Radiator 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), Post-validation Audit (PVA), measurement conditions, performance requirements and the minimum durability specification requirements of various forms of radiator heat exchangers using GMW3420 engine coolant (dexcool®).

1.2 Applicability. This specification is for Internal Combustion Engine Coolant to Air Radiators connected to the engine coolant systems. It also covers low temperature radiators connected to a propulsion coolant system. This specification also applies to Low Temperature (LT) radiators in special combination cooler applications.

This specification defines the testing requirements for validating a coolant-to-air radiator using accelerated testing methods.

2 References

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

2.1 External Standards/Specifications.

ASTM D1384	ASTM D3306	SAE J639	SAE J1344
ASTM D2570	ASTM G85A3		

2.2 GM Standards/Specifications.

GMW3059	GMW8758	GMW15443	GMW16331
GMW3116	GMW14156 (ID)	GMW15531	GMW17010
GMW3286	GMW14157 (ID)	GMW15725	
GMW3420	GMW14192	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.

- Analysis Development Validation Plan and Report (ADVP&R).
- CG2057 Radiator GMW14193 ADVP&R (Validation Cross Reference Index (VCRI) Chart).The supplier shall work with the GM Validation Engineer to comprehend this requirement.
- Drawing specifications.
- GM approved engineering drawings.
- GM1738 Packaging and Identification Requirements for Production Parts.
- Part drawing.

- Release drawing notes.
- Statement of Requirements (SOR) Appendices B, C2, F, G2, G3.
- Statement of Requirements (SOR) drawing guidelines on A/C connections.
- Statement of Requirements (SOR).
- Test reports.

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 radiator shall be submitted in a Boundary Sample document and agreed upon between the supplier, GM Design Release Engineer and GM Manufacturing. The Boundary Sample document shall apply to all GM global production sites. The use of a Boundary Sample document (PowerPoint, a Microsoft product) shall be prepared by the supplier. This document shall contain all cosmetic 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 Boundary Sample document shall be created by the supplier and submitted into a GM database with the agreed upon CG2057 Analysis Development Validation Plan and Report (ADVP&R) plan (the supplier shall work with the GM Validation Engineer to comprehend this requirement). See 4.2. All appearance variations shall be cosmetic-only in nature and shall not result in the non-conformance of the part to the requirements in this standard. 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. Not applicable.

3.1.2.1 Physical Content. Not applicable.

3.1.2.2 Functional Content. The radiator receives hot coolant from the engine supplied by the water pump and transfers heat through the tubes into the fins which have air passing through them supplied by the cooling 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 radiator 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 shall 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 radiator alone. However, the vibration durability test 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 Charged Air Cooler, Condenser, Low Temperature Radiator (LTR), Auxiliary Oil Cooler (AOC) 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 shall 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:	105 d
Test hours:	3000 h
Coordination hours:	500 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 ADVP&R plan, CG2057 (the supplier shall work with the GM Validation Engineer to comprehend this requirement). 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. Coolant used herein is defined as a 50/50 blend of coolant, GMW3420 (dexcool®), and water. Water used herein is defined as clean, potable water per the recommended limits specified in ASTM D3306 unless otherwise specified.

The assembly plant fill process is defined as a process of evacuation of the coolant loop/system down to 1 kPa (absolute) in approximately 15 s throughout the entire coolant loop/system, then filling at a dispense rate of 1 L/s at 275 kPa_g with the radiator inlet not to exceed 138 kPa_g (equivalent to 138 kPa_g of pressure drop).

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 radiator shall not contain more than 0.08 g/L of debris per internal volume of the radiator when tested per 4.4.2.

3.2.1.1.2 Component Data Standard (CDS). 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 coolant pressure drop when tested per 4.4.3, as well as mass and internal volume of the core and end tanks. The results shall be recorded in the release drawing notes as Key Characteristics Designation System (KCDS) "Standard Product Characteristic Documentation Required <DR>" requirements. Results shall represent the "best fit" curve that represents production design. DV part performance shall meet Statement of Requirements (SOR) CDS submission. The Kilowatt of heat rejection, at CDS data test points, during the PV test shall be a minimum of 98% of the DV test part performance or better. Performance minimum tolerances must be met by the ± 3 sigma limit of the sample population tested.

If the SOR includes additional load points, beyond those specified in 4.4.4, include those performance points in the CDS file submitted to GM.

