GM	WORLDWIDE ENGINEERING STANDARDS	General Specification	GMW16153

Charge Air Cooler Ducts

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 Purpose. This standard defines the requirements for pressurized charge air cooler (CAC) duct systems, both hot and cold sides. These systems are typically used with either gasoline or diesel turbocharged or supercharged engines.

1.2 Applicability. Bill of Material (BOM) row 313.27 Charge Air Cooler plumbing.

1.3 Remarks. Not applicable.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GME14090	GMW3059	GMW3600	GMW14872
GMW14908	GMW15272	GMW15357	GMW15758
GMW15760			

3 Requirements

3.1 System/Subsystem/Component/Part Definition. Not applicable.

3.1.1 Appearance. See SSTS/CTS.

3.1.2 Content.

3.1.2.1 Physical Content. Not applicable.

3.1.2.2 Functional Content. Not applicable.

3.1.3 Ambient Environment. Not applicable.

3.1.4 Interfaces. Not applicable.

3.1.5 Usage Definition. Not applicable.

3.2 Product Characteristics.

3.2.1 Performance Requirements.

3.2.1.1 Pressure Drop.

3.2.1.1.1 Procedure. The test shall be performed per GMW14908.

3.2.1.1.2 Requirements. Requirements per CAC duct Subsystem Technical Specification (SSTS); CAC duct Component Technical Specifications (CTS) or GM approved drawing shall be met.

Note: Performance results shall be correlated and evaluated at the thermodynamic conditions that are described in the CAC duct SSTS, CAC duct CTS, or GM approved drawing.

3.2.1.2 Pressure Vibration Temperature (PVT) Test.

3.2.1.2.1 CAC Duct. This procedure evaluates the CAC duct when subjected to cyclic pressure, temperature and vibration conditions. For a principle sketch of the setup of the part, see Appendix A.

3.2.1.2.2 Procedure.

a. Mount CAC ducts which passed Air Leak Test according to paragraph 3.2.1.4 on a stable platform. Setup must include any design intent CAC duct support bracket, mounted as in vehicle position. Place the test platform in an environmental chamber.

b. Completely seal all of the CAC duct fittings except for the mating fitting.

c. Install the CAC duct test sample to the mating component of the test fixture.

d. One end of the CAC duct shall be fixed and the other end rigidly attached to an articulating test fixture. The articulating test fixture shall move in a motion that simulates actual in-vehicle movement. See Appendix B.

e. Connect a regulated air supply to the sample in the feeding end. The regulated air supply shall be electronically controlled and capable of generating the pressure profile shown in Appendix C.

f. Precondition the sample per the Soak Procedure in Appendix D.

g. Maintain chamber (ambient) and regulated charge air temperature per profiles shown in Appendix E. Maximum charge air temperature should be taken from SSTS/drawing for respective duct. In case of inconsistency of values, values shall be decided in agreement with GM Design Responsible engineer and GM Validation Engineer.

h. Apply the pressure profile per Appendix C. Maximum charge air pressure should be taken from CAC duct SSTS, CAC duct CTS or GM approved drawing. In case of inconsistency of values, values shall be decided in agreement with GM Design Responsible engineer and GM Validation Engineer.

i. Subject the CAC test sample to the pressure, temperature and vibration inputs per Figure E1 for the duration to represent R99C50.

j. Inspect the CAC duct assembly for any damage or degradation. Document in the test report all observations/findings from the inspection. Proceed with visual inspection according to paragraph 3.2.1.9. Take digital photographs of any damage/degradation, as required.

k. To establish Weibull slope, continue testing until component failure. Document the failure mode and number of cycles/time to failure. Test report must include digital photographs of the failure mode(s).

3.2.1.2.3 Requirements. After the CAC duct assembly has been subjected to R99C50 of test, the duct must not leak more than 50 mm^3/s when stabilized at 300 kPa in room temperature (+23 ± 2) °C.

3.2.1.3 Increase in Circumference and Deformation. This evaluation shall be done prior to and after the PVT test according to paragraph 3.2.1.2. Refer to Section 4 regarding Design Validation (DV) and Production Validation (PV) requirements.

Definitions:

Prior to PVT Test

- **C1 =** Measurements of circumference along the entire length of CAC hose. The duct circumference measurements shall be made at ≈ 50 mm intervals along the length of the hose, but not closer than 10 mm to the tangent of a formed bend.
- **C1max =** Maximum measured circumference when the CAC duct is exposed to maximum pressure and maximum temperature conditions, per CAC duct SSTS, CTS or GM approved drawing. Record the location along CAC duct where C1max occurs.

