GMOD Procedure 04242015 draft

1 Scope

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

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

Note: This document can be modified at the discretion of General Motors through the release of technical bulletins.

1.1 Purpose. This test procedure covers an engine test for evaluating automotive engine oils for certain high temperature performance characteristics, including oil thickening, varnish deposition and oil consumption. This test is required for the **dexos** specification.

1.1.1 Additionally, secondary supplemental requirements including Mini Rotary Viscometer, Cold Cranking Simulator measurements and Phosphorous Retention measurement shall be conducted.

1.2 Foreword. The original **dexos1** and **dexos2** engine oil specifications used American Society for Testing and Materials (ASTM) D7320, Evaluation of Automotive Engine Oils in the Spark-Ignition Engine to evaluate oils for thickening, piston deposits, and camshaft and lifter wear. The General Motors Oxidation and Deposit Test (GMOD) is part of dexos second (2^{nd}) generation.

1.3 Applicability. This test procedure specifies a General Motors Oxidation and Deposit (GMOD) test engine, test procedure, and test stand configuration items as described in the procedure.

1.4 Appendix. Regard the contents of the Appendix as mandatory information for a valid GMOD test.

2 References

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

2.1 External Standards/Specifications.

ASTM D235
ASTM D3244
ASTM D445
ASTM D4684
ASTM D5185
ASTM D5293
ASTM D7320
SAE J300

2.2 GM Standards/Specifications.

GMW3420

2.3 Additional References.

- ASTM Deposit Rating Manual No. 20
- Data Acquisition and Control Automation II (DACA II) Task Force Report (available through ASTM)
- Dexos specification
- Engine Assembly Manual (EAM)
- Test Stand Manual (TSM)
- Test Monitoring System (TMS)

3 Resources

3.1 Facilities. Fully equipped testing laboratory, such as:

- Intertek Automotive Research
  5404 Bandera Rd
  San Antonio, TX 78238
- Southwest Research Institute
  9503 West Commerce
  San Antonio, TX 78238

3.1.1 Calibration.

3.1.1.1 This is a Test-Stand based calibration system.

3.1.1.2 For a test stand to remain calibrated the GMOD Test Monitoring System (TMS) must be followed. The GMOD TMS is available from the TMC.

3.1.1.3 The test facility and equipment must be inspected by a GM and ASTM TMC representative prior to commissioning a test stand.

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

3.1.1.5 Test stand pre-test checks must be performed and testing with candidate oils cannot proceed if the checks indicate nonconformance.

3.1.2 Dynamometer load cell calibration. For every test the dynamometer load cell will be calibrated at 250Nm after the initial oil leveling run according to the following procedure.

3.1.2.1 Load cell calibration procedure.

1) Prior to calibration, start the engine and perform the oil leveling run.
2) Shut the engine down, leave dynamometer cooling water on, and start performing the load cell calibration within 3 min after shutdown.
3) Dyno excitation is to be set at the minimum.
4) Check dyno for any obstructions such as hoses, driveline guards etc., anything laying on, or across the dyno.
5) Ensure the load cell temperature is at the desired test temperature.
6) 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.

3.1.3 Oil Dipstick Calibration. Throughout the test the oil level is measured using the oil pan dipstick. The table in Appendix 8 shows the relationship between the dipstick mm markings and the oil volume in the oil pan.

3.1.4 Alternatives. Not applicable.

3.2 Equipment.

3.2.1 Engine Parts. Use the engine parts specified in the GMOD Engine Assembly Manual (EAM) (Section 10).

3.2.2 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.

3.2.2.1 Unless otherwise directed, all parts and materials required for testing should be stored and used on a first in –first out basis.

3.2.3 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 shall be used; other items required are 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 +/- 50 rpm with spark plugs removed.

3.2.3.1 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 6 °C. Control 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 an Oberg Oil Filter, oil heat exchanger and gaskets specified in the Test Stand Manual (TSM) (Section 4). Configure the external filter and heat exchanger circuit as specified in the TSM (Section 4). 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 ± 0.7 g/kg of dry air, a dry bulb temperature of 35 °C ± 2 °C, and a static pressure of 0.050 kPa. Measure temperature and pressure at the inlet air adapter as shown in the TSM Appendix C.

