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Road vehicles — Refrigerant systems used in mobile air conditioning systems (MAC) — Safety requirements

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National foreword

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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ISO 13043 was prepared by Technical Committee ISO/TC 22, *Road vehicles*.

Introduction

For many years, R-134a has been the refrigerant of choice for refrigerant systems for mobile air conditioning (MAC) due to its thermodynamic properties, worldwide availability and relative low cost. However, its contribution to global warming is now considered to be unacceptable. Additionally, it has been documented that the rate of growth in atmospheric loading of R-134a is of growing concern.

In 2006, the EU formulated legislation 2006/40/EC to ban the use of greenhouse gases having a global warming potential (GWP) of more than 150. Since R-134a has a GWP >1300, the European Directive has banned the use of R-134a for new model types since 1 January 2011 and for all new vehicles starting on 1 January 2017.

The automotive industry has responded by identifying two materials that would comply with the European Union GWP requirement and offer acceptable refrigeration performance. These products are R-744 (carbon dioxide, GWP of 1) and R-1234yf (2,3,3,3-Tetrafluoroprop-1-ene, GWP of 4).

In certain concentrations, both products could lead to a safety hazard to the vehicle occupants and to technicians who service the vehicle. This International Standard aims to identify refrigerant system safety requirements, to be met through robust engineering solutions and applied to the vehicle design, to maintain a comparable level of safety as that of MAC systems using R-134a.

Road vehicles — Refrigerant systems used in mobile air conditioning systems (MAC) — Safety requirements

1 Scope

This International Standard is restricted to refrigerant systems providing cooling or heating of passenger compartment, battery, etc., in passenger motor vehicles. It provides minimum design requirements for refrigerant containment and safety requirements of these systems.

This International Standard addresses the use of only R-134a, R-1234yf and R-744 refrigerants in vehicle original equipment manufacturer (OEM) and aftermarket (non-OEM) supplied components and systems.

The relevant risks associated with these refrigerant systems are:

— projection of fragments or fluid due to high pressure systems;

— inhalation of toxic substances, including potential decomposition products;

— flame propagation.

Consequently, this International Standard will address the component and system design requirements related to any of these hazards where the refrigerant system is involved.

Any scenario involving other components from the heating, ventilation and air conditioning (HVAC) system (heater, blower, air mixing and distribution) or any other component of the vehicle not related to the refrigerant system will not be covered in this International Standard.

The purpose of this International Standard is to ensure that end-users or service technicians are not exposed to hazards during normal usage, maintenance and repair, and end-of-life disposal of the car. Therefore, manufacturing, storage and transportation of the refrigerant, as well as refrigerant distribution and filling machines in the assembly plant will not be covered in this International Standard. For these situations, the safety of qualified personnel will be addressed by existing standards commonly used among the industry and relevant regulations.

Entire vehicle lifetime has been considered to address durability issues.

For the R-134a system, this International Standard applies to any new model type launched one year after the document is published.

For the R-1234yf and R-744 systems, this International Standard applies from first application of these refrigerants to any vehicle.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ANSI/ASHRAE 34-2007, *Designation and Safety Classification of Refrigerants*

SAE J639, *Safety Standards for Motor Vehicle Refrigerant Vapor Compressions Systems*

SAE J2064 - R-134a and R-1234yf, *Refrigerant Automotive Air-Conditioning Hose and Assemblies*

SAE J2670, *Stability and Compatibility Criteria for Additives and Flushing Materials Intended for Use in R-134a and R-1234yf Vehicle Air-Conditioning Systems*

SAE J2771 - CO2 (R-744), *Refrigerant Removal and Charging Equipment for Mobile Refrigerant Systems*

SAE J2772, *Measurement of Passenger Compartment Refrigerant Concentrations Uunder Ssystem Rrefrigerant Lleakage Cconditions*

SAE J2788 - HFC-134a (R-134a), *Recovery/Recycling Equipment and Recovery/Recycling/Recharging for Mobile Air-Conditioning Systems*

SAE J2842 - R-1234yf and R-744, *Design Criteria and Certification for OEM Mobile Air Conditioning Evaporator and Service Replacements*

SAE J2843 - R-1234yf, *Recovery/Recycling/Recharging Equipment for Flammable Refrigerants for Mobile Air-Conditioning Systems*

SAE J2845, *Technician Training for Safe Service and Containment of Refrigerants Used in Mobile A/C Systems (R-744, and R-1234yf)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
vehicle
vehicle with a combustion engine and/or electric driving motor, intended for use on the road, with or without external body components added, having a permissible maximum mass of at least 400 kg and a maximum design speed equal to or exceeding 50 km/h

NOTE Passenger cars and light commercial vehicles (including light-duty trucks) are covered, with the exception of heavy trucks and road tractors, minibuses, buses and coaches, agriculture tractors and public work vehicles.

