



SURFACE VEHICLE STANDARD

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Design Criteria and Certification for
OEM Mobile Air Conditioning Evaporator and Service Replacements

RATIONALE

Efforts toward sustainability, along with potential new global regulations and the increasing use of heat pumps, make the introduction of new thermal management refrigerants likely. Standards that can be made independent of the fluid type will assist in the efficient introduction of qualified new refrigerants. This update makes the standard independent of the working fluid for refrigerants where the critical temperature is between 85 and 120 °C and typically used in mobile systems. Additionally, the use of tracer gases in place of Helium for the Helium Leak test is added. No changes were made to the R-744 sections.

1. SCOPE

The intent of this standard is to establish a framework to assure that all evaporators conforming to its requirements demonstrate an acceptable health and safety environment for vehicle occupants as determined from the completed risk assessment. R-744 and low pressure (i.e., non-transcritical refrigerants with a critical temperature between 85 and 120 °C) mobile air conditioning (MAC) refrigerant evaporators shall meet the testing and labeling requirements of this standard. SAE J639 contains a list of all refrigerants considered acceptable for use in mobile thermal systems for which this standard applies when the refrigerant is used in a direct expansion architecture. SAE J639 also requires an assessment to be performed to minimize reasonable risks in MAC systems. The evaporator (as designed and manufactured) shall be part of that risk assessment, and it is the responsibility of the vehicle manufacturer to ensure all relevant aspects of the evaporator are included. It is the responsibility of all vehicle or evaporator manufacturers to comply with the standards of this document at a minimum. (Substitution of specific test procedures by vehicle manufacturers that correlate well to field return data is acceptable.) As appropriate, this standard can be used as a guide to support risk assessments.

With regard to certification, most vehicle manufacturers have established formal production part approval processes (PPAP) where compliance certification is established and formally documented. For an evaporator manufacturer of non-original equipment parts (or a vehicle manufacturer that does not have a formal part compliance certification process), then the certification described in this standard is the requirement to which those evaporators shall comply. In this case, the evaporator manufacturer or an independent institution shall complete the evaporator certification according to SAE J2911. An example of the latter would be the completion of witness testing by the evaporator manufacturer with the submission of certification documents by the witness organization.

This standard originated for the introduction of R-1234yf. The content is based upon the associated 2011 Risk Assessment with input from five OEM evaporator manufacturers. R-744 was included as its requirements were understood in 2011. Refrigerant R-152a was excluded from this standard because a single secondary loop refrigerant system is required. This standard also does not apply to R-134a refrigerant evaporators because it is proven in use.

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2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 1-877-606-7323 (U.S. and Canada only) or 1-724-776-4970 (outside U.S. and Canada), www.sae.org.

SAE J639	Safety and Design Standards for Motor Vehicle Refrigerant Vapor Compression Systems
SAE J2727	Mobile Air Conditioning System Refrigerant Emissions Estimate for Mobile Air Conditioning Refrigerants
SAE J2911	Procedure for Certification that Requirements for Mobile Air Conditioning System Components, Service Equipment, and Service Technician Training Meet SAE J Standards

Yu, Y., and Clodic, D., "Measurement of Leak Flow Rates of Mobile Air Conditioning (MAC) Components - How to Reach a Generic Approach," SAE Technical Paper 2007-01-1186, 2007, <https://doi.org/10.4271/2007-01-1186>.

2.1.2 AIAG Publications

Available from Automotive Industry Action Group, 4400 Town Center, Southfield, MI 48075-1104, Tel: 248-799-7995, www.aiag.org.

Measurement System Analysis Reference Manual

2.1.3 ANSI and UL Publications

Copies of these documents are available online at <https://webstore.ansi.org>.

Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

ANSI/UL 969-1991 UL Standard for Safety for Marking and Labeling Systems, UL 969

2.1.4 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9500, www.astm.org.

