 1000 to 2000 rpm, (wide-open throttle, with ignition and fuel off.) Leak check solution (e.g., "snoop" or soapy water) should be squirted on the manifold and evaluated for any sign of leakage. Small bubbles and foam do not generally mean a failure; soap solutions blowing rapidly enough to form a spray could constitute a failure. In most cases, the shield will have to be removed for inspection.

Manifold failures are any condition that would result in a customer complaint such as exhaust noise or a high leakage condition that results in a check engine light as a result of excess oxygen in the exhaust stream.

Any of the conditions listed below should be considered a manifold failure:

- Fastener breakage or excessive loosening
- Cracks resulting in visible leak or audible leak
- Gasket leakage resulting in visible leak or audible leak
- Plugged/failed catalytic Converter ($> 15 \text{ kPa } \Delta P$)

Discoloration, flaking, and ballooning are not considered failures since they would not result in a customer complaint. If leakage is suspected, a stethoscope can be used to pinpoint location of leak. To quantify the leakage, leak check equipment can be used to determine if leak is greater than 2.0 LPM (liters per minute) at 15 kPa.

c. After engine conditioning (Test No. 1272), 25, 50, 100, 250, 500, and every 500 cycles:

- Take oil sample and have it analyzed for fuel dilution and wear metals. If the fuel dilution exceeds requirements (typically 5 to 10%), then raise the oil temperature to exit Step 9. **Note:** Raising the oil temperature to exit Step 9 will add to the heat up time which may add a significant amount of fatigue time to the test. If the oil fuel dilution is still too high then either change the oil or perform an "oil cleaning". An oil change is the most effective at reducing the fuel dilution; the "oil cleaning" will typically reduce the fuel dilution by approximately 40%. Another option for gasoline engines is to use high octane race fuel for the test – this fuel has T60 to T80 evaporation temperatures below 110 °C. If there is not access to an on-site oil analyzer/oven, then make the decision to clean the oil based on previous samples from this engine or previous engines which ran the GETC test.
- The "oil cleaning" routine is defined as follows: run engine at speed B, minimum pedal to hold speed B, with the oil sump controlled to 120 °C (248 °F), and with the coolant-out controlled to 95 °C (203 °F) for 30 minutes.
- Glytek check. This is a check for the presence of coolant in the oil.

d. After engine conditioning (Test No. 1272) and every 1000 cycles:

- Spark plug visual inspection (gasoline engines)
- Cranking compression (Test No. 3707). **Note:** Also check cold engine before the 1272 (per 1272 procedure).
- Cylinder leakage (Test No. 3708). **Note:** Also check cold engine before the 1272 (per 1272 procedure).
- Nitrogen leak (Test No. 1149). Also check whenever coolant aeration is noted, if there is an engine overheat, if the water pump drive belt fails/comes off, or if there is a significant loss of coolant from the cooling system. If a leak is detected start checking more often (e.g., every 500 cycles).

Note: Nitrogen leakage does not necessarily mean that the head gasket has failed to the point that a customer would be effected. The nitrogen test to field relationship varies by engine family, nitrogen leak severity, number of cylinders leaking, etc.

e. After engine conditioning (Test No. 1272) and every 2000 cycles:

- Power Test No.1 (Test No. GMW16166 – WOT1 test) Track actual A/F during test. **Note:** Run the end of test (EOT) power test with a new air filter (to enable direct comparison to SOT test).

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- Black light check for oil and coolant leaks. The oil needs a dye added to it (do this after the oil change, but before the power test), but the coolant does not. On “V” engines with dry valley designs, lift the intake and inspect the valley for leaks also.
- f. Start and end of test:
 - Coolant concentration/take a coolant sample. Also check this whenever the cooling system is disrupted/coolant added.
 - Blow-by (GMW16398)
- g. Before and after test:
 - Head bolt tensions – if the engine has ground fasteners. If engine fails before 8600 cycles, then check the head bolt tensions at that time.
 - Head bolt rotation - mark the bolts before 1272.
- h. At start of test (after other checks are complete and the “health” of the engine has been verified).
 - Thermography of exhaust manifolds (GMW16340). **Note:** This may not be required if this was done on the same type of engine on the identical calibration. Repeat this check during test if there is a calibration change.
 - Hot Acclimation test. See Data Sheet A1: Acclimation Test Worksheet. Repeat this check during test if there is a calibration change.
 - Plot of test cycle (also perform at 4000 cycles and EOT). See 4.3 (f).

4.3.2 Maintenance Intervals.

- a. Oil change – To be specified by General Motors.

Some engines have a problem with fuel dilution in the oil on the GETC test. To prevent premature wear of engine components this fuel dilution should be kept under control. See 4.3.1 (c) for instructions if the fuel dilution exceeds 5%. If the fuel dilution exceeds 10% then there is likely a calibration/setup issue that must be addressed (write an observation/incident report if required).

Note: Significant improvements in oil consumption will result in more rapid oil quality degradation.
- b. Oil filter – conduct with oil change. Cut open and inspect the old filter for signs of problems. **Note:** Save oil filter at least until next oil filter change or as indicated by Test Engineer.
- c. Air filter – if 2 kPa increase in pressure drop across filter at peak power, approximately equal to 2.5% power drop. See also 6.2.11.
- d. Special **Notes:** **(1)** only those parts that field data clearly demonstrates test severity being too high are allowed to be changed during test; **(2)** the taking of oil samples is required, see 4.3.1 (c) (save samples until EOT tear-down analysis is complete or have them analyzed); **(3)** coolant analysis is optional, the taking of samples is recommended.

5 Data

5.1 Calculations. Recorded values to be an average of at least 10 raw signal data points.

5.1.1 Minimum Required Data. The following is the minimum required data for test (the Test Engineer may require additional data):

- a. Date.
- b. Time of day.
- c. Elapsed test time (cycles).
- d. Test facility, location and cell number.
- e. Engine description and identification code.
- f. Fuel type.
- g. Test technician name(s).
- h. Engine speed (rpm).
- i. Dynamometer speed (rpm).

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