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	Acronym
Engine Speed	3000	rpm	SPEED
Engine Load	250	N-m	TORQUE
Oil Filter Return	145	°C	TOLFLT
Coolant Out	115	°C	TCLEO
Coolant System	123	kPa	PCL
Intake Air	35	°C	TAIRIN
Intake Air	0.05	kPa	PAIRIN
Intake Air	11.4	g/kg	HUM
Exhaust Back Pressure	3	kPa	PEXHBR/PEXHBL
Fuel at Fuel Rail	35	°C	TFUELIN
Fuel Rail Pressure	410	kPa	PFUEL
Exhaust Manifold	15	L/min	
Engine Coolant Flow	190	L/min	FCLEO
Fuel Temperature at Rail	35	°C	TFUELIN
Dyno Load Cell delta	+/- 6	°C	

Uncontrolled Recorded Parameters	Units	Acronym
Oil Sump	°C	
Coolant Inlet	°C	
Oil Filter Inlet	°C	
Oil Pump	°C	
AFR via Lambda Sensor		
Exhaust Gas NOx	ppm	
Fuel Flow	kPa	
Crankcase Pressure	kPa	PCC

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 Controller 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 two minute intervals between successive logs for each parameter. See the 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 DACA II report and also conform to total system response requirements as outlined by the Test Monitoring Center (TMC). Documentation verifying compliance must be provided to the TMC representative during annual test stand inspections. In addition the TMC may request to be present when system time response is measured. The following is a list of minimum requirements for GMOD testing:

3.2.9.2.1 Temperature. Use only Type E Chromel-Constantan thermocouple with an accuracy of ± 0.5 °C over a range of 0 °C to 200 °C.

3.2.9.2.1.1 Thermocouple Locations. 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, (Section 6, Sheet 2).
- Oil Pan (Sump). Install the thermocouple in the oil pan as supplied by OHT and specified in the EAM, (Section 7). 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, (section 5).
- 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, (Section 7).
- Inlet Air. Install the thermocouple and pressure pickup in the inlet air adapter, as shown in the TSM, (section 4).
- Exhaust. Install the thermocouples and pressure pickup in the exhaust as shown in the EAM, (section 5).
- Blowby. Install the thermocouple in the blowby cart if the sharp edge orifice blowby meter is used.

3.2.9.2.2 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 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 and Maintenance Procedure must be followed in the TSM (Section 9)
- **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 (section 5).
- **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 (Section 6, Sheet 2), (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 (Section 6, Sheet 2), (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 (Appendix E). 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 (Appendix C).
- **Crankcase Pressure.** Use a transducer having a range of -125 Pa to +125 Pa. Connect the transducer to the engine block oil dipstick tube.

3.2.9.2.3 Air-to-Fuel Ratio Determination. The use of real time systems to verify air to fuel ratio (AFR) using an oxygen sensor is required. Use the specified sensor in the TSM (Section 6).

3.2.9.2.4 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 (Section 6).

3.2.9.3 Measurement Resolution. The minimum resolution for all parameters shall be at least ¼ 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 umit. See Appendix 5, Required Resolution for Data Acquisition.

3.2.9.4 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 5, Maximum System Time Response for QI parameters.

3.2.9.5 Quality Index. Use of the quality index 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:

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

where:

QI	=	quality index,
X_i	=	recorded test measurement parameter,
U	=	upper specification limit for that parameter,
L	=	lower specification limit for that parameter, and
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 5.
- Calibrate the stand instrumentation used for data acquisition and control, on all controlled and non-controlled parameters (see Appendix 5), every six months.
- At a minimum, calibrate the following parameters prior to every reference test sequence, unless the required six–month calibration was completed within 60 days prior to reference test start; engine speed, dynamometer torque, engine coolant out thermocouple, oil filter block thermocouple.
- Calibrate the intake air-humidity system every six months, at a minimum.

3.2.9.6 Parts Modifications. Modify the following parts according to the instructions listed in the EAM and 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.

3.2.9.6.1 Throttle Body. Modify according to print in the TSM (Section 5 and Appendix D).

3.2.9.6.2 Engine Block. Modify according to the EAM.

3.2.9.6.3 Air box. Refer to modification in the TSM (Section 5 and Appendix C).

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 (Section 10).

3.3.1 Exhaust. Use specified exhaust manifolds and takedown tubes as specified in the EAM (Section 5). Configuration at the end of the takedown tubes is to be determined by the test lab.

3.3.2 Engine Control Module (ECM) and Engine Harness. The ECM and engine wiring harness shall be purchased from Chevrolet Performance. These part numbers are in the EAM (Section 10).

3.3.3 Oil Pan and External Oil System Hardware. The system consists of oil pan (EAM Section 3), oil filter adapter, oil heat exchanger, and Oberg oil filter. The system configuration is specified and shown in TSM (Section 4 and Appendix B).

