



Engine Driven Mechanical Vacuum Pump

1 Introduction

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

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

1.1 Scope. This standard covers supplier requirements for general purpose engine driven vacuum pumps.

1.2 Mission/Theme. This specification contains all information necessary to design, analyze, develop, validate, and manufacture engine driven vacuum pumps.

1.3 Classification. This specification covers both belt driven and camshaft driven applications.

2 References

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

2.1 External Standards/Specifications.

ASTM D4066	ISO 9002	ISO 11469	SAE J2044
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2.2 GM Standards/Specifications.

GME14079 (I)	GMW3059	GMW3359	GMW16037
GMW2	GMW3116	GMW14562	GMW16177
GMW5	GMW3155	GMW14671	GMW16290
GMW3044	GMW3157	GMW15725	

(I) = This is a standard that is distributed only internally within General Motors. This standard cannot be distributed outside of General Motors. Contact the GM lead engineer for any instructions.

2.3 Additional References.

2.3.1 Miscellaneous.

- Magma Solidification Software
- McMaster-Carr, 200 Aurora Industrial Parkway, Aurora, OH 44202-8087, Email: cle.sales@mcmaster.com
- Statement of Requirements (SOR)
- Tucker's Pottery, 15 West Pearce Street, Unit Number 7, Richmond Hill, Ontario, Canada, Email: info@tuckerspotttery.com

2.3.2 Engine Oil Types.

- SAE 0W-20
- SAE 0W-30
- SAE 5W-20
- SAE 5W-30

3 Requirements

3.1 System/Subsystem/Component/Part Definition.

3.1.1 Appearance. Not applicable.

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3.1.2 Content.

3.1.2.1 Physical Content. The pump shall have a die cast aluminum pumping chamber, usually containing a rotor with vane elements and inlet and outlet check valves. There will be either one or two vacuum ports; one for brakes and perhaps another for auxiliary functions. This chamber is enclosed with either a steel or aluminum die cast cover. The housing must also incorporate provisions for engine high pressure oil lubrication and a drain leading into the engine oil pan. Filtering and metering of the oil is also incorporated. Additional content includes a coupling, rotor/shaft, sometimes with a bushing and rotor with vane tip seals. The pump assembly also may include mounting bolts, axi-rads to retain the bolts, ring dowels, or independent dowels and perhaps an oil seal for the ports. For belt driven pumps, the pulley would also be shipped with the pump and with a front bearing/bushing with an elastomeric oil lip seal added to protect it.

3.1.2.1.1 Tandem Pump. Some applications will be assemblies with the oil pump in a tandem arrangement driven by a chain, gear or other design. These applications can be supplied by a single vendor of both pumps, or sourced from the oil pump supplier with the Mechanical Vacuum Pump (MVP) as a second tier part. This specification shall apply to the MVP only, and may be submitted in a SOR from the oil pump release engineer and buyer.

This design shall be similar to the cam driven design, except that the sealing is not required to be as rigorous for the oil feed, and the drain reed valve will generally be exposed. The drive will generally be from the chain sprocket or the oil pump, but may vary in execution. A double "D" or other design that can absorb the misalignment may be proposed. The supplier must submit a calculation supporting the misalignment capability of the coupling. A common shaft may also be proposed.

The inlet for the vacuum will generally be routed internally from the engine oil pan area. A seal of some type will be needed, and requirements will vary with the applications. All seal designs require GM Technical Specialist approval.

The oil inlet will also be internally routed from a source in the oil pan. Sealing will vary with application.

3.1.2.2 Functional Content. Function is also addressed in the requirements of the tests in 3.2.1. In general, the pump supplies vacuum to vehicle brake systems and/or auxiliary vacuum operated devices. The functional content is the same as described in 3.1.2.1.1, consisting of the shaft and vane, as well as inlet and outlet check valves.

3.1.2.2.1 Inlet Debris Screen. The screen must have an open surface area of 30 mm² minimum and a mesh debris size of 0.055 mm maximum.

