



General Motors Oxidation and Deposit 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 procedure covers an engine test for evaluating automotive engine oils for certain high temperature performance characteristics, including oil thickening, and piston deposits. Additionally, secondary requirements that shall be conducted include mini rotary viscometer measurements, cold cranking simulator measurements, and phosphorus retention measurements.

1.2 Applicability. This test is required for dexos®: Engine oil specification, GMW17332.

1.3 Remarks This test procedure specifies a General Motors Oxidation and Deposit (GMOD) test engine, test procedure, and test stand configuration items.

2 References

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

2.1 External Standards/Specifications.

ASTM D86	ASTM D1319	ASTM D3343	ASTM D5452
ASTM D130	ASTM D2699	ASTM D4052	ASTM D5453
ASTM D240	ASTM D2700	ASTM D4684	ASTM E168
ASTM D323	ASTM D3231	ASTM D4815	ASTM E191
ASTM D381	ASTM D3237	ASTM D5185	DIN 51453
ASTM D445	ASTM D3244	ASTM D5191	ISO 17025
ASTM D525	ASTM D3338	ASTM D5293	SAE J300
ASTM D664			

2.2 GM Standards/Specifications.

GMW17332

2.3 Additional References.

- ASTM International (ASTM) Data Acquisition and Control Automation (DACA) II Task Force Report
- ASTM Deposit Rating Manual Number 20
- Cannon Instrument Company, State College, Pennsylvania (www.cannoninstrument.com)
- Chevrolet Performance Parts (www.chevroletperformanceparts.com)
- DyneSystems, Incorporated, Jackson, Wisconsin (www.dynesystems.com)
- General Motors Oxidation and Deposit (GMOD) Engine Assembly Manual (EAM)
- General Motors Oxidation and Deposit (GMOD) Lubricant Test Monitoring System (LTMS) Document
- Haltermann Solutions, Houston, Texas (www.haltermannsolutions.com)
- Intertek Automotive Research, San Antonio, Texas (www.intertek.com)
- J-Tec Associates, Cedar Rapids, Iowa (<http://j-tecassociates.com>)
- J-Tec Setup and Maintenance Procedure

- National Institute of Standards and Technology (NIST), Gaithersburg, Maryland
- OH Technologies, Incorporated (OHT), Mentor, Ohio (www.ohtech.com)
- Southwest Research Institute, San Antonio, Texas (www.swri.org)
- Standardized Report Form Set, ASTM TMC
- Test Comments Report Form 14
- Test Stand Manual (TSM)
- Wrico II Limited, San Antonio, Texas, Phone (210)-590-4400

3 Resources

3.1 Facilities. A facility conducting registered dexos® tests must be ISO 17025 accredited for this procedure. Fully equipped testing laboratory, such as:

- Intertek Automotive Research
- Southwest Research Institute

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

3.1.1.1 This is a test stand based calibration system. For a test stand to remain calibrated the GMOD Test Monitoring System (TMS) must be followed. The GMOD TMS is available from the ASTM International (ASTM) Test Monitoring Center (TMC). The test facility and equipment must be inspected by a GM and ASTM TMC representative prior to commissioning a test stand. Test stand pretest checks must be performed, and testing with candidate oils cannot proceed if the checks indicate nonconformance.

3.1.1.2 Dynamometer Load Cell Calibration. For every test, the dynamometer load cell will be calibrated at 250 N·m within 24 h of the test start according to the procedure in 3.1.1.2.1.

3.1.1.2.1 Dynamometer Load Cell Calibration Procedure.

- Turn on and circulate the dynamometer cooling water.
- Dynamometer excitation is to be set at the minimum.
- Check dynamometer for any obstructions such as hoses, driveline guards, etc., and anything laying on, or across the dynamometer. Remove these obstacles that may interfere with the dynamometer.
- Ensure the load cell temperature has stabilized to within 6 °C of the established load cell control temperature (see 3.2.3).
- Using certified weights perform the calibration at the test load of 250 N·m. The stand load cell measurement system shall perform within ± 6 N·m of the 250 N·m calibration standard.