3.2.1.1.3 Leak Test. The radiator shall exhibit a leakage rate ≤ 4 cc/minute dry air when tested per 4.4.1.

3.2.1.1.4 Maximum Pressure Test (Burst). During the procedure recorded in 4.4.4, the radiator shall not present any permanent deformation or leak beyond 4.4.1 or exhibit pressure loss before 345 kPa_g.

3.2.1.2 Endurance Testing Requirements.

3.2.1.2.1 Draincock Wear Test. Radiators with a draincock shall meet Leak Test (4.4.1) after Thermal Cycle Testing (4.4.8). There shall not be any visible cracks on the draincock or the housing after procedure 4.4.5 is completed. The radiator must then pass Leak Test (4.4.1).

3.2.1.2.2 Filler Neck/Pressure Cap Wear Test (if applicable). Radiators with a fill neck shall meet Leak Test (4.4.1) after Thermal Cycle Testing (4.4.8). Then, after running procedure 4.4.6, the cap must be retained in the filler neck in the safety stop position. The radiator must then pass Leak Test (4.4.1).

3.2.1.2.3 Low Temperature Test (Plastic Tank Radiator). The radiator shall not leak during Leg 1 or Leg 2 of the test procedure in 4.4.7. The radiator must pass Leak Test (4.4.1) after each leg.

3.2.1.2.4 Thermal Cycle Durability Test. The radiator must pass Leak Test (4.4.1) prior to and after radiator thermal exposure test in 4.4.8.

3.2.1.2.5 Vacuum Test. After the radiator is vacuum tested in procedure 4.4.9, verify non-movement of rubber gasket by sectioning tank/gasket/header joint and/or visually inspecting with a camera from the inside looking for gasket displacement. The radiator must pass Leak Test (4.4.1).

3.2.1.2.6 Pressure Cycle Durability Test. Run radiator pressure cycle test in 4.4.10. The radiator must pass Leak Test (4.4.1).

3.2.1.2.7 External Corrosion Test (Sea Water Acetic Acid Test (SWAAT)). After the SWAAT test in 4.4.11, the radiator must pass Leak Test (4.4.1).

3.2.1.2.8 External Corrosion Test (Neutral Salt Spray (NSS)). After the Neutral Salt Spray test in 4.4.12, the radiator must pass Leak Test (4.4.1). The dissimilar mating material shall have no > 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. Vehicle level testing will be completed by GM. If the GM Engineer supplies the radiator back to the supplier (post-test), the radiator shall pass Leak Test (4.4.1). The testing includes, but is not limited to, the following tests:

3.2.1.2.9.1 General Durability with Corrosion. When vehicle validation test is completed in 4.4.13, the Condenser Radiator Fan Module (CRFM) components must not result in customer complaint.

3.2.1.2.10 Internal Corrosion Test, ASTM D1384 Solution. After the ASTM D1384 test in 4.4.14, the radiator must pass Leak Test (4.4.1).

Pitting depth shall not exceed 30% of tube gauge as measured on a micrograph.

3.2.1.2.11 Internal Corrosion Test Oyama Water (OY) Solution. After the OY Solution test in 4.4.15, the radiator must pass Leak Test (4.4.1).

Pitting depth shall not exceed 30% of tube gauge as measured on a micrograph.

3.2.1.2.12 Stone Impact Test. This test is only required when the radiator is the first component in the airflow. Radiator stone guard material shall be validated through GMW15725, Type 1 (Performance Requirements for Engine Compartment Plastic Parts), and after being subjected externally to 3 J on the Charpy Impact Testing device as described in 4.4.16, the radiator must pass Leak Test (4.4.1). The radiator plastic grill may have limited damage, but must maintain full function (attachments and stone protection) throughout the test procedure without causing further damage to the radiator or itself.

3.2.1.2.13 Vibration Durability Test. Test the radiator as described in 4.4.17, the radiator shall pass Leak Test (4.4.1) before and after testing. After each test, the radiator shall be able to function 100% without leaking. Failure is defined as, but not limited to, the loss of function, loss of structure, unacceptable performance degradation, and nonconformance of the component as stated in this specification. No fractures shall appear in any mounting brackets. No tears shall appear in any isolators. Post-test inspection results shall be included in the detailed test report.

3.2.2 Physical Characteristics.

3.2.2.1 Dimensions and Capacity. The dimensions, mass, and internal volume of the radiator and the CRFM shall meet all drawing specifications. This shall be proven statistically with a multi-part layout at DV and PV according to the Analysis/Development/Validation (ADV) plan.

3.2.2.2 Mass Properties. The program mass targets provided in the CDS 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. For a REP of 200 000 mi, multiply the test cycles for endurance tests by 1.33.

