# Belt Driven A/C Compressor with Electromagnetic Clutch

## 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:** Unless otherwise stated as gage, pressures listed within the specification are absolute.

**Note:** Unless otherwise stated, all requirements apply to all compressor types defined in Table 1.

**Note:** Unless otherwise stated, all references to compressor means the entire compressor assembly content as defined in 3.1.2, except for shipping caps. This includes all production intent content, whether or not it is listed as optional.

**Note:** Unless otherwise stated, all references to compressor drawing are defined as the drawing or math data approved by GM and released in the GM system. When a drawing has not yet been released, or the referenced information is not on the drawing, the supplier shall document the values used in the Analysis Development Validation Plan and Report (ADVPR).

**Note:** Unless otherwise stated, no function, capability, or performance of the compressor may degrade by more than 5% from beginning of test to end of test nor from design validation to product validation.

**1.1 Purpose.** This specification establishes the minimum functions, performance, reliability, and validation requirements for belt driven air conditioning compressors with electromagnetic clutches.

**1.2 Applicability.** This specification applies to belt-driven fixed piston, fixed scroll and externally variable displacement compressors with an electromagnetic clutch used with R134a and R1234yf refrigerants.

This standard is written such that the requirements are generalized to comprehend the operating envelope of typical automotive air-conditioning systems. In this document, typical A/C systems are defined as single and dual evaporator systems equipped on passenger cars and light and medium duty trucks where the compressor is mounted to the internal combustion engine. The intent is to validate a supplier and design on one program using generic requirements independent of a particular air condition system, where possible, so that reliability can be assured on many programs while reducing resources required for validation. Thus, when compressor internal parts designs are carryover and the air conditioning system for the program is typical, validation of certain requirements can be carryover from previous programs if approved by the GM Component Validation Engineer (CVE) and GM Bill of Materials Family Owner (BFO). Designs or suppliers not previously validated to these requirements require full validation. Non-typical air conditioning systems, such as those incorporating chillers or alternative powertrains, may require additions or modifications to these requirements, such as testing with the specific air conditioning system for the program. In cases of non-typical air conditioning systems, the GM BFO and CVE shall develop alternative requirements to be documented in Appendix C2 and Appendix G2 of the SOR. Where feasible, parts at the supplier's Lower Specification Limit (LSL) and Upper Specification Limit (USL) shall be used for validation to demonstrate appropriateness of the supplier's specification limits and impacts to performance variation. Test conditions are chosen to provide contrast and demonstrate robustness to noise factors.

**1.3 Remarks.** The compressor assembly must conform to all requirements in this specification, as well as the approved engineering drawings. All requirements of this specification must be met in order to demonstrate design and production validation. During technical reviews prior to sourcing, supplier is to provide a completed CG4390 to document requested deviations to these requirements. Prior to sourcing, approved deviations are to be documented in Appendix C2 by the Design Release Engineer (DRE) per CG4391. After sourcing, deviations requested are to be documented in a part work order (PWO) with CG4390 attached. The supplier is to list approved deviation PWOs on the drawing and on appropriate validation documents.

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## 2 References

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

### 2.1 External Standards/Specifications.

| | | | |
|---|---|---|---|
| ANSI S12.54 | ASTM D1474 | ISO 21940-21 | SAE USCAR-2 |
| ANSI S12.55 | ASTM D6304 | JIS Z 8732 | |
| ASHRAE Standard 97 | ISO 3744 | JIS Z 8733 | |
| ASME B46.1 | ISO 3745 | SAE J639 | |

### 2.2 GM Standards/Specifications.

| | | | |
|---|---|---|---|
| 9986181 | GMW3191 | GMW14483 | GMW16044 |
| GMW3059 | GMW3286 | GMW14872 | GMW16290 |
| GMW3097 | GMW3600 | GMW14911 | GMW16376 |
| GMW3103 | GMW8758 | GMW15758 | GMW16955 |
| GMW3116 | GMW14264 | GMW15862 | GMW17053 (ID) |
| GMW3172 | GMW14477 | GMW15920 | |

**Note**: (ID) = This standard is limited to internal distribution within General Motors and shall not be distributed outside this company. Contact the GM Lead Engineer for further instructions.

### 2.3 Additional References.

- 1718760-3 Male European MCON VDA Silver Plated Terminal ((0.5 to 0.76) $mm^2$ Wire Size).
- 1718762-3 Male European MCON VDA Silver Plated Terminal ((1.0 to 1.50) $mm^2$ Wire Size).
- 52477000 (Drawing).
- 963142-2 Single Wire Seal - Large Seal.
- 967067-1 Single Wire Seal - Small Seal.
- Artemis Sound Quality Software. (head-acoustics.de)
- CG3043 Component Environmental Test Plan Template External Supplement to GMW3172.
- CG3878 GM Automotive Reliability Testing for Discrete Semiconductors Related to Au to Cu Wire Bonds.
- CG3879 GM Integrated Circuit (IC) Automotive Reliability Testing for Au to Cu Wire Bonds.
- CG4387 Belt Driven AC Compressor VCRI Template SOR Appendix G3 VCRI Template.
- CG4388 Compressor Service Release Guidelines External Supplement to GMW17583.
- CG4389 Compressor Specific Drawing Requirements External Supplement to GMW17583.
- CG4390 Deviation to Compressor Technical Requirements Template External Supplement to GMW17583.
- CG4391 Program Specific Exceptions to AC Compressor CTS External Supplement to GMW17583.
- General Motors Component EMC and Environmental Test (CEMENT) database.
- GF Zwicker Time Based Loudness Metric.
- GM Best Practice HVACPTC-122.
- GM Best Practice HVACPTC-125.
- GM branding guidelines. See GM Release Engineer.
- GM drafting guidelines. See GM Release Engineer.
- GM Part Number 52457600 (shipping cap).
- GM Part Number 52465700 (shipping cap).
- GM Part Number 13505427 (TE Connectivity Ltd. 1-1703498-3) for the clutch.
- GM Part Number 13505428 (TE Connectivity Ltd. 2-1703498-3) for the control valve.
- Interface Control Document (ICD). See GM Release Engineer.
- Roush lab. (roushperformance.com)



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- Statement of Requirements (SOR), Appendices B, C2 and G2.
- Subsystem Technical Specification (SSTS).
- TE Connectivity Ltd. (http://www.te.com)
- Vehicle Technical Specification (VTS). See GM Release Engineer.

