



Durability Test for Life Assessment of Engine Radial Shaft Lip Seals

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.

Note: The words must, shall or will as used in this document mean a mandatory requirement.

1.1 Purpose.

1.1.1 This group of tests establishes the requirements of gas and diesel engine radial lip seal systems.

1.1.2 Criteria. Validation to this GMW3157 requires: see 1.1.2.1 thru 1.1.2.3.

1.1.2.1 Completing all relevant tests described herein without leakage.

1.1.2.2 Using production-intent design parts in all of the tests.

1.1.2.3 Using production-intent processes whenever possible. Even if production-intent processes are not used, the parts must conform to all engineering specifications including surface finish.

1.2 Applicability.

1.2.1 This group of tests is suited to the evaluation of passenger car and light duty truck unidirectional rotating crankshaft seals, using both elastomeric and Polytetrafluoroethylene (PTFE) lips that experience thermal, rotational, and environmental inputs during service.

1.2.2 Camshaft. Test camshaft seals at one-half ($\frac{1}{2}$) the crankshaft speeds and other deviations as specified (see 1.2.3 and 1.2.4). Written approval of the release engineer must be given for deviations.

1.2.3 This standard is not intended for bi-rotational (i.e., axle shaft) or reciprocating sealing elements (i.e., valve guide seals, bonded piston rings, etc.)

1.2.4 The sealrater test is for Production Part Approval Process (PPAP) validation of multiple tool cavities and non-functional changes to the seal design, contingent on the design passing (or having passed) the lifetime durability test. Changes requiring complete revalidation include, but are not limited to, changes in lip material, seal production processes, mating component surface finish and designed interference (form, fit, and function). The use of the sealrater test only to satisfy a revalidation for process changes must be approved by the release, validation, and supplier quality engineers.

1.2.5 Certain applications may not require completion of the mud/slurry test (e.g., camshaft seals or rear crankshaft seals). Written approval of the release engineer must be given for such deviations and recorded in the test report.

1.2.6 Representative Parts. Validation tests must use production intent design and/or manufacturing processes parts. Key characteristics of the parts must be measured and documented before the procedure is run.

1.3 Remarks. Careful consideration was given during development to avoid overly severe test conditions which might lead to seal changes solely to pass the tests but could be incorrect for the application. Our targets are based on meeting current design durability for a decade (or more), using 98th percentile customer operation conditions for diesel and gas engines.

1.3.1 Creating consensus test hardware and procedures among the supplier test facilities was necessary to permit comparisons between seals and establish confidence in the results. An Interlaboratory Test Program (ITP) using common seals and test shafts was performed using the durability and dust tests by participating supplier labs. Labs demonstrating common test results within expected norms were certified for validation testing. As more test facilities are considered for certification, the ITP conditions shall be repeated.

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1.3.2 This document is intended for the lab test engineer/technician. Document content shall match lab practice and vice versa. GM Powertrain and seal supplier personnel are responsible for maintaining this balance with suitable detail to maintain repeatable and reproducible test results.

1.3.3 No one has done a study to show the correlation between test head and engine experience. Engine conditions combine dimensional variations and environmental conditions that are not duplicated or simultaneously tested using this standards equipment. Despite apparent differences, seal development and quality has progressed significantly because of this type of evaluation.

2 References

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

2.1 External Standards/Specifications.

ARPM OS-1-1	ASME B46	DIN 3761	ISO 4287
ASME 95	ASTM E18	ISO 2372	ISO 12103-1

2.2 GM Standards/Specifications.

9985522	GMW16077	GMW16676	GMW17332
GMW3059	GMW16095		

2.3 Additional References.

- 88861206 GM Service Part for Indicator Dye
- 88861276 GM Service Part for Indicator Dye
- Amann United States of America, 452 Burbank Street, Broomfield, Colorado 80020, (www.amannusa.com)
- Arizona Dust; Available from Powder Technology Incorporated, 14331 Ewing Avenue, South Burnsville Minnesota 55337
- ARPM OS18 Technical Bulletin, publications\OS-102005-revised-106.pdf (see www.arpm.com)
- Association of Rubber Producing Manufacturers (ARPM) OS6, 7321 Shadeland Station Way, Suite 285, Indianapolis, Indiana 46256, (www.arpm.com)
- Crankshaft Material Specification
- Dip Seal Plastics Incorporated, 2311 23rd Avenue, Rockford, Illinois 61104
- Drawings
- Gutermann of America, Incorporated, 24 American Street, Post Office Box 507, Mount Holly, North Carolina 28120 (www.gutermann.com)
- Kaco (Report Number W 15 117 K) and Bruss (OTR 026/15)
- Part Print
- Part Print Requirements
- Production Intent Requirements (Level 1 Cleanliness)
- Production or Production Intent Drawings
- Production Print
- Production Shaft/Seal Drawing Dimensions

3 Test Preparation and Evaluation

3.1 Resources.

3.1.1 Facilities. Only GM Powertrain or designated approved labs are qualified to run validation tests. Certificates are issued every four years listing the qualified site tests and their approved media. First time candidates are added upon successful completion of blind sample testing with a qualified test site. Certificate renewal is required to keep a test facility approved. Labs or equipment changing location during their certification period shall be reviewed for compliance.