After PVT Test

- **C2 =** Maximum circumference due to permanent deformation after PVT test. C2 shall be measured with the CAC duct in an unpressurized state and stabilized at (+23 ± 2) °C (room temperature).
- **C2max =** Maximum measured circumference due to permanent deformation after PVT test, when the CAC duct is exposed to maximum pressure and maximum temperature conditions per CAC duct SSTS, CTS or GM approved drawing. Record the location along CAC duct where C2max occurs.
- **Note:** The circumference measurements shall be measured and recorded prior to and after performing the PVT test. All measurements C1, C1max, C2 and C2max shall be made on the parts installed on the original test rig for PVT testing.

3.2.1.3.1 Procedure.

- Measure and record C1 with the CAC duct in the installed position at (+23 ± 2) °C.
- At a max temperature and max pressure condition of PVT evaluation according to paragraph 3.2.1.2, measure and record C1max.
- After the PVT evaluation according to paragraph 3.2.1.2 has been completed, measure and record C2 with the CAC duct in the installed position at (+23 ± 2) °C.
- At a max temperature and max pressure condition of PVT evaluation according to paragraph 3.2.1.2, measure and record C2max.
- Test report shall include digital photographs of all end-of-test measurements.

3.2.1.3.2 Requirements. Maximum increase in circumference under elevated temperature and pressure:

Prior to PVT Test: (C1 max – C1) / C1 ≤ 12 %.

After PVT Test: (C2 max – C2) / C2 ≤ 12 %.

Maximum permanent deformation prior to and after PVT test at (+23 ± 2) °C without internal pressure:

(C2 – C1) / C1 ≤ 6 %.

3.2.1.4 Air Leak Test.

3.2.1.4.1 Procedure. Place a new CAC duct sample in an environmental chamber.

a. Lower the environmental chamber temperature to -40 °C, stabilize for 30 minutes.
b. Set the CAC duct test pressure to 200 kPa. Measure the leakage.
c. Stabilize the chamber temperature at -30 °C, for 30 minutes.
d. Set the CAC duct test pressure to 200 kPa. Measure the leakage.
e. Stabilize the chamber temperature at -20 °C for 10 minutes, set the CAC duct test pressure to 300 kPa and measure the leakage. Repeat procedure at 0 °C, +50 °C, +100 °C (include +150 °C, +200 °C and maximum temperature per SSTS/CTS, if applicable).

3.2.1.4.2 Requirements. The CAC duct leak rate shall not exceed 10 000 mm^3/s, corrected to standard conditions, when the CAC duct is subjected to the following test conditions:

- -40 °C ≤ T ≤ -30 °C.
- Test pressure: (200 ± 10) kPa.

The CAC joint leak rate shall not exceed 50 mm^3/s, corrected to standard conditions, when the CAC duct is subjected to the following test conditions:

- -20°C ≤ T ≤ +100 °C
  (+150 °C, +200 °C and maximum temperature, if applicable).
- Test pressure: (300 ± 15) kPa.

3.2.1.5 Burst Test.

3.2.1.5.1 Procedure.

- Mount the mating interfaces (e.g. spigot, hose barb etc.) in a test chamber.
- Assemble the mating CAC duct. Both ends of the duct shall be attached to the test chamber and sealed.
- As testing fluid either oil, coolant or air can be used. The test equipment shall be capable of supplying sufficient pressure until burst.
- Completely fill the CAC duct test sample with testing fluid.
- Maintain test chamber ambient temperature at (+100 ± 2) °C for 4 h.

Increase pressure at a rate of (20 ± 5) kPa/s until either burst or leakage occurs. A diagram of pressure vs. time shall be recorded.

3.2.1.5.2 Requirements. The minimum burst pressure shall be 2x (two times) maximum working pressure per CAC duct SSTS, CTS or GM approved drawing or 400 kPa, whichever is higher.

3.2.1.6 Vacuum Test. Definitions: D1 is the diameter or minor axis of ellipse measured at ≈ 50 mm intervals along the length of the hose, but not closer than 10 mm to the tangent of a formed bend or internal and external joint in the assembly.

D2 is the corresponding measurement after the test.

3.2.1.6.1 Procedure.

- Measure diameter or minor axle of ellipse (D1) of the duct.
- Place the CAC duct sample in an environmental chamber.
- Let the duct be heated at +100 °C for 1 h.
- Apply a pressure of 20 kPa below atmosphere pressure or value as measured on the specific application under the conditions agreed with the Charging PMT from Powertrain, for 5 minutes at +100 °C.
- Measure the diameter of the minor axes of ellipse (D2) while pressure and temperature is applied.

3.2.1.6.2 Requirements. Maximum deflection under elevated temperature and pressure:

(D1 – D2) / D1 ± 10 %

3.2.1.7 Regulated Emissions.

If required by the specific vehicle program, the CAC duct system, (including joints) shall meet the Partial Zero Emissions Vehicle (PZEV) regulated emissions requirements.

