GM	WORLDWIDE ENGINEERING STANDARDS	General Specification	GMW14191

Charge Air Cooler Product and Test Procedure Specification

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 shall define the Design Validation (DV), Production Validation (PV), measurement conditions, performance requirements and minimum durability requirements for various forms of Charge Air Cooler (CAC) or Intercooler heat exchanges.

1.2 Applicability. This specification applies to all Air-to-Air CAC heat exchanges that transfer energy between the engine charge air and the ambient air.

This specification defines the testing requirements for validating an Air to Air CAC using accelerated testing methods. The required quantity of test samples is defined in the Statement Of Requirement (SOR) documents CG2055.

1.3 Remarks. All pressure values within this specification are defined as absolute values.

2 References

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

2.1 External Standards/Specifications.

ASTM G85A3	SAE J1726	SAE J1344	

2.2 GM Standards/Specifications.

GMW3059	GMW8758	GMW15443	GMW17010
GMW3116	GMW14156 (ID)	GMW15531	
GMW3286	GMW14157 (ID)	GMW15758	
GMW3600	GMW14573	GMW15920	

(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.

- CG2055 Charge Air Cooler GMW14191 ADV&R
- GM1738 Packaging and Identification Requirements for Production Parts
- Statement of Requirements (SOR)

3 Requirements

3.1 System/Subsystem/Component/Part Definition. All requirements of this specification shall be met in order to demonstrate compliance with Design Validation (DV), Product Validation (PV) and Product Validation Audit (PVA) evaluations.

3.1.1 Appearance. The appearance of the condenser shall be submitted and agreed upon between the supplier, GM Design Release Engineer and GM Manufacturing. The same document shall apply to all GM global production sites. The use of a boundary sample PowerPoint document shall be prepared by the supplier. This document shall contain all appearance variation(s) such as “crazy fin”, fin bunching, fin drop, braze frame marks, finger bent fins, and any other physical variance acceptability. For example:

GM will accept no more than two (2) crazy fins per core, excluding the top and bottom fins. Maximum number of crazy fins per core including the top and bottom fins is four (4): two (2) in the center of the core and one (1) on both the top and bottom core cover.

A generic or specific picture (computer aided design (CAD) picture not permitted) must accompany each variation showing the type of defect and any agreed upon variation. This document shall be created by the supplier and submitted into a GM database with the agreed upon CG2055 Analysis Development Validation Plan and Report (ADVP&R) plan. See section 4.2. Any part coming into a GM plant that varies from this boundary sample document may be rejected at the plant's discretion.

3.1.2 Content.

3.1.2.1 Physical Content. Not applicable.

3.1.2.2 Functional Content. The Charge Air Cooler (CAC) receives hot charge air supplied by the engine turbo charger through the charge air cooler inlet duct. It transfers heat through the tubes into the fins which have air passing through them supplied by the fan and/or by ram air.

3.1.3 Ambient Environment. Unless otherwise specified, the standard ambient testing temperature environment is defined as 23 °C ± 5 °C.

3.1.4 Interfaces. All subcomponents and interfaces that build up the charge air cooler (CAC) including the upper assembly level (if required) must be documented in a block diagram supporting the Design Failure Mode and Effects Analysis (DFMEA), Process Failure Mode and Effects Analysis (PFMEA) and Design Review Based on Failure Mode (DRBFM) as required.

3.1.5 Usage Definition. The passing of these test procedures permit the use of the part globally. If more than one material supplier, or more than one toolset produce the same part in different regions, then a separate round of validation testing shall occur. The supplier should coordinate this activity with GM Engineering to determine the level of testing required and any other opportunity to combine testing.

3.1.6 Test Vehicle/Test Piece. All testing shall be performed on the charge air cooler (CAC). However, the vibration and Noise and Vibration (N&V) test shall be tested with any and all components attached as it is installed in the vehicle. This includes fan motor(s) and shroud assembly and attaching subcomponents like Charge Air Cooler, Radiator, Condenser and Isolators, etc. The testing setup shall be approved by the GM Validation Engineer. The specified sample quantity shall be agreed prior to testing in the ADVP&R plan. All subsystem components required for validation shall be provided by GM.

3.1.7 Test Time. Total testing time should be considered when planning delivery of parts to meet GM key dates contained in the GM Global Vehicle Development Process (GVDP) schedule. It is highly recommended to leave a buffer of at least two weeks between test completion and the GM milestone when planning, due to an unexpected failure where re-validation would be required. Following is an estimated plan of how long it takes to validate and test one heat exchanger product or part number. Times may vary based on test cell availability and capacity.

Calendar time:	45 d
Test hours:	1000 h
Coordination hours:	100 h

3.1.8 Test Required Information. The performance measurements and durability test results are to be summarized and reported to GM on the Supplier Analysis/Development/Validation (ADV) plan, CG2055. Full test reports shall be available for viewing by GM personnel per GMW15920.