3.2.3.2 Reliability Requirements. This standard, as written, supports demonstration of the required reliability of 99.0% or greater at a 50% confidence (R99C50) at the REP for the heat exchanger when tested in a component test. The supplier shall utilize "vehicle equivalent" laboratory test setups to simulate "in vehicle" orientations. If the orientation may be different from vehicle to vehicle, 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. In contrast to DV, the Endurance Tests specified for Product Validation (PV) are intended to confirm the reliability demonstrated during PV of components manufactured from high volume tooling and at all manufacturing sites.

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 shall 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.

Service parts shall be adequately protected to ensure satisfactory assemblies after a storage period of five years beyond the date of shipment from the manufacturer’s plant.

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

3.3 Design and Construction. Not applicable.

3.3.1 Materials, Processes and Parts Selection Guidelines.

3.3.1.1 Material Guidelines.

Refer to SOR Appendix F. Elastomeric and aluminum materials supplied under this specification must be homogeneous, free of defects and surface contamination such as bloom, talc, mold release agents, and flash. Machine surface finish must be measured on a 30 part layout and be according to drawing specification. See SOR for drawing guidelines on A/C connections.

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 shall 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.

3.3.2.1 Drawing Requirements. Radiator assemblies supplied under this specification must conform to the detailed drawing approved by Design Release Engineer (DRE).

3.3.3 Identification and Marking. The radiator 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 radiator 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 to comply with GMW16331, Identification and Branding Requirements on GM Parts. 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 radiator 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.

KCDS requirements shall be defined on the GM approved engineering drawings. The radiator 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.

3.4 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 Radiator see form CG2057 (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

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

Note: 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 CG2057 (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 Leak Test Procedure. For all DV testing, and post-test PV and PVA, the radiator shall be pressurized to a minimum of 250 kPa_g for > 60 s when submerged under water between 100 mm to 150 mm at an ambient temperature of 23 °C ± 5 °C or when checked by use of a mass spectrometer or by a pressure decay system or mass flow. For PV and PVA, only the use of a mass spectrometer, pressure decay system or mass flow with equivalent leak rate demonstration shall be used from the production process.

4.4.2. Internal Cleanliness Procedure.

4.4.2.1 Equipment.

- A < 10 micron pore size filter.
- A 0.5 membrane filter paper.
- Filtering assembly.
- Vacuum filtering flask.
- Graduated Beakers.
- Analytical balance sensitive to 0.1 mg.
- Drying oven.
- Desiccators.
- Tweezers.
- Magnification device with scale.
- Reagent grade solvent, i.e., methanol or acetone or equivalent.

Note: Reagent grade solvents are highly volatile and flammable and should be handled with extreme care and safety. The reagent grade solvent shall be compatible with the radiator component parts and assemblies. If possible, radiator component part compatibility with the Reagent grade solvent shall be confirmed on a test sample prior to testing.

4.4.2.2 Facilities. All glassware and the test area used for determining radiator cleanliness compliance with this document must be clean and free from debris.

4.4.2.3 Pre-instructions Step 1. Filter the selected test solvent through the filter paper.

4.4.2.4 Pre-instructions Step 2. Place a filter paper and radiator in the drying oven at 100 °C (212 °F) for 15 minutes. Remove the radiator and allow to cool. Remove the filter paper from drying oven and place in a desiccator to cool to 20 °C (68 °F). Remove filter paper from the desiccator and weigh it to the nearest 0.1 mg (3.5×10^{-6} oz) with an analytical balance. Set the tare weight of the scale to 0 with the filter paper on the scale.

4.4.2.5 Process Instructions Step 1. Position the radiator so that the inlet and outlet ports are facing upwards. Pour a volume of filtered solvent equal to 40% of the total internal volume of the radiator into the radiator coolant inlet port, and cap the inlet and outlet ports.

4.4.2.6 Process Instructions Step 2. Tip the radiator back and forth in such a manner that the inlet and outlet tanks are alternately filled with solvent. Repeat the back and forth tipping for ten (10) cycles to ensure that the solvent flushes all the internal surfaces. One cycle shall be the tipping of the radiator back and forth, so that all of the solvent flows from inlet end of the tank to the outlet end and then back to the inlet tank.

4.4.2.7 Process Instructions Step 3. Drain half of the solvent from outlet portal of the radiator into a graduated beaker. Drain the other half of the solvent from the inlet portal of the radiator into a graduated beaker. Filter the solvent through the previously prepared and weighed filter paper which has been set up in the vacuum filtering assembly.