3.2.1.8 Cyclical Corrosion Test.

3.2.1.8.1 Test Procedure. Subject the test assembly to cyclical corrosion per GMW14872.

UH; All; 4 per cycle; method SH/SM, Exposures B and D with metal component combined with counter material as used in assembly.

3.2.1.8.2 Requirements. Cosmetic corrosion requirements per GMW15272 after Exposure B, shall be met. Assembly must meet all of the requirements of the Leak Test (paragraph 3.2.1.4) and the Burst Test (paragraph 3.2.1.5) after Exposure D. Assembly must meet the functional corrosion requirement per GMW15272 after exposure D.

3.2.1.9 Destructive Test (Visual Inspection). Purpose of test is to verify robust and leak free connection on all internal and external joints in the assembly. This evaluation shall be done with all parts out of PVT Test according to paragraph 3.2.1.2, after Test according to paragraph 3.2.1.3.

3.2.1.9.1 Test Procedure.

- Put CAC duct on stable surface and prepare part as described in Appendix F.
- Perform visual inspection for any kind of damage on hose/pipe.

3.2.1.9.2 Requirements. Hose, pipe or duct shall not have any damage which could result in a failure or leakage of the assembly.

3.2.2 Physical Characteristics. Not applicable.

3.2.2.1 Dimensions and Capacity. Not applicable.

3.2.2.2 Mass Properties. Not applicable.

3.2.3 Reliability.

3.2.3.1 Reliability Evaluation Point (REP). The REP of the component/subsystem as defined in CAC duct SSTS or CAC duct CTS.

3.2.3.2 Reliability Requirements. This specification has been designed to provide a default reliability performance of 99 % at 50 % confidence level (R99C50) for the reliability Evaluation Point referenced in paragraph 3.2.3.1. Reliability Demonstration is provided by the DV Endurance Tests specified in paragraph 4.1.1. Endurance Tests specified for PV according to paragraph 4.1.2., are intended to demonstrate conformance to the reliability demonstrated during DV. Please note that if this component requires a reliability demonstration value different than the previously stated R99C50, a different DV Endurance test schedule will be required.

3.2.3.3 Accelerated Test Methods. GM encourages the use of appropriate Accelerated Test Methods, wherever possible, for example, the use of an over-stress test to reduce test time. GM Validation Engineering must review and accept Reliability demonstration test plans prior to the supplier submitting the Analysis / Development / Validation (ADV) Test Plan for approval.

3.2.4 Serviceability. Special scheduled maintenance or repair procedures are not permitted. All connections shall be reusable and withstand a minimum of five (5) remove and install procedures and pass Air leak Test requirements per section 3.1.2.4 at +100 °C afterwards. Torque for screw-type clamps shall be provided for service publications. No special tools shall be required for servicing the CAC duct system joints.

3.2.5 User System/Subsystem/Component/Part Interface. Not applicable.

3.3 Design and Construction.

3.3.1 Materials, Processes and Parts Selection Guidelines.

3.3.1.1 Material Guidelines. Not applicable.

3.3.1.2 Processes Guidelines. Not applicable.

3.3.1.3 Parts Guidelines. Not applicable.

3.3.2 Design Guidelines and Constraints. Not applicable.

3.3.3 Identification and Marking. According to GME14090, GMW16331.

3.3.4 Workmanship. Not applicable.

3.3.5 Interchangeability. Not applicable.

3.3.6 Duct Construction. The duct shall be designed, so that any presence of internal duct abrasions, cuts or flaws shall **not** constitute a deviation from this specification.

3.3.6.1 Duct Insert. The duct insert (if needed) must not extend past the end of the duct. The insert must be radiused, or chamfered, in order to eliminate burrs or sharp edges which might cause hose damage under conditions of assembly, vibration or pressure impulse.

3.3.6.2 Design Restrictions. Grooves, upsets, burrs or serrations are not permitted on the duct stem outer diameter (OD), or shell inner diameter (ID), except in the case that these grooves, upsets, or serrations do not cause hose cutting, higher internal pressure drop or other damage under any condition or combination of assembly component dimensioning or tolerance allowed by supplier production specifications.

3.4 Documentation. Not applicable.

3.5 Support of System/Subsystem/Component/Part After Sale. Not applicable.

3.6 System/Subsystem/Component/Part Operator Training. Not applicable.

3.7 System/Subsystem/Component/Part Characteristics. Not applicable.

4 Validation

4.1 General. The tests in this GM Engineering Standard are development tests, production tests and in-process tests. Development tests shall be performed and passed in order to obtain the approval from the responsible GM Release Engineer prior to start of production. Production tests shall be performed and passed with each manufactured part.