## 3 Requirements

**3.1 System/Subsystem/Component/Part Definition.** The compressor assembly is a subsystem that consists of a clutch and compression mechanism. Variable compressors additionally have a control valve. The compression mechanism accepts low pressure, low temperature refrigerant at an inlet port, compresses this refrigerant by a variety of mechanisms, and exhausts a high temperature, high pressure refrigerant at an outlet port. Mechanical power to drive the compressor is supplied by a separate power source, such as the vehicle power plant, and is transferred to the compressor via the clutch to the compression mechanism. Variable compressors have the displacement controlled by the control valve in response to an input signal and refrigerant conditions. The compressor type shall be classified according to Table 1. This classification is used within this document to define requirements that are specific to a compressor type.

**Table 1: Compressor Type Classification**

| Compressor Type | Compressor Technology | Compression Mechanism |
|---|---|---|
| Type A | Fixed Piston | Compression by pistons displacing a fixed volume per compressor shaft revolution. |
| Type B | Fixed Scroll | Compression by scrolls displacing a fixed volume per compressor shaft revolution. |
| Type C | Externally Controlled Variable Displacement | Compression by pistons displacing a variable volume per compressor shaft revolution. Displacement is controlled by a control valve according to an external input signal and refrigerant conditions. |

**3.1.1 Appearance.**

**3.1.1.1 Color and Finish.** Typical appearance is compressor body with a natural aluminum finish and the clutch with a low gloss black finish to match with other underhood components. Deviations from this are permissible, but must be approved by the releasing GM engineering group.

**3.1.2 Content.** This section specifies the requirements for the physical and functional content of the Air Conditioning (A/C) compressor.

**3.1.2.1 Physical Content.** The physical content of the compressor includes the following:

- Inlet (Suction) Port.
- Outlet (Discharge) Port.
- Electromagnetic Clutch Assembly.
- Electrical Connector for Clutch.
- Stator Thermal Fuse.
- Stator Diode.
- Mounting Provisions.
- High Pressure Relief Valve (required, removable for some countries with approval of Compressor Global Subsystem Leadership Team (GSSLT)).
- Control Valve Device (Type C).
- Electrical Connector for Control Valve (Type C).
- Shipping Caps.


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- Lubricant.
- Discharge Shutoff Valve (optional for Type A and B, required for Type C).
- Suction Throttle Valve (optional, Type C must have casting provisions even in production).
- Electrical Connector Brackets (as needed).

**3.1.2.2 Functional Content.** The A/C compressor is to provide the following functions.

**3.1.2.2.1** The compressor circulates refrigerant in the A/C system.

**3.1.2.2.2** The compressor affects pressure out of the evaporator.

**3.1.2.2.3** The compressor provides high pressure and high temperature gas to the condenser.

**3.1.2.2.4 High Pressure Relief Valve (HPRV).** The compressor shall provide provisions for a high pressure relief device that complies with SAE J639.

**3.1.2.2.4.1 High Pressure Relief Valve Location.** The pressure relief valve design, location and orientation must follow GM Best Practice HVACPTC-125 (the supplier shall work with the GM responsible engineer to comprehend these requirements): Location of the compressor high pressure relief valve. The spray pattern of the HPRV must be provided by the supplier and reflected in the supplied math data as an object that can be toggled on and off for purposes of confirming compliance with this Best Practice. Confirmation of adherence to HVACPTC-125 shall be performed for each packaging environment and compressor combination, in accordance with GMW14911.

**3.1.2.2.4.2 HPRV Spray Deflector.** Depending on the results of the study performed for HPRV spray pattern and orientation, a spray deflector may be required. The spray deflector can be a feature in the in the compressor body or added content. The effect of the deflector on the spray pattern and orientation, as well as any assembling tolerances, must be reflected in the supplier math data.

**3.1.2.2.5 Control Device (Type C).** The control device controls compressor displacement to meet system needs. The control is achieved via force balance by diverting discharge refrigerant to the crank case which is bled to the suction chamber. Displacement is stable when inertial and pneumatic forces are in balance.

**3.1.2.2.5.1 External Control Valve.** The external control valve (ECV) operates pneumatically to control compressor to a target suction pressure. The suction pressure target is determined by an external electrical input of a pulse width modulated voltage input. Increasing current to the ECV decreases the suction pressure target.

**3.1.2.2.5.2 Internal Control Valve.** Not applicable.

**3.1.2.2.6 Thermal Protection Switch.** Not applicable.

**3.1.2.2.7 Electromagnetic Clutch Assembly.** The electromagnetic clutch assembly is composed of a pulley, hub and stator. It transfers torque from the pulley to the compressor shaft via a hub when voltage is applied to the stator by the vehicle. The clutch does not transfer torque to the compressor shaft when voltage is not applied to the stator. The clutch receives torque from an engine belt.

**3.1.2.2.7.1 Pulley.** The pulley is also known as the rotor. The pulley is grooved to accept a belt connected to the engine. The pulley transfers rotational energy to the hub via a friction surface to rotate the compressor. The pulley rotates on a bearing that is attached to the compressor body. The pulley is aligned with the crankshaft pulley. The size of the pulley in relation to the size of the engine crankshaft pulley determines the rotational speed of the compressor in relation to that of the engine.

**3.1.2.2.7.2 Hub.** The hub is also known as the armature. The hub transfers torque from the rotor to the compressor shaft. The neutral position of the hub is such that it does not contact the rotor when a magnetic field is not applied by the stator. The hub deflects from its neutral position and contacts the pulley when a magnetic field is applied by the stator. When the magnetic field is applied, the hub and pulley rotate together such that the compressor speed matches the belt speed. The hub may include a method of torque damping to reduce pulsations caused by compression events.

**3.1.2.2.7.3 Stator.** The stator is also known as the field coil. The stator contains a coil of wire that generates a magnetic field when current flows through it. The stator has a connector for connecting to the vehicle wiring harness. The stator contains a thermal fuse and a diode.

**3.1.2.2.7.3.1 Stator Thermal Fuse.** The stator thermal fuse permanently disconnects the stator circuit when the compressor is seized, so that engine belt and clutch integrity are maintained. The thermal fuse does not disconnect the stator circuit when the compressor is operating normally.



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**3.1.2.2.7.3.2 Stator Diode.** The stator diode prevents damage to the vehicle electronics by preventing reverse flow of current when the relay supplying power to the stator is opened.

**3.1.2.2.8 Discharge Shutoff Valve.** The discharge shutoff valve (DSV) prevents flow out of the discharge port unless the compressor internal pressure is a minimum amount above the discharge port pressure. This prevents oil migration.