Note: The spent filtrate can be used for future radiator testing after it has been filtered through a filter paper.

4.4.2.8 Post-instructions. Remove the filter paper from the filtering assembly and place it in the drying oven at 100 °C (212 °F) for 15 minutes. Remove the filter paper from the drying oven and place paper in desiccator to cool to 20 °C (68 °F). Remove the filter paper from the desiccators and weigh it to the nearest 0.1 mg (3.5×10^{-6} oz) with an analytical balance.

4.4.2.9 Data Collection. The dry filter paper with the debris minus the dry filter paper without the debris equals the debris weight. Compare the measured debris weight to the debris weight limit to determine if this requirement has been met.

4.4.3 Component Data Standard. The radiator performance shall be measured for a minimum of 36 test points (raw data only), six fluid flow rates for each fluid, covering the entire operating range. In addition, the test points shall be selected in such a way that they will provide a full heat transfer performance characterization over the entire coolant fluid flow regimes. For coolant fluid, the test points shall be:

- Two test points in the laminar flow regime; Reynolds Number ≤ 2300, smooth tubes.
- Two test points in the transition flow regime; 2300 ≤ Reynolds Number ≤ 6420, smooth tubes.
- Two test points in the turbulent flow regime; Reynolds Number ≥ 6420, smooth tubes.

Note 1: Transition Reynolds numbers must be provided for any tubes with internal turbulators or for any special tube designs.

Note 2: To achieve the turbulent coolant flow regime, coolant inlet temperature may be increased up to 125 °C ± 0.5 °C.

Note 3: The six air test points shall correspond to air velocities: 1 m/s, 3 m/s, 5 m/s, 7 m/s, 9 m/s, 12 m/s.

Note 4: CDS with raw test data must be submitted after the tests have been performed and before final PPAP can be approved.

Note 5: If there is change in design (number of tubes, fin density, etc.) during the DV or PV phase, the CDS data must be resubmitted.

4.4.3.1 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.

4.4.3.2 Inlet Conditions.

- Air Inlet Temperature = ambient temperature of 23 °C ± 5 °C.
- Coolant Inlet Temperature = 105 °C ± 0.5 °C.

4.4.4 Maximum Pressure Test (Burst) Procedure.

- Fluid: water.
- Pressurization rate: 2 kPa_g/s.
- Fluid temperature: ambient.
- Ambient air temperature: 23 °C ± 5 °C.
- Raise pressure to 345 kPa_g and hold for 30 s. Depressurize and inspect cooler for deformation and leak test per 4.4.1.
- Continue the test until failure and record pressure and area of failure.

4.4.5 Draincock Wear Test Procedure. The draincock shall be actuated from the full open position to full closed position for 38 cycles after the thermal cycle exposure in 4.4.8. The draincock shall be wetted with coolant.

4.4.6 Filler Neck/Pressure Cap Wear Test Procedure. The pressure cap shall be installed and removed 75 times after the thermal cycle exposure in 4.4.8. The pressure cap shall be wetted with coolant.

Step 1: Install and remove radiator cap 74 times. Cap is installed by rotating the radiator cap until it reaches its fully installed position. In order to start the cap on the filler neck, a small downward force may be exerted perpendicular to the cap. Cap is removed by rotating it until it hits the safety stop on the filler neck cam. Then push down and rotate until the safety stop is cleared. Complete removal by rotation only.

Step 2: Install cap the 75th time. Now rotate the cap in the removal direction, until it hits the safety stop. Apply a torque of 12 N·m in the removal direction with no down force.

4.4.7 Low Temperature Test (Plastic Tank Radiator) Procedure.

Test Flow: Presoak, Leg 1, and then Leg 2.

4.4.7.1 Presoak.

Expose Radiator as follows:

- Fluid: dexcool® 70%/water 30%.
- Prerequisite soak time > 10 h at -40 °C ± 2 °C.

4.4.7.2 Leg 1.

Expose the radiator as follows:

- Fluid: dexcool® 70%/water 30%.
- Temperature: -40 °C ± 2 °C.
- Coolant flow rate: no coolant flow.
- Coolant pressure: 0 kPa_g to 200 kPa_g ± 10 kPa_g.
- Frequency: 0.2 Hz.
- Total Quantity of Cycles: 96 cycles.