4.1.1 Design Validation (DV). CAC ducts shall be tested with the following procedures.

Table 1 Test Table

Paragraph	Test	Minimum # Samples
3.2.1.1	Pressure drop	3
3.2.1.2	PVT test	All parts from paragraph 3.2.1.4
3.2.1.3	Increase in circumference	All parts from paragraph 3.2.1.2
3.2.1.4	Air Leakage	per Table 2
3.2.1.5	Burst test	6
3.2.1.6	Vacuum Test	3
3.2.1.7	Regulated Emissions (if applicable)	6
3.2.1.8	Cyclic Corrosion	6
3.2.1.9	Destructive test (Visual inspection)	All parts from paragraph 3.2.1.2

4.1.1.1 Testing.

4.1.1.1.1 Test Samples. CAC duct samples shall be made per GM released 2D/3D math data. The samples shall be assembled according to production intent process. 2D drawings as well as assembly instructions will be provided to GM Release Engineer. If required a specially made spigot fitting can be used as interface part.

CAC duct samples that have the worst case tolerance stack-up, (both ± 3 sigma), shall be used for Design Validation (DV) testing. An equal number of +3 sigma and -3 sigma shall be used. The tolerance distribution of parts to be tested shall be decided in agreement with GM Design Responsible engineer and GM Validation Engineer.

4.1.1.1.2 Performance Test Requirements. These are tests designed to demonstrate the performance of the component, but not necessarily the reliability.

4.1.1.1.3. Endurance Test Requirements. These tests are designed to demonstrate the component reliability. The method of test to failure is preferable.

4.1.1.1.4 Test to Failure. If you choose to define tests that are run to failure, the number of samples shall be defined as required to achieve R99C50 and use Weibull analysis to determine slope. This shall be decided in agreement with GM Design Responsible engineer and GM Validation Engineer.

Note:

- If any failure occurs in the first life of customer usage, stop the entire test. Do a Design Review Base on Test Result (DRBTR). Perform root cause analysis. If and as determined, redesign the part / product and start testing all over again.
- First life/customer usage shall be normal stress, second and third life can be accelerated and/or Step Stress.
- Upon failure, plot Weibull slope and calculate reliability demonstrated.
- If no failures by the end of the 3rd life, remove half of the samples from test stand and do the functional tests followed by a DRBTR.
- Continue test to failure with the other remaining samples using steps of stress method to induce failure and do the functional tests followed by a DRBTR to analyze failed samples.

4.1.1.1.5. Success Testing. If you choose to define tests that are run for a finite number of cycles, the number of samples shall be defined as required to achieve R99C50 with a minimum of 8 samples, using a Weibull slope of 2 (see Table 2).

Note: One (1) life of customer usage is defined as ten (10) cycles of durability testing according to Figure E1.

Table 2: Example for number of Samples Required for Endurance Tests, based on a Weibull slope of 2

Reliability Requirement	Success Test - of Customer Usage Lives	Minimum Sample Size Required	
		Test to Failure (TTF)	Success Testing
		Sample Size	Sample Size
R99C50	Not applicable	see paragraph 4.1.1.1.4	
R99C50	2.1		16 Sample (no failures)
R99C50	2.4		12 Sample (no failures)
R99C50	2.9		8 Sample (no failures)

4.1.1.2 Design Level Requirements. All duct/hose assemblies manufactured for Engineering Source Approval per this specification shall be completely representative of production level materials, components, processes and tooling. The exceptions are those assemblies needing to be specially manufactured under extremes of dimensions and/or tolerances to meet the test requirements of the specification. Any exceptions to this requirement shall be reviewed beforehand and approved by the GM Design Responsible engineer and GM Validation Engineer.

4.1.1.3 Design Validation (DV) Approval Requirements.

4.1.1.3.1 Approval Requirements. Approval shall be provided by the GM Design Responsible Engineer and the GM Validation Engineer.

4.1.1.3.2 Documentation All test samples shall be qualified dimensionally. All data points shall be reported. For samples destructively tested, failure mode shall be reported. All test specimens shall be retained by the supplier for one year, and be available for review by the GM Design Responsible engineer and GM Validation Engineer, if requested. Test Procedures referencing specific minimum test values, shall be met by the -3 sigma limit of the sample population tested.

4.1.2 Product Validation (PV).

4.1.2.1 CAC Ducts Required Tests. CAC ducts shall be tested for conformance per the following sections:

Table 3: Test Table

Paragraph	Test	Minimum # Samples
3.2.1.1	Pressure drop	3
3.2.1.2	PVT test	All parts from paragraph 3.2.1.4
3.2.1.3	Increase in circumference	All parts from paragraph 3.2.1.2
3.2.1.4	Air Leakage	per Table 2
3.2.1.5	Burst test	6
3.2.1.6	Vacuum test	3
3.2.1.7	Regulated Emission (if applicable)	6
3.2.1.8	Cyclic Corrosion Note 1	6
3.2.1.9	Destructive test (Visual inspection)	All parts from paragraph 3.2.1.3

Note 1: This testing is not required in PV as long as material is identical to material used for DV testing.