3.1.1.3 Oil Dipstick Calibration. Throughout the test the oil level is measured using the oil pan dipstick. The table in Appendix A, Table A11 shows the relationship between the dipstick millimeter markings and the oil volume in the oil pan.

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. No alternatives to the equipment specified in 3.2 is allowed.

3.2.1 Engine Parts. Use the engine parts specified in the GMOD Engine Assembly Manual (EAM). Use all engine parts as received from the supplier, central parts distributor, or original equipment manufacturer, unless modifications are specified in this test procedure or the GMOD EAM. Unless otherwise directed, all parts and materials required for testing should be stored and used on a first in/first out basis.

3.2.1.1 Parts Modifications. Modify the following parts according to the instructions listed in the EAM and Test Stand Manual (TSM). If a part modification is considered necessary, it must be brought to the attention of the GMPT test representative for consideration and approval. Should a desired modification not be described in this or any GMOD procedure then it is not allowed.

3.2.1.1.1 Throttle Body. Modify according to print in the TSM.

3.2.1.1.2 Engine Block. Modify according to the EAM.

3.2.1.1.3 Engine Intake Air Box. Refer to modification in the TSM.

3.2.2 Engine Speed and Load Control. Use dynamometer speed and torque control systems that are capable of controlling the speed and torque as specified in Table 1, On Test Settings. A Midwest 1014 dynamometer (available through DyneSystems, Incorporated) shall be used; another item required is a secondary throttle body to give more precision to the speed control. The engine shall start using an air starter mounted on the rear of the dynamometer capable of cranking the engine at 300 rpm $\pm$ 50 rpm with spark plugs removed.

3.2.3 Control the Load Cell Temperature. Enclose the dynamometer load cell to protect it from the variability of laboratory ambient temperatures. Maintain air in the enclosure within the operating temperature range specified by the load cell manufacturer within a variability of no more than $\pm$ 6 °C. The test lab is to determine what temperature the load cell will be controlled at during every test. This will be within the manufacturer's specified range and is called the test lab's Established Load Cell Control (ELCC) temperature. During a test the load cell temperature will not vary more than $\pm$ 6 °C from ELCC temperature. Control the temperature by a means that does not cause uneven temperatures on the body of the load cell.

3.2.4 Engine Cooling System. The coolant system supplies pressurized coolant at a flow rate of 190 L/minute and controls temperature to 115 °C at the engine coolant outlet. The system incorporates the following features: Variable Frequency Drive (VFD) pump, flow meter, and low point drains. The system integrates with the test stand data acquisition and control computer for process control and maintains the specified engine coolant temperature and flow. The coolant system is a closed system pressurized to 123 kPa. The engine coolant side of the system shall be flushed with clean water at least once each reference period.

3.2.5 Engine Oil Temperature Control System. The system consists of a modified Oberg Oil Filter (available through OH Technologies (OHT)), oil heat exchanger, and gaskets specified in the TSM. Configure the external filter and heat exchanger circuit as specified in the TSM. The system uses engine coolant through a valve as necessary to control the engine oil temperature.

Note: Do not use copper lines or fittings in the oil system.

Note: Do not use magnetic plugs in the oil system.

Note: Use suitable hose and fittings when plumbing the oil cooling system.

3.2.6 Fuel System. The fuel system contains a pressurized, recirculation fuel system, including a pressure regulator. The fuel temperature and pressure will be controlled as stated in Table 1, On Test Settings. The system should be switched off, so no fuel flow is capable at the injector rail during engine shutdowns.

3.2.7 Induction Air Supply Humidity, Temperature, and Pressure. Maintain the throttle body intake air at a moisture content of 11.4 g/kg $\pm$ 0.7 g/kg of dry air, a dry bulb temperature of 35 °C $\pm$ 2 °C, and a static pressure of 0.050 kPa. Measure temperature and pressure at the inlet air adapter as shown in the TSM.

