



Elastomers for High Temperature Fluid Sealing Applications

1 Scope

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

Note: In the event of conflicts between the content/intent of this document and a supplier version, this and only this document shall take precedence.

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

This specification covers elastomers used in static sealing of high temperature gasket and seal components (e.g., turbo, exhaust gas recirculation, etc.) in engine oil or coolant. For high temperature application requirements specific to turbo charging see GMW16189 Sealings in Turbo Charger Applications.

1.1 Material Description. Materials covered by this specification are divided into Classes and Types of oil and coolant resistant elastomers. Table 1 describes the Class (Class A, Class B, etc.) of elastomers meeting the designated temperature range and Type 1 and Type 2 meeting the designated application of gasoline or diesel engine. Part performance requirements are in 3.8 and Table 6. See 1.4 Remarks.

Table 1: Material and Application Criteria Designation

Class	Type	Temperature Range (Degrees Celsius) Note 1	Application	Elastomer Note 2	See Table
A	1	-14 to 225	Gas Engines. Oil, high pressure. High tear, high 5% to 10% fuel dilution resistance.	FKM/FPM	4, 5, 6
A	2	-15 to 200	Diesel Engines. Standard use for oil exposure.		
A	3	-15 to 225	Gas Engines. Standard use for oil exposure, high pressure. Moderate tear, moderate 5% to 10% fuel dilution resistance.		
A	4	-15 to 200	Diesel Engines. Standard use for oil exposure.		
B	1	-29 to 200	Gas Engines. Better low temperature and fluid resistance, improved elongation and tear. Oil only.		
B	2		Diesel Engines. Better low temperature and fluid resistance, improved elongation and tear. Oil only.		
B	3		Gas Engines. Better low temperature and fluid resistance. Oil only.		
B	4		Diesel Engines. Better low temperature and fluid resistance, improved elongation and tear. Oil only.		

Class	Type	Temperature Range (Degrees Celsius) Note 1	Application	Elastomer Note 2	See Table
C	1	-25 to 180	Gas Engines. Improved coolant resistance. Coolant only.		
C	2		Diesel Engines. Improved coolant resistance. Coolant only.		
C	3		Gas Engines. Standard use for coolant only.		
C	4		Diesel Engines. Standard use for coolant only.		

Note 1: As defined by ASTM D1329, TR10 and SAE J2236 respectively.

Note 2: Nomenclature as defined by ASTM D1418 or ISO 1629.

Key: Fluorocarbon Rubber (FKM/FPM).

1.2 Symbols. Identify the elastomer nomenclature using ASTM D1418 or ISO 1629.

1.3 Applicability. See Table 1. Press-in-place and O-ring elastomers with high immersion test temperatures. Only parts fitting the scope and application may use this specification.

1.3.1 Table 1 currently represents compounds in the 70 hardness range to 80 hardness range.

1.4 Remarks. Approved compound properties for each type of elastomer are listed in Table 4, Table 5 and Table 6. Table values by type are a compilation of data from multiple approved compounds and hardness ranges.

1.4.1 For fluorocarbon rubber (FKM/FPM) polymer types, in methanol and ethanol diluted conditions, the percent fluorine level is most important. In biodiesel diluted conditions with oil, the cure type and no metal oxides take precedence over percent fluorine.

1.4.2 This global standard was developed with careful consideration to cost containment, legal considerations, best practices, lessons learned, etc., to establish consensus material quality and performance. Because this is a global standard, the elastomer supplier is only required to generate data for the initial approval using the CG5498; High Temp Data Sheet for this standard, avoiding numerous regional and divisional requirements and expense.

1.4.3 Turbo System Oil Pressure. The oil impulse pressure conditions can reach 1400 kPa $\pm$ 100 kPa, (14 bar $\pm$ 1 bar or 203 psi $\pm$ 15 psi) for the 5 s of oil circulation which occurs immediately following cold start-up. Expect oil pressure at 800 kPa $\pm$ 100 kPa (8 bar $\pm$ 1 bar or 116 psi $\pm$ 15 psi) during circulation.