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

3.1.1.2 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.

3.1.2 Equipment. All approved labs must have equipment (see 3.1.2) unless otherwise specified. A schematic of the test system is in Appendix A, Figure A1 and Appendix A, Figure A2. Minor variations from the schematic (component layout) is permitted, between test labs, provided it does not alter test results as verified in a common part test with a qualified lab(s).

A new system with test head, heater and/or reservoir for testing GM seals must be certified by qualified GM personnel (see 3.1.2.10), this includes replacing existing models with a new one by the equipment manufacturer.

Service replacement is permitted without recertification on all existing units in place at the time of the last certification, provided the replacements have the same design, size, performance and function.

Major changes requiring re-certification by qualified GM personnel are (see 3.1.2a thru 3.1.2e and 3.1.2.10);

- New equipment under your custom requirements dedicated to GMW3157.
- Pump components with different outputs requiring total replacement.
- New test heads.
- Increased capacity of a test system.
- Reduced level of activity.

3.1.2.1 Rotary Test Unit. The machine shall have a test head (see Appendix B, Figure B3) for retaining test fluid and positioning the seal(s) on a rotatable shaft supported by an externally mounted spindle. In addition, the following conditions are required:

3.1.2.1.1 The test head support must be sufficiently rigid to ensure minimum vibration.

3.1.2.1.2 Equipment capable of testing up to 150 mm Outer Diameter (OD) seal and 100 mm OD shaft diameter.

3.1.2.1.3 The rotary test unit shall be suitably constructed to maintain pressure and test fluid level required for the test.

3.1.2.1.4 The head shall be equipped with a collector for leak determination.

3.1.2.1.5 The rotary test unit shall be vented to the atmosphere; the length and diameter of vent pipe to be agreed upon between tester and requester. Running pressure and vacuum test will require valves to close the vent pipe.

3.1.2.1.6 Internal pressure can be applied to the head with gauging to monitor the intended level.

3.1.2.1.7 The test head shall be designed and constructed to maintain a preset seal bore alignment to the test shaft axis within $\pm 0.05^\circ\text{mm}$ through the operating temperature range.

3.1.2.1.8 Maximum rotational speed up to $8000 \text{ r}\cdot\text{min}^{-1}$ (8000 rpm).

3.1.2.1.9 Test temperature range of -40°C to 150°C .

3.1.2.1.10 Spindle. The spindle must be capable of cycling and/or maintaining constant shaft speeds within $\pm 50 \text{ r}\cdot\text{min}^{-1}$ (50 rpm). The spindle must be sufficiently rigid to maintain shaft run out under dynamic conditions within $\pm 0.05^\circ\text{mm}$ up to $8000 \text{ r}\cdot\text{min}^{-1}$ (8000 rpm). See 3.2.3.4.

3.1.2.1.11 Programmable rotational test equipment with a peak shaft speed of $8000 \text{ r}\cdot\text{min}^{-1}$ (8000 rpm) speed accuracy of $\pm 50 \text{ r}\cdot\text{min}^{-1}$ ($\pm 50 \text{ rpm}$) adjustable shaft eccentricity of $0.50 \text{ mm} \pm 0.05 \text{ mm}$ Total Indicator Reading (TIR), adjustable shaft to bore alignment of $0.50 \text{ mm} \pm 0.05 \text{ mm}$ TIR, and shaft fore-aft reciprocation of $1.0 \text{ mm} \pm 0.1 \text{ mm}$.

3.1.2.1.12 Test head may be heated electrically and/or by heat transfer fluid.

3.1.2.1.13 Test head internal dimensions must be able to accommodate the internal spray ring (see 3.1.2.8.4). This includes room to connect and properly position it avoiding contact with other internal flow control and measuring devices.

3.1.2.2 Thermal Test Chamber with Temperature Controller. Chamber internal volume sufficient to house the components scheduled for test which can cycle from -40°C to $150^\circ\text{C} \pm 3^\circ\text{C}$ (-40°F to $302^\circ\text{F} \pm 5^\circ\text{F}$) at a rate of 2 h to reach temperature limits and hold it for the required cycle limits (see Table 8 and Table 9). Test chamber must have plumbing and wiring access hole(s). Temperature controller with programming feature must maintain

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$\pm 3\text{ }^{\circ}\text{C}$ of set temperature. Unit (with temperature indicator) must have multiple Thermocouple (T/C) channels to monitor chamber and part temperature. Sensor input must accept designated temperature measuring device. Due to different mass and size of rotary test heads, a higher electric or fluid heat compensation may be required to comply with the test cycle requirements.

3.1.2.3 Fume Hood or Vent. Appropriate industry approved construction and performance to prevent vapors as required by regulation.

3.1.2.4 Temperature Monitor. Computer controlled data analyzer capable of measuring in $-40\text{ }^{\circ}\text{C}$ to $150\text{ }^{\circ}\text{C}$ range to $\pm 3\text{ }^{\circ}\text{C}$ accuracy. Accepts designated temperature measuring devices.

3.1.2.5 Part Temperature Measuring Device. Capable of measuring in $-40\text{ }^{\circ}\text{C}$ to $150\text{ }^{\circ}\text{C}$ range to $\pm 3\text{ }^{\circ}\text{C}$ accuracy. For example; these two (2) thermocouples must meet requirements 3.1.2.5a and 3.1.2.5b.