4.4.7.3 Leg 2.

Expose the radiator as follows:

- Fluid: dexcool® 70%/water 30%.
- Temperature: -40 °C ± 2 °C to 120 °C ± 2 °C.
- Coolant Flow Rate: no coolant flow.
- Coolant pressure: 200 kPa_g ± 10 kPa_g continuous.
- Definition of one cycle: temperature decrease 1.25 h, hold 3.25 h, temperature increase 1.25 h, hold 6.25 h (12 h/cycle).
- Total Quantity of Cycles: 15 cycles.

4.4.8 Thermal Cycle Durability Test Procedure.

Expose the radiator to 2750 thermal cycles as follows:

- Coolant temperature: 0 °C ± 2 °C to 100 °C ± 2 °C.
- Coolant pressure: 150 kPa_g ± 10 kPa_g.
- Cycle time: 7 cycles/h; 3.5 minutes at 0 °C, 3.5 minutes at 100 °C; 45 s transition (± 5 s on cycle segments).
- Check leakage visually after every 250 cycles.

4.4.8.1 Reliability. The Reliability Evaluation Point (REP) for this procedure is 2750 cycles. This is a component test. This is an endurance test. Weibull analysis shall be used to determine the reliability. Refer to 4.1.5 for Weibull parameters.

4.4.9 Vacuum Test Procedure. Expose the radiator to 5 cycles as follows:

Pressure low limit: 0.013 bar (absolute) ± 0.003 bar. Cycle: Decrease the pressure to the lower limit in a period not > 20 s, hold the lower limit pressure for a period of 5 s, increase the pressure to standard conditions or a higher limit pressure in an approximate period of 3 s (but not greater than a maximum period of 8 s), hold the pressure for a period of 10 s, end of cycle. See Figure 1.

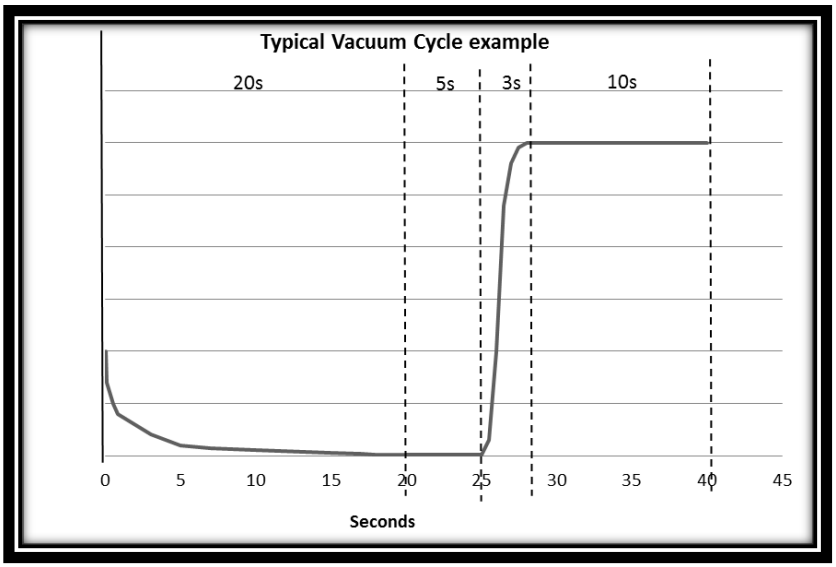

Figure 1: Vacuum Cycle

4.4.10 Pressure Cycle Durability Test Procedure.

4.4.10.1 Leg 1.

Fluid: 100% dexcool® or equivalent.

Expose the radiator to 130 000 cycles as follows:

- Pressure: 30 kPa_g to 210 kPa_g.
- Frequency: 0.2 Hz (12 cycles/minute).
- Cycle: pressure increase (1.25 s), hold (1.25 s), pressure decrease (1.25 s), and hold (1.25 s). See Figure 2.
- Coolant temperature: 115 °C ± 2 °C.
- Ambient temperature: 23 °C -5/+2 °C.