3.1.1
air exchange rate
AER
number of times that the air in the passenger compartment is replaced per hour

3.1.2
air inlet plenum
chamber located in front of the passenger compartment where the air is collected before entering into the vehicle, usually separating water, snow, and debris from the air prior to its entry into the HVAC module

3.1.3
engine bay
space for a combustion engine and/or an electric driving motor

NOTE 1 In a front-engined vehicle, it is the space between the front grille, the front side fenders, the front of dash (or firewall) in front of the passenger compartment, closed by the engine bonnet.

NOTE 2 In a rear-engined vehicle, it is the space between rear end and vehicle compartment rear bulkhead, embedded between engine compartment side panels (fender apron), closed by the hatchback and underneath closed out to various degrees by an underbonnet shield.

NOTE 3 In a mid-engined vehicle, it is the space between rear end and passenger compartment rear bulkhead, embedded between engine compartment side panels (fender apron), closed by an engine compartment cover and underneath closed out to various degrees by an underbonnet shield.

3.1.4
underhood
space in the engine bay where the components of the refrigerant system are located

NOTE 1 In a front-engined vehicle, it contains mechanical or electric compressor, condenser/gas cooler, refrigerant sensor, accumulator or receiver/drier, at least one expansion device, piping, assemblies, charge and/or service ports, and an optional internal heat-exchanger.

NOTE 2 In a rear-engined and mid-engined vehicle, it contains mechanical or electric compressor and piping.

3.1.5
vehicle lifetime
design life of the vehicle as specified by the vehicle manufacturer in terms of mileage and years of life

3.1.6
vehicle interior
passenger compartment
vehicle space occupied by the driver and passengers while driving

NOTE This space is normally sealed from the exterior environment, but has a certain air exchange rate.

3.1.7
original equipment manufacturer
OEM
vehicle manufacturer

3.2
mobile air conditioning
MAC
system used to provide occupant comfort by heating or cooling and dehumidifying the air that is delivered into the passenger compartment, by an electric blower and/or ram air from various air distribution ducts and outlets in the interior of the vehicle

NOTE The heating phase may include the use of waste engine heat and/or electric heating elements. The cooling phase is provided by a refrigerant system. The MAC also provides the ability to deliver conditioned airflow to clear vision (glazing/window) areas during inclement weather conditions. Air filtering devices with a sufficient degree of separation protect the HVAC units and occupants of the vehicle from the entry of water, snow, and other airborne debris.

3.2.1
battery chiller cooling system
refrigerant system with circuit extension consisting of an evaporator in a brine (water/anti-freeze mixture) loop with the intention to chill the circulating brine

3.2.2
battery direct cooling system
refrigerant system with circuit extension consisting of integrated evaporator in the battery assembly

3.2.3
double (dual) evaporator system
air conditioning system with a refrigerant loop with one compressor, one condenser and two evaporators and expansion devices, usually in parallel and usually both placed in or adjacent to the passenger compartment

3.2.4
high pressure side
refrigerant system from the compressor discharge chamber to the expansion device inlet chamber

3.2.5
low pressure side
refrigerant system from the expansion device discharge chamber to the compressor inlet chamber, including the compressor crankcase

3.2.6
refrigerant system
system consisting of refrigerant components, e.g. compressor, condenser/gas cooler, accumulator or receiver/drier, refrigerant sensor, at least one expansion device and one evaporator, piping assemblies, charge and/or service ports and an optional internal heat exchanger

NOTE The various parts of a refrigerant system fulfil design intent leak tightness and form a closed refrigerant cycle, in which the refrigerant can circulate at different pressures. The refrigerant lines make a connection between the components. Pressure and temperature sensors sense the refrigerant condition. For performance enhancements, an internal heat exchanger can be integrated between a high and low pressure side. The refrigerant cycle is built up during the assembly of the refrigerant system components in the vehicle, connecting the components to the vehicle body, and filling the designated refrigerant charge.

3.3
refrigerant system components
parts and subassemblies constituting the refrigerant system

3.3.1
accumulator
vessel capable of holding liquid refrigerant which is connected between the evaporator exit and inlet of compressor or internal heat exchanger

NOTE 1 The accumulator may contain the desiccant for removing moisture from the refrigerant. The accumulator may contain an integrated internal heat exchanger.