4.1.2.2 Test Samples. Production test samples shall be produced on production representative equipment including the effects of manufacturing-induced variation. Sample selection of components to be utilized for PV Reliability requirements demonstration purposes shall be in concurrence with the guidelines set forth in GMW15760, referenced in GMW3600.

4.1.2.3 Test Requirements. PV tests are intended to verify that production parts meet the same requirements as the previously tested DV samples. PV testing shall be performed with the same rigor as DV, especially with respect to Endurance Tests.

4.1.2.4 Product Validation Approval. PV approval shall be provided by either the appropriate GM Supplier Quality Engineer or GM Validation Engineer.

4.1.2.5 Documentation. Documentation shall be per normal Production Part Approval Process (PPAP).

4.1.3 Post Validation Audit (Reference GMW15758). These tests shall be successfully completed with parts from normal production runs.

Table 4: Test Table

Paragraph	Test	# Samples
3.2.1.4	Air Leakage	6
3.2.1.5	Burst test	6

4.1.3.1 Test Samples. Six (6) test samples shall be selected from a normal production run, or 3000 pieces, whichever is smaller. Samples shall be selected at random per GMW15760 to represent the entire production population. The test in Table 4 shall be performed on these samples.

4.1.3.2 Approval. Post validation tests are self-approved by the supplier, and are subject to audit by GM Supplier Quality Engineering.

4.1.3.3 Lot Retention. In case of post validation test nonconformance, the affected production lot shall be retained by the supplier until root cause analysis is complete. The supplier shall then decide the disposition of the affected production lot. The supplier has 3 options for this retained lot; it shall be either:

1) Scrapped
2) Corrected and certified (which may mean lot testing the revised part again) based on the root cause analysis, or
3) Shipped without correction if deemed to be acceptable based upon the root cause analysis.

In any event, GM Supplier Quality Engineering and GM BOM Familiy Owner shall be notified whenever any of the above options are exercised.

4.1.3.4 Documentation. Records shall be maintained for one year from date of test.

4.1.3.5 Alternative Post Validation Compliance. The supplier may request an exemption from post validation testing provided that he can demonstrate that sufficient process controls are in place so as to make post validation testing unnecessary. Approval shall be provided by either GM Supplier Quality Engineering or the GM Release Engineer.

4.2 Validation Cross Reference Index. Approval for final VCRI or ADVP&R shall be provided by GM's SVE.

4.3 Supporting Paragraphs. Not applicable.

5 Provisions for Shipping

Not applicable.

6 Notes

6.1 Glossary. Not applicable.

6.2 Acronyms, Abbreviations, and Symbols.

ADV	Analysis / Development / Validation
B	Factor to achieve actual displacement in test
BOM	Bill of Material
C1	Origin circumference prior to PVT test
C1max	Origin circumference under elevated temperature and pressure prior to PVT test
C2	Circumference after PVT test
C2max	Circumference under elevated temperature and pressure after PVT test
CAC	Charge Air Cooler
CTS	Component Technical Specification
D1	Origin diameter prior testing
D2	Diameter during testing
DRBTR	Design Review Based on Test Result
DV	Design Validation
EOT	End of Test
GSSLT	Global Subsystem Leadership Team
HVAC	Heating Ventilation Air Conditioning
ID	Inner Diameter
MATSPC	Global repository of GM approved materials for corresponding GM Engineering Standards
OD	Outer Diameter
PPAP	Production Part Approval Process
PTC	Powertrain Cooling
PV	Product Validation
PVT	Pressure Vibration Temperature
PZEV	Partial Zero Emissions Vehicle
QC	Quick Connection
REP	Reliability Evaluation Point
S	Maximum deflection in car
SSTS	Subsystem Technical Specification
Tcont.	Maximum continuous Temperature
Texc.	Maximum excursion temperature
TTF	Test To Failure
VCRI	Validation Cross Reference Index

7 Additional Paragraphs

7.1 All parts or systems supplied to this standard must comply with the requirements of GMW3059, **Restricted and Reportable Substances for Parts.**