1.4.4 Turbo System Coolant Pressure. The maximum coolant impulse pressure conditions can reach 517 kPa $\pm$ 50 kPa (5.2 bar $\pm$ 0.5 bar or 75 psi $\pm$ 7 psi) which occurs immediately following cold start-up. Expect coolant pressure at 150 kPa $\pm$ 50 kPa (5.2 bar $\pm$ 0.5 bar or 22 psi $\pm$ 7 psi) during circulation.

1.4.5 O-rings. Some prints/drawings identify "D" or race track shapes as O-rings. To avoid confusion, testing and table data only apply to the ASTM D1414 definition of an O-ring.

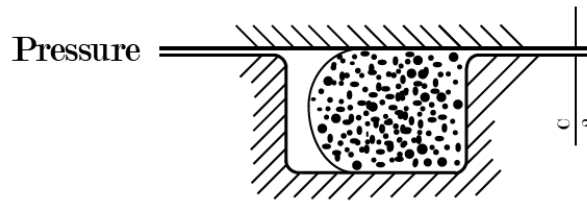
1.4.5.1 Tensile and elongation properties of O-rings are measured by spool separation, however, during this step, the elongation across the specimen width is not uniform. To minimize data variation, the recommended ratio of O-ring inner diameter (ID) to cross section width should be a ratio of nine (9) to one (1) or greater (see Table 3).

Note: The ratio for SAE AS568, the 214 size is seven (7) to one (1).

Of greater interest is tensile stress at 20% elongation to 50% elongation because it is closer to the insertion and removal performance of the O-ring.

1.4.5.2 For a 70 hardness compound to an 85 hardness compound, the maximum fluid pressure limit applied to an O-ring is 10.3 MPa. A back-up ring is preferred at a 7.8 MPa (78 bar or 1 131 psi) pressure or higher. The maximum joint gap, see Figure 1, for a 70 nominal hardness compound without an additional/back-up O-ring is 0.15 mm at 7.8 MPa maximum pressure and 0.35 mm for 3.4 MPa maximum pressure.

Figure 1: Joint Gap



2 References

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

2.1 External Standards/Specifications.

ASTM D92	ASTM D1505	ISO 48	ISO 7619-1
ASTM D297	ASTM D2240	ISO 815	ISO/IEC 17025
ASTM D395	ASTM D3182	ISO 1101	SAE AS568
ASTM D412	ASTM D3677	ISO 1629	SAE J1351
ASTM D471	ASTM E1131	ISO 1817	SAE J2236
ASTM D624	ASTM SF105	ISO 2781	SAE J2979
ASTM D1329	IATF 16949	ISO 2921	TR10
ASTM D1414	IEEE/ASTM SI 10	ISO 3601	
ASTM D1415	ISO 34-1	ISO 4650	
ASTM D1418	ISO 37	ISO 7111	

2.2 GM Standards/Specifications.

GMW3059	GMW15117	GMW16955	GMW17821
GMW3155	GMW16317	GMW17113	
GMW14270	GMW16678	GMW17205	

2.3 Additional References.

- Appropriate Industry Statistical Standards, Methods or Practices requiring a minimum of n=30 data points
- Association for Rubber Product Manufacturers (ARPM) Handbook
- Association for Rubber Product Manufacturers (ARPM) Indianapolis, Indiana (arpminc.com)
- Association for Rubber Product Manufacturers (ARPM) Inspection Guide Publication (OR-1)
- Automotive Industry Action Group (AIAG) D-22, Best Practice, (Note: The supplier shall work with the GM Design Responsible Engineer to comprehend this requirement), Unified Procedure for approval of rubber and plastic formulation ingredient changes. AIAG at 26200 Lahser Road, Suite 200, Southfield, Michigan 48033-7100
- Automotive Industry Action Group (AIAG) D22 Template, available from GM Global Propulsion Systems Materials Engineering
- CG5498 High Temp Data Sheet
- Component Technical Specification (CTS)
- Detail Drawing
- Environmental Protection Agency Stewardship Program
- GM Supplier Production Change Request (SPCR), available from GM Global Propulsion Systems Materials Engineering
- GMW17978 Test Matrix, available from GM Global Propulsion Systems Materials Engineering
- Hyper-realistic GM Material Property Database for Finite Element Modeling