3.1.9 Personnel/Skills. The personnel and skill requirements are the responsibility of the supplier.

3.1.10 Testing Conditions. Not applicable.

3.2 Product Characteristics.

3.2.1 Performance Requirements.

3.2.1.1 Fixed-value Performance Testing Requirements.

3.2.1.1.1 Internal Cleanliness. The charge air cooler (CAC) shall not contain more particles as described below when tested per 4.4.1.

- Maximum Weight: 25.0 mg

- Maximum Particle Size: 3.500 mm
- Maximum Particle Area: 2.58 mm^2

3.2.1.1.2 Component Data Standard (CDS) Conformation. CDS data is not only a planning tool for achieving a "near" component accuracy as starting point. It is used for calculating all initial simulations and eventually actual component performance for preproduction and production. Therefore, all CDS data must represent "real" world performance and production intent. All CDS data shall be confirmed and reported on the CDS. This includes heat dissipation, air side pressure drop, and charge side pressure drop when tested per Section 4.4.2. The results shall be recorded in the release drawing notes as Critical Key Characteristics (CKC) requirements. Results should represent the "best fit" curve that represents production design. DV part performance shall meet SOR CDS submission. The Kilowatt of heat rejection at CDS data test points at PV shall be a minimum of 98% of DV part performance or better.

3.2.1.1.3 Leak Test. The charge air cooler (CAC) shall exhibit the following leakage rate when tested per Section 4.4.3.

- CAC Core: ≤ 4 cm^3/minute
- CAC Assembly: ≤ 10 cm^3/minute

3.2.1.1.4 Maximum Pressure Test (Burst). During the procedure recorded in 4.4.9, the charge air cooler (CAC) shall not present any permanent deformation or leak beyond Section 4.4.3 or exhibit pressure loss before 500 kPa.

3.2.1.2 Endurance Testing Requirements.

3.2.1.2.1 Low Temperature Test (For Plastic Tank Charge Air Cooler Only; Not Required for Aluminum Tanks). The charge air cooler (CAC) shall not leak during the test procedure in Section 4.4.4. The charge air cooler (CAC) must pass Leak Test per Section 4.4.3 after test procedure.

3.2.1.2.2 Thermal Shock Test (For Plastic Tank Charge Air Cooler Only; Not Required for Aluminum Tanks). The charge air cooler (CAC) shall not leak during the test procedure per Section 4.4.5. The charge air cooler (CAC) must pass Leak Test per Section 4.4.3 after test procedure.

3.2.1.2.3 Heat Aging Test (For Plastic Tank Charge Air Cooler Only; Not Required for Aluminum Tanks). Run charge air cooler (CAC) Heat Aging Test per Section 4.4.7. The charge air cooler (CAC) must pass Leak Test per Section 4.4.3 after test procedure.

3.2.1.2.4 High Temperature Cycle Test. Run charge air cooler (CAC) High Temperature cycle test per Section 4.4.6. The charge air cooler (CAC) must pass Leak Test per Section 4.4.3 after test procedure.

3.2.1.2.5 Thermal Cycle Durability Test. Run charge air cooler (CAC) thermal cycle test in Section 4.4.8.The charge air cooler (CAC) must pass Leak Test 4.4.3 prior to and after test procedure 4.4.8.

3.2.1.2.6 Pressure Cycle Durability Test. Run charge air cooler (CAC) pressure cycle test in Section 4.4.10. The charge air cooler (CAC) must pass Leak Test per Section 4.4.3 after test procedure.

3.2.1.2.7 External Corrosion Test (Sea Water Acetic Acid Test - SWAAT). After the SWAAT test per Section 4.4.11.1, the charge air cooler (CAC) must pass Leak Test per Section 4.4.3. A maximum of 10% fin debonding is allowed.

3.2.1.2.8 External Corrosion Test (Neutral Salt Spray (NSS)). After the Neutral Salt Spray test in 4.4.11.2 the charge air cooler (CAC) must pass Leak Test 4.4.3. The dissimilar mating material shall have no more than 1.32 g ± 0.13 g (60 µm ± 6 µm) cosmetic mass loss. This procedure is only required when two different materials are in contact with one another which can cause galvanic corrosion. This does not include GM released fasteners nor GM standard parts applied to other different materials.

3.2.1.2.9 Vehicle Validation General Durability with Corrosion. When vehicle validation corrosion test is completed in 4.4.13, the Condenser Radiator Fan Module (CRFM) components, including the charge air cooler (CAC), must pass GMW15443 and GMW15531. This is a GM run test. If the GM engineer supplies the charge air cooler (CAC) back to the supplier (post-test), the charge air cooler (CAC) shall pass Leak Test 4.4.3.

3.2.1.2.10 Vibration Durability Test. Run test according to GMW17010. The charge air cooler (CAC) shall pass Leak Test per Section 4.4.3 after test procedure. The CAC or any component mounted to the CAC shall not show any visual or structural damage.

3.2.2 Physical Characteristics.

3.2.2.1 Dimensions and Capacity. The dimensions of the charge air cooler (CAC) shall meet all drawing specifications. This shall be proven statistically with a multi-part layout at DV and PV according to the ADV plan.

3.2.2.2 Mass Properties. The program mass targets provided in the CDS and/or CTS must be met and confirmed before testing can begin.