7.2 All pressure values specified in this document shall be considered as relative to nominal atmosphere.

8 Coding System

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

GMW16153

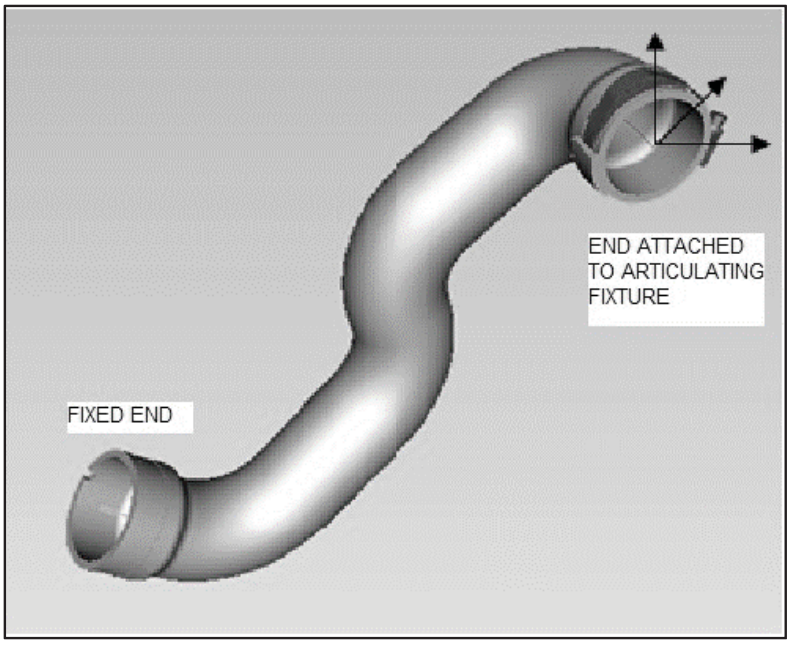
9 Release and Revisions

This standard was originated in November 2008. It was first approved by Plumbing GSSLT in May 2009. It was first published in May 2009.

Issue	Publication Date	Description (Organization)
1	MAY 2009	Initial publication.
2	JAN 2014	Destructive Test according to paragraph 3.1.2.9 added Paragraphs 3.2.1.8.1 and 3.2.3.1 updated Appendix B, C, E and H added Tables 1 and 3 updated
3	OCT 2014	Completely updated. Appendices F and G removed, following Appendices renumbered. (UBFBP & CAC ducts GSSLT)

Appendix A

Figure A1: Hose/Duct to be exposed to Internal Pressure and Temperature



Appendix B: Movement in Pressure Pulsation Test

Movement in Pressure pulsation test, paragraph 3.2.1.2.2 shall be performed as follows.

The CAC duct SSTS, CAC duct CTS or GM approved drawing shall document the maximum deflection in the normal coordinate system.

Table B1

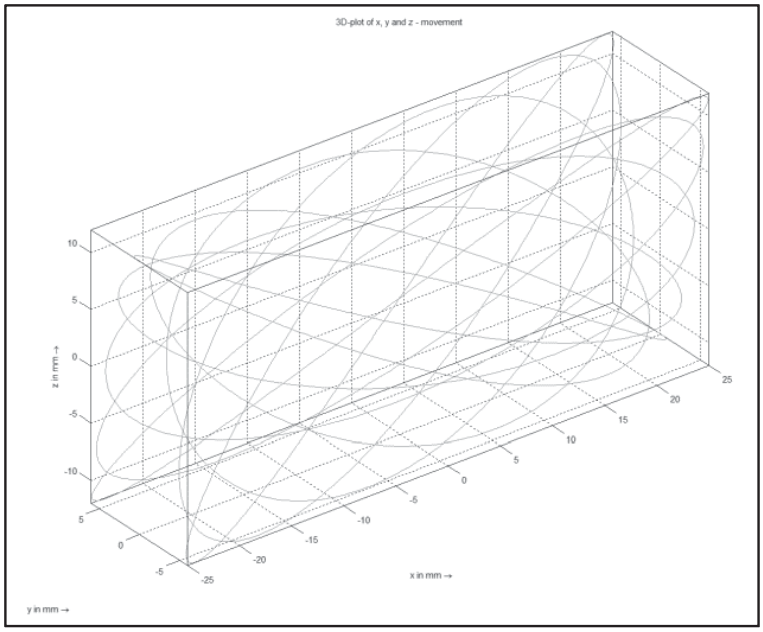
Axis	Max. deflection	Frequency
X	± per SSTS, CTS or GM approved drawing	0.9 Hz
Y	± per SSTS, CTS or GM approved drawing	1.0 Hz
Z	± per SSTS, CTS or GM approved drawing	1.1 Hz

The movement shall be applied to the turbo compressor or the throttle housing side of the duct. The fixed end shall be the connection to the Charge air cooler side. Figure B1 shows an example of the resultant 3D motion in standard coordinate system. A linear (1D) motion is not accepted.