3.2.8 Instrumentation. As needed to measure the parameters found in Table 1, On Test Settings.

Table 1: On Test Settings

Controlled Parameters	Set Point	Units
Engine Speed	3000	rpm
Engine Load	250	N·m
Oil Filter Return	145	°C
Coolant Out	115	°C
Coolant System	123	kPa
Engine Coolant Flow	190	L/minute
Intake Air	35	°C
Intake Air	0.05	kPa
Intake Air	11.4	g/kg
Exhaust Back Pressure	3	kPa

Controlled Parameters	Set Point	Units
Fuel at Fuel Rail	35	°C
Fuel Rail Pressure	410	kPa
Exhaust Manifold	15	L/minute
Dynamometer Load Cell Delta	± 6	°C
Uncontrolled Recorded Parameters	Units	
Oil Sump	°C	
Coolant Inlet	°C	
Oil Gallery	kPa	
Oil Pump	kPa	
Air to Fuel Ratio (AFR) via Lambda Sensor		
Exhaust Gas Mono-Nitrogen Oxide (NOx)	ppm	
Fuel Flow	kPa	
Crankcase Pressure	kPa	
Exhaust Temperatures, All Cylinders	°C	
Manifold Absolute Pressure (MAP)	kPa(A)	

3.2.9 Automated Data Acquisition Equipment and Control. The test requires the use of automated data acquisition and control for all measured parameters outlined in this procedure. The system chosen by individual testing laboratories shall be capable of integrating with the GMOD Engine Control Module (ECM) which will be required as specified in this procedure. The system shall also be capable of meeting or exceeding certain test specific performance requirements for maximum allowable response times and minimum allowable sample rates. In addition to the aforementioned requirements, the system shall also be capable of data logging to test specific archival files for each test parameter at minimum allowable record intervals, that is, no greater than 2 minute intervals between successive logs for each parameter. See the ASTM Data Acquisition and Control Automation (DACA) II Task Force Report and additional requirements as outlined in this procedure.

3.2.9.1 Sample Rate. The preferred sample rate is 100 Hz with the minimum allowable sample rate for the GMOD data acquisition and control system set at 1 Hz.

3.2.9.2 Measurement Accuracy. All measurement devices used for sensing speed, load, flow, pressure, and temperature shall meet the minimum requirements as outlined in the ASTM DACA II report and also conform to total system response requirements as outlined by the TMC. Documentation verifying compliance must be provided to the TMC representative during annual test stand inspections. In addition, the TMC representative may request to be present when system time response is measured. A list of minimum requirements for GMOD testing is in 3.2.9.2.1 through 3.2.9.2.5.

3.2.9.2.1 Measurement Resolution. The minimum resolution for all parameters shall be at least one-fourth ($\frac{1}{4}$) the required accuracy for that parameter, that is, if an accuracy of 1.0 units is required, then the minimum resolution for that parameter = 0.25 unit. See Appendix A, Table A7.

3.2.9.2.2 System Time Response. Total system time response is the time required for the complete data acquisition system including all filtering, transducer lines, and surge tanks to measure a step change input for a given parameter. Determine system time response times by measuring the time required to reach a certain percentage of an imposed step change. For first order systems, use the time to 63.2% of the imposed step change; for moving average systems use the time to 45.4% of the imposed step change. See Appendix A, Table A8.