3.1.2.2.2 Inlet Check Valve. An inlet check valve is required on the pump air inlet to prevent oil backflow. If two ports are needed, the main brake port must be protected from loss of secondary port system integrity. The secondary port can be fed from the brake port and orificed within the pump to a level so that performance in 3.2.1.1 is achieved with the secondary port open. An independent secondary porting arrangement would normally be used. The check valve must meet the requirements of GMW14562.

The inlet check valve must be sealed by an O-ring and held in place with a flange and screw. The screw must not be a self-tapping or thread cutting design, but rather a straight thread entering a drilled and tapped hole in the aluminum housing. The design must be preapproved by the Technical Specialist. The O-ring design and material, usually fluoroelastomers (FKM) or hydrogenated acrylonitrile butadiene rubber (HNBR), must be approved by the Sealing and Fastening Technical Specialists.

3.1.2.2.3 Reverse Rotation Check Valve. A check reed valve is required on the pump to protect from reverse rotation damaging the pump. It routes from the inlet port to the outlet, and is normally closed.

3.1.2.2.4 Outlet Check Valve. An outlet check reed valve is required to exhaust entrained air and oil back into the engine, and to prevent backflow.

3.1.2.2.5 Anti-drain Back Valve. The preferred design execution is to configure the oil outlet port large enough to reduce the cold start torque spike from residual oil in the pump to a level within the vane stress capability. This is to be done either alone or together with a provision to relieve the vacuum in the pumping chamber quickly after engine shutoff. If this is not possible, an anti-drain back valve may be required in the oil inlet port to prevent the pump from drawing oil into the pump chamber from residual vacuum and oil pressure at engine shutoff. Testing from a warm engine condition to shut down and after overnight soak shall determine the residual oil to be dealt with for cold start evaluation. This testing will establish the efficacy of the port, the vacuum relief feature or the added valve.

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3.1.2.2.6 Rear Cover. If steel, the rear cover must be double disc ground to a flatness of 0.05 mm within 100 mm. Cast covers must be machined to meet this value. Surface roughness values (maximum μm) are 3.0 Ra, 2.0 Rz, 20 Rz1max and 20.0 waviness. Reference Section 6.1 Glossary for roughness definitions.

3.1.2.2.6.1 Rear Cover Screws. The screws for attaching the rear cover to the pump housing casting shall meet the requirements of GMW3359 or GMW3044 8K240/120T, and have straight threads. No self-tapping or thread cutting screws shall be used. The casting holes shall be drilled and tapped according to industry standard and as approved by the GM Powertrain Fastening Technical Specialist. The holes shall have a minimum counterbore of 1.0 mm depth and a lead in chamfer at the bottom of the counterbore.

Should there be a temporary reason to apply a sealer to the threads to address a casting porosity issue, Precote 85 shall be used, or an equivalent approved by the GM Powertrain Fastener Technical Specialist. Use of sealer must be approved and directed by GM Powertrain, if needed to deal with casting porosity. Cost of the pre-applied sealer bolts must be borne by the pump supplier when driven by casting porosity.

3.1.2.2.6.2 Rear Cover Seal. The rear cover seal shall be a press-in-place design approved by the GM Powertrain Sealing Technical Specialist. Void volume and contact width worst case must be confirmed by analysis. Material must be FKM or silicone, and, in any case, approved by the Sealing Technical Specialist.

3.1.2.2.7 Pump Casting(s). The pump casting must be free from harmful porosity, from gas porosity, shrinkage porosity or blows from water on the die. This is to be evaluated after machining. Use of impregnation is not allowed, and if necessary on a temporary basis, must be approved by GM Powertrain Engineering and the expense borne by the supplier. Impregnation may be used only once on a given casting.

To avoid porosity, the casting must be analyzed with solidification software, such as Magma, early in casting development. Gating errors must be corrected, and overflows provided, along with a chill vent if required to deal with these issues. First castings must be x-rayed, and then cut where heavy sections are present to assess adequacy of the die design, and corrections made as necessary.