- a. A Resistive Temperature Differential (RTD) or,
- b. American National Standards Institute (ANSI) Type J or Type T (blue), sheathed solid bare wire diameter (gauge) with wire insulation.

See 3.1.2.7 for thermocouple locations.

3.1.2.6 Device Capable of Counting Revolutions. Count/record the total number of shaft rotations using an encoder to measure speed. Dynapar brand, model number H23036010024E, meets the requirements.

3.1.2.7 Thermocouple Locations. Use thermocouples to monitor, maintain and record fluid media inlet temperature to achieve the Table 6 fixture temperatures. Thermocouple (T/C) at the oil inlet to the spray ring or immersed in oil near the bottom of the rotary test unit. For test facilities heating the test head, for the thermocycle conditions (see 4.2.2.2) mount a T/C to control the band heater around the rotary test unit.

3.1.2.8 Fluid Circulatory System.

3.1.2.8.1 Reservoir. External to thermal chamber with sufficient volume capacity to accommodate fluid expansion. A typical capacity is 4 L to 10 L (1 gal to 3 gal) depending on the number and size of components tested. Reservoir is fabricated from non-reactive material to fit the requirements. The setup must be capable of maintaining test fluid temperature within $\pm 3\text{ }^{\circ}\text{C}$. Heat must be supplied so that the test fluid is warmed uniformly. Acceptable methods are immersion heaters, external electrical heaters with wall temperature controllers or circulation of externally heated fluid. Chromalox (Emerson Electric) or Mohawk units have a thermocouple for controlling/monitoring fluid temperature leaving fluid pump. A high limit thermocouple to monitor reservoir fluid temperature and shutdown the system is recommended. Float level controls with alarm to prevent overflow or overflow are optional.

Note: Use the minimum amount of oil needed to maintain the proper fixture fluid feed rates. This promotes reservoir oil degradation by oxidation and heat. Maintain Table 1 test conditions.

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Table 1: Functional Tests and Conditions

Test	Type/Equipment	Purpose/Description	Evaluation Criteria
Sealrater			
Test A	General Performance Gas and Diesel Engine/Rotary Test Unit	To screen new designs and a quality control for evaluating material, new tool and process changes. The assembly, including gasket/seal, fasteners and structural interfaces is cycled thermally, while the shaft speed is held constant and the lip is exposed to a constant level of oil (see Table 7, fluid level).	Oil Leak
Lifetime Durability			
Test B1	Durability Gas Engines/Rotary Test Unit	To evaluate the durability of oil seals under high speed and low lubrication. The assembly, including gasket/seal, fasteners and structural interfaces is cycled on a thermal and rotational schedule while oil is sprayed internally. The effect of crankcase pressure and vacuum on seal durability is part of the test schedule. Pressure represents naturally aspirated and charged engine applications.	Oil leak at shaft Oil leak around crankcase Shaft wear Seal lip conditions: crack, hard, tear, wear, soft, debris in grooves, and coking
Test B2	Durability Diesel Engines/Rotary Test Unit	To evaluate the durability of oil seals under moderate speed. The assembly, including gasket/seal, fasteners and structural interfaces is cycled on a thermal and rotational schedule while oil is sprayed internally. The effect of crankcase pressure and vacuum on seal durability is part of the test schedule. Pressure represents naturally aspirated and charged engine applications. For all diesels except Duramax.	Oil leak at shaft Oil leak around crankcase Shaft wear Seal lip conditions: crack, hard, tear, wear, soft, debris in grooves, and coking
Test B3	Durability Diesel Engines/Rotary Test Unit	Same as Test B2. Duramax only.	Same as Test B2
Dust			
Test C	Environmental Contamination Resistance/Rotary Test Unit	To evaluate the durability of oil seals to dust. The assembly, including gasket/seal, fasteners and structural interfaces are exposed to a specified mixture of airborne contaminants (Arizona Dust) while the shaft rotates and oil is sprayed internally. It is desirable to represent the dust-exclusion function of the damper itself on this test, either using the actual damper or a test part that provides similar characteristics.	Oil leak at shaft Oil leak around crankcase Shaft wear Seal lip conditions: crack, hard, tear, wear, soft, debris in grooves, and coking
Slurry			
Test D		Newton millimeters (N/mm).	3 minimum
Oil Pressure Limit Boundary Condition			
Test S	Screening/Rotary Test Unit	Maximum pressure the seal lip begins to lift or leak oil.	Vent pressure limit

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3.1.2.8.2 Pump and Heater; Oil, Circulating. A typical capacity is 24 L per minute (6 gal/minute), 35 kPa to 105 kPa (5 psi to 15 psi) pressure range. Chromalox (Emerson Electric) or Mohawk units meet the requirements. The pump is mounted to the feed line between the reservoir and rotary test unit.

3.1.2.8.3 Secondary Pump (optional). A ½ Horsepower (HP), 110 V mounted on fluid return line from test head drain to reservoir.