ASTM G85-02 Standard Practice for Modified Salt Spray (Fog) Testing

2.1.5 ISO Publications

Copies of these documents are available online at www.iso.org/store.

ISO 554:1976	Standard atmospheres for conditioning and/or testing - Specifications
ISO 1185:2007	Water quality - Determination of selected elements by inductively coupled plasma optical emission spectrometry (ICP-OES)
ISO 9000:2000	Quality management systems - Fundamentals and vocabulary
ISO/TS 16949	Quality management systems - Particular requirements for the application of ISO 9001:2000 for automotive production and relevant service part organizations

2.1.6 Other Publications

QDAS Leifdaten	Measurement System Capability Reference Manual
VDA Band 3	Ensuring Reliability of Car Manufacturers - Reliability Management (VDA Volume 3.1, 3rd Edition 2000)
VDA Volume 04	Quality Assurance in the Process Landscape (2 nd Edition, 2011)

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Standard.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 1-877-606-7323 (U.S. and Canada only) or 1-724-776-4970 (outside U.S. and Canada), www.sae.org.

SAE J1739	Potential Failure Mode and Effects Analysis (FMEA) Including Design FMEA, Supplemental FMEA-MSR, and Process FMEA
SAE J2772	Measurement of Passenger Compartment Refrigerant Concentrations Under System Refrigerant Leakage Conditions
SAE J2773	Standard for Refrigerant Risk Analysis for Mobile Air Conditioning Systems

Spessel, C. and Philippe, M., "Reliability of Evaporators Regarding Corrosion," SAE Technical Paper 2004-01-0216, 2004, <https://doi.org/10.4271/2004-01-0216>.

2.2.2 ISO Publications

Copies of these documents are available online at www.iso.org/store.

ISO 13043	Road vehicles - Refrigerant systems used in mobile air conditioning systems (MAC) - Safety requirements
ISO 10304-1:2007	Water quality - Determination of dissolved anions by liquid chromatography of ions

3. DEFINITIONS

All physical dimensions and units are expressed in SI units, and all indicated pressures are assumed to be gauge pressure unless otherwise noted. For the definition of components, system architectures, and typical system operating limits, refer to SAE J639.

3.1 NORMAL USE

This standard is intended for the use of the vehicle during normal driving and does not address damage that may occur in a vehicle collision (this should be addressed in the vehicle risk assessment by the vehicle manufacturer).

3.2 DESIGN LIFE OF THE VEHICLE

For this standard, the design life is 10 years and 6000 working hours in a moderately corrosive environment similar to Central Europe as a normal design life.

3.3 ORIGINAL EQUIPMENT (OE)

Designation of products or components from a vehicle manufacturer, or contracted by a vehicle manufacturer, who complies with ISO/TS 16949 standards.

3.4 PRESSURE CONSIDERATIONS

The burst pressure is defined in SAE J639. This standard does not consider using an evaporator as a high pressure component.

4. TECHNICAL REQUIREMENTS

4.1 Introduction

This standard establishes product and process design requirements, along with validation testing and acceptance criteria for evaporators intended for use with refrigerants listed in SAE J639. Significant refrigerant leakage by the evaporator into the passenger cabin could potentially pose a health and safety risk to vehicle occupants. To ensure appropriate risk, evaporators and evaporator assemblies shall:

- Be designed, manufactured, and tested to minimize evaporator leakage for the design life of the vehicle
- Meet certification and documentation standards
- Meet requirements for evaporator labeling to ensure compliance to this standard and proper handling in service

4.2 Evaporators Used by Original Equipment (OE) Vehicle Manufacturers

Evaporators installed in new vehicles and made available for service through the distribution channels of the vehicle manufacturer or OEM supplier are considered original equipment (OE) evaporators. These OE evaporators shall comply with this standard as a minimum; substitution of specific test procedures, which correlate well to field return data, by vehicle manufacturers is acceptable. Formal compliance certification and risk assessments must be established and documented.