Castings must be made in a facility that has rotary degassing of the molten metal at each transfer from a central melting furnace to a holding furnace.

Metal density and chemistry must be measured at each metal transfer.

Dies must be run in automatic cells with:

- Auto ladling or Striki-Westofen type dosing furnaces
- Auto die spray
- Robot or extractor part removal
- Fixed die open time

Development must be done in advance to assure dry dies between shots to avoid blows. Die casting machines must have real time shot monitoring to allow for part rejection after each shot, should key parameters be out of range. Casting suppliers must be approved by the Technical Specialist.

3.1.3 Ambient Environment. Can vary by application, but assumed to be -40 °C to 150 °C. Exposure to contaminants covered in Section 4. This environment is divided into the following elements:

- Underhood temperature -40 °C to 100 °C with excursions to 120 °C
- Engine oil temperature -40 °C to 130 °C with excursions to 150 °C
- Relative Humidity 10% to 95%
- Altitude, -200 m to 3500 m
- Vibration (function of application – submitted to supplier after business award) of 10G in each orthogonal direction can be assumed as a starting point
- Torsional, to be quantified in the application SOR
- Engine shaking three (3)-axis, to be quantified in the application SOR

3.1.4 Interfaces. Several interfaces can be divided into three general categories.

3.1.4.1 Belt Driven. Interfaces include a pressed on pulley, the engine block where a mounting pad is located, requiring a seal or a mounting bracket and feed and drain oil lines. Other interfaces are the brake vacuum line and the auxiliary vacuum lines from a secondary port.

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3.1.4.2 Camshaft Driven. Interfaces in addition to the camshaft with the pump coupling and vacuum lines, include the engine cylinder head for mounting and access to oil ports, the camshaft cover, and sealing to both. The coupling shall be an Oldham design for cam driven applications.

3.1.4.2.1 Cam Interface. The requirements for compatibility of the Oldham coupling to the engine camshaft must be detailed by the supplier.

- Material compatibility
- Hardness
- Cam slot clearances/tolerances

3.1.4.2.1.1 Coupling Lubrication. The preferred oiling for the coupling shall be provided by internal cam cover splashed oil. A passage internal to the pump can be used if splash is not present or is insufficient. On some applications, should internal routing be impossible, the oiling for the coupling will come from the camshaft via a drilled passage. Some applications have the oil drain located over the coupling, and no other provision is required. The design of this provision must be approved by the release engineer and the Technical Specialist.

3.1.4.2.1.2 Coupling Torque. The torque applied to the coupling is a function of the pump design and oil viscosity and temperature. This torque data shall be submitted to the pump release engineer, by the pump supplier, from test data.

3.1.4.3 Oil Pump Driven. In tandem pump applications, the drive from the oil pump (other tandem pump arrangements include fuel pumps, alternators, or other rotating accessories) is to be able to absorb the inherent misalignment and must be compatible relative to material and hard enough to resist wear. Precise requirements are application specific, and addressed in the SOR.

3.1.4.4 Vacuum Port Fitting(s). Must meet SAE J2044 requirements for North America and GME14079 for Europe. Fittings must be steel, zinc, aluminum or brass unless approved as a resin based polymer composite. If a polymeric part is proposed, analysis and test data to address service abuse is required. Polymeric proposals require Technical Specialist approval. If there is a secondary port, its size will be specified in the SOR, depending upon the subsystem requirements involved.

3.1.4.4.1 Port Orientation. Port orientation is application specific, but will generally be vertical, where possible, to be flexible across vehicle platforms.

3.1.4.4.2 Vacuum Fitting Size. Brake pipe outer diameter (OD) size shall be specified in the application SOR, based on the application requirements. Some pumps may not be used to supply brake vacuum, but most will. The brake fitting must be independent of the secondary fitting, if equipped, except as described in 3.1.2.2.1. The secondary port diameter shall be specified with the application.