3.1.2.8.4 Spray Ring (see Table 1, Test B1 thru Test B3). A 135 mm spray ring. Provisions in the rotary test unit must permit fore to aft positioning for a proper fluid spray. The fluid entry connection to the ring may be shaped to provide ring location flexibility provided the required spray pattern is achieved and no fluid leaks from the connection. The spray ring face is beveled inward to the inside diameter to permit some oil spray toward the seal to shaft interface. Holes flush mounted to the face direct oil forward toward the seal adapter plate. There are more holes at the top than bottom of the ring. See spray ring Appendix B, Figure B1 front and Figure B2 rear.

3.1.2.8.5 Delivery Lines; Supply and Return. Use compression, pipe threads or flare fittings for all connections. Use 15.7 mm (0.62 in) Inner Diameter (ID) 13 mm (½ in) National Pipe Thread (NPT) minimum rated above maximum system test pressures and pulses, and 9.5 mm (¾ in) ID, 13 mm (½ in) OD, optional minimum for test heads of small depth. For lower pressure media systems, non-corrosive, rigid stainless steel lines with quick connect end fittings are possible.

3.1.2.8.6 Valves and Pressure Gauges. Locate solenoid valve between the reservoir and rotary test head to prevent oil starvation/surging during startup and preheat conditions. Closed loop function preventing oil from getting to the test head.

3.1.2.8.7 Supply and Return Lines. These components are made from non-corrosive material(s) that withstand the fluid, temperature and pressure environment of this test. Rotary test units have single fluid entry/exit accommodating up to two (2) seals. The system design and features must maintain suitable fluid pressure to permit proper internal spray pattern with gauging and flow meters to confirm and control settings.

3.1.2.9 Data Acquisition System. A recording system to gather and store data from the measurement system sufficient to document that the test was run in conformance with the specification (i.e., that speed and temperature set points were achieved and held for the specified time). See Section 8 Coding System for list of parameters.

3.1.2.10 Changes in Test Equipment. As components are replaced, newer versions represent changes that could alter a test cell result. The GM Powertrain technical specialist shall be notified of any equipment changes in a timely manner and any proper steps taken to determine the effect (if any) on the test. Once reviewed, a written change approval is provided by the GM technical specialist and kept in the test lab records.

3.1.3 Test Vehicle/Test Piece. The minimum number of specimens is required for each test. See 3.1.4 for Table 1, Test A, Test B1, Test B2, Test B3, Test C, Test D and Test S test timing requirement.

3.1.4 Test Time. See Table 1 for test reference.

	Test A	Test B1	Test B2	Test B3	Test C	Test D	Test S
Calendar time:	Not applicable	12 weeks	12 weeks	16 weeks	Not applicable	4.5 days	2 days
Test time:	360 hours	Not applicable	Not applicable	Not applicable	480 hours	97 hours	1.2 hours
Coordination time:	48 hours	168 hours	168 hours	168 hours	48 hours	24 hours	24 hours

3.1.5 Test Required Information. Only GM Powertrain or designate approved labs are qualified to run validation tests. Site certificates are issued every four (4) years listing the qualified tests. New candidates are added upon successful completion of blind sample testing with a qualified site.

3.1.6 Personnel/Skills. Conforms to company requirements. Technician training records must be available upon request.

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3.2 Preparation.

3.2.1 Sample Inspection.

3.2.1.1 Gather the subject components and inspect to ensure compliance to Table 2.

3.2.1.2 Identify each seal with a permanent serial number in easily visible location.

3.2.1.3 If multiple cavity tools are used, note which cavity on each component.

3.2.1.4 Recording Information. Report 3.2.1.1 thru 3.2.1.3.

3.2.2 Sample Preparation.

3.2.2.1 Oil Seal. For single element garter spring and laydown lip designs. Occasionally seals are integrated into cover assemblies and not into a bore groove. To evaluate this "assembly" a portion of the cover may be machined or milling away maintaining the seal to cover envelope and then mounting it in a bore plate that mounts to the test head. In situations where this is not practical, the seal shall be tested independently.

3.2.2.1.1 Grease Removal. For test seals shipped with grease, remove and save the grease that interferes with part measurement. Make the grease-free measurements, then reapply the grease to production part intent before running Table 1 tests. No grease residue from the removal or reapplication process is permitted on the tested seal surfaces unless specified.

Test seals may be shipped grease free, measured then shipped back for production grease application. The grease applied seals are then returned for Table 1 testing.

3.2.2.2 Seal, Shaft and Housing Cleanliness. All test parts must be clean to Production Intent Requirements (Level 1 Cleanliness) and free of surface defects (e.g., pitting, rust, burrs, nicks, gouges, etc.)

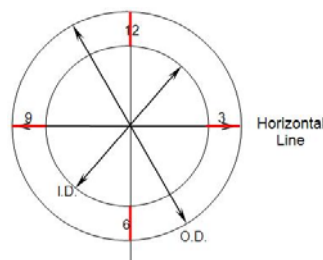
3.2.2.3 Measure the dimensional characteristics in Table 2.