NOTE 2 An accumulator is used where the expansion device is an orifice or where the system is a transcritical R-744 system.

3.3.2
compressor
component that mechanically increases the pressure of the refrigerant vapour by sucking it in as low temperature and low pressure refrigerant from the evaporator or internal heat exchanger outlet and compressing it to high temperature and high pressure refrigerant for supply to the condenser or gas cooler inlet

3.3.3
condenser
device (heat exchanger) in which vaporized refrigerant is liquefied by removal of heat and the heat is released to the ambient air flowing through it

3.3.4
connecting technology
serviceable fitting technology used between components and piping assemblies in the refrigerant cycle

3.3.5
crimping
area of the refrigerant piping in which the pipe is permanently connected with the hose

3.3.6
desiccant
hygroscopic substance that absorbs or bonds free water from the enclosed refrigerant system until it becomes saturated

NOTE Commonly encountered desiccants are solids, and work through absorption or adsorption of water, or a combination of the two. Desiccants may work through physical or chemical bonding of water molecules.

3.3.7
evaporator
device (heat exchanger) absorbing heat from vehicle compartment air flow prior to entering the vehicle compartment or from other sources (battery, secondary loop fluid, etc.)

NOTE The refrigerant is converted from a predominately liquid state to a predominately vapour or superheated vapour state in the evaporator.

3.3.8
expansion device
orifice or regulating valve through which the refrigerant expands to a saturated low pressure vapour prior to entering the evaporator

NOTE The refrigerant is throttled from the high pressure side to the low pressure side.

3.3.9
flexible hose
flexible part of the refrigerant piping assembly, which allows relative movement between components in the vehicle

3.3.10
gascooler
device (heat exchanger) which is used for heat removal from the refrigerant in the supercritical refrigerant in a transcritical system

3.3.11
heating, ventilation and air conditioning unit
HVAC
part of the vehicle interior, which essentially consists of housings, blower, air filter, evaporator, heater core and/or electrical heater, air damper, motors, cable controls, air ducts, etc.

NOTE The system boundaries for interior components are the air inlet openings for outside air or recirculation air and the outlet openings to the passenger compartment.

3.3.12
internal heat exchanger
device which is used for defined heat transport from high pressure liquid side to low pressure suction side of the refrigerant system

3.3.13
liquid receiver/dryer
vessel which is permanently connected to the high pressure side of the system by inlet and outlet connections for accumulation of liquid refrigerant before the expansion device

NOTE The receiver contains the desiccant for moisture removal. The receiver is often an integrated element of the condenser.

3.3.14
lubricant
fluid partly circulating in the refrigerant system together with the refrigerant for reducing friction between surfaces in relative motion essentially by use of a fluid film

3.3.15
tubing
rigid refrigerant line including reinforcing and connecting pieces and connection seals

3.3.16
piping assembly
tubing or hoses (including bellows, connection technology) that interconnect the various parts of a refrigerating system

NOTE The piping assembly is fitted on both ends with connection technology to the component.

3.3.17
pressure relief device
mechanical device designed to automatically relieve pressure from the refrigerant system in order not to exceed the maximum pressure

3.3.18
pressure/temperature sensor
device used to measure pressure and/or temperature in a refrigerant system

NOTE An electrical or digital signal is generated from this device and sent to the vehicle electrical system for control of the refrigerant system. It is attached to a component or line/hose of the refrigerant system, sealed to the circuit, and in direct contact with or in the flow of the refrigerant.

3.3.19
service port
connection used to service the mobile air conditioning system (MAC), that enables the refrigerant circuit to be charged, discharged, evacuated, and pressure checked

3.4
refrigerant system boundary conditions
physical conditions at the boundaries of the refrigerant system

NOTE All physical dimensions and units are expressed in SI units and all indicated pressures are assumed to be absolute pressure, unless otherwise noted.

3.4.1
ambient temperature
temperature of air surrounding the vehicle

3.4.2
component inside temperature
internal temperature in a component, which the component will achieve in a vehicle, mainly impacted by ambient temperature, air temperatures surrounding the components, heat conductivity from/to other components, heat convection from/to a fluid, heat radiation from/to other components, engine speed, status of the system and considered refrigerant

NOTE This temperature can be determined on the inner surface of the component used in the application and reaches its minimum when there is no heat flux to the refrigerant system. In most cases, a technically relevant temperature difference between refrigerant flow and component inner surface does not occur.