3.2.3 Reliability.

3.2.3.1 Reliability Evaluation Point. This specification, as written, provides a test exposure representing a Reliability Evaluation Point (REP) of 15 years of corrosion and 240 500 km (150 000 mi) of severe customer usage at the vehicle level.

3.2.3.2 Reliability Requirements. This specification, as written, supports the demonstration of the required reliability (R) of 97% or greater at a 50% confidence (C) (R97C50) at the REP for the charger air cooler component. The supplier shall utilize “vehicle equivalent” laboratory test setups to simulate “in vehicle” orientations. If the orientation may be different from one vehicle to another, use the orientation which will provide the worst-case loads for all physical level Reliability demonstration testing. Reference GMW14156 Test Reliability Requirements Guidelines, and GMW14157 Statistical Confidence Level for Reliability Validation Testing.

The Reliability Demonstration is provided by the Design Validation (DV) Endurance Tests specified in 3.8.1. In contrast to DV, the Endurance Tests specified for Product Validation (PV) in 3.8.2 are intended to confirm the reliability demonstrated during PV of components manufactured from high volume tooling and at all manufacturing sites.

Note: Test to Failure (TTF) is always the preferred method. Failure is defined as, but not limited to, the loss of function, unacceptable performance degradation, and non-conformance of the component as stated in this specification.

Note: The required number of test samples may be negotiable if it is not practical to run, for example, 23 samples. The negotiation of sample size should consider test equipment limitations, physical size of test samples, test duration, etc. However, reduction of the sample size may require inclusion/use of longer test durations or other test methods such as Highly Accelerated Stress Screening (HASS), Highly Accelerated Stress Testing (HAST), Calibrated Accelerated Life Testing (CALT), Highly Accelerated Life Testing (HALT), etc. Weibull slope values available from previous failure testing may be considered as a way to reduce the sample size and/or test duration. (For detail, refer to GMW14156 and GMW14157.)

3.2.3.3 Accelerated Test Methods. GM encourages the use of appropriate Accelerated Test Methods, wherever possible. For example, the use of accelerated stress testing to reduce test time (GMW8758 Calibrated Accelerated Life Testing).

Note: GM Validation Engineering shall review and accept Reliability demonstration test plans prior to the supplier submitting the ADV Test Plan for approval.

3.2.4 Serviceability. All serviceable parts shall be able to be disassembled within the assembly (if required) and returned without showing signs of degradation. For example, a screw into a plastic tank boss should be able to disassemble and reassemble without losing thread engagement. Plastic clips must be able to return to their “before” and “after” positions without cracks or breakage. GM’s requirement is that the part must be able to be disassembled and reassembled at least 10 times without damage. The supplier must demonstrate by test, using real or surrogate data, that the design can withstand re-use without breakage. The supplier must choose the right design, torque, and consider all other factors that might influence serviceability. In-vehicle serviceability to be approved by GM Service Engineer prior to first design freeze.

Note: GM Validation Engineering shall review and accept Reliability demonstration test plans prior to the supplier submitting the ADV Test Plan for approval.

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. Not applicable.

3.3.1.1 Material Guidelines. Not applicable.

3.3.1.2 Processes Guidelines. Not applicable.

3.3.1.3 Parts Guidelines. Not applicable.

3.3.1.4 Recycling. Materials shall be recyclable per GMW3116 (Recyclability/Recoverability). Attempts should be made to minimize the variety of materials used to make recycling more viable. All plastic parts shall be identified for recycling per SAE J1344.

3.3.2 Design Guidelines and Constraints. Not applicable.

3.3.3 Identification and Marking. The charge air cooler (CAC) assemblies supplied under this specification shall be visually identified in a manner exclusive and unique to each supplier to permit rapid identification of each respective charge air cooler (CAC) assembly manufacturer by the responsible GM Supplier Quality Engineer. Identification methods must be submitted to and approved by the GM Design Release Engineer. All assemblies must be labeled with the GM part number, date code and tool/cavity number in a visible location. All labels shall conform to GMW14573.

3.3.4 Workmanship. All exterior surfaces shall be clean and free of weld and/or braze splatter, flash, ridges, sharp edges, flux paste, roughness and manufacturing lubricants.

All charge air cooler (CAC) connections shall have the sealing surfaces and threads free of damage, and foreign material (e.g., paint, dirt, etc.) Sealing surfaces shall be smooth and free of nicks, and scratches to assure positive sealing.

Key Product Characteristics (KPC) shall be defined on the GM approved engineering drawings. The charge air cooler (CAC) assembly shall have manufacturing capability such that all dimensions are targeted at print nominal dimensions. The supplier shall submit a detailed improvement plan which describes how their manufacturing process for each part/operation shall achieve a process distribution of a value determined by the GM Supplier Quality Engineer.

3.3.5 Interchangeability. Not applicable.

3.3.6 Packaging. See GM1738, Packaging and Identification Requirements for Production Parts.

3.3.7 Materials Environmental Conditions Not applicable.

3.3.8 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

3.4 Documentation. All documentation for testing shall be approved before final Production Part Approval Process (PPAP) can be approved. For PV, the supplier shall submit a completed and signed off GMW3600 Validation Commodity form in order to finalize that all the requirements for the component(s) have been met. For Charge Air Cooler (CAC) see form CG2055 (the supplier shall work with the GM Validation Engineer to comprehend this requirement).