Table 2: Measurement Criteria for Radial Lip Seals

Operation	Measurement	Measurement/Procedure	Units
1	Main Sealing Lip Inner Diameter (Garter Spring Only)	Optical Comparator, Plug Gauge or Coordinate Measurement Machine (CMM) with Video Probe	Millimeters (mm) as Shown in Figure 1
2	Inner Diameter of Minor/Dust Lip	Optical Comparator, Plug Gauge or CMM with Video Probe	mm
3	Outer Diameter	Vernier Caliper, Micrometer, Optical Comparator, or CMM with Touch Probe	Millimeters (mm) as Shown in Figure 1
4	Main Lip to Shaft Radial Force (Circumferential Sum). Allowed to Test Seals From Same Batch For Pretest Measurements	Radial Load Meter. New and Aged Specimens. Thirty (30) s delay. Association of Rubber Producing Manufacturers (ARPM) OS6	Newtons of Force (N_f) in Designated Measurement Time Delay
5	Concentricity Seal Lip and Outside Surface	Optical Comparator, or CMM with Touch or Video Probe	Millimeters (mm) in Figure 1 Range of Red Line Distances at 3 o'clock, 6 o'clock, 9 o'clock and 12 o'clock Positions Minimum

Key: N_f is newtons of force per OS-6 (the measure of radial lip force).

Figure 1: Seal Measurement Locations



Key: OD = Outer Diameter.

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3.2.3 Shaft Preparation.

3.2.3.1 Production Test Shaft. Validation tests require the intended production shaft surface, production crankshaft and/or damper hub. The shafts and housings are to be selected to represent the limits of the manufacturing process. Production shafts should not vary much with dimensions at nominal or the lower specification limit. The specifications vary for each application and must be obtained from the release/validation engineer. If modifications are made, the test shafts and housing bore may be altered dimensionally but must still conform to the original specifications for surface finish, hardness, machine lead and roundness using production intent process equipment. See Table 3 and 4.1.1.3 and Appendix C, Section C1.

3.2.3.1.1 Discard any production test shafts that do not conform dimensionally or that have surface defects at the intended seal contact test location. Defects in non-test locations are permitted provided they present no mounting or running problems during the test schedule.

3.2.3.2 Machined Test Shaft. If production test shafts and housings, to run all GMW3157 tests, are not available at the time validation must be performed see Appendix E, Table E1, Note 2, the characteristics described apply to crankshaft and damper hub test shafts. If the supply of available production shafts is limited, run the Table 1 durability, Test B1 (see Table 8), Test B2 (see Table 9) and Test B3 (see Table 10). The test part quantities are identified in each table. All test shafts for crankshaft seal validation per GMW3157 will follow common surface finishes and the supported measurement techniques to verify they are acceptable.

3.2.3.3 Before testing, measure the test shaft per Table 3. Use the Crankshaft Material Specification as identified by the supplier or off the print.

3.2.3.4 Shaft Balance Procedure. To extend bearing life, control vibration and maintain shaft Dynamic Run Out (DRO) tolerance for the duration of the test, use geometrically balanced test shafts for rear crank seals that specify dynamic run out > 0.1 mm combined with periods of high speed (see Table 7, Table 8 and Table 9.) See velocity limits per ISO 2372. Balancing is typically not required on smaller front crank seals, but the final determination is a function of the equipment design where two (2) components rotating at different revolutions per minute may amplify the vibration level as their frequencies overlap creating harmonic peaks.

3.2.3.4.1 The tester has the option of using static or dynamic balancing techniques. Static or single plane uses a balancing model applied to only one (1) component (the shaft). This technique removes weight to cancel out the off-center mass associated with the high side of the DRO during the fabrication of the test shaft. Dynamic techniques balance the entire system covering the sum of all rotating components using an accelerometer and condition monitoring software. However, rather than removing weight, weights are added.

3.2.3.4.2 Verifying the effectiveness of the balancing procedure can be by a dynamic run out excursion using a high speed proximity probe and high speed data acquisition. The dynamic run out is compared to the static run out throughout a speed range of 0 r min⁻¹ to 8000 r min⁻¹ (0 rpm to 8000 rpm). The second method uses an accelerometer which can be as simple as a vibration pen placed on the test machine bearing housing. Conformance to shaft DRO requirements can then be determined.

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Table 3: Shaft and Bore Finish Requirement