4.3 Other Evaporators (From Non-OE Suppliers or Used by Vehicle Manufacturers without Formal Certification and Documentation Processes)

An evaporator produced by a non-OE supplier (or used by a vehicle manufacturer without formal certification and documentation processes) may only be installed in vehicles if the component shall fulfill the requirements described in this standard. Compliance to this standard shall be certified and documented as described below.

Certification of evaporators from non-original equipment manufacturers shall meet the requirements of SAE J2911.

This SAE J2911 qualified institution shall issue a "Certificate of Conformity," stating that the examined evaporator meets the essential safety requirements covering design, manufacture, and testing; follows appropriate conformity assessment procedures; and carries the necessary labels and other information. Details of the certificate are found in Appendix D.

4.3.1 Responsibility for Certification

The manufacturer shall supply documentation to SAE as described in SAE J2911 that includes the information listed in the following sections. The manufacturer shall provide an appropriate number of evaporators that are representative of the evaporator production being certified and the intended heating, ventilation, and air conditioning (HVAC) system.

4.3.2 Documentation Submission and Certification Submission

The manufacturer shall complete and submit form SAE J2842 Appendix D as the actual certification document.

5. EVAPORATOR DESIGN AND CERTIFICATION REQUIREMENTS

The evaporator in this standard is defined as a component (the evaporator core body and permanently attached lines and fittings) installed in the HVAC module intended for climate control of the passenger compartment of a vehicle. The evaporator assembly in this standard is defined as a component assembly (with removable attaching lines, fittings, or devices) installed in the HVAC module intended for climate control of the passenger compartment of a vehicle. The evaporator or the evaporator assembly shall be treated as the component specified in this standard according to each section.

5.1 Evaporator Design

5.1.1 Evaporator Design Requirements and Design Best Practices

The evaporator is located within the HVAC module and is connected to the refrigerant circuit.

Substandard evaporator design, damage, or misuse during assembly, shipping, or service may increase potential risks to vehicle occupants. The requirements specified in this standard contain an approach for design, assembly to the HVAC housing, production quality, and production testing of the assembly. Other relevant manufacturing and transportation practices such as storage, packaging, and shipping shall be documented and retained by the manufacturer.

Evaporators shall be designed appropriately for all vehicle operational conditions (AC on or off), as well as vehicle off (storage and soak), as would be expected over the lifetime of a vehicle. The evaporator shall have appropriate corrosion behavior and protection to meet this specification or the equivalent, based on evaporator field return data.

Evaporators as assembled in an HVAC module must include consideration of forces and torques from the assembly and disassembly of attaching lines and components. Any attaching tubing/pipe or other components in the evaporator assembly must withstand anticipated production, transport, and assembly forces on those components without degradation of the refrigerant retention characteristics from those specified in this standard.

Any tubing or piping used in the assembly may be strengthened with brackets, connecting flanges, etc., to protect them from potentially damaging mechanical loads resulting from assembly operations, handling, or transportation that would degrade the refrigerant retention characteristic of the assembly. See 5.7 for the allowable leak rate of an evaporator assembly.

Material composition should comply with local or national environmental rules and requirements (e.g., banned and regulated substances). The materials for the evaporator shall be suitable for the maximum and minimum operating temperature and pressure ranges listed in SAE J639.

Evaporator designs must have adequate material resistance to any chemical reactions with the refrigerant and lubricant (including normal degradation of both over time) to meet this standard and shall be capable of operating without significant degradation of the refrigerant retention characteristics from those specified in this standard under the anticipated working temperature and pressure cycles, for the life of the vehicle. This includes exposure to a deep vacuum (for charge extraction and filling).

The design specifications of the evaporator shall include considerations for changes in material properties due to aging based upon assembly, shipping, expected usage, exposure to corrosion, and storage to achieve evaporator life targets.