**3.1.2.2.9 Suction Throttle Valve.** The suction throttle valve (STV) dampens the pressure pulsations of suction gas at low and mid displacement conditions while minimizing flow restriction near maximum displacement conditions. This reduces suction pressure pulsation which can improve noise, vibration, harshness (NVH). Type C compressors must have provisions in the casting to allow installation of the STV without changes to the die, including during production.

**3.1.3 Ambient Environment.**

Test according to GMW3172. A test plan for compliance with GMW3172 shall be documented in CG3043 and submitted to the CEMENT database. The classifications to be used for GMW3172 are:

- Electrical Load — Code Letter C.
- Mechanical Load — Code Letter A.
- Operating Temperature — Code Letter Z (refer to Table 2).
- Climatic Loads — Code Letter O.
- Chemical Loads — Code Letter E.
- Dust and Water Protection — Code Letters IP6K8 and IP6K9K.

The operating temperature requirements are given in Table 2, with a maximum temperature of 125 °C and a Field ΔT (worst case one day temperature range) of 69 °C. The operating types, functional status classes, functional requirements and other details relating to GMW3172 are detailed in Appendix B.

**Note:** The vibration and maximum temperature requirements in this document assume the compressor is mounted to the engine, either directly or via a bracket. The dust, water and corrosion requirements in this document assume the compressor is mounted underhood, low on the vehicle with no splash protection. For the purposes of GMW3172 salt mist test requirements, the component type shall be sealed component with or without a pressure exchange membrane (IP Water Code 8). For the purposes of GMW3172 salt spray test requirements, the component location shall be non-interior component with direct exposure to salt spray (IP Water Code 9K). These assumptions are considered to be worst case and are made to facilitate re-use of parts across programs.

**Table 2: Operating Temperature Requirements for GMW3172**

| Applicability | FSC | $T_{min}$ | $T_{max}$ | $T_{PH}$ | $T_{RPS}$ |
|---|---|---|---|---|---|
| Component Operating | A | 0 °C | 125 °C | 140 °C | N/A |
| Component Not Operating | C | -40 °C | 125 °C | 140 °C | N/A |

**FSC** Functional Status Classification
**N/A** Not applicable
**$T_{max}$** Maximum Temperature
**$T_{min}$** Minimum Temperature
**$T_{PH}$** Post Heating Temperature
**$T_{RPS}$** Repaint & Storage Temperature

**3.1.4 Interfaces.** All necessary information to define interfaces to other parts must be indicated on the compressor drawing by 12 weeks prior to Structure Vehicle Engineering Release (SVER).

**3.1.4.1 Electrical Interfaces.** The electrical interfaces to the vehicle of all electrical connections on the compressor must be defined and agreed upon by the appropriate GM Design Release Engineers (DRE) in the electrical interface control document (ICD). Pin identification, polarity, wire sizes, circuit diagrams, electrical characteristics, and input and output capabilities must be documented on the compressor drawing.


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**3.1.4.2 Mechanical Interfaces.** The mechanical interfaces to the vehicle, such as the pulley and all attachment points on the compressor, must be defined and agreed upon by the appropriate GM DREs in the mechanical interface control document (ICD). Requirements for compliance to the ICD must be documented on the compressor drawing.

**3.1.4.3 Controls Interfaces.** The controls limits required to maintain compressor durability in the vehicle, such as clutch cycling limit or high speed protection control, must be defined on the drawing and agreed upon by the appropriate GM Controls Strategist and BFO. The supplier shall be responsible for confirming the calibration values used by the appropriate GM Vehicle Calibrator are within acceptable limits. This shall be done at the 65%, 80%, 99% and 100% calibration milestones.

**3.1.5 Usage Definition.** Not applicable to this document. This information must be indicated in the Subsystem Technical Specification (SSTS) document of each program.

**3.2 Product Characteristics.**

**3.2.1 Performance Requirements.** This section specifies the functional requirements for the A/C compressor. Data shall be submitted on compressors run sequentially through these performance tests for validation purposes at each stage of development.

**3.2.1.1 Performance Tests.**

**3.2.1.1.1 Minimum Refrigerant Mass Flow Rate and Coefficient of Performance (COP).** The minimum refrigerant mass flow rate and COP requirements are to be met per the conditions defined in Table 3, Table 4 and Table 5 according to compressor type (where x = compressor displacement (cc/rev)), when tested per 4.3.1.1.1. COP is defined as cooling capacity divided by power consumption (using the same units). The supplier shall indicate the actual capability of the compressor at these conditions on the drawing. Variation in random samples, taken from production, shall not have more than 5% less refrigerant mass flow rate nor more than 10% lower COP than the values indicated on the drawing. This requirement is subject to audit at a GM approved third party at the expense of the supplier upon GM BFO request. These requirements are to be met with all production intent content. For Type C compressors, test half of the samples with suction throttle valve and report results separately for samples with and without suction throttle valve. Equivalent cooling performance is for reference only and is calculated using 10 K superheat and 5 K subcool.

**Table 3: Mass Flow and Power Consumption Requirements – Type A**

| Conditions | | | | Requirement – R134A | | | Requirement – R1234YF | | |
|---|---|---|---|---|---|---|---|---|---|
| Compressor Speed (rpm) | Suction Pressure (kPaA) | Suction Temperature (Degree °C) | Discharge Pressure (kPaA) | Minimum Refrigerant Mass Flow Rate (kg/h) | Minimum Equivalent Cooling Performance (kW) | Minimum COP | Minimum Refrigerant Mass Flow Rate (kg/h) | Minimum Equivalent Cooling Performance (kW) | Minimum COP |
| 800 | 500 | 26 | 2000 | 155*(x/200) | 5.41*(x/200) | 2.74 | 174*(x/200) | 4.39*(x/200) | 2.30 |
| 2000 | 280 | 9 | 1600 | 185*(x/200) | 6.72*(x/200) | 1.80 | 208*(x/200) | 5.46*(x/200) | 1.53 |

***** Multiplier symbol
**rpm** Revolutions per minute
**x** Compressor displacement (cc/rev)


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**Table 4: Mass Flow and Power Consumption Requirements – Type B**

| Conditions | | | | Requirement – R134A | | | Requirement – R1234YF | | |
|---|---|---|---|---|---|---|---|---|---|
| Compressor Speed (rpm) | Suction Pressure (kPaA) | Suction Temperature (Degree °C) | Discharge Pressure (kPaA) | Minimum Refrigerant Mass Flow Rate (kg/h) | Minimum Equivalent Cooling Performance (kW) | Minimum COP | Minimum Refrigerant Mass Flow Rate (kg/h) | Minimum Equivalent Cooling Performance (kW) | Minimum COP |
| 1200 | 500 | 26 | 2000 | 115*(x/90) | 4.02*(x/90) | 2.50 | 129*(x/90) | 3.26*(x/90) | 2.13 |
| 2100 | 280 | 9 | 1600 | 128*(x/90) | 4.65*(x/90) | 2.20 | 144*(x/90) | 3.78*(x/90) | 1.87 |