3.3.4 Coolant System Hardware. The coolant system consists of components as specified in the TSM (section 8).

3.3.5 Driveline. A specified driveline is to be used for this test, as specified in the TSM (Section 3).

3.4 Test Time.

Calendar time:	4.16 days
Test hours:	100 hours
Coordination hours:	NA

3.5 Test Required Information. Reagents and Materials.

3.5.1 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 7.

3.5.1.1 Make certain that all tanks used for transportation and storage are clean before filling with test fuel.

3.5.1.2 Verify that there is enough test fuel available prior to starting a test.

3.5.2 Engine Coolant. The engine coolant is ShellZone Extended Life DEX-COOL.

3.5.3 Engine Build Cleaning Materials. Use the cleaning materials specified in the EAM (section 11) 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

3.5.3.1 GMOD Test Engine Internal Component Cleaner. Part number GMOD-001.

May be obtained from:

Wrico II Limited

Phone (210)-590-4400

Part Number GMOD-001

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.

3.5.4 Sealing and Anti-seize Compounds. Use the sealing compounds specified in the EAM (section 11).

3.5.4.1 Teflon tape may be used, provided it does not come into contact with engine oil.

3.6 Personnel/Skills.

3.6.1 Engine build technicians will need to participate in the annual unified engine build workshops.

3.6.2 All raters of GMOD engine pistons shall attend an TMC Light Duty Deposit Rating Workshop every 12 months ± 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.

4.1.1 Engine Build. Follow the instructions in the EAM to build the GMOD engine.

4.1.2 Engine Installation. Install the engine into the test cell with engine mounts as documented in the TSM (Section 1).

4.2 Conditions.

4.2.1 Environmental Conditions. Follow the requirements of this standard.

4.2.2 Test Conditions. Follow the requirements of this standard.

4.3 Instructions. Run the test according to the following instructions and the GMOD Operating Procedure and Specifications in Appendix 1.

4.3.1 Dual throttle body spanning check. Prior to every test start a simultaneous spanning check will 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

1) Clean the external oil system thoroughly before each test to prevent contamination of subsequent tests.
2) Flush the external oil system for 20 minutes using the solvent flush cart with organic solvent.
3) Blow dry all of the lines to and from the external oil system until all solvent is removed.
4) Once dry, remove the oil cooler and clean in the ultrasonic cleaner for one hour.
5) 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.
6) Blow out all the instrumentation pressure transducer oil lines for a minimum of two minutes until all oil is removed.

4.3.3 Cooling System Cleaning

1) 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 following procedure:
2) Prepare a cleaning mixture in the flushing tank by mixing GMOD Test Engine Internal Component Cleaner (GMOD-001, see 3.5.3.1) at 19 g per 1 L of water. Heat the mixture to (60 ± 3.0) °C.
3) Circulate the mixture at 160 L/min flow rate for 30 min.
4) Immediately following step 4.3.4, thoroughly flush all system components with water at (60 ± 3.0) C.
5) Ensure that all low points in the system are drained after cleaning.

4.3.4 Engine Coolant Jacket (Flushing)

1) 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 following procedure:
2) 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.
3) For the following segments of this cleaning procedure, minimize the elapsed time between steps in order to avoid rusting of the coolant jacket.
4) Remove the oil pan drain plug. Open the engine block petcocks and pass hot water (60 to 70) °C through the engine coolant jacket for 2 min. 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 to 45) L.
5) Energize the flushing tank heaters. Circulate water through the engine at a flow rate of 115 to 130 L/min through the engine until the temperature of the water flowing out of the engine reaches 70 ± 3.0°C. Isolate the engine from the flush cart.
6) While the flush cart is isolated from the engine with water still circulating, add GMOD Test Engine Internal Component Cleaner (GMOD-001, see 3.5.3.1) at 19 g/L of water to the water in the flushing tank. Continue to circulate the mixture in the flush cart for 3 to 5 min
7) Circulate the mixture through the engine for 30 min.
8) 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.
9) Flow hot tap water through the engine and flush cart system for 2 to 5 min. 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.
10) Immediately after neutralizing the engine block, drain all flush water.
11) 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.
12) Connect the engine to the external engine cooling system.
13) Immediately charge the engine jacket with coolant.

4.3.5 Coolant Charging

1) Charge the engine jacket with the coolant specified in section 3.5.2, according to the following procedure:

2) Use a charging adapter installed between the external cooling system and the engine.
3) Completely fill the engine cooling system with coolant.
4) 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.
5) Until the test is started, circulate the coolant at a temperature of (49.0 ± 3.0) °C and a flow rate of 190 L/min.