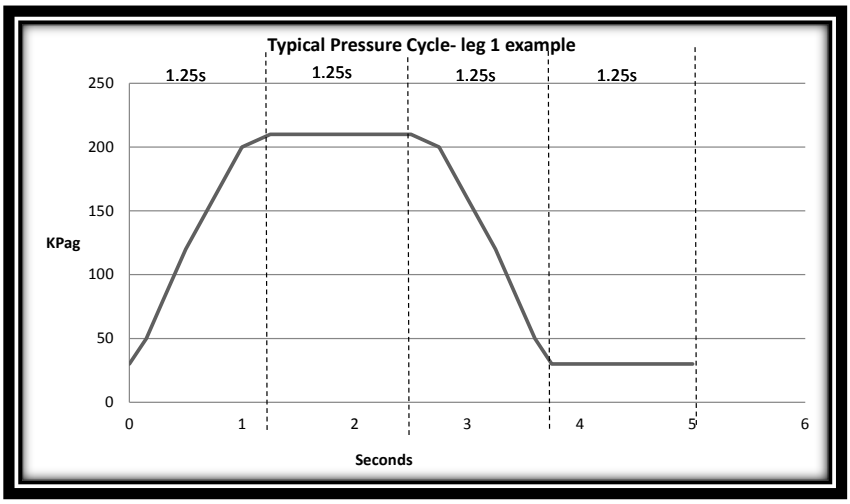

Figure 2: Pressure Cycle Leg 1

4.4.10.2 Leg 2.

Expose the radiator to an additional 20 000 cycles as follows:

- Pressure: 30 kPa_g to 280 kPa_g.
- Frequency: 0.2 Hz (12 cycles/minute).
- Cycle: pressure increase (1.25 s), hold (1.25 s), pressure decrease (1.25 s), and hold (1.25 s). See Figure 3.
- Coolant temperature: 115 °C ± 2 °C.
- Ambient temperature: 23 °C ± 5 °C.

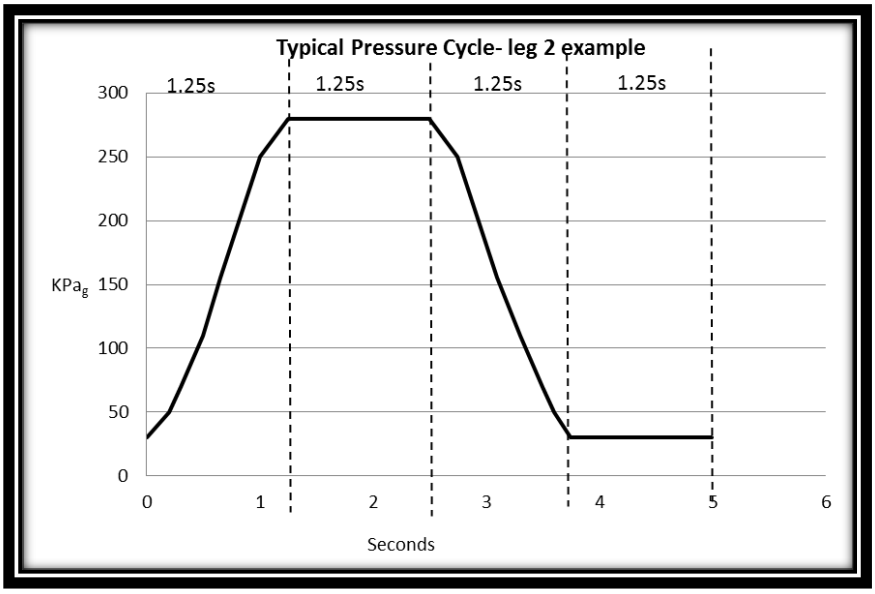

Figure 3: Pressure Cycle Leg 2

4.4.10.3 Higher Life Testing Requirement. Some radiators that will be used for heavy duty diesel, high sport, and commercial applications may need to be tested with the following modifications:

- Leg 1: Same as previously stated.
- Leg 2: 20 000 cycles - pressure: 30 kPa_g to maximum excursion pressure.
- Leg 3: To be Determined (TBD) cycles (see following Note) - Pressure: 30 kPa_g to maximum extreme pressure. (This portion of the test is reserved for extreme conditions only). A reduction in Leg 2 may be required to achieve this portion of the test.

Note: Check, prior to sourcing, the Statement of Requirements (SOR) and with the GM Engineer for the number of TBD cycles when this testing requirement is necessary.

4.4.10.4 LT Radiator Testing Exception. Some radiators that will be used for low temperature applications or with an electric pump need to be tested with only Leg 1 but 150 000 cycles.

- Check the Statement of Requirements (SOR) and with GM Engineering to understand if this testing requirement is necessary prior to sourcing.

Note: Parts tested to this LT Radiator exception shall be indicated on the part drawing as, "LT radiator use only."

4.4.10.5 Reliability. The REP for this procedure, is 150 000 cycles. This is a component test. This is an endurance test. Weibull analysis shall be used to determine the reliability. Refer to 4.1.5 for Weibull parameters.

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

4.4.11.1 Exceptions. Design Validation testing and Production Validation may be changed by the use of the analysis tool, DRBFM. Results of this DRBFM shall be a report as part of the ADVP&R for this requirement if sample size and testing at DV or PV is changed from approved ADVP&R.