* Multiplier symbol
rpm Revolutions per Minute

**Table 5: Mass Flow and Power Consumption Requirements – Type C**

| Conditions | | | | Requirement – R134A | | | Requirement – R1234YF | | |
|---|---|---|---|---|---|---|---|---|---|
| Compressor Speed (rpm) | Suction Pressure (kPaA) | Suction Temperature (Degree °C) | Discharge Pressure (kPaA) | Minimum Refrigerant Mass Flow Rate (kg/h) | Minimum Equivalent Cooling Performance (kW) | Minimum COP | Minimum Refrigerant Mass Flow Rate (kg/h) | Minimum Equivalent Cooling Performance (kW) | Minimum COP |
| 850 | 420 | 20 | 2000 | 120*(x/170) | 4.08*(x/170) | 2.24 | 135*(x/170) | 3.26*(x/170) | 1.90 |
| 1600 | 375 | 16 | 1600 | 204*(x/170) | 7.71*(x/170) | 2.59 | 230*(x/170) | 6.42*(x/170) | 2.20 |
| 2600 | 340 | 13 | 1600 | 254*(x/170) | 9.47*(x/170) | 2.00 | 286*(x/170) | 7.82*(x/170) | 1.70 |
| 5000 | 300 | 10 | 1800 | 267*(x/170) | 9.18*(x/170) | 1.18 | 300*(x/170) | 7.30*(x/170) | 1.00 |

**Note**: Control valve current shall not exceed that from the High Speed Protection Control on the drawing.
**Note**: These requirements shall be met with all optional content, including suction throttle valve.
* Multiplier symbol
rpm Revolutions per Minute

**3.2.1.1.2 Maximum and Minimum Speed Definition.** The compressor speed capability is to be documented on the drawing per CG4389. The compressor shall be capable of at least the values in Table 6.


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**Table 6: Maximum and Minimum Compressor Speed Definitions**

| | Type A | Type B | Type C |
|---|---|---|---|
| Maximum Continuous rpm | ≥ 9500 | ≥ 9500 | ≥ 9500 (reduced control valve current) |
| Maximum Excursion rpm | ≥ 11 000 | ≥ 12 000 | ≥ 11 000 (reduced control valve current) |
| Maximum Continuous rpm for Maximum Control Valve Current (Type C only) | N/A | N/A | ≥ 5000 |
| Minimum Continuous rpm | ≤ 700 | ≤ 900 | ≤ 700 |
| Minimum Intermittent rpm | ≤ 550 | ≤ 700 | ≤ 550 |

**3.2.1.1.2.1 Maximum Continuous rpm.** Maximum continuous compressor speed is defined per the durability test specification at condition ten (10) of the appropriate table for the compressor type in Appendix A. The compressor must run a minimum of 10 separate periods of 1 h at this condition at the maximum continuous rpm documented on the compressor drawing. The maximum continuous rpm on the drawing must be equal to or greater than the maximum continuous rpm shown in Table 6, when tested per 4.3.1.1.2.1.

**3.2.1.1.2.2 Maximum Excursion rpm.** Maximum excursion compressor speed is defined per the durability test specification at condition eleven (11) of the appropriate table for the compressor type in Appendix A. The compressor must run a minimum of 10 separate periods of 1 minute at this condition maximum excursion rpm documented on the compressor drawing. The maximum excursion rpm on the drawing must be equal to or greater than the maximum excursion rpm at the speed shown in Table 6, when tested per 4.3.1.1.2.2.

**3.2.1.1.2.3 Minimum Continuous rpm.** Minimum continuous compressor speed is defined per the durability test specification at condition four (4) of the appropriate table for the compressor type in Appendix A. The compressor must run a minimum of 10 separate periods of 2 h at this condition at the minimum continuous rpm documented on the compressor drawing. The minimum continuous rpm on the drawing must be equal to or less than the minimum continuous rpm shown in Table 6, when tested per 4.3.1.1.2.3.

**3.2.1.1.2.3.1 Minimum Intermittent rpm.** Minimum intermittent compressor speed is defined per the durability test specification at condition four (4) of the appropriate table for the compressor type in Appendix A. The compressor must run a minimum of 10 separate periods of 1 minute at this condition at the minimum continuous rpm documented on the compressor drawing. The minimum continuous rpm on the drawing must be equal to or less than the minimum continuous rpm shown in Table 6, when tested per 4.3.1.1.2.3.1.

**3.2.1.1.2.4 High Speed Protection Control (HSPC) (Type C).** The compressor shall be allowed to require operation according to a high speed protection control (HSPC). HSPC is defined as a control calibration that reduces control valve current due to high compressor speed to protect the compressor from overheat. The HSPC shall be piecewise linear and expressed as a table and a graph. The HSPC strategy must be approved by the GM BFO and defined on the compressor drawing per CG4389. The compressor shall be able to operate per 4.3.1.1.2.4.

**3.2.1.1.2.4.1 Maximum Continuous rpm for Maximum Control Valve Current (Type C).** Maximum continuous compressor speed for maximum control valve current is defined per the durability test specification at condition 13 of Table A1 in Appendix A. The compressor must run a minimum of 10 separate periods of 3 h at this condition at the speed shown in Table 6, when tested per 4.3.1.1.2.4.1.

**3.2.1.1.2.4.2 Required Suction Pressure Capability During HSPC (Type C).** The HSPC must not require operating the compressor below the control valve current that would result in the compressor suction pressure target being > 200 kPaG. This requirement shall be met with the worst case tolerance control valve. This requirement shall be tested at steps ten (10), 11 and 12 of Table A1 in Appendix A. The compressor must run a minimum of 10 separate periods of 3 h at this condition at the speed shown in Table 6, when tested per 4.3.1.1.2.4.2.


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**3.2.1.1.2.5 Minimum Compressor Displacement (Type C).** Minimum displacement is defined as the lowest stable controllable displacement of the compressor. The minimum displacement of the compressor shall be < 5% of the maximum displacement, when tested per 4.3.1.1.7. The displacement of the compressor at startup or off (no current to the control valve) may be greater than this value.

**3.2.1.1.3 Maximum Oil Circulation Amount Allowed.** The compressor must be able to maintain all durability requirements with oil circulation amounts in the actual system not to exceed 2% in the range of (1000 to 3000) compressor rpm, when tested per 4.3.1.1.3.