The Factor B shall be applied to the maximum deflection per CAC duct SSTS, CAC duct CTS or GM approved drawing. B shall be as follows:

- For the first 3 h in every cycle of PVT test: **B_1 = 0.6**
- For the next 3 h in every cycle of PVT test: **B_2 = 1.1**
- For the next 3 h in every cycle of PVT test: **B_1 = 0.6**
- For the next 4 h no movement (cool down phase)
- For the last 2 h in every cycle of PVT test: **B_1 = 0.6**

Figure B1: 3D Motion



Appendix C: Pressure Profile

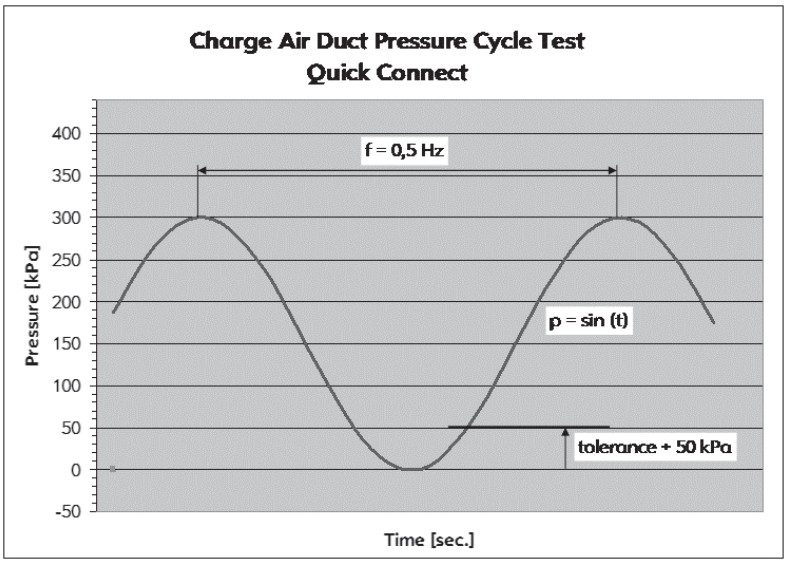
Maintain pressure at sin(t) profile with maximum pressure as stated per CAC duct SSTS, CAC duct CTS or GM approved drawing for the duct. Safety margin of P_g +30 kPa for gasoline engines, +50 kPa for Diesel engines shall be added.

Tolerance for pressure profile is P_g: ± 10 kPa.

Lowest pressure shall be P_g: 0 kPa + 50 kPa/0 kPa.

Any pressure profile substitution must receive prior approval from the GM Validation Engineer.

Figure C1: Pressure Profile Example



Appendix D: Soak Procedure

Lower chamber ambient temperature to (-30 ± 1) °C.

Maintain temperature at -30 °C for 2 h.

Raise chamber ambient temperature to:

- (+100 ± 1) °C for “cold side” CAC duct designs. “Cold side” = duct that is downstream of the CAC heat exchanger.
- (+150 ± 1) °C for “hot side” CAC duct designs. “Hot side” = duct that is upstream of the CAC heat exchanger.

Maintain the chamber ambient temperature at the specified level, (either +100 °C or +150 °C), for 4 h.

Appendix E

E1 Temperature Setting

E1.1 Test Chamber (Ambient Environment). From -30 °C to +135 °C per Figure E1 or from -30 °C to maximum temperature per CAC duct SSTS; CAC duct CTS or GM approved drawing for the duct (according to Figure E1), but +100 °C minimum.

E1.2 Charge Air Side (Internal CAC Side).

E1.2.1 Cold Side. For the first life of durability testing from -30 °C to excursion temperature per CAC duct SSTS; CAC duct CTS or GM approved drawing for the duct (per Figure E1). After the first life, until end of test, from -30 °C to continuous temperature per CAC duct SSTS; CAC duct CTS or GM approved drawing for the duct (according to Figure E1).

E1.2.2 Hot Side. For the first life of durability testing from -30 °C to excursion temperature per CAC duct SSTS; CAC duct CTS or GM approved drawing for the duct (per Figure E1). After the first life, until end of test, from -30 °C to continuous temperature per CAC duct SSTS; CAC duct CTS or GM approved drawing for the duct (according to Figure E1).