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.

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

4 Validation

4.1 General.

4.1.1 Validation Phase Definitions. Reference GMW15758 (ADV Process Development and Validation Terminology) for the definitions of Design Validation, Product Validation, and Post Validation Audit.

4.1.2 Test Samples. Reference GMW15758 for explanations of how parts for Design Validation, Product Validation, and Post Validation Audit shall be produced and selected. Test samples' dimensions and materials must be within specification.

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

4.1.3.1 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this specification shall be determined correctly with respect to its physical definition. When test facilities or test equipment are changed between DV and PV testing, GM Component Validation Engineer approval is required.

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

4.1.5 Endurance Test Requirements. These tests are designed to demonstrate the component reliability. Endurance testing may be conducted using either Test to Failure, 4.1.5.1 or Success Testing, 4.1.5.2. Test to Failure (TTF) is always the preferred method.

4.1.5.1 Test to Failure. Failure is defined as, but not limited to, the loss of function, unacceptable performance degradation, and nonconformance of the component as stated in this specification. Use of Weibull analysis is required to determine the reliability.

Note: The required number of test samples may be negotiable (considering test equipment limitations, test sample physical size, test duration, etc.) Weibull slope values available from previous failure testing may be considered as a way to reduce the sample size and/or test duration. Reduction of sample size shall not cause demonstration of the reliability requirement to be unfulfilled. In no case shall the sample size be less than four. In no case shall the Weibull slope be > 3.0 (even with previous failure data).

Note:

- If any failure occurs in the 1st life of customer usage, stop the entire test. Do a Design Review Based on Test Results (DRBTR), perform root cause analysis. If, as determined necessary by root cause analysis, redesign the part or product and start testing all over again.
- Upon failure after the 1st life, plot Weibull slope and calculate reliability demonstrated.
- If no failures by the completion of required reliability demonstration, remove half of the samples from test stand and do the functional tests followed by DRBTR.
- Continue test to failure with the remaining samples (consider using stepped stress methods to induce failure) and do the functional tests followed by DRBTR to analyze failed samples.

4.1.5.2 Success Testing. Refer to Table 1 for success test.

Table 1: Number of Samples Required for Endurance Tests [Note 1]

Minimum Sample Size Required			
Reliability Requirement	**Quantity of REPs (lives)**	**Slope (beta)**	**Success Testing (samples)**
R99C50	2.25	3.0	6

Note 1: The slope values listed may be reduced by the GM Validation Engineer for new design or new suppliers.

Note:

- If any failure occurs in the 1st life of customer usage, stop the entire test. Do a Design Review Based on Test Results (DRBTR), perform root cause analysis. If necessary, as determined by root cause analysis, redesign the part or product and start testing all over again.
- Upon failure after the 1st life, plot Weibull slope and calculate reliability demonstrated.

4.2 Validation Cross Reference Index.

4.2.1 Analysis/Development/Validation Plan and Report. The ADVP&R template is CG2055 (the supplier shall work with the GM Validation Engineer to comprehend this requirement). This document contains all component requirements, associated test procedures, test flows, and the quantity of parts to be tested at DV, PV, and PVA phases. This document is to be completed by the supplier and approved by the appropriate heat exchanger GM Design Release Engineer and GM Component Validation Engineer. Exceptions and/or clarifications may be in the SOR Appendix C2, G2, and/or G3, and shall be comprehended in the final approved ADVP&R.

4.2.2 Test and Results Approvals. Both test plans, and test results shall be approved as noted in the following.

4.2.2.1 DV Approval. Approval shall be provided by the appropriate GM Component Validation Engineer.

4.2.2.2 PV Approval. Approval shall be provided by the appropriate GM Component Validation Engineer.

4.2.2.3 PVA Approval. Test results are self-certified by the supplier. Results shall be available for audit by the GM Component Validation Engineer, GM Design Release Engineer, or the GM Supplier Quality Engineer.

4.2.2.3.1 Alternative Compliance. Supplier may request an exemption from Post Validation Testing, provided supplier can demonstrate that sufficient process controls are in place so as to make testing unnecessary. The

approvals required are to be provided by the GM Validation Engineer, GM Supplier Quality Engineer and GM Bill of Materials (BOM) Family Owner (BFO).

4.2.2.3.2 Lot Retention. In the case of a Post Validation Audit test result not meeting requirement, 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 three options for this retained lot; it shall be either:

a. Scrapped.

b. Corrected and certified (which may mean lot testing the revised part again) based on the root cause analysis.

c. Shipped without correction if deemed to be acceptable based upon the root cause analysis.

In any event, GM Supplier Quality Engineering shall be notified whenever any of the previously listed options is exercised. GM Supplier Quality Engineering approval is required for Option c. Lot acceptance test procedure is defined in the SOR Appendix B.