Row	Shaft and Bore Condition	Value (Includes Print Tolerances)	Measurement	Default	Notes
1	Shaft Machined Lead	No measurable lead unless agreed upon by tester and requester	Lead angle conducted in accordance to Appendix C, C1.8.1	Lead angle to be less than ± 0.05 degree	Follow print direction on lead pumping cross section and lead depth.
2	Shaft Surface Roughness Use Bill of Material (BOM) and Use Print Recommendations	R_a , R_z and R_{z1} maximum (optional) R_{mr} minimum and maximum same as those of the production engine shaft	Use production finish shaft. Condition must conform to ISO 4287 or ASME B46 or GMW16676. Measurement cut-off = 0.80 mm 90 degree diamond tip stylus Ball Size = 2.0 μ m Styleless Type = Skidless Filter Type = M1 Digital Gaussian or Gaussian	BOM for new engines Production intent print if available	Plunge grind finish is permitted if production shafts are not available. Other finish methods shall be agreed upon between tester and requester. Refer to drawing as requirements may change over time.
3	Shaft Surface Hardness (minimum)	Minimum hardness same as those of the production engine shaft	Use Rockwell C Hardness Tester (Rc) per ASTM E18.	As Received Rc per Drawing	Shaft surface hardness per production intent. Note: Rockwell C is not relevant for all shaft materials.
4	Carrier Housing Surface Roughness	R_a , R_z and R_{z1} maximum minimum and maximum same as those of the production print.	Use production intent part carrier finish. Measure perpendicular to machining marks. Measurement to GMW16676. Measurement cut-off = 0.8 mm 90 degree diamond tip stylus Ball Size = 2.0 μ m Styleless Type = Skidless Filter Type = M1 Digital Gaussian or Gaussian Reference ASME 95	Use GM Bill of Material for new engines Part Print Requirements if available	Check with release engineer or tech specialist as requirements change over time.
5	Roundness with and with out Flywheel ^{Note 1}	Millimeters (mm) Maximum with flywheel same as those of the production engine shaft	Minimum zone center method or diametric method	Use GM Bill of Material for new engines Part Print Requirements if available	Row 6 and 7: Flexplate/flywheel not necessary to mimic shaft distortion, only production-intent bolts and thickness of flexplate/flywheel at crankshaft interface. Shim stock may be used to transfer bolt loads to crankshaft.
6	Carrier Housing Roundness	As per print or Drawing.	Minimum zone center method or diametric method	Not applicable	Not applicable.

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Row	Shaft and Bore Condition	Value (Includes Print Tolerances)	Measurement	Default	Notes
7	Crankshaft Flange and Damper Hub Porosity within Seal Contact Area	No porosity allowed. Flange Porosity within sealing bead OD contact area: Less than 0.5 mm diameter, 3.0 mm minimum spacing. Non-connecting speck porosity less than 0.25 mm acceptable. Pores closer than 3.0 mm minimum spacing considered a single pore	Not applicable	Per production intent drawing Bill of Material/Bill of Design (BOD) on new engines	Row 8: Crank flange/damper hub porosity: None allowed. Additional text for bore surface. Bore only. Scanning Electron Microscope (SEM) is good method to evaluate porosity.
8	Nodules on Surface During Machining.	No standard measurement.	Not applicable	Not applicable	Count per mm ² . Cast Iron only. A maximum level is desired for acceptability. Spring loaded seals. Camshaft and Crankshaft Rear (RR).

Note 1: Four (4) μm maximum without and 12 μm maximum with flywheel.

Key: R_a = Arithmetical Mean Roughness, R_z = Average Peak to Valley Height, R_{z1} maximum = Maximum Surface Roughness, R_{mr} = Material Ratio of the Profile, RR = Rear (GM Print Nomenclature for Rear), R_c = Rockwell C hardness Tester. (See 6.1 for further explanation).

Table 4: Finish Requirements for Running Contact Surfaces Note 1, Note 2, Note 3

Running Contact Surface	Material Reference	Material Reference	Material Reference	Reference
Crankshaft	Cast Iron	Steel		DIN 3761
Test Finish Process	Plunge Grind, Paper Polish			Lay of grind to be the same direction as seal relative movement on the shaft.
Camshaft	Grey Iron	Steel		
Test Finish Process	Plunge Grind, Paper Polish			Lay of grind to be the same direction as seal relative movement on the shaft.
Torsional Damper	Cast Iron	Steel	Aluminum	Lay of grind to be the same direction as seal relative movement on the shaft.
Test Finish Process	Diamond Hone, Plunge Grind, Turned (Cast Iron/Steel), Paper Polish			Per Part Print
Cartridge Sleeve		Stamped Steel Coated		Purchased Assembly
Test Finish Process		As received		As stamped, turned or ground

Note 1: This table provides preparation information for the finish on which a seal will be tested when production representative parts are not available.

Note 2: The materials for each part or component represent those in current production.

Note 3: At the time of testing a production intent print containing finish requirements may not be available. In such cases, testing cannot proceed until the GM Design Release Engineer provides the minimum required measurement parameters identified in GMW3157 Table 3.

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3.2.4 Test Units. A unit is one (1) seal on one (1) test shaft with spray ring. One (1) or more units may be used with a thermal chamber. Band heaters are permitted around the test head. A maximum of two (2) test units are permitted with a common fluid reservoir.

3.2.5 Test Media.

3.2.5.1 Use only the engine oil specified on the Production Print for that seal. If an older 998 number is on the drawing, use current GM Worldwide (GMW) production factory-fill fluid replacement for that engine. Use anyone of the multiple approved oil sources for the GMW fluids listed in Table 5. Once an approved oil source is selected for testing, all follow-up testing if needed (e.g., due to a design/material change) to complete a single seals validation to this document should use the same source, viscosity and grade. Use the appropriate test conditions in Table 1.

3.2.5.2 Add appropriate dye to test fluid for Ultraviolet (UV) inspection. As oil is changed, new dye must be added. Commercial dyes vary in concentration so adjust the amount used to achieve the desired response with the UV light output.

Service Parts Organization North America, use Dye-Lite TP-3400 IR (88861206 GM Service Part for Indicator Dye) or Dye-Lite TP-3400 (88861276 GM Service Part for Indicator Dye) for oil and oil-based fluids (available at 6200 Grand Pointe Drive, Grand Blanc, Michigan 48439).

Instructions provide the suggested dilution ratio.