3.4.3
component outside temperature
external temperature, which the component will achieve due to an outside heat flux in a vehicle mainly impacted by air temperature surrounding the component, heat conductivity from/to other components, heat convection from/to a fluid, and heat radiation from/to other components

NOTE This temperature can be determined on the outer surface of the component used in the application and may reach its maximum when the refrigeration system is not operating or discharged. The component outside temperature is mainly dependent on the location of the component in the vehicle and the ambient and operating conditions. The operating conditions change often during vehicle operation.

3.4.4
maximum pressure
highest pressure for which the refrigerant system is designed

3.4.5
maximum temperature
highest temperature for which the refrigerant system is designed

3.4.6
operating pressure
pressure in the component of the refrigerant system when in operation

3.4.7
outer surface temperature of engine components
external temperature, which an engine component achieves when the vehicle's engine is operating, mainly impacted by engine load, vehicle speed, ambient temperature, air temperatures surrounding the components, heat conductivity from/to other components, heat convection from the exhaust gas to the air, and heat radiation from/to other components under dynamic conditions

NOTE This temperature can be determined on the outer surface of the engine component used in the application and reaches its maximum when the engine is operating a high load and the vehicle speed is low or zero. The component outside temperature is also dependent on its location relative to the exhaust, the location of the component inside the engine compartment and the ambient/operating conditions. The operating conditions change often during vehicle operation.

3.5
refrigerant
fluid used for heat transfer in a refrigerating system, which absorbs heat at a low temperature and a low pressure and rejects heat at a higher temperature and a higher pressure usually involving changes of the state of the fluid

3.5.1
R-1234yf
HFO-1234yf, 2,3,3,3-Tetrafluoroprop-1-ene (CF3CFCH2) used as a refrigerant

NOTE As with an R-134a refrigerant cycle, in an R-1234yf refrigerant cycle, both the heat absorption and heat rejection take place below the critical point (R-1234yf condenses like R-134a in the high-pressure side).

3.5.2
R-134a
HFC-134a, 1,1,1,2-Tetrafluoroethane (CH2FCF3) used as a refrigerant

3.5.3
R-744
carbon dioxide used as a refrigerant

NOTE In an R-744 refrigerant cycle, heat absorption takes place below the critical point. At moderate ambient temperatures, heat rejection occurs at subcritical temperatures and R-744 condenses. At high ambient temperatures, heat rejection in the refrigerant cycle occurs in the supercritical region. This leads to a transcritical cycle, in which the compressor discharges refrigerant at a condition (pressure) above the critical point.

3.6
safety
set of means, conditions or requirements intended to minimize risk

3.6.1
hazard
event which has the potential to cause harm to either an individual or the environment

3.6.2
risk
numerical estimate of the probability or likelihood that a given hazard will occur

NOTE Risks are estimated via the process of risk assessment.

4 Safety targets

4.1 General

The purpose of this International Standard is to minimize possible risk to persons, occupants, vehicles, traffic participants, property and the environment caused by failures of the MAC system and the refrigerant that is used. The safety target is to maintain a comparable level of safety as that of MAC systems using R-134a. Potential hazards may be associated with the following.

a) The physical and chemical characteristics of refrigerants (i.e. pressure, toxicity, flammability) as well as refrigerant charge amount, pressures and temperatures occurring in refrigeration cycles.

b) The volume of the passenger compartment, air exchange rate in the interior of the vehicle, and parts of the refrigerant system located in the interior space of the vehicle.

c) An elevated concentration of the refrigerant in the interior or underhood, which may constitute a health hazard by direct inhalation or by inhalation of refrigerant decomposition products.

d) An unexpected exposure to an open flame due to ignition of a sufficient refrigerant concentration in the air.

e) An unexpected exposure to refrigerant decomposition products infiltrating the cabin from ignition or thermal decomposition of leaked refrigerant underhood.

f) Stress factors related to refrigerant release such as noise-related startling, irritation, or other distractions of the driver, which may represent a hazard for the occupants or other road users.

g) The quality and durability of air conditioning system components over vehicle lifetime shall be considered, as this may affect the level of risk.

h) An inappropriate repair or serious failure in service leading to refrigerant system leakage errors with refrigerant quality and quantity.

i) The occurrence of car accidents and vehicle malfunctions which may impact the level of risk associated with the refrigerant system.

j) Increased refrigerant concentration in the passenger compartment due to higher charge amount and additional lines connectors (e.g. by implementation of battery cooling system, dual evaporator systems, etc.).

k) Elevated outer surface temperature of engine components associated with the use of R-1234yf in the context of a robust development of MAC systems and their application in vehicles. The risks shall be identified through a systematic risk analysis process encompassing detailed analysis of the system and components, the system environment, and the intended use. Historical failure data shall be considered when available. The severity and probability of each risk associated with all identified hazards shall be considered.