4.3.6 Test Oil Charging.

Charge the engine with the test oil as follows:

1) Install a new or cleaned Oberg oil filter element as specified in the TSM (Section 4).
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 NIST.
4) Add an initial fresh test oil fill of 15.0 +/- 0.2 lb to the engine through the oil add tube on the oil pan.

4.3.7 Engine Oil Pump Priming

Prime the engine oil pump according to the following 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 ± 50 rpm, until oil pressure attains 100 kPa.
5) Install the spark plugs.

4.3.8 Engine Start-up and Shutdown Procedures. Start and stop GMOD engines according to the following procedures and the test states and set points listed in Table 1, On Test Settings.

4.3.9 Engine start-up. Use the following procedure to start the GMOD engine.

1) Before cranking engine, supply (13 to 15) Volts dc power to the Engine Control Module (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 pre-heated and ready for closed-loop control when the AFR readings are over 20:1 prior to engine start.
2) Start the coolant flowing through the exhaust manifolds.
3) Turn on the ignition. Perform the Dual Throttle Body Spanning Check as stated in 4.3.1**.**
4) With the ignition on, turn on the fuel and crank the engine until the engine starts or for a maximum of 15 seconds. If the engine fails to start, investigate the cause, correct and attempt to restart.
5) After starting the engine allow 1 minute for the engine to stabilization at idle and to verify that oil pressure is adequate.

4.3.10 Initial Oil Leveling Run (10 Minutes)

1) After the 1 minute stabilization period ramp the speed to 1500 r/min, set the load to 40 Nm and begin timing the ten minute Initial Oil Leveling Run.
2) Control the engine coolant outlet temperature to 50 C, 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.
3) Circulate the process water through the exhaust manifolds at 15 LPM and coolant at 190 LPM through the engine.
4) Ten 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.
5) Shut the engine down in accordance with section 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.
6) Record this value as the Initial Oil Level on the Oil Level Check Sheet, Appendix 2.
7) Perform the Dynamometer Load Cell Calibration as stated in section 3.1.2.1
8) Following the completion the Dynamometer Load Cell Calibration the engine is ramped up to test conditions over a 15 minute period.

4.3.11 Scheduled Shutdown Procedure

Use the following procedure when stopping the GMOD engine for oil level checks:

1) Reduce the engine speed and load to 1500 r/min and 40Nm with a linear ramp-down over 30 s.
2) Turn off the ignition voltage.
3) With the engine stopped, continue to circulate the process water through the exhaust manifolds at 15LPM and coolant at 190LPM through the engine.
4) Set the Coolant Out and Oil Filter Return Temperature to 50C.

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 section 5.7. 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 hr, 40 hr, 60 hr, 80 hr, 100 hr. Use this procedure to take these oil samples.

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

4.3.14 20 Hour Oil Leveling Procedure. Record the oil level every 20 hours according to the following procedure.

1) Shut the engine down in accordance with section 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.
2) Record these values on the Oil Level Check Sheet, Appendix 2.
3) Following the completion of each 20 hour oil level the engine is ramped up to test conditions over a 15 minute period.

4.3.15 Blowby Flow Rate Measurement

Measure the engine blowby flow rate according to the following instructions, and within 15 min of the end of test, 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 following 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, section 9) above the rocker cover oil separators.

4.3.15.3 Use the sharp-edge orifice 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 (Section 9)

4.3.15.4 If using the sharp edge orifice meter follow the procedure below.

1) Orient the blowby meter horizontally during measurements.
2) 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.
3) Connect a surge tank, drawing RX-117431C, to the condenser.
4) Connect the blowby flow-rate meter to the surge tank.
5) 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.

NOTE 10—Temperature stabilization is necessary to reduce condensation precipitation of the blowby gases. The moisture content of blowby gases is generally between (17 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.

6) Do not evacuate or direct the exhaust line for the engine blowby gas being measured toward any low pressure evacuation systems.
7) Select an orifice size such that the observed blowby flow, ΔP, lies in the midrange of the calibration curve. Record the orifice size used.
8) Control the crankcase pressure at (0 ± 12.4) Pa.
9) Maintain blowby gas flow through the orifice meter for 2 min. 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.
10) Record the uncorrected blowby flow rate in litres 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 6, Blowby Flow Rate Determination.
11) Alternatively, use the following equation to correct the blowby flow rate:
12)

$$CF_{si} = \left(3.1002\left(\frac{Pkpa}{273.15 + t°C}\right)\right)0.5 \qquad (4)$$

13) where:

CF_{si} = corrected blowby flow rate, L/min,

$Pkpa$ = blowby pressure, kPa, and

$t°C$ = temperature, °C.