4.4.12 External Corrosion Test (Neutral Salt Spray) Procedure. GMW3286 – 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.

- Test time = 1000 h ± 5 h continuous.

4.4.12.1 Exceptions. Design Validation testing and Production Validation may be changed by the use of the analysis tool, DRBFM. Results of this DRBFM shall be a report as part of the ADVP&R for this requirement if sample size and testing at DV or PV is changed from approved ADVP&R.

4.4.13 Vehicle Validation. Vehicle level testing, including but not limited to the following procedures, will be conducted:

- GMW15443 (Vehicle Established Road General Durability Test) or
- GMW15531 (Passenger Vehicle Developing Road Regions General Durability Test).

These tests are run by GM. The supplier shall participate in solutions for concerns discovered during testing.

4.4.14 Internal Corrosion Tests Procedure. Fluid: ASTM D1384 Solution.

- Flow schedule weekdays: 16 h ON, 8 h OFF.
- Flow schedule weekends: Continuous flow.
- Total test time: 168 h/week for ≈ 18 weeks, less 2 x 8 h shutdown per week (equals 152 h/week total test time).
- Coolant temperature: 104 °C ± 2 °C.
- Flow rate: 1.8 m/s.
- Pressure: Not to exceed 250 kPa_g. Pressure takes precedence over flow rate when exceeded.

4.4.14.1 Test Exceptions. For the ASTM D1384 solution, use ASTM D2570 method except as noted. Expose the radiator to 3000 h as follows:

Coolant composition:

- First 72 h: 50% dexcool®, 50% ASTM D1384.

- Final 2928 h: 17% dexcool®, 83% ASTM D1384.

ASTM D2570 test apparatus can be substituted with a permanent neutral component system.

4.4.14.2 Small Radiator Exceptions. For small radiators, like wheel-house High Temperature (HT) radiators that are smaller than 50% of the full-size HT radiator, calculate the total cross sectional area of the tubes (m^2) and determine the flow rate going to the cooler (m^3/s). Divide the flow rate by the cross sectional area. Multiply the answer (m/s) by 1.2. This shall be the flow rate used. Use no less than 0.5 m/s.

Note: Parts tested to this Small Radiator exception shall be indicated on the part drawing as, "Small radiator use only."

Design Validation testing and Production Validation may be changed by the use of the analysis tool, DRBFM. Results of this DRBFM shall be a report as part of the ADVP&R for this requirement if sample size and testing at DV or PV is changed from approved ADVP&R.

4.4.14.3 Low Temperature Radiator Exceptions. For Low Temperature (LT) full-size radiators, use procedure 4.4.14. For small LT radiators, smaller than 80% of the full-size HT radiator, calculate the total cross sectional area of the tubes (m^2) and determine the flow rate going to the cooler (m^3/s). Divide the flow rate by the cross sectional area. Multiply the answer (m/s) by 1.2. This shall be the flow rate used. Use no less than 0.5 m/s.

Note: Parts tested to this LT Radiator exception shall be indicated on the part drawing as, "LT radiator use only."

Design Validation testing and Production Validation may be changed by the use of the analysis tool, DRBFM. Results of this DRBFM shall be a report as part of the ADVP&R for this requirement if sample size and testing at DV or PV is changed from approved ADVP&R.

4.4.15 Oyama Water (OY) Solution Procedure. Use ASTM D2570 method except as noted as follows.

- OY water composition:
  - Chloride (Cl^-): 195 mg/L ± 1 mg/L.
  - Sulfate (SO_4^{2-}): 60 mg/L ± 0.2 mg/L.
  - Iron (Fe^{3+}): 30 mg/L ± 0.1 mg/L.
  - Copper (Cu^{2+}): 1 mg/L ± 0.01 mg/L.
- Expose the radiator to 3000 h as follows:
  - Coolant composition:
    - First 72 h: 50% dexcool®, 50% OY water.
    - Final 2928 h: 17% dexcool®, 83% OY water.
  - Coolant temperature: 104 °C ± 2 °C.
  - Coolant flow rate: 1.8 m/s core tube velocity.
  - Flow schedule weekdays: 16 h ON, 8 h OFF.
  - Flow schedule weekends: Continuous flow.
  - Pressure: Not to exceed 150 kPa_g.

ASTM D2570 test apparatus can be substituted with a permanent neutral component system.