- Part Drawing
- Production Part Approval Process (PPAP) (Appendix C)
- Relevant Test Procedure
- Safety and Industrial Hygiene (S&IH) Technical Standard (TS), S&IH TS 3.4-160-02
- Statement of Requirements (SOR), Appendix D (Elastomer Finite Element Data Request Form)
- United States Environmental Protection Agency Stewardship Program

3 Requirements

3.1 Compound Characterization for Finite Element Modeling. All elastomeric compounds qualifying to this standard must be entered into the hyper-realistic GM Material Property Database for finite element modeling unless otherwise specified as not required by the Component Statement of Requirements (SOR) or Component Technical Specification (CTS). If no SOR or CTS exists for elastomer compounds or a Finite Element Analysis (FEA) requirement is not listed, the default is to require FEA data collection. See Table 2.

Axel Products, Incorporated is GM's sole global contract test facility as the equipment and test methods used are unique and confidential. Data developed for FEA purposes by another test facility is not recognized. The Material Submission with the Elastomer Finite Element Data Request Form SOR Appendix D Other Requirements Template is submitted with each elastomeric compound. Follow the form instructions. Sealant approval cannot proceed without a submission for FEA characterization.

Table 2: Candidate Compound Requirements for Finite Element Analysis (FEA) Modeling Data

Part or Component Design Level	Compound Readiness at Submission Time	Intent	Requirements at Time of Characterization ^{Note 1}
Design Development, Production or Production Intent	Available from production batch process only.	Represent properties from each mixing location(s).	One or more of the following: • Production drawing content met • Production Part Approval Process (PPAP) started or successfully completed • Design development before tooling and parts tested • Satisfies all relevant GM documents • Compound selected for production intent process and design

Note 1: All validation testing including GMW3155 may not be completed at the time of compound characterization. Maintaining entries in the database will be reevaluated if the compound was the reason for a non-compliance to test requirements.

3.1.1 Minimum Data Requirements. Due to the high-cost of these elastomer compound candidates, specification values (with noted exceptions) are statistically based on a six (6) sigma limit spread in normal distribution data from a minimum of three (3) production lots per compound mixing site and three (3) data points to five (5) data points per test requirement. Tentative approval, signified by the letter "T," will be given based on data from one (1) production and two (2) laboratory batches. Tier One (1) sources shall be responsible for continuing to submit data until the total number of samples is met for full qualifications as stated in the first line of this 3.1.1. Appropriate industry statistical standards, methods or practices requiring a minimum of n=30 data points should be used when generating data.

3.1.2 Elastomer Test Specimens Preparation. Specimens used to develop all table properties are die cut specimens from ASTM D3182 sheet stock molded to the same conditions as for actual products, with post cure if applicable. Precondition sheets at 50% relative humidity (RH) and 23 °C for at least 16 h before testing. As an option, specimens from non-post cure compounds may be used from production molds. Report the cure time and temperature conditions for all molded specimens on the CG5498; High Temp Data Sheet.

3.1.3 Number of Test Specimens. New elastomer approvals shall be based on the median of five (5) specimens per test unless otherwise specified. Tests designated as once for initial approval, not for further statistical analysis, shall be run on a minimum of three (3) specimens, with each specimen meeting the stated requirements. A CG5498; High Temp Data Sheet is available for this standard and will be used to submit all test results.

3.1.4 Test Frequency. Chemical requirements per 3.7.1, long term aging tests (i.e., ≥ 1008 h) in Table 4 and part performance requirements in Table 5 and Table 6, except part micro-hardness, shall be performed once for initial compound approval. Should the compound change as defined in 3.4, all tests shall be repeated.

3.1.4.1 The CG5498; High Temp Data Sheet indicates the data required for each test and number of production batches. Upon completion of the data requirements for table development, the approved compound source is only required to satisfy IATF 16949 requirements, Production Part Approval Process (PPAP) (Appendix C), and the approved suppliers internal test frequency. For statistical reporting of data, use the GMW17978 test matrix, available from GM Global Propulsion Systems Materials Engineering. Report all individual values.