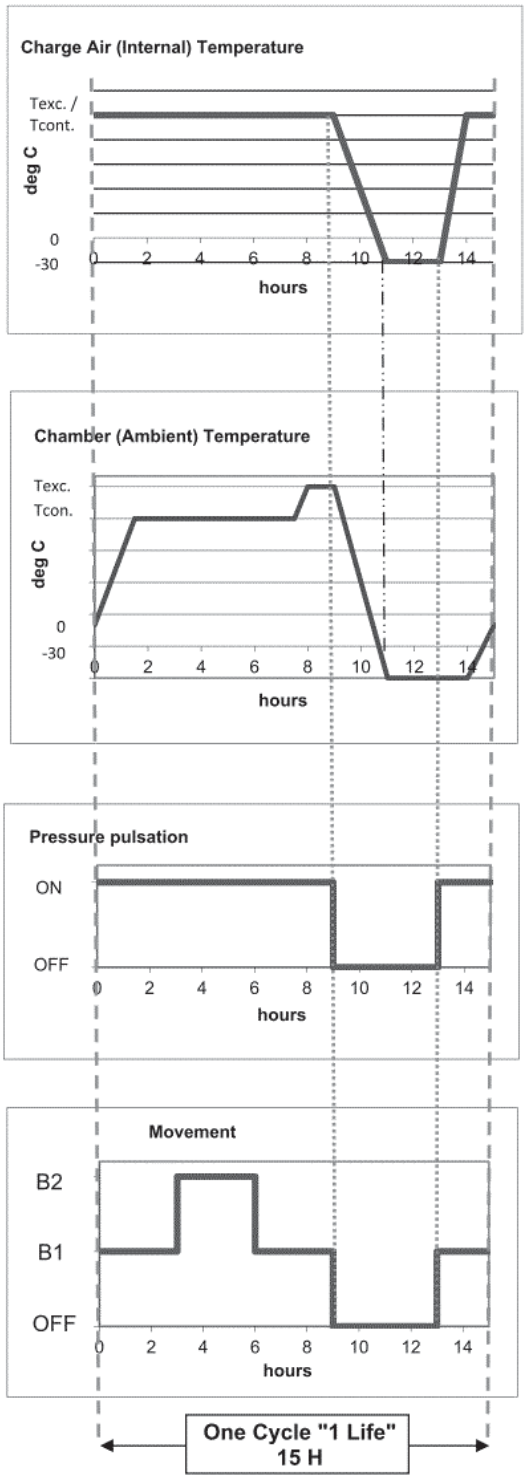
Figure E1: Graph for PVT Test

Time (h)	Charge Air Temp (C)
0	Texc. / Tcont.
9	Texc. / Tcont.
11	-30
13	-30
14	Texc. / Tcont.
15	Texc. / Tcont.

Time (h)	Chamber (Ambient) Temp (C)
0	20
1,5	Tcont.
7,5	Tcont.
8	Texc.
9	Texc.
11	-30
14	-30
15	20

Time (h)	Pressure Pulsation 1=ON ; 0=OFF
0	1
9	1
9	0
13	0
13	1
15	1

Time (h)	Movement circular
0	B1
3	B2
6	B1
9	0
13	B1
15	B1



Temperature Cycling according to appendix E
Pressure Cycling according to appendix C

One Cycle 15 h
Total Test Time ("1 Life"): 10 Cycles = 150h

GM Confidential

Appendix F

Figure F1: Example of Test Method for Rubber Hoses

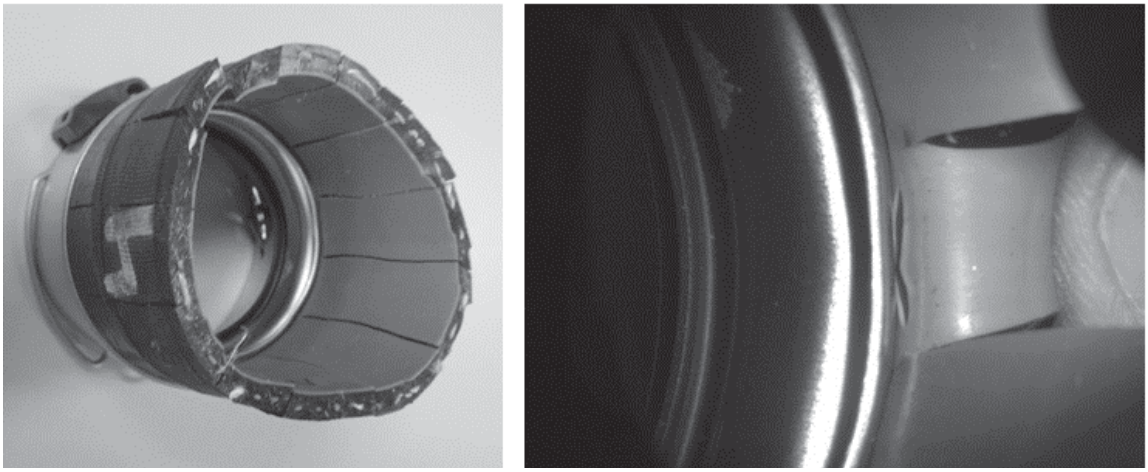


Figure F2: Example of Test Method for Plastic and Metal Ducts