3.2.9.2.3 Quality Index (QI). Use of the QI method of measuring the control capability of the test stand is required for certain parameters. The following formula should be used and a minimum of 2400 data records are required for the final, end-of-test values:

$$QI = 1 - \frac{1}{n} \sum \left(\frac{U + L - 2X_i}{U - L} \right)^2 \quad (1)$$

Where:

- QI = Quality index
- X_i = Recorded test measurement parameter
- U = Upper specification limit for that parameter
- L = Lower specification limit for that parameter
- N = Total number of data points taken as determined from test length and procedural specified sampling rate

- The upper and lower values used for QI calculations for the required parameters are listed in Appendix A, Table A6.
- Calibrate the stand instrumentation used for data acquisition and control, on all controlled and non-controlled parameters (see Appendix A, Tables A6, A7 and A8), every 6 months.
- At a minimum, calibrate the following parameters prior to every reference test sequence, unless the required 6 month calibration was completed within 60 days prior to reference test start: engine speed, dynamometer torque, engine coolant out thermocouple, and oil filter return thermocouple.
- Calibrate the intake air humidity system every 6 months, at a minimum.

3.2.9.2.4 Temperature Measurement and Thermocouple Locations. Use only Type E Chromel-Constantan thermocouples with an accuracy of ± 0.5 °C over a range of 0 °C to 200 °C.

Locate the sensing tip of all thermocouples in the center of the stream of the medium involved, unless otherwise specified.

- **Oil Filter Return Temperature.** Install the thermocouple in the tapped hole in the oil pressure block specified in the EAM.
- **Oil Pan (Sump).** Install the thermocouple in the oil pan as supplied by OH Technologies, Incorporated (OHT) and specified in the EAM. The thermocouple tip extends 25 mm inside the oil pan.
- **Engine Coolant In and Out.** Install the thermocouples in the coolant manifold as supplied by OHT, with the sensing tip centered in the coolant flow as shown in the EAM.
- **Fuel.** Install the thermocouple and pressure pickup in the fuel rail fittings on the inlet side of the fuel rail as shown in the TSM.
- **Inlet Air.** Install the thermocouple and pressure pickup in the inlet air adapter, as shown in the TSM.
- **Exhaust.** Install the thermocouples and pressure pickup in the exhaust as shown in the EAM.
- **Blowby.** Install the thermocouple in the blowby cart if the sharp edge orifice blowby meter is used.

3.2.9.2.5 Pressure Measurement and Pressure Sensor Location. Use electronic pressure transducers located as indicated in this test procedure.

- **Blowby Flow Rate Measurement.** Use the sharp-edge orifice blowby meter, part number RX-116169-A1, revision N (available from ASTM TMC), or the J-Tec VF563AA (available from J-Tec Associates) to measure engine blowby flow rates. If the J-Tec meter is used then the J-Tec Setup and Maintenance Procedure must be followed in the TSM.
- **Intake Manifold Vacuum.** Use a transducer having a range of 0 kPa to 100 kPa. Connect the transducer to the vacuum outlet as shown in the TSM.

- **Engine Oil Gallery Pressure.** Use a transducer having a range of 0 kPa to 700 kPa. Connect the transducer to the location shown in the EAM (front of block).
- **Oil Pump Outlet Pressure.** Use a transducer having a range of 0 kPa to 700 kPa. Connect the transducer to the location shown in the EAM (in port, oil to filter).
- **Exhaust Back Pressure.** Use a transducer having a range of 0 kPa to 10 kPa. Attach the line to the exhaust down pipe as shown in the TSM. Use good laboratory practice to ensure that water does not accumulate in the lines during engine operation.
- **Inlet Air Pressure.** Use a transducer having a range of -125 Pa to +125 Pa. Connect the transducer to the air inlet as shown in the TSM.
- **Crankcase Pressure.** Use a transducer having a range of -125 Pa to +125 Pa. Connect the transducer to the engine block oil dipstick tube.

3.2.9.3 Air to Fuel Ratio Determination. The use of real time systems to verify AFR using an oxygen sensor is required. Use the specified sensor in the TSM.

3.2.9.4 Exhaust Gas Mono-Nitrogen Oxide (NOx) Determination. The use of real time systems to verify NOx using electronic exhaust gas analyzers is required. Use the specified NOx sensor in TSM.