**3.2.1.1.4 Compressor Discharge Temperature Compliance.**

**3.2.1.1.4.1 Compressor Material Robustness to Temperature.** All compressor component material properties must be compliant to a continuous discharge refrigerant temperature of 150 °C and an excursion temperature of 160 °C. Excursion is defined as maximum of 5 minutes intermittent for 100 occasions, when tested per 4.3.1.1.4.

**3.2.1.1.4.2 Compressor Discharge Temperature Limit.** The refrigerant temperature at the compressor outlet shall not exceed 160 °C during intermittent (5 minutes) operation and 150 °C during continuous operation of the compressor. This shall be validated by measuring the discharge temperature during the customer usage simulation test (Appendix A), per 4.3.1.2.2.

**3.2.1.1.5 High Pressure Relief Valve Function.** The HPRV shall meet the requirements of 3.1.2.2.4 and SAE J639. The opening pressure of the high pressure relief valve shall be between 3430 kPaG and 4140 kPaG. In no case shall any high pressure relief valve have an activation pressure > 4140 kPaG. The closing pressure of the pressure relief valve shall be > 2750 kPaG. The HPRV shall be self-sealing. In cases where the pressure relief valve is not required (it will be noted as such in the SOR and on the drawing), the maximum operating pressure of the system shall be considered to be 4500 kPaG for purposes of determining the burst pressure requirement in 3.2.1.1.7.3. Testing shall be per 4.3.1.1.5.

**3.2.1.1.6 Noise/Vibration.** (Stakeholders: GM Integration Area (0C) Noise and Vibration, Vehicle Partitioning and Product Structure (VPPS) 30 HVAC and Powertrain Cooling). The generation and submission of data for the proposed representative compressor to these requirements is required. The A/C compressor shall enable compliance with all program vehicle level noise and vibration requirements found in the current GM program Vehicle Technical Specification (VTS). The supplier must cooperate with GM in determining the root cause and resolution of any A/C compressor system generated vehicle level noise and vibration deviations from the program VTS paragraphs for noise and vibration. Testing shall be conducted at a lab approved by GM Engineering (Roush lab or other as approved by BFO). Design Validation (DV) testing shall be performed using maximum imbalance parts. This may require preparing special samples that are modified (such as having added or subtracted mass).

**3.2.1.1.6.1 Airborne Compressor Sound Power.** Airborne sound power shall be quantified per GMW14477 with the compressor mounted on rubber isolators or mounted hard to table. GMW14477 references the following sound power standards:

- Precision Grade Standards: ANSI S12.55, JIS Z 8732, ISO 3745 (preferred).
- Engineering Grade Standards: ANSI S12.54, JIS Z 8733, ISO 3744 (accepted).

**3.2.1.1.6.1.1 Full Band Compressor Airborne Sound Power.**

**3.2.1.1.6.1.1.1 Full Band Compressor Airborne Sound Power (Types A and C).** Full band compressor sound power shall be less than the curve defined by the following equation, where Compressor Speed in rpm = crpm:

Full Band Compressor Sound Power Limit = (0.006 × crpm) + 59 dB when mounted on rubber isolators

or

Full Band Compressor Sound Power Limit = (0.005 × crpm) + 64 dB when mounted hard to table

Full band compressor sound power is quantified as linear weighted overall sound power summation of data in the (250 to 6400) Hz band (dB reference quantity: 1 pW, root mean squared (rms)) with the compressor operating at each of the high and low displacement conditions specified in test procedure GMW14477. Full Band compressor noise must not exceed the limit line for compressor speeds ≤ 5000 rpm.


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**3.2.1.1.6.1.1.2 Full Band Compressor Airborne Sound Power (Type B).** Full Band compressor sound power shall be less than the curve defined by the following equation, where Compressor Speed in rpm = crpm:

Full Band Compressor Sound Power Limit = (0.006 × crpm/1.2) + 59 dB when mounted on rubber isolators

or

Full Band Compressor Sound Power Limit = (0.005 × crpm/1.2) + 64 dB when mounted hard to table

Full Band compressor sound power is quantified as linear weighted overall sound power summation of data in the (250 to 6400) Hz band (dB reference quantity: 1 pW, root mean squared (rms)) with the compressor operating at each of the high and low displacement conditions specified in test procedure GMW14477. Full Band compressor noise must not exceed the limit line for compressor speeds ≤ 5000 rpm.

**3.2.1.1.6.1.2 Critical Band Compressor Airborne Sound Power.** Critical band compressor noise shall be less than the values defined in Table 7.

**Table 7: Critical Band Noise Limit - 20 bar**

| Compressor Speed (rpm) | Critical Band Sound Power (dB(A)) |
|---|---|
| 1000 | 57 |
| 2000 | 65 |
| 3000 | 71 |
| 4000 | 77 |
| 5000 | 80 |

Critical band compressor noise is quantified as the summation of A-weighted sound power in the (250 to 1000) Hz One-Third Octave Bands (dB(A) reference quantity: 1 pW, rms) with the compressor operating at 2000 kPaG (20 bar) discharge pressure at maximum displacement per GMW14477.

**3.2.1.1.6.1.3 Critical Band Compressor Airborne Sound Power Sensitivity to Discharge Pressure and Compressor Displacement at Low Speeds.** Critical band compressor sound power (average of tested samples) at 1000 crpm and 2000 crpm shall not increase > 6 dB at discharge pressures and displacements specified in GMW14477 (various setpoints ranging from 1000 kPaG discharge pressure and minimum displacement to 2500 kPaG discharge pressure and maximum displacement). Critical band compressor noise is quantified as the summation of A-weighted sound power in the (250 to 1000) Hz One-Third Octave Bands (dB(A) reference quantity: 1 pW, rms) with the compressor operating at conditions specified in GMW14477.

**3.2.1.1.6.1.4 Critical Band Compressor Airborne Sound Power Sensitivity to Swashplate Position at Low Speeds (Type C).** Critical band compressor sound power at 1000 crpm and 2000 crpm shall not vary by > 4 dB during swashplate sweep as defined in GMW14477. Critical band compressor noise is quantified as the summation of A-weighted sound power in the (250 to 1000) Hz One-Third Octave Bands (dB(A) reference quantity: 1picoWatt, rms).

**3.2.1.1.6.2 Clutch Engagement and Disengagement Noise.** The average loudness of ten (10) clutch engagement/disengagement events shall not exceed (the value in Table 8) GF Zwicker Time Based Loudness Metric. Due to inadequate standards for this metric, Artemis Sound Quality software must be used for this analysis using acquisition parameters defined in GMW14477.