3.1.5 Qualifying to Existing Table Requirements. Each candidate elastomer compound shall meet the Table 1 listed requirements. Individual compound property tests represent characteristics that are significant to the intended usage (see Table 1, temperature range and application columns). All Table 1 data can represent the collective property profile of more than one (1) compound and hardness. Therefore, it may be inappropriate to use this data for quality control of a single compound.

3.1.5.1 All elastomer approvals are granted based on ASTM D3182 sheet data. Part Table 1 testing becomes relevant for validation, audit, or field studies after the part is available and produced from production intent tooling. When more than one (1) production source or tool is providing parts, it is the Tier 1 source responsibility to evaluate parts from multiple mold cavities and tooling as required by the design and release responsible product engineer.

3.1.6 Global or Cross Regional Compounds. Compound formulations produced in more than one (1) mix facility but sharing a common compound identification, shall be subject to review. The level of testing and approval may be by polymer source and/or mix site depending on the variation permitted in ingredient selection and process conditions. Approvers are responsible for tracking and maintaining a log of the production compound and managing local variation as part of the formal approval process. Approval and material database records will capture the relevant mix locations.

3.1.6.1 Contingency. As part of the approval process, each compound supplier shall have a designated alternative mix operation. Compound from that location(s) shall be evaluated to 3.1.1 tentative approval conditions.

3.1.7 Document References and Changes. Use the latest published version at the time of submission for first approval. The following addresses whether an approved material still meets the standard when one or more of the procedures referenced in the standard changes after it was first approved.

3.1.7.1 Role and Responsibility. After first approval, if the referenced standard changes, GM GPS expects the tiered supplier (Tier 1, Tier 2, Tier 3, etc.) to monitor industry standard documents for changes and evaluate the impact of the change to determine if it affects required limits. GM is responsible for timely notification to suppliers of its own test standards referenced in this document.

3.1.7.2 New Data Requirements and Timing. A change herein is defined as procedural and/or a new limit or range requirement. Data is required only where the change level affects specified limits. The appropriate tier supplier is only required to test to a change(s) that occurred since the supplier's initial full data approval. Data must be submitted to GM GPS Engine Material Engineering within 180 business days of the published revision in GM Global Document Management (GDM) system (for GM Standards), or date document arrives at the external standards contract distributor. Time limits may be extended for regulatory health and safety issues only. No testing is required if the revised document has no changes (revision date only change) or if the changes do not involve fit, form or function as defined in GMW17205.

3.1.7.3 How Document Changes Affect Material Compliance. All product produced after the changes are published in GM Global Document Management shall meet the new requirements. Production ready compound (i.e., a fully tested and process capable formulation developed on production scale equipment. Currently in production and in use by automotive end users) approved under the previous edition requirements and already in the delivery pipeline or in inventory will be used until the product is used. Decisions involving regulatory changes will be handled separately, and existing product may be immediately removed as a result.

3.1.7.4 Any previously approved compound failing to meet the changing requirements will be removed from the GM Materials Approved Source List by the GM Powertrain Integration and Sealant Specialist Team.

3.2 Test Preparation and Evaluation.

3.2.1 Test Samples. Unless otherwise specified, the shape and size of test pieces shall be in accordance with the relevant test procedure and comply with 3.1.2.

3.2.1.1 Elastomer Test Specimens Parts. Only parts meeting minimum dimension requirements shall be tested to Table 5. (See GMW17821).

3.2.1.2 O-ring Specimens. Use the straight length or complete O-ring size limits specified in ASTM D1414 or ISO 3601 to qualify for finished part testing (see Table 5 and 3.2.8.1).

3.2.2 Property Requirements. In Table 4 and Table 5, follow the relevant test procedure requirements for test specimen selection if the compound is anisotropic or mill/flow direction is known. Report results in the direction as indicated per the relevant test procedure requirements. If no direction is indicated, test and report in the lowest result direction.