3.3 Test Vehicle/Test Piece.

- **Test Engine and Related Hardware.** The test engine is a V-8 with a displacement of 5.7 L. Hardware may only be purchased from suppliers as noted in the EAM.
- **Exhaust.** Use specified exhaust manifolds and takedown tubes as specified in the EAM. Configuration at the end of the takedown tubes is to be determined by the test lab.
- **ECM and Engine Harness.** The ECM and engine wiring harness shall be purchased from Chevrolet Performance Parts. These part numbers are in the EAM.
- **Oil Pan and External Oil System Hardware.** The system consists of oil pan EAM, oil filter adapter, oil heat exchanger, and Oberg oil filter. The system configuration is specified and shown in TSM.
- **Coolant System Hardware.** The coolant system consists of components as specified in the TSM.
- **Driveline.** A specified driveline is to be used for this test, as specified in the TSM.

3.4 Test Time.

Calendar time: 4.2 days

Test hours: 100 hours

3.5 Test Required Information.

3.5.1 Reagents and Materials.

- **Test Fuel.** Use only Exhaust and Evaporative Emissions (EEE) Lube Cert gasoline, product code HF003. The single source supplier is Haltermann Solutions. A typical analysis of this fuel can be found in Appendix A, Table A10. Make certain that all tanks used for transportation and storage are clean before filling with test fuel. Verify that there is enough test fuel available prior to starting a test.
- **Engine Coolant.** The engine coolant is ShellZone Extended Life dexcool®.
- **Engine Build Cleaning Materials.** Use the cleaning materials specified in the EAM for cleaning of parts to be used in the test.

Note: Only these specific materials and sources have been found satisfactory. If chemicals other than these are proposed for use, equivalency shall be proven and presented to GMPT for approval.

- **GMOD Test Engine Internal Component Cleaner.** Part number GMOD-001 available through Wrico II Limited.

Note: If permitted by the hazardous materials disposal practices in a laboratory, sodium carbonate can be used to neutralize the oxalic acid in used GMOD Test Engine Internal Component Cleaner.

- **Sealing and Anti-seize Compounds.** Use the sealing compounds specified in the EAM. Teflon tape may be used, provided it does not come into contact with engine oil.

3.6 Personnel/Skills. Engine build technicians will need to participate in the annual unified engine build workshops.

All piston deposit raters of GMOD engine pistons, shall attend a TMC Light Duty Deposit Rating Workshop every 12 months $\pm$ 30 days and produce data that meet the TMC definition of Blue, Red, or White for piston deposits. If a rater is unable to meet this requirement, the rater can continue to rate GMOD pistons after the completion of the workshop for a grace period of 45 days and shall contact TMC.

4 Procedure

4.1 Preparation.

- **Engine Build.** Follow the instructions in the EAM to build the GMOD engine.
- **Test Stand Engine Installation.** Install the engine into the test cell with engine mounts as documented in the TSM.

4.2 Conditions.

4.2.1 Environmental Conditions. Follow the requirements of this standard.

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.

4.3 Instructions. Run the test according to the following instructions and the GMOD Operating Procedure and Specifications in Appendix A, Tables A1 through A3.

4.3.1 Dual Throttle Body Spanning Check. Prior to every test, start a simultaneous spanning check to be conducted on both throttle bodies. This is a visual check to ensure both throttle body valves have the same position and rate of opening. Make adjustments as required.

4.3.2 External Oil System Cleaning.

- a. Clean the external oil system thoroughly before each test to prevent contamination of subsequent tests.
- b. Flush the external oil system for 20 minutes using the solvent flush cart with organic solvent.
- c. Blow dry all of the lines to and from the external oil system until all solvent is removed.
- d. Once dry, remove the oil cooler and clean in the ultrasonic cleaner for 1 h.
- e. Disassemble the Oberg filter housing and clean the filter in the solvent bath, then blow dry until all solvent is removed. Visually inspect the filter to ensure it is clean before reassembly of the housing.
- f. Blow out all the instrumentation pressure transducer oil lines for a minimum of 2 minutes until all oil is removed.