- a. Gasoline Engine Oil: 14.8 mL per 3.78 L to 5.76°L (0.5 oz per 4 quarts to 6 quarts).
- b. Diesel Engine Oil: 14.8 mL per 3.78 L (0.5 oz per 4 quarts).
- c. Automatic Transmission Fluid: 29.6 mL per 11.35 L (1 oz per 12 quarts).

Note: If the oil is very dirty, you may need to add more dye to obtain a good fluorescent response (additional dye will not harm the engine).

3.2.5.3 Oil Changes. Note: Documented revisions to Table 5 may not keep pace with fluid changes. Before starting any test, contact the design responsible engineer, test lab and/or fluids material engineer to verify the correct current test media. A GMW3157 testing source is required to be aware of oil changes as they occur in GM Powertrain and to test to the new fluid changes within six (6) months of their initial planned release by GM Powertrain. Our intent is to have the testing started or completed before the new oil is released to the GM assembly plant as factory fill. This applies to seals already released for production using the earlier oil version but will be affected by the change to the new factory fill oil. An example is a change from Generation One (1) to Generation Two (2) of a GMW Dexos oil. Any adverse effects due to new oil exposure are to be immediately reported to the acting design release engineer.

Table 5: Test Media

Test Media	Type	Change Interval
Arizona Dust	ISO 12103-1 A2 Fine and Coarse Dust ^{Note 1}	None
Ultraviolet Dye Meeting 9985522	Not applicable	Once per Interval
Slurry	Equal parts of ISO 12103-1, Arizona Dust A2 Fine and A4 Coarse Dust in 10% by mass with potable water	Due to evaporation, refill with water every 24 h except on weekends
GMW17332 (0W-20), (0W-30), (5W-20), (5W-30)	GMW17332 (default for improved low temperature flow)	Test time 336 h Adjusted to match time cycle
GMW16095 (5W-30)	GMW16095	Test time 336 h Adjusted to match time cycle
GMW16077 (0W-40)		

Note 1: Arizona Dust; Available from Powder Technology Incorporated, 14331 Ewing Avenue, South Burnsville Minnesota 55337.

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3.3 Conditions.

3.3.1 Environmental Conditions. Not applicable.

3.3.2 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.

3.4 Instructions.

3.4.1 Test Instruction Responsibilities of Design Release Engineer (Test Requester).

- Designate the required tests by document number and letter (see 8 Coding System).
- Supply representative parts (1.2.6).
- Designate shaft and bore finish (3.2.3), finish requirements (Table 4), and test media (Table 5).
- Any deviations in test conditions (3.3.2) or Table 6 assembly conditions.
- Frequency of system integrity checks (4.1.1.8).

3.5 Data. Reports shall include any portion of this document using the words measure, measurement or record in the appropriate manner. Examples include but are not exclusive to; seal part number, dimensions, 3.7 Documentation, Table 3 surface finish measurements in 3.2.3, Production (see 3.2.3.1) or Machined Test Shaft (see 3.2.3.2), Table 4 finish method of the test part, 4.1.1.8, 3.2.5 Test Media with Table 5 used. (Note: Documented revisions to Table 5 may not keep pace with fluid changes. Before starting any test, contact the design responsible engineer, test lab and/or fluids material engineer to verify the correct current test media.) Identify assembly conditions used, see Table 6.

3.6 Safety. This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

3.7 Documentation. Samples of components or material released to this standard shall be tested for conformity with the requirements of this standard and approved by the responsible GM Department prior to the start of delivery of production level components or materials.

Any change to the component or material, e.g., design, function, properties, manufacturing process and/or location of manufacture requires a new release of the product. It is the sole responsibility of the supplier to provide the customer, unsolicited, with documentation of any change or modification to the product/process, and to apply for a new release.

If not otherwise agreed to, the entire verification test shall be repeated and documented by the supplier prior to start of delivery of the modified or changed product. In some cases, a shorter test can be agreed to between the responsible GM department and the supplier.

3.7.1 Test Results. See 1.3.2.

4 Requirements and Procedure

4.1 General.

4.1.1 Installation Position.

4.1.1.1 Spray Ring (Test B1 see Table 8 and Test B2 see Table 9 and see Table 1). Locate inside the rotary test unit the ring with holes facing forward to maintain the required fluid exposure to/at the face plate. Alternative holes allowing oil to contact the seal to shaft interface are permitted. The ring must not move during the test. See 3.1.2.8.4 Spray Ring and Appendix B, Figure B3.

4.1.1.2 All connections must be leak free. Use leak detection fluid and drip trays to monitor joints. Seal the test head (block off all external leak paths) so only the desired fluid inlet and outlet and vent are open.

4.1.1.3 Install components in the test head in the designated orientation per tester and requester (see Table 6). Since the seal dimensions are "as received", the mating surfaces are modified and tested to represent the limits of the shaft-to-seal and seal-to-housing conditions. Use the limiting values specified in Table 6 for the application

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unless data analysis suggest the use of other tolerances (deviations from given values must be approved by release and validation engineers).