3.1.4.5 Cam Cover Sealing. In general, there shall be no face sealing to the cam cover. The nose of the casting entering the cover shall be sealed with a radial lip seal, independent of the cylinder head oil port face seal. This eliminates potential worm track passages across the cam cover and cylinder head, and the accompanying "T" joint sealing issues. O-ring nose/spigot sealing should be avoided.

3.1.4.6 Engine Oil. Oil will be supplied from either before or after the engine oil filter, dependent upon the application. In the US, the oil is SAE 0W-20 mineral oil according to GMW16177, with SAE 5W-20/SAE 5W-30, and perhaps others, as stated in the SOR. Other regions and some special applications will differ. Oil will vary in condition over the change interval that is planned or expected in service or which is specified in the SOR. Although not preferred, "dirty oil" can be produced as new oil with added abrasives as follows:

- 0.8 g steel shot (crushed)
- 0.8 g iron machining chips
- 0.8 g Arizona fine sand

The above is mixed into 2 L of new SAE 0W-20 or SAE 5W-20 oil, or as specified, according to GMW16177.

The preferred source of "dirty oil" is diesel engine test oil drained from GM dynamometer durability engines. This mixture must be continually mixed to keep the particles in suspension. Diesel drain oil from retail outlets can be used if dynamometer oil is not available. Gas engine oil is not to be used, regardless of application.

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3.1.4.6.1 Engine Pump Inlet Oil Pressure. For guidance, the following information is provided, however, applications will vary. See SOR for application specific values.

- 10.0 bar during cold starts at -40 °C or -30C
- 0.50 bar at 90 °C
- 2.5 bar to 4.0 bar at 45 °C
- Application values, if different, are specified in the SOR

3.1.4.6.2 Biofuel Contamination. Biofuel grades of B10 or B20 may be used, and there will be a dilution of the oil with this fuel of perhaps 6%. The actual biofuel to be used and the level of dilution will vary with applications. The "dirty oil" must contain this biofuel contamination as defined in the SOR.

3.1.5 Usage Definition. General Purpose.

3.2 Product Characteristics.

3.2.1 Performance Requirements.

3.2.1.1 Pump Down – Primary Port. Pump must achieve the levels of vacuum versus time as shown in Table 1, with the maximum vane clearance, for the primary port. Other performance requirements may be applicable for specific applications. Performance is to be measured at 90 °C oil temperature.

Table 1: Primary Port Performance

Vacuum (kPa)	Time (seconds)
50	5
70	10
90	30

Performance at -30 °C and 120 °C must also be reported for all operating points. Additional requirements may apply at these temperatures, based upon specific Application SOR requirements.

Note: The performance to 50 kPa in the vehicle must be achieved in 4 s, based on the assistance from boosted fast idle speeds during the first cold start. This is a function of calibration of the engine control system, and is a GM responsibility.

3.2.1.1.1 Pump Down – At Altitude. The pump performance will degrade at altitude as a natural consequence of the reduction in barometric pressure, for which there is no possible compensation. It is important that any device running on vacuum, i.e., turbo waste gate, be able to operate at this reduced level of vacuum. The loss of vacuum at 3000 m is 250 millibars (mb), so only 650 mb is available to operate devices. Suppliers are to report the pump down performance at 3000 m and at 500 mb and 650 mb (or maximum millibars).

3.2.1.1.2 Pump Down at Cold Starts. At cold start conditions down as low as -40 °C, the pump must begin to pump down within 1 s of engine first fire or consistent pump rotation (in other words, independent of engine stalls). The evacuation performance must pass the requirements of 3.2.1.1 after initiation of pump down.

3.2.1.2 Pump Down – Auxiliary Port. Under the same conditions as in 3.2.1.1, except that the system volume is 0.5 L, or as specified. The auxiliary port shall achieve the minimum performance shown in Table 2.

Table 2: Auxiliary Port Performance

Vacuum (kPa)	Time (seconds)
50	10
70	20
90	40

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Performance at -30 °C and 120 °C must also be reported for all operating points. Additional requirements may apply at these temperatures, based upon specific Application SOR.