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**Table 8: Clutch Engagement and Disengagement Noise**

| | Type A | Type B | Type C |
|---|---|---|---|
| Maximum Clutch Engagement/Disengagement Noise (sones) | 21 | 21 | 21 |

**3.2.1.1.6.3 Compressor Attachment Boss Vibration.** The compressor vibration measured on the compressor case shall be less than the curve defined by the following equation, where Compressor Speed in rpm = crpm:

$$\text{Boss Vibration Limit} = 5.62e^{(0.00065 \times \text{crpm})}\ \text{m/s}^2\ \text{rms}$$

Compressor vibration is quantified as the power based summation of tri-axial vibration in the (200 to 2000) Hz band with the compressor operating at load conditions specified in GMW14477.

Power based summation:

$$\text{Tri-axial vibration} = \sqrt{X^2 + Y^2 + Z^2}$$

**Where:**

***X***, ***Y***, and ***Z*** are vibration levels summed in the (200 to 2000) Hz band ($m/s^2$ rms) measured in three orthogonal axes anywhere on the exterior surface of the compressor body, provided one of the accelerometer axes is parallel to the axis of compressor rotation.

The power based summation of tri-axial vibration at each mounting boss must not exceed the target for compressor speeds < 5000 rpm. Additionally, each orthogonal direction of acceleration must be < 0.9 times the power-based summed tri-axial vibration level. Acceleration of the compressor must not be dominated by acceleration along a single axis (e.g., the axis of piston motion).

**3.2.1.1.6.4 Compressor Line Pressure Pulsation.**

**Table 9: Compressor Line Pressure Pulsation**

| | Type A | Type B | Type C |
|---|---|---|---|
| Discharge Pulsation (kPaG rms) | 12 | 40 | 12 |
| Suction Pulsation without STV (kPaG rms) | 2 | 5 | 2 |
| Suction Pulsation with STV (kPaG rms) | 1.2 | 2.5 | 1.2 |

**3.2.1.1.6.4.1 Compressor Line Pressure Pulsation - Discharge.** Compressor line discharge pressure summed in the (10 to 1000) Hz band must not exceed the value in Table 9 at any speed < 5000 rpm with the compressor operating at load conditions specified in GMW14477.

**3.2.1.1.6.4.2 Compressor Line Pressure Pulsation - Suction.** Type C compressors shall be evaluated with and without suction throttle valve at DV. Type C compressors must have provisions in the casting to allow installation of the STV without changes to the die, including during production. Type A and B compressors shall be evaluated without suction throttle valve unless the valve is production intent.

**3.2.1.1.6.4.2.1 Suction Pulsation without Suction Throttle Valve.** Compressor line suction pressure summed in the (10 to 1000) Hz band must not exceed the value in Table 9 at any speed < 5000 rpm with the compressor operating at load conditions specified in GMW14477.

**3.2.1.1.6.4.2.2 Suction Pulsation with Suction Throttle Valve.** Compressor line suction pressure summed in the (10 to 1000) Hz band must not exceed the value in Table 9 at any speed < 2500 rpm with the compressor operating at load conditions specified in GMW14477.



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**3.2.1.1.6.4.3 External Control Valve Noise and Vibration Requirements**. Electronic control valve noise and vibration shall be evaluated on a bench per GMW16376 with a worst case valve installed in the compressor assembly. Evaluation shall be performed at maximum and minimum Pulse Width Modulation (PWM) frequency per 3.2.1.1.10.1.2. This test shall be performed and the results reported. There is not a requirement for maximum allowable noise at this time. The compressor supplier shall work with GM engineering to develop component level criteria. The vehicle level requirement will be used until bench method and criteria are created and agreed by GM BFO.

**3.2.1.1.6.4.4 Pressure Inversion Noise and Vibration Requirements**. There shall be no objectionable A/C compressor noises nor vibrations when evaluated per 4.3.1.1.6.7.1 with suction pressure up to 300 kPa higher than discharge pressure when the compressor and engine are turned off and evaporator after blow is activated. This testing will be performed with all applicable optional content, such as discharge shutoff valve and suction throttle valve. This test shall be performed and the results reported. There is not a requirement for maximum allowable noise at this time. The compressor supplier shall work with GM engineering to develop criteria. The vehicle level requirement will be used until bench method and criteria are created and agreed by GM BFO.

**3.2.1.1.6.5 A/C Compressor Vehicle Level Noise and Vibration.**

**3.2.1.1.6.5.1 Subjective Vehicle Level Noise and Vibration Requirements.** All functions of the HVAC system, including the A/C compressor, installed in the vehicle, shall meet a noise and vibration subjective rating of ≥ 8 per GMW14264, including evaluations at cold and hot ambient temperatures.

**3.2.1.1.6.5.2 Objective Vehicle Level Noise and Vibration Requirements.** The HVAC system installed in the vehicle must meet objective noise and vibration requirements defined in the VTS and the HVAC/PTC Integration SSTS when evaluated per GMW14483. The A/C compressor supplier must cooperate with GM and other associated suppliers in determining the root cause and resolution of any vehicle level noise and vibration deviations resulting from A/C compressor operation.

**3.2.1.1.6.5.3 Cold Ambient Vehicle Level Noise and Vibration Requirements.** At cold ambient temperatures of (-30 to 0) °C, there shall be no unusual noises, whistles or tones from the compressor and pulley bearing assembly (clutch disengaged) that exceed trace levels during the Vehicle Drive-Away A/C Off Sweep condition as described in GMW14483.

**3.2.1.1.6.5.4 Hot Ambient Noise and Vibration Requirements.** The compressor supplier shall further ensure that the integration of its compressor design to the vehicle enables the overall noise level measured at the vehicle interior to not exceed the sound level, decibel (dB) difference specified in the HVAC/PTC Integration SSTS (default of 3 dB if value is not defined at compressor sourcing) between A/C Off and A/C On operation at any operating condition including hot ambient temperatures up to 40 °C. Perform evaluations per GMW14483 for ambient temperatures of (20 to 40) °C.

**3.2.1.1.6.5.5 Mild Ambient Noise and Vibration Requirements.** There shall be no objectionable A/C compressor pulsation growl or rattle cyclical noises experienced at A/C off and mild ambient conditions when evaluated per the vehicle level procedure GMW14483 at temperatures between (10 and 20) °C. The compressor supplier shall work with GM engineering to develop a bench test/procedure to be used developing criteria. The vehicle level requirement will be used until agreed upon bench method and criteria are created.