3.2.2.1 O-ring property limits for Table 5 are based on one of two sizes (see Table 3) use the size of the one closest to your production application.

Table 3: Standard O-Ring Sizes

Specification (Size)	Spool Diameter, millimeter (mm)	Test Pull Rate ± 25 mm/minute	Ratio of O-ring Inner Diameter (ID) to Cross Section Width in millimeter (mm) (see 1.4.5.1)
ISO 3601-1-111	3.18	152.4	4 to 1
ISO 3601-1-220	12.7	254	9.8 to 1

3.2.2.2 Sample preparation mold conditions are to be representative of mold conditions for production parts.

3.2.3 Conditioning. Condition as specified in the relevant test procedure.

3.2.4 Equipment. Conforming to the relevant test procedure.

3.2.5 Deviations. Only improvements (e.g., increase in test time, harsher test media, etc.) or corrections (e.g., publication error, missing information, etc.) from the requirements of this standard are permitted, provided there has been agreement between the tester and requester. Use of test procedure/condition deviations are considered temporary (up to six (6) months) until a consensus is reached and revisions made to this document by the sponsor. No specification limit deviation or test exemption(s) to accommodate material compliance to this standard is permitted on the production print or any relevant documentation by source or end user. All issues must be worked out through revision of this standard.

3.2.6 Test Fluids. Test parts (see Table 5) in designated fluids. Consult the GM engine fuel and lubricant group to obtain further approved fluid source information.

3.2.6.1 Immersion Testing in Fluids at Elevated Temperature. Test specimens must not contact each other or the sides of the vessels during immersion testing. Testing of coolant at the Table 5 temperatures requires a pressure vessel with pressure relief provisions. Pressure inside the vessel during the test must be maintained. A complete loss of pressure during or at the end of the test must be retested. The test temperatures were kept at 40 °C which is under the selected oil flash/fire point per ASTM D92 Cleveland Open Cup. Engine test oil oxidizes and thickens rapidly at temperatures beyond 145 °C. Use glassware and a condenser (see 3.2.6.2) for ease of clean-up.

3.2.6.2 Pressure Vessel for Coolant. Fuel dilution in oil requires GMW16678 equipment with the constant stirring of fluid during the test. Normally coolant immersion testing doesn't require stirring, however to meet the required property limits for these higher test temperatures stirring achieves thermal and mix uniformity and promotes aeration of the coolant. The pressure vessel caps should use perfluoro elastomers (FFKM) or polytetrafluoroethylene (PTFE) ring seals to minimize fluid evaporative loss. The total test fluid volume shall not exceed 60% of the internal pressure vessel volume including all the tested specimens. The ratio of test fluid volume to specimen volume is 35 ± 5 to 1.

3.2.6.3 Reaction Flask Glassware for Oil. See Figure 2. A one (1) liter reaction flask with flat flanges and bottoms (flange to bottom depth 165 mm minimum) are recommended for elevated temperature testing of specimens in oil. A flat flange reaction head with gasket has multiple standard taper necks with a 24/40 glass ground fitting. The conical reaction head with a 10/30 ground fitting for a thermometer to monitor test fluid temperature is recommended. Unused openings can be sealed with non-reactive plugs or fitted glass caps. Avoid using greases to the standard taper fittings that would contaminate the test oil. Do not allow the heated oil level to reach/exceed the joint between the flask and the head unit. The ratio of test fluid volume to specimen volume is 35 ± 5 to 1. The covered beaker and flask are placed in an air circulating oven at the Table 4 elevated temperature (175 °C).

Figure 2: Glassware for Physical Property Immersion Tests



3.2.7 Compression Set Testing of Parts (Table 5). Press-in-place gaskets shall be compressed lying on their side. Side stabilization features must be removed if occurring in the tested length. The minimum specimen width for testing shall be 10 mm minimum. Avoid grinding to reach parallel plane conditions that would introduce unwanted heat into the specimen.

3.2.8 Testing part tensile properties per Table 5 is only possible if ISO 37 Type 4 specimens can be cut from the production part. The remaining tests must be performed on test pieces provided the dimensions are suitable. See 3.2.1.1 and Appendix A, A1.2.