4.2.3 Documentation. Documentation shall be provided as required by the normal Production Parts Approval Process (PPAP) process. Refer to GMW3600 and SOR Appendix G2. Documents shall be managed according to GMW15920.

4.3 Supporting Paragraphs. Not applicable.

4.4 Test Procedure. See 3.2.1 for Performance Requirements.

4.4.1 Internal Cleanliness.

4.4.1.1 Procedure. Extract and measure materials from CAC per SAE J1726.

4.4.2 Performance Measurement.

4.4.2.1 Measurement and Correction. The heat dissipation, air pressure drop, and charge air pressure drop shall be measured and reported. Measurements shall be taken for the conditions in 4.4.2.2 and 4.4.2.3 and reported on the Component Data Standard (CDS).

4.4.2.2 Inlet Conditions.

- Air Inlet Temperature (RAM air through the core), T_A = 25 °C ± 0.5 °C
- Charge Air Inlet Temperature, T_C = max. excursion charge air inlet temperature per CTS; use T_C = 160 °C ± 0.5 °C if CTS is not available.
- Charge Air Inlet Pressure, P_C = max. excursion charge air pressure per CTS; use P_C = 240 kPa pressure if CTS is not available.

4.4.2.3 Test Conditions. Road Simulation Point:

- Cooling airflow, kg/s (6 flows): Air velocities ranging from 1 m/s to 12 m/s with equal increments in between; for instance 1 m/s, 3 m/s, 5.5 m/s, 8 m/s, 10 m/s, and 12 m/s.
- Charge airflow, kg/s (6 flows): Max charge airflow per engine CTS (typically 0.20 kg/s to 0.40 kg/s) followed by increments of 80%, 60%, 40%, 20% and 10% of max flow; use 0.4 kg/s if CTS is not available.

Note: If CTS values are not available and values in section 4.4.2.2 and 4.4.2.3 will be used, it is mandatory to review the values as soon as CTS values are available.

Note: Same CAC in different engine performance categories requires different measurements.

Note: RAM air = Airflow through heat exchanger.

Note: Transition Reynolds numbers must be provided for any tubes with internal turbulator or for any special tube designs.

Note: CDS with raw test data must be submitted after the tests have been performed and before final PPAP can be approved.

Note: If there is change in design (number of tubes, fin density, etc.) during the DV or PV phase, the CDS data must be resubmitted.

4.4.2.4 ADVP&R Requirement. Measurements shall be corrected to the inlet conditions in 4.4.3.2 under the same coolant fluid regimes and air velocities as in 4.4.3.

4.4.3 Leak Test Procedure.

4.4.3.1 Validation. Submerge CAC under water and collect air leak.

Water Temperature: 25 °C ± 5 °C.

CAC Air Pressure: 300 kPa ± 10 kPa minimum.

Duration: 60 s minimum.

4.4.3.2 Series. Pressurize all CAC (100%) with dry air and measure air leakage.

Air Temperature: Room Temperature.

CAC Air Pressure: 350 kPa ± 10 kPa.

Duration: 10 s minimum.

4.4.4 Low Temperature Test Procedure. (For Plastic Tank Charge Air Cooler only; not required for aluminum tanks).

4.4.4.1 Procedure. Expose the CAC to one (1) cycle as follows:

Duration: 10 h.

Chamber Temperature: -40 °C ± 2 °C.

Pressure: No charge air pressure.

4.4.5 Thermal Shock Test Procedure. (For Plastic Tank Charge Air Cooler only; not required for aluminum tanks).

4.4.5.1 Procedure. Expose the CAC to five (5) cycles as follows:

High Chamber Temperature, T_1: 140 °C ± 2 °C.

Charge Air Pressure: no charge air pressure.

Low Chamber Temperature, T_2: -40 °C ± 2 °C.

Frequency: One (1) cycle/day.

Cycle: Temperature increase to T_1 (1 minute), hold T_1 (8 h), Temperature decrease T_1 to T_2 (1 minute), hold T_2 (16 h). See Figure 1.

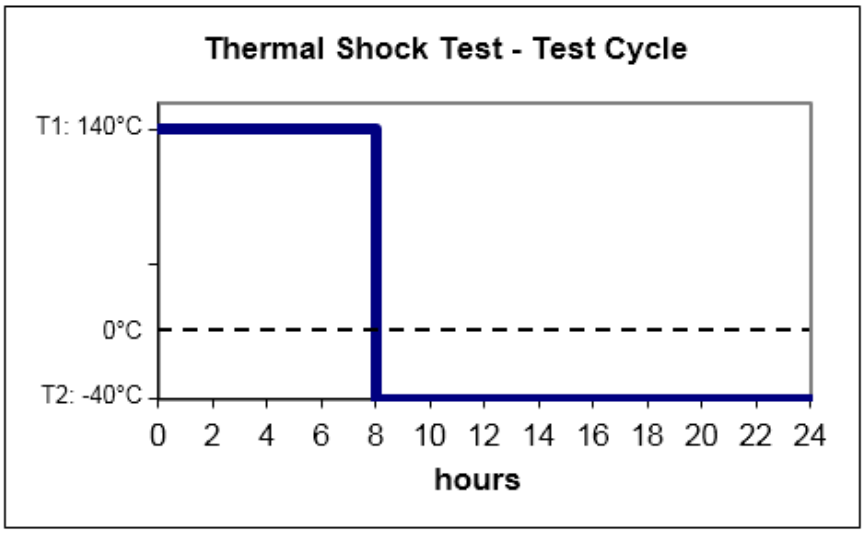

Figure 1: Thermal Shock Test – Test Cycle

Note: In case the CAC assembly is designed with different materials for inlet and outlet endtank, but one is plastic, this test is mandatory.