Table 6: Assembly Condition Requirements (Front and Rear) ^{Note 1}

Row	Assembled Condition	Value	Measurement	Note
1	Shaft Eccentricity - Dynamic Run Out (DRO)	0.20 mm TIR ± 05 mm TIR	Measure the shaft eccentricity using the dial gauge on the test shaft	Dynamic centerline offset. Deflection of the shaft. Adjust the shaft eccentricity using the tester control. The value provided is Bill of Material (BOM) compliant at publication, however, use the latest version of BOM at Sealing and Fastening web site.
2	Shaft to Bore Misalignment (STBM)	0.50 mm TIR ± 05 mm TIR	See Figure 9: Shaft to Bore Misalignment	Static centerline offset. Seal with respect to the shaft center. The tester has eccentricity control dial gauge to move the seal center down.
3	Seal to Housing Axial Alignment (installed)	Seal Squareness (Seal Cock): Crankshaft and camshaft seals. Front and Rear. 0.08 mm per 25 mm of outer seal diameter. Tolerance ± 10% of calculated seal cock.	Inclination is the difference between maximum and minimum measurements of the distance from the edge of the housing to the flat center of the seal crankcase leading edge around the seal periphery. Flatness of Rear Seal Cover: 0.025 mm on all portions of the surface within a 100 mm diameter 0.05 mm overall length	Unitized Seal: Fore to aft "cocked" or squareness at installation. The gauge resolution shall be at least ten times the specification limit resolution. For integrated module retainer. Test as received. Seal exceeding 100 mm OD the seal cock limit is 0.3 mm maximum.
4	Seal to Housing Assembly	For Sealrater Test A, (see 4.2.2) minimum interference Durability Table 8, Test B1 and Table 9, Test B2 minimum and maximum	Two (2) at minimum and One (1) at maximum	Static seal to housing. Minimum for low- limit retention loads and maximum for maximum internal stress (elastomeric OD) evaluation. This maximum int. fit will capture high comp-set condition for elastomeric designs.

Note 1: Unless otherwise specified these Table 6 requirements are default values for testing the application (Design Release Engineer (DRE)/Print).

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4.1.1.4 Install test head(s) in environmental chamber with drip tray and plumb according to the schematic shown in Appendix A, Figure A1 and Appendix A, Figure A2 diagrams.

4.1.1.5 Connect fabricated external fluid reservoir with volume sufficient to accommodate fluid expansion. The test fluid capacity varies; 4 L to 10 L (1 gal to 3 gal) capacity is typical, depending on the number of fixtures in the circuit.

4.1.1.6 A 70 kPa $\pm$ 10 kPa (10 psi) supply line pressure usually provides sufficient spray pattern for oil, depending on the number of fixtures in the circuit. Control by flow. Each fixture must have sufficient drainage to prevent fluid from filling the fixture above the joint interface, unless specified by the requester. Parking angle provision.

4.1.1.7 Add dye to test fluid for Ultraviolet inspection. See 3.2.5.2.

4.1.1.8 The operator makes one final check of the integrity of the unit connections. Additional checks on later component changes should be discussed with the responsible engineer and noted in the test report.

4.1.1.9 Media Maintenance Intervals: See Table 5 required fluid change intervals for fixture testing.

4.1.2 Internal Oil Pressure/Vacuum in Rotational Test Unit.

4.1.2.1 During the durability test cycle it may be necessary to validate seal (front and rear) performance where pressure and vacuum in the crankcase exist, such as those engines at worst case operational conditions as part of the durability test cycle. If there is no pressure above atmospheric and/or vacuum, the test is not required. The test will be run at the Table 8 and Table 9 levels unless otherwise specified by the test requester.

4.1.2.2 Test Requirement (Pressure). Completed as part of durability test.

4.1.2.2.1 As shown in Appendix A, Figure A1, filtered plant air is regulated by valve and pressure switch to achieve 3.0 kPa $\pm$ 1 kPa (0.44 psi $\pm$ 0.14 psi) for five (5) minutes (using a programmed controller) during each 12 h cycle. This is the default range for all new or unknown engine crankcase conditions.

4.1.2.3 Test Requirement (Vacuum). Completed as part of durability test.

4.1.2.3.1 As shown in Appendix A, Figure A2, vacuum is delivered at 4.0 kPa $\pm$ 1 kPa (0.58 psi $\pm$ 0.14 psi) by pump, regulator and switch for five (5) minutes (using a programmed controller) during each 12 h cycle. This is the default range for all new or unknown engine crankcase condition. The system must be capable of reaching 14 kPa $\pm$ 2 kPa (2°psi $\pm$ 0.3 psi) vacuums if necessary.

4.2 Performance Requirements.

4.2.1 Ambient Conditions. All tests to be run at laboratory ambient conditions.

4.2.2 Sealrater Test A (Table 7).

4.2.2.1 Run six (6) seals to the hot schedule in Table 7 and one to the cold schedule for fifteen 24 h cycles (360 h) or until a failure is noted. Three (3) of the six (6) seals are run at zero STBM and no cock to evaluate the potential for excessive line to line contact pressure.

4.2.2.2 Test temperature control is maintained using the oil temperature monitoring thermocouple. Locations must be inside the test head below the fluid level or at the oil entry or exit points of the test head.

4.2.2.2.1 Optional Temperature Monitoring. Rotary test unit head air temperature, fluid reservoir, or radial seal lip.

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