The risk assessment methodology is described in 4.2. Information supporting the risk assessment for each refrigerant is given in 4.3.

The minimum subsidiary requirements for systems and components safety are described in Clauses 5 and 6.

4.2 Risk assessment

The risk assessment of a MAC system is a multi-step process in which different types of data are reviewed and then brought together to develop a mathematical estimate of potential health risk. The risk assessment procedure consists of the following steps.

a) A review of toxicity data available for the refrigerant. Data may be obtained from the peer-reviewed scientific literature or from newly commissioned studies. In the latter case, the study reports shall be reviewed to ensure the studies were conducted appropriately in terms of the study design, the reporting of results, any deviations noted from the study protocol, and the conclusions drawn by the testing laboratory from the data.

b) Determining the most significant toxicological effects for refrigerant exposures, the levels at which these occur, and any human health criteria related to these effects, including any safety factors considered to be necessary.

c) An evaluation of the absolute toxicity as well as the relative toxicity of the refrigerant as compared to R134a based on the available toxicity data.

d) An assessment of the flammability of the refrigerant, including, if applicable, determining the upper and lower flammable limits, the minimum ignition energy, the minimum ignition temperature, the autoignition temperature, and the fundamental burning velocity.

e) An assessment of potential concentrations of refrigerant in air in the event of a refrigerant release in the passenger compartment, engine compartment, or vehicle repair areas.

f) For fluorinated hydrocarbon refrigerants, determination of the potential for, and magnitude of, exposure to hydrogen fluoride (HF) due to refrigerant combustion or thermal decomposition.

g) Estimation of probabilities of specific risks relating to refrigerant exposure, refrigerant ignition and HF exposure, as applicable, through the use of Fault Tree Analysis (FTA), Failure Mode and Effects Analysis (FMEA) or any equivalent method.

4.3 Relevant inputs and scenarios for the risk assessment

4.3.1 R-134a MAC systems

R-134a is the current globally accepted refrigerant and proven-in-use for safety in MAC systems. Therefore, no risk assessment is required.

4.3.2 R-1234yf MAC systems

The refrigerant safety strategy will be for each vehicle manufacturer to carry out a risk assessment for R-1234yf refrigerant systems that will be used in new vehicles. The risk assessments shall include, but not be limited to, consideration of the inputs below (values are given in Annex A):

a) Relevant inputs

   1) Toxicity of refrigerant and decomposition products

      i) Permissible Exposure Limit (PEL)

      ii) Occupational Exposure Limit (OEL)

      iii) Acute Toxicity Exposure Limit (ATEL)

      iv) Toxicity Hazard Index (HI) = Estimated Exposure Concentration (ppm)/ATEL (ppm)

      v) Acute Exposure Guideline Level (AEGL-2) for potential refrigerant decomposition products

   2) Refrigerant flammability

      i) Lower Flammability Limit (LFL)

      ii) Upper Flammability Limit (UFL)

      iii) Minimum Ignition Energy (MIE)

      iv) Autoignition temperature

      v) Heat of combustion

      vi) Burning velocity

      vii) Hot surface ignition temperatures

      viii) Relevant ignition source

      ix) Refrigerant/oil mixture concentration

Refrigerant concentrations shall be determined via modelling or measurement. Results shall be calculated as time-weighted average (TWA) values for a timeframe compatible with the relevant toxicity limits. For flammability, the peak concentration shall be used for comparison to the flammability limits.

b) Scenarios that shall be considered in the risk assessment:

1) Exposure to R-1234yf concentration above health limits due to a small or large leak in the passenger compartment. A small leak (corrosion leaks as defined in SAE J2772) is associated with a leak in the MAC system during normal operation whereas a large leak (as defined in SAE J2772) is associated with a piping failure caused by a vehicle collision.

2) Exposure to R-1234yf concentration above health limits during vehicle service.

3) Ignition event associated with a small or large leak in the passenger compartment.

4) Ignition event associated with a small or large leak in the engine compartment.

5) Ignition event due to R-1234yf release during vehicle service.