4.4.6 High Temperature Cycle Test Procedure.

Air Inlet Temperature (RAM air through the core), T_A = 49 °C ± 0.5 °C.

Expose the CAC to ten (10) cycles. Test cycle is described in Table 1.

Table 1: High Temperature Cycle

Low Performance Gasoline (< 110 kW)	Low Performance Diesel (< 125 W)/ High Performance Gasoline (> 110 kW)	High performance Diesel (>125 kW)	Duration (Minutes)	CAC Air Inlet Temperature (°C)	Pressure (kPa) Note 1 Pressure increase from Pmin to Pmax	Note
			60	100	160 to 250	Duration between Pmin and Pmax: 10 s to 20 s
			30	160		
			30	190	250 to 280	
			5	215	280 to 340	
All			120	Cool Down	Ambient	Ambient temperature should be reached

Note 1: Pmin to Pmax = Pminimum to Pmaximum

Note: The duration time does not include the heating up and cooling down phase.

4.4.7 Heat Aging Test Procedure. (For Plastic Tank Charge Air Cooler only; not required for aluminum tanks).

Expose the CAC to one (1) cycle as follows:

For the inlet side:

Chamber/Ambient and Charge Air Temperature: Max. Excursion charge air temperature as stated in CTS; minimum 170 °C ± 2 °C.

Charge Air Pressure: Max. excursion charge air pressure as stated in CTS; minimum 250 kPa ± 10 kPa.

Duration: 150 h.

For the outlet side:

Chamber/Charge Air Temperature: Max. excursion underhood temperature as stated in CTS; minimum125 °C ± 2 °C.

Charge Air Pressure: Max. Excursion charge air pressure as stated in CTS; minimum 250 kPa ± 10 kPa.

Duration: 150 h.

Note: If Inlet and Outlet tank material is the same, only 1 Cycle for complete CAC assembly is required.

4.4.8 Thermal Cycle Durability Test Procedure.

Expose the Charge Air Cooler (CAC) to 4500 cycles as follows:

Ambient Temperature: T_A = 49 °C ± 0.5 °C.

Charge Air Inlet Temperature: T_{C1} = 49 °C ± 5 °C, T_{C2} = Max. excursion charge air inlet temperature as stated in CTS; minimum 160 °C ± 5 °C.

Charge Air Inlet Pressure: P_C = 200 kPa ± 5kPa.

Cycle time: 12 cycles/h.

Charge Air Inlet Temperature Cycle (see Figure 2): Temperature increase T_{C1} to T_{C2} (1 minute), hold T_{C2} (2 minutes), temperature decrease T_{C2} to T_{C1} (1 minute), hold T_{C1} (1 minute).

Check leakage visually after every 450 cycles.

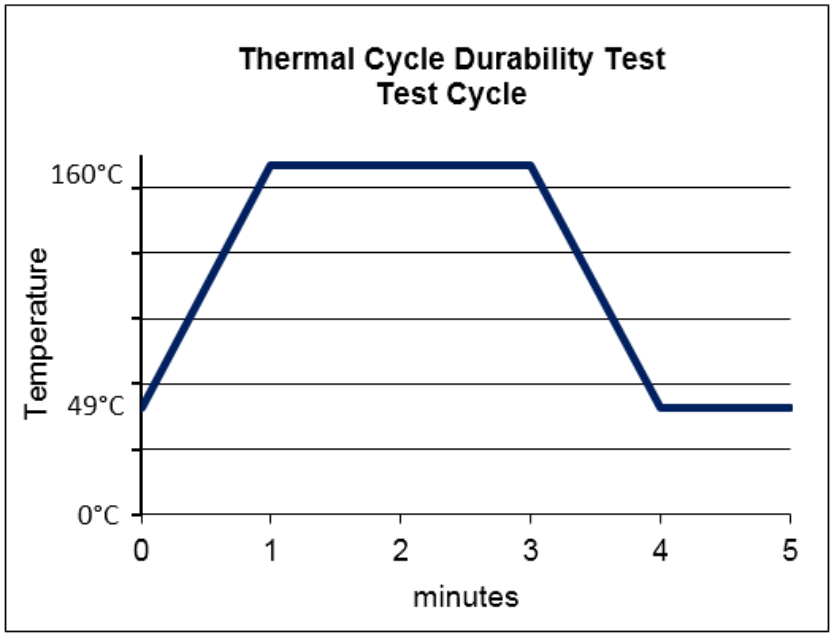

Figure 2: Thermal Cycle Durability Test – Test Cycle

4.4.8.1 Reliability. The Reliability Evaluation Point (REP) for this procedure is 4500 cycles. Weibull analysis shall be used to determine the reliability. The Reliability Requirement is: Reliability = 97% at Confidence = 50% (R97C50). If the Supplier cannot provide data to demonstrate the Weibull slope, use a value of β = 2.0. If TTF data is available for a component of similar construction, a Weibull slope of maximum 3.0 may be used (i.e., If TTF data shows a slope of 4.5, only a value of 3.0 maximum may be used for the new product).