14) Disconnect the surge tank from the condenser.

4.3.16 Engine Oil Quality Testing Instructions.

After completing all phases of the Initial Oil Leveling Run, conduct the Engine Oil Quality portion of the test for 100 hours, according to the following procedure:

1) Start the engine, and maintain the ignition voltage between (13 to 15) volts.
2) Ramp the engine speed up to the test conditions over a 15 minute period.
3) Operate the engine under the test conditions listed in Table 1, GMOD On Test Settings.
4) Following the completion of each 20 hour oil level the engine is ramped up to test conditions over a 15 minute period.
5) For each 20 hour segment of the engine oil quality testing period of 100 hours, test time is counted from the moment when all test conditions listed in Table 1 are reached and stabilized. Start calculating QI values when temperatures are stable or when test state warm up times are exceeded. If engine is shutdown for any reason except oil leveling, start counting down time. Maximum allowable down time for the test is 15 hours.
6) Every 20 hour conduct the oil sampling and oil leveling according to 4.3.13 and 4.3.14. Record the time when the final leveling is completed at 100 hours; be aware that completion of most of the engine disassembly takes place within 12 hours of this time.

4.3.17 Test Termination. Terminate the test as follows:

1) Terminate the test at the completion of the engine oil quality testing period of 100 hours, following the taking of the purge and analysis samples and completion of the end of test oil leveling procedure.
2) Record the end-of-test time after the final engine oil level procedure is completed.
3) Drain the oil sump.
4) Drain the engine coolant.
5) Remove the engine from the test stand and transport it to the disassembly area for determination of results.

4.3.18 Engine Disassembly

1) Plan the disassembly so that the parts to be rated for sticking, deposits, and plugging (pistons and rings) are removed from the engine within 12 h of the completion of the final test oil level.
2) Preparation of Parts for Rating of Sticking, Deposits and Plugging—Prepare the specified parts for rating according to the following instructions:
3) Check all piston rings for freedom of movement in the grooves when removing the pistons from the engine.
4) Determine which rings are hot-stuck or cold-stuck and record the piston number and ring identification (for example, piston No. 3, top ring) for such rings on Form 8, Summary of Oil Ring Land Deposit Rating, in Standardized Report Form Set (see Appendix 3). Record the total number of hot-stuck rings on Form 4, Test Result Summary.
5) At time of disassembly, remove all piston rings that are free. Leave any stuck rings, including pinched rings in place. Apply a rating of 100 % heavy carbon in the groove to any piston groove that cannot be rated, due to the presence of a stuck or pinched ring.
6) If the piston deposits cannot be rated immediately after the pistons are removed from the engine, store the pistons in a desiccators for no longer than 72 h from end of test before rating.
7) Note: Do not wipe the pistons before storing them.

4.4 Data Collection during Candidate and Reference Tests

4.4.1 Test Operating Parameters. Collect the test operating parameters, controlled and uncontrolled, as shown in Table 1, On Test Settings.

4.4.2 Engine Operating Parameters. Collect the engine operating parameters from the ECM as shown in Table 4.

Table 4. ECM Data

Parameter	Units
Engine Speed	RPM
ECT	C
IAT	C
MAF	g/s
STFT B1	
STFT B2	
LTFT B1	
LTFT B2	
Timing Advance	Degree
Control Voltage	V

4.4.3 Data Collection 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.

5 Data

5.1 Calculations. Use calculations as required to interpret the results.

5.2 Interpretations of Results.

5.2.1 Piston Deposit Ratings—Rate the pistons for piston skirt varnish as well as deposits on the ring lands, under-crown area, and in the ring grooves.

1) Gently wipe off excess oil from the piston skirts with a soft cloth.
2) Do not apply any chemicals or build-up oil to the pistons prior to rating them for deposits.
3) Third land and skirtsRate each piston top groove, 2nd groove, oil ring groove, 2nd land, and undercrown area (where the horizontal and vertical planes meet) for deposits using ASTM Deposit Rating Manual

No. 20 rating techniques and breakdown methods. Carbon deposit ratings will consist of only two levels: Heavy (0.00 merit value) or Light (0.75 merit value).