3.2.1.3 Background Vacuum Leakage. Performance reported in 3.2.1.1 and 3.2.1.2 must be valid with a background system leakage at 100 L/h, if a secondary port is required and vacuum leakage is used to control a vacuum operated device, such as a turbocharger.

3.2.1.4 Power Consumption. Must be reported as a function of pump speed at the following conditions:

- Oil: SAE 0W-30 or SAE 5W-20, or as specified, according to GMW16177
- Barometric Pressure, 1 bar = 10 N/cm² at sea level
- Oil temperature, 90 °C
- Ambient temperature, 25 °C ± 3 °C
- Inlet engine oil pressure, 1.00 bar to 4.0 bar, or as specified in the SOR
- Pump speed, 300 rpm to 3000 rpm sweep
- Performance at -40 °C and 120 °C ambient temperatures must also be reported

There may be different performance requirements for tandem or belt driven pumps, since these are driven at different drive ratios from the cam driven applications. Engine idle speed differences will also result in modification of these requirements. These requirements will be specified in the Application SOR.

Reference: Power consumption for a pump with a pumping chamber with a 3:1 diameter to depth ratio and a 190 cc/revolution capacity shall not exceed 200 W at 2500 rpm as specified in the SOR. This is a basic pump design requirement, and not tied to a particular application.

3.2.1.5 Cold Ambient Temperature Performance.

3.2.1.5.1 Starting Torque. Supplier shall report the torque required to start the pump at the minimum ambient temperature of -30 °C or -40 °C, and the duration and amplitude of the torque during the start event with the maximum residual oil in the pump. This value shall not exceed 25 N·m.

3.2.1.5.2 Cold Start Internal Oil Pressure – Belt driven Application. There shall be no buildup of pressure behind the shaft oil lip seal in front of the bushing/bearing on belt driven pump applications during cold starts down to -40 °C with an engine inlet oil pressure of 10.0 bar.

3.2.1.5.3 Cold Start Pump Torque Requirement. The coupling, rotor, shaft (if equipped) and vane shall support the torque to turn the pump when it is filled with oil at -40 °C at the acceleration rate of engine starting, or 30 N·m, until this information is available.

3.2.1.6 Pump Noise. Supplier shall report the noise performance of the pump as a function of pump speed and output as a family of curves, or waterfall plot, of noise level in decibels (dBA) vs. frequency. Test conditions are to be the same as in 3.2.1.2. See Appendix A for **requirements**. Should development testing be required, pump discharge pressure and pressure rise can be used to measure the noise performance.

3.2.1.7 Speed Range. Minimum engine speed is 500 rpm, except as specified, and the maximum speed is 4500 rpm up to 7500 rpm, as specified in the SOR. Drive ratio is 0.50 on cam driven engines, and may vary on belt or oil pump driven applications from 0.50 to 1.00.

3.2.1.8 Inlet Check Valve Cold Performance. The valve must be soaked for 30 days at ambient temperature with the assembly, leak test or performance test oil used in the assembly process present. Following that, a 10 h soak at -40 °C must be performed with full vacuum applied during this soak time. The valve must then immediately release from its seat upon pump rotation and vacuum demand on a cold start.

3.2.2 Physical Characteristics.

3.2.2.1 Dimensions and Capacity. Each application will have capacity specified as a chamber volume value based upon a pump down requirement tailored to its particular requirements. Data supplied for the purpose of supplier approval, independent of application, shall be generated from 190 cm³ pumps to compare suppliers.

3.2.2.1.1 Mounting Face Perpendicularity (Cam Driven). The mounting surface on the cylinder head (oil port surface) must be perpendicular to the drive end shaft within 0.30 mm or as otherwise specified.

3.2.2.1.2 Mounting Surface Parallelism (Belt Driven). For belt driven pumps mounted to the side of the engine, the mounting surface must be parallel to the shaft within 0.30 mm or as otherwise specified.

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