3.2.8.1 Testing O-ring Parts (Table 5). For O-rings in the 7 mm inner diameter (ID) to 100 mm ID range, select the test conditions for size and speed.

3.2.8.1.1 Test Spool Diameters.

- O-rings with < 12.7 mm ID shall be pulled on 3.18 mm diameter spools.
- O-rings from 12.73 mm ID to 25.40 mm ID shall be pulled on 6.35 mm diameter spools.
- O-rings > 25.40 mm ID shall be pulled on 12.7 mm diameter spools.

3.2.8.1.2 Test Pull Rate.

- O-rings with < 12.7 mm ID shall be pulled at 152.4 mm per minute.
- O-rings from 12.73 mm ID to 38.1 mm ID shall be pulled at 254.0 mm per minute.

c. O-rings > 38.1 mm ID shall be pulled at 508.0 mm per minute.

3.3 Test Units. Report data in the appropriate International System of Units using the Institute of Electrical and Electronic Engineers IEEE/ASTM SI 10 document.

3.4 Managing Change. Any change in cost, design, function, properties, manufacturing process, and/or location of manufacture to the component or material, requires a new release of the product. It is the sole responsibility of the supplier to immediately 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 before 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.

3.4.1 Change Characterization. Elastomer polymer or ingredient changes to the approved production compounds are made by submitting the Automotive Industry Action Group (AIAG) D22 Template, assigning a number(s) to the appropriate listed changes, and a GM Supplier Production Change Request (SPCR). GM report forms are available from GM GPS Engine Materials Engineering. Submit a completed D22 form to GM Powertrain Materials Engineering before submitting a SPCR.

3.5 Facilities. GM North America GPS Only. All data must be generated by an ISO/IEC 17025, IATF 16949 or GM accredited laboratory and certified to the test methods in this standard.

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

3.5.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this document shall be determined correctly with respect to its physical definition.

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

3.7 Additional Table Requirements.

3.7.1 Chemical Requirements Characterization Tests. To verify a match, compare a finished part or sheet specimen to the original validated compound, using one (1) or a combination of the following tests and the tests specified in Table 5 and Table 6.

3.7.1.1 Infrared Spectroscopy. ISO 4650 or ASTM D3677.

3.7.1.2 Thermogravimetric Analysis (TGA), Temperature Scanning Method. ISO 7111 or ASTM E1131, first derivative to determine composition.

3.7.1.3 Density or Specific Gravity. ASTM D297, hydrostatic method, ASTM D1505, density gradient or ISO 2781. Values shall be included on the part print with a ± 0.02 range for mass calculation.

3.7.1.4 Micro-hardness (Surface). Part micro-hardness measurements, per ASTM D1415 Type M or ISO 48 Method M. Surface measurements shall follow conditions 3.7.1.4.1 through 3.7.1.4.5. See GMW17821.

3.7.1.4.1 A 1.5 mm minimum specimen thickness. Specimen must be solid.

3.7.1.4.2 Measurements from an edge must be 2 mm or more.

3.7.1.4.3 Reading locations must be 6 mm apart, however the reverse side may be used.

3.7.1.4.4 The top and bottom surfaces must be parallel (< 5 degrees) and flat.

3.7.1.4.5 Repeat readings must be on the same cross-sectional thickness.

3.7.1.4.6 Test Area (Definition). The test area is the location of the specimen which the indenter is used. The surface to be measured is as molded, not buffed and uncut. The surface shall be smooth, clean, and free from cavities or orange-peel. In case of gaskets without flat surface portion, the measurement must be done on the cross section to avoid influence of the shape. In this case, the remark "measured on cross section" must be stated on the drawing and in the CG5498; High Temp Data Sheet.

3.7.1.4.7 Test pieces taken from elastomeric components shall be 4.4 mm width, 6 mm length to 20 mm length, and 1.5 mm thickness. Laminated test pieces are not permitted. Press-in-place gaskets may use a stabilization feature as a micro-hardness measurement pad. The pad must be 4.4 mm $\times$ 4.4 mm. The indenter width is