4) Perform these ratings in a rating booth, using a 20-segment piston-rating cap, a piston rating stand, and a 22W circular rating lamp.
5) The undercrown area to be rated is defined as the area on the undercrown of the piston that is approximately 3”x1” between the pin bosses (See Appendix 4, Piston Undercrown Rating Area). Rate only the area on the underside of the piston crown. Do not rate any parts on the inside surface of the piston skirts as part of the undercrown rating.
6) Report any unusual deposits observed in the Test Comments report form 14.
7) If multiple ratings are deemed necessary of a given part or parts, consensus rating may be used according to the following:
8) The raters shall be from the laboratory in question, no outside raters may be used unless requested and directed by General Motors.
9) No averaging of ratings is permitted.
10) Report only one rating value, which is agreed to by the involved raters.
11) Average each individual piston (thrust side and anti-thrust side) for inclusion in the Weighted Piston Deposit (WPD) results.
12) Calculate the average of the eight oil ring land (land 3) ratings and record this as the average oil ring land deposits on Form 8, Summary of Oil Ring Land Deposit Rating (ORLD), and on Form 4, Test Results Summary, in Standardized Report Form Set (see Appendix 3).
13) WPD Rating —This weighted piston rating is comprised of skirt varnish, top groove, 2nd groove, oil ring groove, under-crown, 2nd land, and 3rd land.
14) Calculate the WPD result for each individual piston is calculated using the following weighting factors:

    Piston Undercrown 10%

    2nd Land 15%

    3rd Land (ORLD) 30%

    Piston Skirts Average Piston Varnish (APV) 10%

    Top Groove 5%

    2nd Groove 10%

    Oil Ring Groove 20%
15) Calculate the WPD result for each piston by multiplying the rated result for each piston part by the weighting factor in 5.2.7.7 (in decimal form) to determine a weighted rating for that piston part. The Weighted Piston Deposit result is the sum of the weighted ratings for the individual piston parts.
16) The WPD result for the test is calculated by a simple average of the eight individual piston WPD ratings.

5.2.2 Percent Viscosity Increase. Determine the viscosity of a sample of the fresh test oil and of the nine test samples by analysis according to the following instructions:

1. Do not filter the samples.
2. Use ASTM Test Method D445**.**
3. Use either the Cannon-Fenske Routine Viscometer of the Ostwald Type for Transparent Liquids or the Cannon-Fenske Opaque Viscometer of the Reverse-Flow Type for Transparent and Opaque Liquids.
4. Conduct the measurement at 40 °C.
5. Record the results in the Standardized Report Form Set (see Appendix 3).

- Critically examine the relationship of the viscosity of the initial oil sample (sample taken after the oil leveling run) to that of the new oil. The viscosity of the initial sample can legitimately be as much as 10 mm2/s less than that of the new oil, because of permanent shearing effects. If the difference is greater than 10 mm2/s, explore possible causes such as failure to purge the oil sample line [removing the 472 mL purge sample] prior to withdrawing the 59 mL analysis sample, or an excessive amount of build-up oil in the system.

- Calculate the change in viscosity in mm2/s, from the value for the initial sample, for the last five samples. Record the changes on Form 7, Used Oil Analysis Results, in Standardized Report Form Set, Appendix 3. Record the final percent viscosity increase on Form 4, Test Result Summary.

5.2.2.1 Calculation instructions for special cases related to percent viscosity increase:

- Instructions for calculating and reporting results if the Final Original Units Result on Form 4 for percent viscosity increase is zero or negative. (1) The minimum result that will be considered for the percent viscosity increase is 0.1 %. Substitute 0.1 % for the original unit result and complete the calculations on Form 4. A notation is required in the Test Comments of Form 14 indicating that the Original Units Result has been modified for a special case.
- Instructions for calculating and reporting results of the Viscosity Result on Form 7 for Viscosity Increase Data is Too Viscous to Measure (TVTM). (1) The maximum kinematic viscosity result reported will be 8000 mm2/s using either equipment noted in 5.3.3, use a tube size of 500 or less. If the measured viscosity is 8000 mm2/s using tube size 500, this will be considered the maximum reportable viscosity. Report 8000 mm2/s on Form 7 for entry in the column listed as Viscosity and use this value for the calculating Change and Percent. (This will provide consistent TVTM data for reporting purposes and it also expands the maximum viscosity to fill the space allowed by the Data Dictionary.) (2) Complete the calculations on Form 4 for percent viscosity increase using the percent value for the final drain from Form 7 except that the Severity Adjustment (SA) displayed and used for percent viscosity increase calculations will be set to zero (0). A notation is required in the Test Comments Section of Form 14 indicating that the SA has been modified for a special case.