**3.2.1.1.6.5.6 External Control Valve Noise and Vibration Requirements.** There shall be no objectionable A/C compressor electronic control valve noises nor vibrations (a rating ≥ 8 per GMW14264) when evaluated on the vehicle per GMW16376 with a worst case valve installed in the compressor. This requirement shall be met at maximum and minimum PWM frequency per 3.2.1.1.10.1.2. Evaluate per 4.3.1.1.6.6, A/C Compressor Electronic Control Valve Noise Evaluation.

**3.2.1.1.6.5.7 Pressure Inversion Noise and Vibration Requirements.** There shall be no objectionable A/C compressor noises nor vibrations (a rating ≥ 8 per GMW14264) when evaluated on the vehicle with suction pressure up to 300 kPa higher than discharge pressure when the compressor and engine are turned off and evaporator after blow is activated. This testing will be performed with all applicable optional content, such as discharge shutoff valve and suction throttle valve. Evaluate per 4.3.1.1.6.7.2.

**3.2.1.1.7 Leakage.**

**3.2.1.1.7.1 Refrigerant Leakage with Pressure.** Refrigerant leakage shall be confirmed by helium mass spectrometry leak test using the supplier's method. Correlation between refrigerant pressure and leak rate and


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helium pressure and leak rate must be provided and approved by GM BFO. Helium may be diluted with an inert gas, provided the correlation to refrigerant leakage accounts for this.

**3.2.1.1.7.1.1 Online Leakage Check.** Leakage shall not exceed 8 g/y of refrigerant with 1500 kPaG internal pressure in the compressor when tested with the compressor ambient at 25 °C. This test shall be performed with helium mass spectrometry on 100% of compressors at the end of the production line. This requirement applies to both R134a and R1234yf.

**3.2.1.1.7.1.2 Static Leakage Check.** Leakage shall not exceed 25 g/y of refrigerant when tested with the compressor ambient at 87 °C. The compressor shall be charged with the following amount of refrigerant.

Refrigerant Charge (g) = Compressor Internal Volume (cc) × 0.4

When conducting original validation or offline checks, the compressor must be attached to a fixture that places representative loads upon the attachment points (powertrain mounting bosses and A/C ports) when testing for leakage. The attachment bolts should be torqued to be at 95% of their failure values determined during validation testing (see 3.2.2.5). This requirement applies to R134a and R1234yf.

**3.2.1.1.7.2 Leakage with Vacuum.** The compressor shall hold a vacuum of 710 Torr for a minimum of 1 h. The procedure shall be to evacuate to 710 Torr (710 mm Hg) then shut off the vacuum source. Pressure shall not increase by > 75 Torr in 1 h. The compressor shall not be operated during this test.

**3.2.1.1.7.3 Burst Pressure.** Burst pressure is the internal pressure which causes the compressor to structurally fail which would result in refrigerant leakage.

**3.2.1.1.7.3.1 External Burst Pressure.** The compressor assembly shall not burst externally (structural failure resulting in leakage out of the compressor) when tested at twice the maximum opening pressure of pressure relief valve defined in 3.2.1.1.5. Test per 4.3.1.1.8.1.

**3.2.1.1.7.3.2 Internal Burst Pressure.** The compressor assembly shall not burst internally (structural failure resulting in leakage from high pressure to low pressure cavities of the compressor) when tested at twice the maximum opening pressure of pressure relief valve defined in 3.2.1.1.5, while the low pressure cavities are maintained at a pressure not to exceed 1380 kPaG. Test per 4.3.1.1.8.2.

**3.2.1.1.8 Internal Contaminant.**

**3.2.1.1.8.1 Internal Contamination Limit.** Non-friable internal contaminant shall not exceed 30 mg. Maximum contaminant size shall not exceed 0.5 mm × 0.5 mm × 1.0 mm for materials with a Brinell hardness of 95 or less. Maximum contaminant size shall not exceed 0.3 mm × 0.3 mm × 0.3 mm for materials with a Brinell hardness of > 95. This requirement shall be validated per 4.3.1.1.9.1.

**3.2.1.1.8.2 Internal Contaminant Robustness.** The compressor shall meet all requirements of this document with the level of contaminants specified in 3.2.1.1.8.1 entering the suction port. This requirement shall be validated per 4.3.1.1.9.2.

**3.2.1.1.9 Electromagnetic Compatibility.** The compressor must meet GMW3097 and GMW3103.

**3.2.1.1.10 Capacity Control (Type C).** The function of the capacity control device is to adjust compressor displacement to attempt to get actual refrigerant inlet conditions to the target condition.

**3.2.1.1.10.1 External Capacity Control.** The control valve shall be of the suction pressure type, where current to the control valve correlates to a target suction pressure. The control valve shall reduce the compressor displacement when suction pressure is below the target. The control valve shall increase the compressor displacement when suction pressure is above the target. The control valve characteristic requirements are documented in Table 10. The control valve characteristics will be agreed upon by supplier and GM BFO and documented on the compressor drawing prior to production release per CG4389.



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**Table 10: External Control Valve Requirements**

| Characteristic | Requirement |
|---|---|
| Usage Type (High Side or Low Side Drive) | High Side Driven |
| Nominal Voltage | 12 V |
| Short Circuit Resistance | Yes, at Maximum Voltage at Control Valve U ≤ 15 V |
| Coil Resistance R20 at 20 °C (Ω) | A Finite Value Between 8.4 and 10.6 ± 0.5 |
| Insulation Resistance at 500 V | ≥ 10 MΩ |
| $I_{PWM\ IH\ Max}$ Maximum Current Allowed in the Active State | < 1.0 A Maximum (nominal 0.8 A) |
| $I_{PWM\ IH\ Min}$ Minimum Current Required in the Active State | ≥ 0.09 A Minimum |
| $V_{PWM\ IH\ Min}$ Minimum Input Voltage in the Active State | 9.0 V Minimum |
| $V_{PWM\ IH\ Max}$ Maximum Input Voltage in the Active State | 16.0 V Maximum |
| Pulse Width Modulation (PWM) Input Frequency Capability | (400 to 700) Hz |
| Electrostatic Discharge (ESD) Protection - Handling and Powered | Per GMW3097 |
| Temperature Capability | Per 3.1.3 |
| Minimum Compressor Suction Pressure Setpoint (including tolerance) at Maximum Control Valve Current (12.0 V, maximum PWM frequency, R134a) | ≤ 150 kPaG |
| Maximum Compressor Suction Pressure Setpoint (including tolerance) at Minimum Control Valve Current (12.0 V, maximum PWM frequency, R1234yf) | ≥ 280 kPaG |
| Compressor Suction Pressure Tolerance at Maximum Control Valve Current (12.0 V, maximum PWM frequency, R134a) | ± 35 kPa |
| Compressor Suction Pressure Tolerance at Minimum Control Valve Current (12.0 V, maximum PWM frequency, R1234yf) | ± 30 kPa |