4.3.3 Cooling System Cleaning.

- a. Clean the external cooling system of either a new or used test stand, or a new flushing tank assembly. Clean the used test stand system prior to a reference test. Use the procedure:
 1. Prepare a cleaning mixture in the flushing tank by mixing GMOD Test Engine Internal Component Cleaner (GMOD-001, see 3.5.1) at 19 g/1 L of water. Heat the mixture to $60\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$.
 2. Circulate the mixture at 160 L/minute flow rate for 30 minutes.
 3. Immediately following 4.3.4, thoroughly flush all system components with water at $60\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$.
 4. Ensure that all low points in the system are drained after cleaning.

4.3.4 Engine Coolant Jacket (Flushing).

- a. After installing the engine on the test stand, chemically clean the engine coolant jacket to ensure the proper rate of heat transfer to the jacket coolant, according to the procedure:
 1. Connect the flushing tank to the engine so that the cleaning solutions enter at the coolant inlet on the coolant manifold and exit at the outlet of the coolant manifold.
 2. For segments 3 through 12 of this cleaning procedure, minimize the elapsed time between steps in order to avoid rusting of the coolant jacket.
 3. Remove the oil pan drain plug. Open the engine block petcocks and pass hot water ($60\text{ }^{\circ}\text{C}$ to $70\text{ }^{\circ}\text{C}$) through the engine coolant jacket for 2 minutes. Check for coolant leaks around the intake manifold, front cover, rear cover, and oil pan drain plug. If coolant is leaking, take appropriate steps to stop the

leak. If no leaking is evident, fill the flushing tank and engine block with water to provide a total volume of 38 L to 45 L.

4. Energize the flushing tank heaters. Circulate water through the engine at a flow rate of 115 L/minute to 130 L/minute through the engine until the temperature of the water flowing out of the engine reaches $70^{\circ}\text{C} \pm 3^{\circ}\text{C}$. Isolate the engine from the flush cart.
5. While the flush cart is isolated from the engine with water still circulating, add GMOD Test Engine Internal Component Cleaner (GMOD-001, see 3.5.1) at 19 g/L of water, to the water in the flushing tank. Continue to circulate the mixture in the flush cart for 3 minutes to 5 minutes.
6. Circulate the mixture through the engine for 30 minutes.
7. Stop the circulation pump and drain the contents of the engine and flushing tank into a suitable container.
Note: Before disposal, the drained material should be neutralized according to applicable local and federal hazardous material guidelines.
8. Flow hot tap water through the engine and flush cart system for 2 minutes to 5 minutes. The water flowing through the engine during this step shall make a single pass through the engine and flush cart. Continue flowing water through the engine until the pH of the water flowing out of the engine is neutral. Check the pH of the rinse water at the return port in the flush tank.
9. Immediately after neutralizing the engine block, drain all flush water.
10. Disconnect the flush cart plumbing and remove any trapped water by blowing compressed air through the coolant outlet on the water pump adapter on the front of the engine block.
11. Connect the engine to the external engine cooling system.
12. Immediately charge the engine jacket with coolant.

4.3.5 Coolant Charging.

- a. Charge the engine jacket with the coolant specified in 3.5.1, according to the procedure:
 1. Use a charging adapter installed between the external cooling system and the engine.
 2. Completely fill the engine cooling system with coolant.
 3. Operate the circulating pumps to aid in the removal of air and consequently decrease the time to achieve clarity of the coolant. During this period, operate any proportioning valves in the coolant system several times.
 4. Until the test is started, circulate the coolant at a temperature of $49.0^{\circ}\text{C} \pm 3.0^{\circ}\text{C}$ and a flow rate of 190 L/minute.

4.3.6 Test Oil Charging.

- a. Charge the engine with the test oil as follows:
 1. Install a new or cleaned Oberg oil filter element as specified in the TSM.
 2. Ensure the oil container and equipment used to pour the oil into the engine is clean and free of any residue from past oils.
 3. Weigh the oil using a scale that is calibrated every 6 months using standards traceable to National Institute of Standards and Technology (NIST).
 4. Add an initial fresh test oil fill of $6.8\text{ kg} \pm 0.09\text{ kg}$ ($15.0\text{ lb} \pm 0.2\text{ lb}$) to the engine through the oil add tube on the oil pan.