5.3 Test Documentation. Tests registered for dexos® qualification must store and submit data as prescribed by the data dictionary and the Standardized Report Form Set. Reference and non-reference oil tests, should also be reported on these same forms if the results are intended to be submitted as candidate oil results against a specification

5.3.1 Oil Sample analysis required for all samples:

- Viscosity at 40 and 100C (D445),
- Fuel Dilution % (D3525M),
- Area (IIIG) Oxidation & Nitration (E168),
- DIN 51453 Oxidation & Nitration,
- TAN (ASTM D664),
- Inductively Coupled Plasma Optical Emission Spectrometry (ICP) (D5185) and

5.3.2 Conduct a CCS test (ASTM D5293) and a MRV test (ASTM D4684) on the EOT used oil sample with the following exceptions:

- For non-reference oils run a CCS test (ASTM D5293) on the EOT (100 h) analysis sample at the temperature that is specified for the test oils given viscosity grade in Table 1 of SAE J300. Report results on Form 7, Used Oil Analysis Results, in the Standardized Report Form Set (see Appendix 3).
- Run the MRV test (ASTM D4684), MRV-TP1 at new oil viscosity grade using SAE J300 specifications if a passing CCS result is obtained.
- If the CCS fails, run the MRV at the same temperature as the CCS (one grade higher based on SAE J300). Report the EOT MRV test results along with the test temperature in degrees Celsius along with yield stress as follows:
- If a yield stress is obtained at the designated temperature greater than 35 Pa, report the yield stress in pascals and note the apparent viscosity as not measured (NM).
- If a yield stress is not obtained at the designated temperature exceeding 35 Pa, report the yield stress as “<35” to indicate that the yield stress did not exceed 35 Pa. (3) Report the results on Form 7.
- If the percent Viscosity Increase for the kinematic viscosity at EOT is higher than 500 %, the CCS and the MRV tests are not required. A notation is required in the Test Comments section of Form 14 indicating that the CCS and MRV were not run and enter not measured (NM.

- If the test oil is a straight grade oil, CCS and MRV tests are not required. A notation is required in the Test Comments section of Form 14 indicating that the CCS and MRV were not run and enter not measured (NM).
- Start the MRV test within 504 h of the GMOD EOT.
- Upend the sample for MRV testing five times before starting the test.

5.3.3 Testing Oil Samples for Wear Metals—Use ASTM Test Method D5185 to perform ICP Analysis on the initial and all 20 h oil samples for iron, copper, and lead concentrations in the oil. Report the results of the ICP Analysis on these three metals on Form 7a Standardized Report Form Set, Appendix 3.

5.3.4 Measurement of the Phosphorus Retention of a test lubricant after 100 h of GMOD test operation.

5.3.4.1 The oil samples used for measurement of the phosphorus retention in the GMOD test are the initial oil sample, removed from the engine following the initial run-in, and the end-of -test 100 h oil sample.

5.3.4.2 The phosphorus (P) retention calculation is:

Phosphorus Retention = Ca tl / Ca t100) X (P t100 / P tl) X 100 where :

Calcium (Ca) tI = analytical results from the initial oil sample,

P tI = analytical results from the initial oil sample,

Ca t100 = analytical results from the end-of-test oil sample,

and

P t100 = analytical results from the end-of-test oil sample.

5.3.4.3 Use ASTM D5185 to measure calcium and phosphorus concentrations. For oils where calcium is not the highest concentration detergent metal, substitute the highest concentration detergent metal into the equation for calcium.

5.3.4.4 End-of-Test Oil Sample Testing—The phosphorus and calcium elemental concentrations for all oil samples are to be reported in milligrams per kilogram as determined using Test Method D5185. All samples, initial and end-of-test, are to be run sequentially, in duplicate, using the same calibration (that is, as close in time as practical). Background correction, internal standard, and peristaltic pump are required. Use sample dilutions of at least 1:20. Once a dilution is established, use it for all samples from a test. Report the average of the two determinations as the final result. If the duplicate determinations are outside the repeatability calculations shown in Table 2 of ASTM Test Method D5185, follow the procedure shown in 6.2 of ASTM Test Method D3244.

5.3.5 Blowby Flow Rate Measurements. Plot blowby flow rate measurements on Form 10, Blowby Values & Plot, in Standardized Report Form Set (see Appendix 3).

5.3.6 Oil Consumption Computation—Compute the oil consumption for the test as follows, an example is shown in Table 3:

1. Determine final drain in lbs.
2. Subtract final weight from initial fill (15.0 lbs).
3. Add approximate external volume to the result in 5.5.2 and record this value on Form 6.