**$I_{PWM\ IH}$** = Interleaved Pulse Width Modulation
**$V_{PWM\ IH}$** = Variable Pulse Width Modulation

**3.2.1.1.10.1.1 Suction Pressure Setpoint and Tolerance.** The control valve suction pressure setpoint and accuracy requirements in Table 10 shall not be exceeded through the entire output range due to voltage, temperature, hysteresis, repeatability, altitude, life, etc. A minimum of six control valves shall be tested sweeping the control valve current from minimum to maximum and maximum to minimum current, at the conditions in Table 11, before and after the control valve durability test per 3.7.1.1.1. The increasing and decreasing current sweeps should be performed over a duration of at least 60 s each. The results will be reported as a graph of control valve current, suction pressure and discharge pressure versus time and a table of suction and discharge pressures at a minimum of six currents from each sweep and each valve for each condition in Table 11. Test samples shall include control valves at the USL and LSL of suppler suction pressure setpoint. This test is to be performed on a compressor assembly and suction pressure is to be measured within 100 mm of compressor suction port. Testing shall be performed with R134a and R1234yf refrigerants.


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**Table 11: External Control Valve Setpoint and Tolerance Verification Conditions**

| Test Conditions | | | | | Test Results | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | LSL Suction Pressure Valve | | USL Suction Pressure Valve | |
| Condition Number | Voltage (V) | Ambient Temp (°C) | PWM Input Frequency (Hz) | Control Valve Current (A) | Suction Pressure (R134a) (kPaG) | | Suction Pressure (R1234yf) (kPaG) | |
| | | | | | New Valve | After ECV Durability | New Valve | After ECV Durability |
| 1 | 12.0 | 125 | Lowest Allowed per the Drawing | Lowest Allowed per the Drawing | | | | |
| 2 | 12.0 | 125 | Lowest Allowed per the Drawing | Highest Allowed per the Drawing | | | | |
| 3 | 12.0 | 125 | Highest Allowed per the Drawing | Lowest Allowed per the Drawing | | | | |
| 4 | 12.0 | 125 | Highest Allowed per the Drawing | Highest Allowed per the Drawing | | | | |
| 5 | 16.0 | 0 | Lowest Allowed per the Drawing | Lowest Allowed per the Drawing | | | | |
| 6 | 16.0 | 0 | Lowest Allowed per the Drawing | Highest Allowed per the Drawing | | | | |
| 7 | 16.0 | 0 | Highest Allowed per the Drawing | Lowest Allowed per the Drawing | | | | |
| 8 | 16.0 | 0 | Highest Allowed per the Drawing | Highest Allowed per the Drawing | | | | |

**Temp** Temperature

**3.2.1.1.10.1.2 Pulse Width Modulation (PWM) Input Frequency Capability.** The control valve shall be capable of operating at the PWM input frequency defined in Table 10 without objectionable noise while meeting control valve durability per 3.7.1.1.1. The compressor assembly shall meet control accuracy and startup requirements per 3.2.1.1.10.1.1 and 3.2.1.1.10.1.2 across this PWM input frequency range with both R134a and R1234yf refrigerants.



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**3.2.1.1.10.1.3 External Control Valve Setting Adjustment.** 100% of the control valves shall be checked and adjusted at maximum and minimum control valve current to meet the requirements of suction pressure setpoint and accuracy in Table 10. The check and adjustment may be done with a different method and criteria only with approval of the GM BFO. In order to obtain such approval the supplier must provide proof of correlation of the supplier method and criteria to the requirements in Table 10.

**3.2.1.1.10.1.4 Start-up.** A production compressor shall reach pumping capacity as defined in Table 12 Start-up Requirements without break-in.

**3.2.1.1.10.1.4.1** Run test with typical system components for the application on a laboratory test bench.

**3.2.1.1.10.1.4.2** Compressor speed equals 700 rpm and control valve current at maximum value indicated on the compressor drawing.

**3.2.1.1.10.1.4.3** Condenser ambient equals 30 °C with typical system condenser. Set condenser air flow to 1.5 m/s.

**3.2.1.1.10.1.4.4** Evaporator ambient = 40 °C and 50% Relative Humidity (RH) with 12 V provided to the HVAC blower.

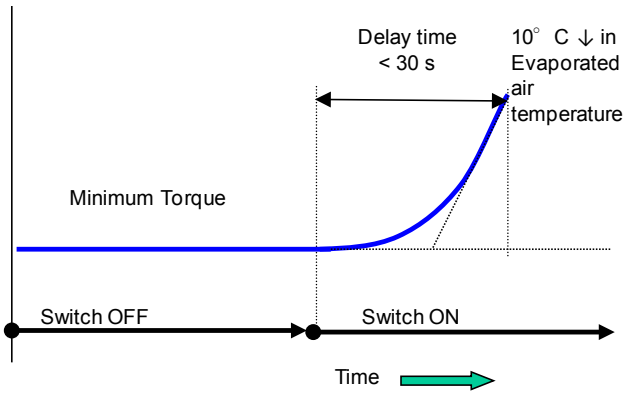
**3.2.1.1.10.1.4.5** Refrigerant charge quantity shall be the production charge or the middle of the subcool plateau.

**Table 12: Start-up Requirements (Type C)**

| Conditions | Control Valve Type | Time to Full Pumping | Additional Criteria |
|---|---|---|---|
| Switch **ON**; no liquid refrigerant in compressor. | External | ≤ 10 s | Compressor torque after switch **ON** per Figure 1. |
| Switch **ON**; attain liquid refrigerant in compressor per the pre-run condition in 4.3.1.2.5. Wait no more than 15 s to engage clutch once compressor reaches conditions in 3.2.1.11.2. | External | < 80 s | Compressor torque after switch **ON** per Figure 1 substituting (80 for 30) s |
| Switch **OFF**; maximum control current and maximum displacement. | External | < 2 s from (100 to 20)% AND < 2 s from 20% to Minimum Stroke | Compressor torque after switch **OFF** per Figure 2. |

**Note:** Time to full pumping capacity shall be when a 10 °C decrease in evaporator air out temperature is realized with start time being time of clutch engagement.

**Figure 1: Compressor Torque after Switch On**





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