4.4.9 Maximum Pressure Test (Burst) Procedure.

Precondition charge air cooler (CAC) for 45 h at 120 °C ± 2 °C without charge air pressure.

Ambient Temperature: 25 °C ± 5 °C.

Raise pressure to 500 kPa within one (1) minute and hold for 30 s. Depressurize and inspect charge air cooler for deformation and run leak test per Section 4.4.3.

Continue testing, increase pressure until failure and record pressure and failure mode.

4.4.10 Pressure Cycle Durability Test Procedure.

Expose the CAC to 250.000 cycles as follows:

Charge Air Inlet Pressure, P_C; 0 kPa to max. continuous pressure as stated in CTS; min. 250 kPa.

Charge Air Inlet Temperature, T_C = max. continuous temperature as stated in CTS; min. 140 °C ± 5 °C.

AND

Expose the CAC to 50.000 cycles as follows:

Charge Air Inlet Pressure, P_C; 0 kPa to max. excursion pressure as stated in CTS; min. 300 kPa.

Charge Air Inlet Temperature, T_C = max. excursion temperature as stated in CTS; min. 160 °C ± 5 °C.

Ambient Temperature: 25 °C ± 5 °C.

Pressure Cycle: 0.5 Hz (30 cycles/minute). See Figure 3 for an example.

Tolerance for pressure profile is P_g: ± 10 kPa.

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

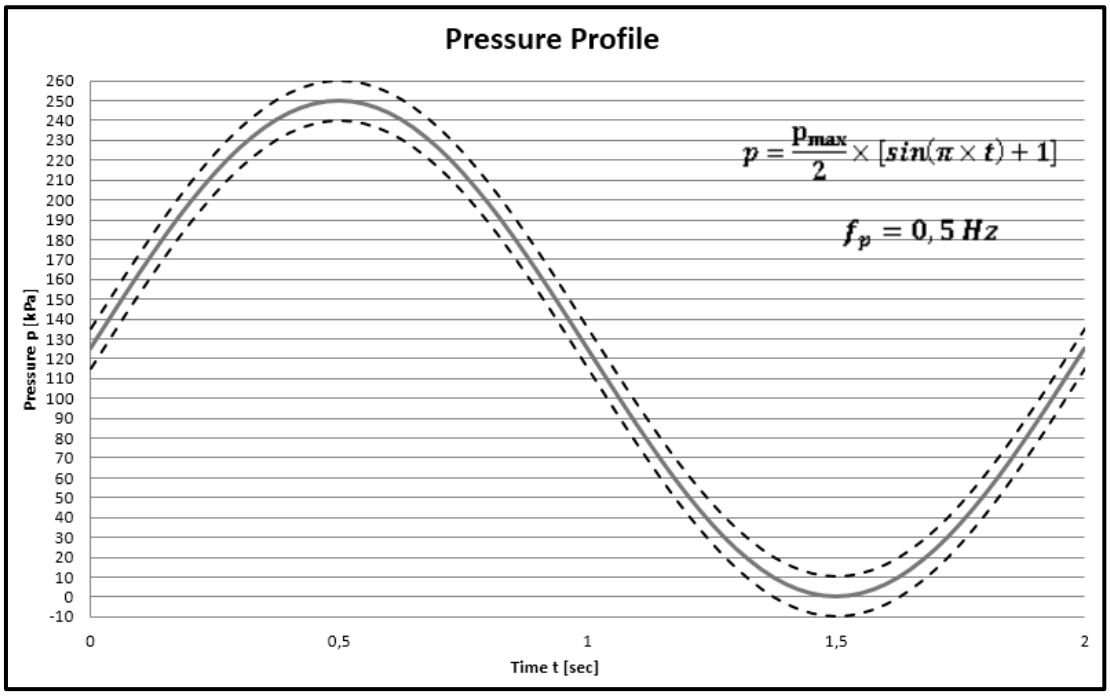

Figure 3: Pressure Profile Example

Note: Safety margin of P_g +30 kPa for gasoline engines, +50 kPa for diesel engines shall be added to the pressure value as stated in the CTS.

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

4.4.10.1 Reliability. The Reliability Evaluation Point (REP) for this procedure is 300.000 cycles. Weibull analysis shall be used to determine the reliability. The Reliability Requirement is: Reliability = 97% at Confidence = 50% (R97C50). If the Supplier cannot provide data to demonstrate the Weibull slope, use a value of β = 2.0. If TTF data is available for a component of similar construction, a Weibull slope of maximum 3.0 may be used (i.e., If TTF data shows a slope of 4.5, only a value of 3.0 maximum may be used for the new product).