Table 3 Calculation of oil consumption, example.

GMOD Oil Consumption	lbs	Qts
Initail Fill of engine	15.0	7.7
EOT Drain of engine	4.3	2.2
Oil in engine & external system	1.5	0.8
Total oil consumption	9.2	4.7

Note: ~Total Oil Consumption includes oil samples removed (~0.4 quarts)

5.3.7 Photographs of Test Parts.

Take color photographs of the test parts for inclusion in the test report, as follows:

1. Photograph pistons after completing all ratings.
2. Do not coat the pistons with build-up oil (for preservation) before the photographs are taken. Do not re-install piston rings.
3. Photograph all eight piston thrust sides in one shot. Piston labels are not required (see ~~12.10.7~~).
4. Photograph all eight piston anti-thrust sides in one shot. Piston labels are not required (see ~~12.10.7~~).
5. Size the final piston photographs for inclusion in the test report so that the overall piston height is not less than 5 cm, but small enough that three photographs can be mounted in a column on the 28 cm dimension of a (22 by 28) cm sheet of paper.
6. Assemble the photographs on two pages, with the thrust side photographs on one page, and the anti-thrust photographs on the other page. Is this needed? Contradicts 3 and 4.
7. Mount the photographs on each of the two pages with the reciprocating axes of the pistons parallel to the 28 cm dimension of the page. Arrange the photographs in two vertical columns of three each, with the No. 1 piston in the upper left corner of the page, No. 2 piston in the upper right corner, No. 3 piston in the center of the left column, and so forth.

5.4 Retention of Test Parts.

5.5 Determination of Operational Validity

Determine and document the operational validity of every GMOD test conducted, according to the following:

1. Refer to the GMOD LTMS document.
2. Complete the report forms to substantiate that the test stand, engine build-up, installation of the engine on the test stand, and the test operation conformed to the procedures specified in this test method.
3. Inspect the test records for instances of downtime (excluding the initial oil level run of the test), and record any such instances on Form 13, Downtime and Outlier Report Form, in Standardized Report Form Set (see Appendix 3). When performing each 20 h oil level adjustment, identify as downtime any time in excess of 55 min from the time when the engine ramps down until the test is back on test operating conditions. Enter the total downtime on Form 13, Downtime and Outlier Report Form. If the total downtime exceeds 24 h, note on Form 1, that the test is invalid.

5.6 Complete Test Forms

5.7 Complete Downtime, Off Test Time, and Outlier Report. The number of hours the test stand is operating under conditions not allocated by GMOD is no more than 20.0. This includes both downtime and off-test condition time. Test is invalid if downtime and off test time exceeds 20.0 hours. Off test time is anytime during a test the engine is not at test conditions. Each 20 hour oil level check is allowed 55 minutes from the time the engine ramps down to when it restarts. Time in excess of 55 minutes will be recorded as downtime. The time the engine spends at off test conditions (conditions other than 1500 r/min, 40 Nm and 3000 r/min, 250 Nm, ramping up or down) is to be reported as downtime. Off test conditions during the Initial Oil Leveling Period will be reported in the test report notes section but will not be considered as downtime.

6 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

7 Notes

7.1 Glossary.

7.2 Acronyms, Abbreviations, and Symbols.

AFR Air Fuel Ratio

APV Average Piston Varnish

ASTM American Society for Testing and Materials

Ca Calcium
CCS Cold Cranking Simulator
DACA Data Acquisition and Control Automation
EAM Engine Assembly Manual
ECM Engine Control Module
EEE Exhaust and Evaporative Emissions
EOT End of Test
GM General Motors
GMOD General Motors Oxidation and Deposit
ICP Inductively Coupled Plasma
MRV Mini Rotary Viscometer
NM Not Measured
OHT OH Technologies Incorporated
ORLD Oil Ring Land Deposit
P Phosphorus
PPM Parts per Million
QI Quality Index
RPM Revolutions per Minute
SA Severity Adjustment
SAE Society of Automotive Engineers
TMC Test Monitoring Center
TMS Test Monitoring System
TSM Test Stand Manual
TVTM Too Viscous To Measure
VFD Variable Frequency Drive
WPD Weighted Piston Deposit

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Test to GMWXXXX

9 Release and Revisions

This standard was originated in (replace with date [month/year] standard number was issued). It was first approved by (replace with approving organization's name) in (replace with original approval date [month/year]). It was first published in (replace with original publication date [month/year]).

Issue	Publication Date	Description (Organization)
1	MMM YYYY	Initial publication.