4.3.7 Engine Oil Pump Priming.

- a. Prime the engine oil pump according to the instructions:
 1. Remove the spark plugs.
 2. Turn the ignition power off.
 3. Turn the fuel off.
 4. Crank the engine at a speed of $300\text{ rpm} \pm 50\text{ rpm}$, until oil pressure attains 100 kPa.
 5. Install the spark plugs.

4.3.8 Engine Startup and Shutdown Procedures. Start and stop GMOD engines according to the procedures in 4.3.9 and 4.3.10, and the test states and set points listed in Table 1.

4.3.9 Engine Startup. Use the following procedure to start the GMOD engine.

- a. Before cranking engine, supply 13 Volts Direct Current (VDC) to 15 VDC power to the ECM, fuel pump, and all AFR control units for a minimum of 30 s to assure all systems are prepared for closed loop AFR control. The lambda sensors are preheated and ready for closed loop control when the AFR readings are over 20:1 prior to engine start.
- b. Start the coolant flowing through the exhaust manifolds.
- c. Turn on the ignition. Perform the Dual Throttle Body Spanning Check as stated in 4.3.1.
- d. With the ignition on, turn on the fuel and crank the engine until the engine starts or for a maximum of 15 s. If the engine fails to start, investigate the cause, correct and attempt to restart.
- e. After starting the engine, allow 1 minute for the engine to stabilize at idle and to verify that oil pressure is adequate.

4.3.10 Initial Oil Leveling Run (10 Minutes).

- a. After the 1 minute stabilization period, ramp the speed to 1500 rpm, set the load to 40 N·m, and begin timing the 10 minute Initial Oil Leveling Run.
- b. Control the engine coolant outlet temperature to 50 °C and the oil filter return temperature to 50 °C. Run the temperature control valve for the oil wide open to obtain maximum cooling during the initial run.
- c. Circulate the process water through the exhaust manifolds at 15 L/minute and coolant at 190 L/minute through the engine.
- d. Ten (10) minutes after the start of the initial run, and just prior to stopping the engine, remove an oil purge sample of 472 mL, and then take the initial oil sample of 118 mL.
- e. Shut the engine down in accordance with 4.3.11. Return the 472 mL oil purge to the engine. Wait 15 minutes and obtain the engine oil level. This will establish the engine full mark.
- f. Record this value as the initial oil level on the Oil Level Check Sheet, Appendix A, Table A4.
- g. The engine can now be ramped up to test conditions over a 15 minute period.

4.3.11 Scheduled Shutdown Procedure. Use this procedure when stopping the GMOD engine for oil level checks:

- a. Reduce the engine speed and load to 1500 rpm and 4 N·m with a linear ramp down over 30 s.
- b. Turn off the ignition voltage.
- c. With the engine stopped, continue to circulate the process water through the exhaust manifolds at 15 L/minute and coolant at 190 L/minute through the engine.
- d. Set the Coolant Out and Oil Filter Return Temperatures to 50 °C.

4.3.12 Non-Scheduled Shutdowns. For any non-scheduled shutdowns, record in detail the time off test, the reasons for the shutdown and any other pertinent observations. A definition of downtime can be found in 5.6. If possible the shutdown procedure in 4.3.11 should be used. Include this record in the Test Notes Section of the final test report.**4.3.13 Oil Sampling Procedure.** The following oil samples are taken during the test: New Oil, Initial Oil Level Check, 20 h, 40 h, 60 h, 80 h, 100 h. Use this procedure to take these oil samples.