4.4.11 Corrosion.

4.4.11.1 External Corrosion Test Procedure – Sea Water Acetic Acid Test (SWAAT). ASTM G85A3; 360 cycles.

4.4.11.2 Cosmetic Corrosion Test (Salt Spray) Procedure. Test per GMW3286.

Test time = 1000h ± 5 h

Note: This procedure is only required when two different materials are in contact with one another which can cause galvanic corrosion. This does not include GM released fasteners nor GM standard parts applied to other different materials.

4.4.12 Vibration Durability Test Procedure. Test per GMW17010.

Note: This test is performed at the sub-system level (complete CRFM), unless the CAC is a stand-alone component.

4.4.13 Vehicle Validation General Durability with Corrosion Procedure. GMW15443 (General Durability) and GMW15531 (Passenger Vehicle Established Roads General Durability). These tests are run by GM. The supplier shall participate in solutions for concerns discovered during testing.

4.5 Safety.

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

4.6 Deviations from this Standard. Deviations from the requirements of this standard shall have been agreed upon by the responsible GM Design Release Engineer and submitted into the GM database for historical and reference purposes (see 4.2). Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.7 Additional Requirements.

4.7.1 Changes. Any change to the component or material, i.e., design, function, properties, manufacturing process and/or location of any change or modification to the product/process and manufacture requires a new release of the product. This includes changes in Tier 1 sub-supplier chains. It is the sole responsibility of the supplier to provide the customer, unsolicited, with documentation of any change or modification of the production product/process and to apply for a new release. If not otherwise agreed to, the entire DV/PV test shall be repeated and documented by the supplier prior to start of delivery of the modified or changed product. In some cases a shorter test can be agreed to between the responsible GM Supplier Quality Engineer and the supplier.

4.7.2 DRBFM. Required for all changes a Design Review Based on Failure Modes (DRBFM) shall be conducted by the supplier for all product and process changes as described in 4.7.1.

4.8 Documentation.

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

5 Provisions for Shipping

Not applicable

6 Notes

6.1 Glossary. Not applicable.

6.2 Acronyms, Abbreviations, and Symbols.

ADV	Analysis/Development/Validation
ADVP&R	Analysis Development Validation Plan and Report
C	Confidence
CAC	Charge Air cooler
CAD	Computer Aided Design
CALT	Calibrated Accelerated Life Testing
CDS	Component Data Standard
CKC	Critical Key Characteristics
CRFM	Condenser Radiator Fan Module
CTS	Component Technical Specification
DFMEA	Design Failure Mode and Effects Analysis
DRBFM	Design Review Based on Failure Mode
DV	Design Validation
GM	General Motors
GSSLT	Global Subsystem Leadership Team
GVDP	Global Vehicle Development Process
HALT	Highly Accelerated Life Testing
HASS	Highly Accelerated Stress Screening
HAST	Highly Accelerated Stress Testing
HT	High Temperature
HVAC	Heating, Ventilation and Air Conditioning
kPa	Kilopascal (absolute)

KPC	Key Product Characteristics
LT	Low Temperature
Max.	Maximum
Min.	Minimum
N&V	Noise and Vibration
NSS	Neutral Salt Spray
PFMEA	Process Failure Mode and Effects Analysis
PPAP	Production Part Approval Process
PTC	Powertrain Cooling
PV	Production Validation
PVA	Post-validation Audit
R	Reliability
RAM air	Unpowered air flow, airflow through heat exchanger.
REP	Reliability Evaluation Point
SOR	Statement of Requirements
SWAAT	Sea Water Acetic Acid Test
TTF	Test to Failure
WOT	Wide Open Throttle

7 Additional Paragraphs

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

8 Coding System

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

GMW14191

9 Release and Revisions

This standard was originated in June 2005. It was first approved by the CRFM SSLT in August 2005. It was first published in August 2005.

Issue	Publication Date	Description (Organization)
1	AUG 2005	Initial publication.
2	APR 2010	- external/GM standards updated - test procedure structure revised and wording revised for better clarification - Section 4.6 revised, conditions/chart added - Section 4.3 revised, requirements for validation and series testing - Section 4.9 revised, a changed temperature - Section 4.12 revised, added temperature and fan operation information - Appendix B added, rinse procedure for water soluble metals - Appendix C added, test sample quantity PV/DV (HVAC)
3	SEP 2016	External/GM standards updated; document structure updated; REP 15 years/150k mi implemented; Type I and II CAC definition changed to one common CAC type; Pressure values defined absolute values throughout the document; Performance Measurement revised; Leak Test requirement revised; Thermal Shock test: Graph added; High Temperature Cycle test revised; Heat Aging Test revised; Thermal Cycle test revised; Maximum Pressure Test revised; Pressure Cycle Durability Test revised; SWAAT Test duration revised; Cosmetic Corrosion Test duration revised; Vibration Durability Test revised (GMW17010); Section 4.1.2 Soluble metal deleted; Appendix A, B and C deleted. (HVAC-CRFM Global Subsystem Leadership Team (GSSLT))