4.4.15.1 Small Radiator Exceptions. For smaller radiators, like wheel-house HT radiators that are smaller than 50% of the full-size HT radiator, calculate the total cross sectional area of the tubes (m^2) and determine the flow rate going to the cooler (m^3/s). Divide the flow rate by the cross sectional area. Multiply the answer (m/s) by 1.2. This shall be the flow rate used. Use no less than 0.5 m/s.

Note: Parts tested to this Small Radiator exception shall be indicated on the part drawing as, "Small radiator use only."

Design Validation testing and Production Validation may be changed by the use of the analysis tool, DRBFM. Results of this DRBFM shall be a report as part of the ADVP&R for this requirement if sample size and testing at DV or PV is changed from approved ADVP&R.

4.4.15.2 Low Temperature Radiator Exceptions. For Low Temperature (LT) full-size radiators, use procedure 4.4.15. For small LT radiators, smaller than 80% of the full-size HT radiator, calculate the total cross sectional area of the tubes (m^2) and determine the flow rate going to the cooler (m^3/s). Divide the flow rate by the cross sectional area. Multiply the answer (m/s) by 1.2. This shall be the flow rate used. Use no less than 0.5 m/s.

Note: Parts tested to this LT Radiator exception shall be indicated on the part drawing as, "LT radiator use only."

Design Validation testing and Production Validation may be changed by the use of the analysis tool, DRBFM. Results of this DRBFM shall be a report as part of the ADVP&R for this requirement if sample size and testing at DV or PV is changed from approved ADVP&R.

4.4.16 Stone Impact Resistance/Mounted Grill Protector Procedure. See GMW14192 for Stone impact testing procedure and substitute condenser with radiator.

4.4.16.1 Radiator Plastic Grille Protector. When applicable, the Radiator Plastic Grille Protector shall be on the radiator testing during the following tests: Heat Transfer, Thermal Cycle Durability, Pressure Cycle Durability, Vibration Durability, External Corrosion, and Stone Impact Resistance.

4.4.17 Vibration Durability Test. Test per GMW17010.

4.4.17.1 Reliability. This is a subsystem test. This is an endurance test. Weibull analysis per 4.1.5 shall be used to determine the reliability.

4.5 Safety.

4.5.1 Precautions. This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all of the potential 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 local, regional, state and national regulatory limitations prior to use. See SAE J639 for more information.

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 GM Validation 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 Validation 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.

Crazy Fin: An effect where the fin pitch goes "crazy" with no proper spacing.

6.2 Acronyms, Abbreviations, and Symbols.

ADV	Analysis/Development/Validation
ADVP&R	Analysis Development Validation Plan and Report
AOC	Auxiliary Oil Cooler
BFO	Bill of Materials (BOM) Family Owner
BOM	Bill of Materials
CAD	Computer Aided Design
CDS	Component Data Standard
CRFM	Condenser Radiator Fan Module
DFMEA	Design Failure Mode and Effects Analysis
DRBFM	Design Review Based on Failure Mode
DRBTR	Design Review Based on Test Results
DRE	Design Release Engineer
DV	Design Validation
GVDP	Global Vehicle Development Process
HT	High Temperature
HVAC	Heating, Ventilation and Air Conditioning
KCDS	Key Characteristics Designation System
kPa_g	Kilopascal (gage)
LT	Low Temperature
LTR	Low Temperature Radiator
N&V	Noise and Vibration
NSS	Neutral Salt Spray
OY	Oyama Water
PFMEA	Process Failure Mode and Effects Analysis
PPAP	Production Part Approval Process
PV	Production Validation
PVA	Post-validation Audit
REP	Reliability Evaluation Point
SOR	Statement of Requirements
SWAAT	Sea Water Acetic Acid Test
TBD	To be Determined
TTF	Test to Failure

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:
GMW14193

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	JUN 2008	3.3.2.1 thru 3.3.2.1.5 added; 4.12.1.1 Coolant composition revised. (CRFM SSLT)
3	OCT 2013	Complete revision. (CRFM Global Subsystem Leadership Team)
4	APR 2015	Removed all ADV references, updated to new 150 000 mi requirement, added section for low temperature radiators, updated corrosion test references, made corrections on internal cleanliness, and stone impact testing. (HVAC - CRFM Global Subsystem Leadership Team)
5	AUG 2016	Revised reliability requirement R99C50 and Weibull parameters. Section 3.8 (deleted) and content moved to 4.1 and 4.2. Stone impingement requirement 3 J, new impacter. Typos corrected in internal corrosion, Leg 2 is 2928 h. (HVAC - Powertrain Cooling and Thermal Integration Engineering)