If the evaporator or evaporator assembly, including mating or attaching parts, are assembled from different materials, then galvanic corrosion must be considered in the validation/certification process.

5.1.2 Evaporator Manufacturing Requirements

The evaporator production process covers the manufacturing and testing of the evaporator or the assembly of the evaporator and other parts as it is delivered for further assembly or distribution.

Robust manufacturing processes are required to ensure evaporator designs appropriately minimize potential risks to vehicle occupants. Design and process Failure Mode and Effects Analysis (FMEA) must be completed for evaporators used in a MAC system using R-744 or R-1234yf.

The evaporator manufacturing process must take into account and ensure the following:

- All critical characteristics coming from the Design-FMEA (on the complete evaporator assembly and on each component in the assembly) must be addressed.
- All critical characteristics coming from Process-FMEA (on process parameters) must be addressed.
- All design and process critical characteristics shall be included in the quality control plan for the evaporator.

5.2 Pressure Strength and Endurance

5.2.1 Burst Requirements

Evaporators shall meet or exceed specific minimum burst pressure requirements as defined in the latest published version of SAE J639. For new evaporators, these values shall be a minimum of 2X the maximum low-side refrigerant gauge working pressure.

5.2.2 Burst Pressure

For R-744 MAC systems, increase the pressure by 1.0 MPa/s up to 50% of the minimum burst pressure and afterward by 0.1 MPa/s until the minimum burst pressure is achieved. The evaporator must hold this pressure for 1 minute without rupture or structural failure. Continue adding 0.1 MPa/s until the actual burst pressure is reached.

For low pressure MAC systems, increase the pressure by 100 kPa/s up to 50% of the minimum burst pressure and afterward by 10 kPa/s until the minimum burst pressure is achieved. The evaporator must hold this pressure for 1 minute without rupture or structural failure. Continue adding 10 kPa/s until the actual burst pressure is reached.

The values obtained for burst pressures shall be recorded and documented.

As actual burst pressure is achieved, no fragmentation from the evaporator shall occur.

5.3 Fatigue Resistance under Cycling Pressure

5.3.1 Requirements

The pressure cycle test is targeted to simulate a minimum of 10 years of life or 6000 working hours.

Each test evaporator shall first successfully pass the Mechanical Structural Resistance test in 5.4 and, then the evaporator shall be tested to the following cycling requirement between lower and upper pressure, with a defined frequency, at a 60 °C working fluid temperature.

The fatigue resistance under cycling pressure shall be determined based on Weibull analysis. In a cumulative Weibull function such as fatigue, time to failure is the key characteristic of interest which is represented by the number of cycles. Also, the Weibull Slope (or Modulus) is a parameter representing the typical failure characteristic of a given evaporator design.

For non-transcritical refrigerants, using the reference values below for R-1234yf, the maximum value of the pressure in the cycle is 1.0 MPa,a or 0.9 MPa,g. Additionally, the maximum working pressure = Psat at 56 °C is 1.5 MPa,g. Thus, as is typical of pressure cycling this pressure is less than the maximum working pressure at 60% of the maximum working pressure and implies an $r = 1.0$ or no test acceleration of pressure in the equation below.

Noting the above, for non-transcritical refrigerant applications, the peak pressure in the evaporator pressure cycling test shall be 60% of the saturation pressure at 56 °C. The values applied to R-1234yf are shown in Table 1 for reference.