- a. Within 90 s of the engine ramp down to 1500 rpm, remove all oil samples from the engine oil sampling valve according to the instructions:
 1. Before taking the samples in each of the steps, first remove the purge sample of 472 mL; then remove a 59 mL analysis sample. Initial oil leveling sample is 118 mL and the End of Test (EOT) sample size is 237 mL. All other samples are 59 mL.
 2. Stop the engine according to the procedure in 4.3.11 for 15 minutes to allow the oil to return to the crankcase.
 3. Return the 472 mL purge back to the engine and conduct the 20 h oil level check.
 4. No new oil additions are allowed.

4.3.14 Twenty (20) h Oil Leveling Procedure. Record the oil level every 20 h according to the procedure:

- Shut the engine down in accordance with 4.3.11. Return the 472 mL oil purge to the engine. Determine the oil level after the 15 minute period, in millimeters, using the calibrated dipstick.
- Record these values on the Oil Level Check Sheet, Appendix A, Table A4.
- Following the completion of each 20 h oil level the engine is ramped up to test conditions over a 15 minute period unless the test time has reached 100 h.

4.3.15 Blowby Flow Rate Measurement. Measure the engine blowby flow rate according to the following instructions, and within 15 minutes of the EOT, at hours: 1, 6, 11, 16, 21, 26, 31, 36, 41, 46, 51, 56, 61, 66, 71, 76, 81, 86, 91, 96 and 99.

Observe the requirements:

4.3.15.1 The engine must be running according to the oil test control settings, Table 1.

4.3.15.2 Measure the blowby flow rate after the tee (see TSM) above the rocker cover oil separators.

4.3.15.3 Use the sharp-edge orifice blowby meter, part number RX-116169-A1, revision N, or the J-Tec VF563AA to measure engine blowby flow rates. If the J-Tec meter is used then the J-Tec Setup, Installation, and Maintenance Procedure must be followed in the TSM.

4.3.15.4 If using the sharp-edge orifice meter follow the procedure:

- Orient the blowby meter horizontally during measurements.
- Direct the blowby gas into a suitable vent hood at all times, other than when the blowby flow rate is being measured. Do not allow the vent system to create a draw on the crankcase.
- Connect a surge tank, part number RX-117431C, to the condenser.
- Connect the blowby flow rate meter to the surge tank.
- When permanently installed blowby meters are not used, portable cart applications are allowed. However, position the cart near the testing area for a sufficient time period to assure temperature stabilization of the system components prior to taking any blowby measurements.
- Temperature stabilization is necessary to reduce condensation precipitation of the blowby gases. The moisture content of blowby gases is generally between 17 g/g and 20 g/g. Correction factors are based on this and other average gas-analysis data of the blowby gases. Therefore, it is important that the blowby gases being measured at the orifice plate be as close in molecular composition and temperature as possible to the blowby gases exiting the condenser.
- Do not evacuate or direct the exhaust line for the engine blowby gas being measured toward any low pressure evacuation systems.
- Select an orifice size such that the observed blowby flow, ΔP , lies in the midrange of the calibration curve. Record the orifice size used.
- Control the crankcase pressure at $0 \text{ Pa} \pm 12.4 \text{ Pa}$.
- Maintain blowby gas flow through the orifice meter for 2 minutes or more to ensure flow stability, prior to taking the actual readings. Due to the relatively low flow rates, allow time for the engine blowby gas to fill the system and further enhance temperature stabilization.
- Record the uncorrected blowby flow rate in liters per minute and correct it for an atmospheric pressure of 100 kPa and a temperature of 37.8°C , using the correction factors given in Appendix A, Table A9.
- Alternatively, use the following equation to correct the blowby flow rate:

$$CF_{si} = \left(3.1002 \left(\frac{P_{kpa}}{273.15 + t^{\circ}\text{C}} \right) \right)^{0.5} \quad (4)$$

Where:

- CF_{si} = Corrected blowby flow rate (liters per minute)
 P_{kpa} = Blowby pressure (kilopascals)
 $t^{\circ}\text{C}$ = Temperature (degrees Celsius)

- Disconnect the surge tank from the condenser.