The reliability requirement is 95% with a confidence of 50%. Sample size and number of equivalent lives are dependent on the evaporator design and shall be selected to demonstrate the aforementioned reliability requirements. Refer to VDA Band 3 for calculation methods. The calculation is listed below:

$$C = 1 - R^{n \times (r \times L_v)^b}$$

where:

C = confidence

R = reliability

r = factor for acceleration of stress according to Woehler (=1 if using the same amplitude)

Lv = number of lives; extension of testing time longer than default

b = measure of scattering of the failures (Weibull slope)

n = number of samples

Table 1 - Pressure cycling requirements

	R-744	R-1234yf
Lower/Upper Pressure	5 to 10 MPa (abs)	0.1 to 1 MPa (abs)
Number of Cycles Equivalent 10 Years	130000 cycles	22000 cycles
Frequency	1.25 Hz ± 1 Hz	1.25 Hz ± 1 Hz

Table 2 - Example calculation for R-1234yf with R95 at C50

Weibull Slope	Sample Quantity	Lives	Total Cycles
1	3	4.50	99098
1	4	3.38	74324
1	5	2.70	59459
1	6	2.25	49549
2	3	2.12	46692
2	4	1.84	40437
2	5	1.64	36168
2	6	1.50	33016

5.3.2 Test Method

The pressure cycle test can follow a trapezoidal or sinusoidal pattern. Test fluid is a hydraulic oil or refrigerant oil at +60 °C ± 5 K over the entire test time. This pressure cycle test shall be run until failure (release of hydraulic or refrigerant oil) for new evaporator models. Once the Weibull slope is established, the equation in 5.3.1 can be used to determine the appropriate number of cycles for a given number of samples. If the required number of cycles is reached, a refrigerant leak test shall be completed and passed (after the evaporator is cleaned) as described in 5.7.2.

5.4 Mechanical Structural Resistance

5.4.1 Requirements for the Structural Resistance of Tube Connections

Integrity of the tube or pipe connection to the evaporator core is essential to refrigerant retention. The appropriate resistance of the tubes/pipes is tested by bending and rotating the connection tubes/pipes in one direction, followed by applying a torque or force that returns them to the original location. After testing, a metallurgical check shall be performed to locate any cracks that may have formed. The test is intended to be performed once.

5.4.2 Test for Structural Resistance of Tube Connections

The evaporator assembly (with attaching lines or fittings) shall be installed on the test bench and the following test sequence shall be carried out (the following forces/torques shall be applied at the interface position to the thermal expansion device or at the pipe connections outside of the HVAC module):

- Apply a vertical force in the Z-direction to the evaporator tubes and increase until either a minimum displacement of +5 mm with reference to the zero position, or a maximum of 100 N, is reached. Then, change the direction of the force to -Z-direction and increase until either a minimum displacement of -5 mm with reference to the zero position, or a maximum of 100 N, is reached. Again, change the direction of the force and increase until the reference zero position or a maximum of 100 N is reached.
- Apply a horizontal force in the Y-direction to the evaporator tubes and increase until either a minimum displacement of +5 mm with reference to the zero position, or a maximum of 100 N, is reached. Then, change the direction of the force to the -Y-direction and increase until either a minimum displacement of -5 mm with reference to the zero position, or a maximum of 100 N, is reached. Again, change direction of the force and increase until the reference zero position or a maximum of 100 N is reached.
- Apply a horizontal force in the X-direction to the evaporator tubes and increase until a minimum displacement of +5 mm with reference to the zero position or a maximum of 100 N is reached. Then, change the direction of the force to the -X-direction and increase until a minimum displacement of -5 mm with reference to the zero position or a maximum of 100 N is reached. Again, change the direction of the force and increase until the reference zero position or a maximum of 100 N is reached.
- Apply a torque equal to production assembly torque, but not less than $5 \text{ N}\cdot\text{m} \pm 0.5 \text{ N}\cdot\text{m}$, to the tube in the direction of expansion device assembly.
- Apply a torque equal to the assembly torque, but not less than $5 \text{ N}\cdot\text{m} \pm 0.5 \text{ N}\cdot\text{m}$, in the opposite direction of expansion device assembly.

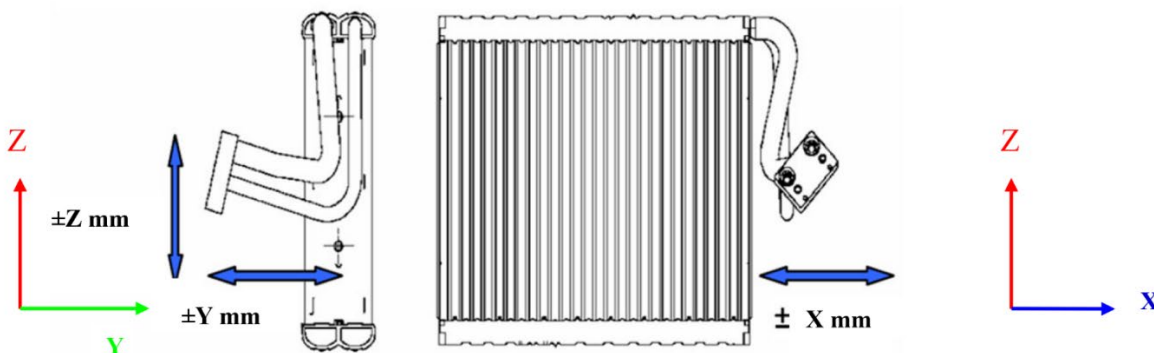


Figure 1 - Multidirectional pipe bending for evaporator

5.4.3 Acceptance Criteria

The evaporator assembly must not leak (as described in 5.7.2) after performing test sequence a. through e. in 5.4.2. No cracks should be initiated when analyzed by metallurgical inspection at the connection (brazed or other connection) of pipe to the evaporator core.

5.5 Structural Resistance to Corrosion

5.5.1 Requirements for Corrosion Resistance

Evaporator manufacturers shall perform the corrosion testing procedure described in 5.5.2.2 and Appendix B. Original equipment manufacturers of evaporators can substitute corrosion test procedures based on historical standards that give good correlation to field return data. The intent of this standard is to achieve 10-year (or 6000 working hours) corrosion leakage resistance in a moderately corrosive environment.

5.5.2 Corrosion Reliability Tests

5.5.2.1 Requirement for Evaporator Resistance to Corrosion

a. General Test Requirements

Successful completion of the corrosion testing is contingent on passing the refrigerant leakage test in 5.7.2. All brazed joints may show surface corrosion but not separation. For the braze joint between the tube/plate to fin, this is demonstrated via inspection of the remaining bond. For braze joints that provide refrigerant containment integrity of the evaporator (including, but not limited to, plate to plate, tube to header, connecting tube to evaporator, etc.), this is demonstrated via the leakage test mentioned previously.

As mentioned earlier, original equipment manufacturers of evaporators can substitute corrosion test procedures based on historical standards that show good correlation to field return data and meet the intent as mentioned above.

b. Acceptable Leak Rate

When tested to the loss of pressure integrity, the leak rate shall be less than:

1. For non-transcritical refrigerants and using as a reference 0.03 g/s at 0.55 MPa for R-1234yf, the leak rate is calculated from the Hagen-Poiseuille equation (also known as Poiseuille's Law) as described in SAE Technical Paper 2007-01-1186 and shown below which accounts for the differences in test pressure and refrigerant properties. A more detailed application of this leak model is described in SAE J2727 where the constant terms factor out and the leak rate change is calculated as an Emissions Rate (ER) ratio and can be appropriately applied here.

$$\dot{m} = \frac{\pi r^4 M (P_{in}^2 - P_{out}^2)}{16 \mu L R T} \quad (\text{Eq. 1})$$

where:

$\dot{m}$ = mass flow rate [kg/s]

r = equivalent leak path radius [m]

μ = dynamic (absolute) viscosity [Pa-s]

L = effective leak path length [m]

M = molar mass [kg/kmol]

R = universal gas constant = 8.3145 [kJ/kmolK]

T = temperature [K]

P_{in} = inlet pressure [Pa A]

P_{out} = outlet pressure [Pa A]