6) Liquid or fragment projection resulting from high pressure system burst.

7) Exposure to decomposition products (e.g. hydrogen fluoride) above health limits (AEGL2) resulting from refrigerant thermal decomposition in the event of a refrigerant release caused by MAC system failure or a vehicle fire produced by vehicle failure.

4.3.3 R-744 MAC systems

The refrigerant safety strategy for each vehicle manufacturer is to carry out a risk assessment for R-744 refrigerant systems that will be used in new vehicles. The risk assessments shall include, but not be limited to, consideration of the inputs below (values are given in Annex A).

a) Relevant inputs

1) Refrigerant toxicity

i) ATEL[1)] 5-minute TWA and peak exposure limits as determined from studies in medical literature.

ii) PEL

iii) OEL

Refrigerant concentration data shall be determined via modelling or measurement. Results shall be calculated as TWA values for a timeframe compatible with the relevant toxicity limits.

b) Scenarios that shall be considered in the risk assessment:

1) Exposure to R-744 concentration above health limits due to a small or large leak in the passenger compartment. A small leak (corrosion leaks as defined in SAE J2772) is associated with a leak in the MAC system during normal operation whereas a large leak (as defined in SAE J2772) is associated with a piping failure caused by a vehicle collision.

2) Exposure to R-744 concentration above health limits during vehicle service.

3) Liquid or fragment projection resulting from high pressure system burst.

4) Potential startling of the vehicle driver due to rupture of the high pressure system, resulting in a possible accident.

1) Equivalent to the IDLH (Immediately Dangerous to Life and Health) value established by the U.S. National Institutes of Occupational Safety and Health (NIOSH) for 30-minute exposures.

5 System level requirements

5.1 Refrigerant system

5.1.1 Refrigerant type

The system shall only be charged with the refrigerant which it was intentionally designed for.

5.1.2 Maximum refrigerant amount

The vehicle manufacturer specifies the upper amount of charge in the refrigerant system.

The maximum charge amount shall consider the tolerances of the manufacturing and service charging equipment.

5.1.3 Determination of the refrigerant concentration in a vehicle

The refrigerant will be contained in the evaporator that is directly exposed to the passenger compartment or air distribution system. An increased refrigerant concentration in the passenger compartment breathing air may arise due to an unexpected leakage and this refrigerant concentration is mostly influenced by leak size and vehicle and component operation mode.

The reference procedure for measuring concentration in the cabin is SAE J2772.

5.1.3.1 Vehicle passenger compartment net volume and air exchange rates

The vehicle manufacturer specifies the geometrical dimensions and thus the volume of the vehicle during the development process. It can vary slightly by vehicle interior variants.

The OEM shall consider a minimum air exchange rate depending on the net cabin volume and the refrigerant amount, ensuring that the refrigerant concentration does not reach the maximum level as defined in 4.3.

5.1.3.2 Reference method

SAE J2772 focuses on the determination vehicle cabin refrigerant concentration arising from an assumed refrigerant leak. It is an established industry standard for determination of refrigerant concentration in a vehicle interior compartment. For the generation of a refrigerant level in the vehicle compartment, an external refrigerant source is inserted into the HVAC-module airflow to the passenger compartment. The measurement shall cover vehicle compartment design boundaries, possible usage of the vehicle HVAC operation mode and the refrigerant system.

5.1.4 Maximum specific refrigerant charge for R-744 refrigerant systems

The maximum specific charge for a R-744 system shall not exceed 250 g/dm^3 of internal refrigerant system volume to provide a sufficient margin for the low pressure side pressure relief device.

NOTE The critical point of R-744 is at 31,1 °C (88 °F) and 7,38 MPa. Once the temperature of the coldest component rises above 31,1 °C (88 °F), all R-744 in the system will be superheated and the system pressure will depend on the temperatures of the system components and the total refrigerant charge. With a specific charge of 250 g/dm^3 and a temperature of all components of 60 °C (140 °F), the resulting static system pressure will be 9,3 MPa at 80 °C (176 °F) and the system pressure will be 10,8 MPa. For example, a refrigerant system for a full size vehicle with a total system internal volume of 1,5 dm^3 shall contain not more than approximately 375 g of R-744.

5.1.5 Refrigerant additives

OEMs shall ensure that additives specified by them shall not result in higher levels of toxicity or flammability above those considered in the risk assessments. OEMs cannot foresee what additives may be introduced in the aftermarket. Suppliers of aftermarket additives shall be solely responsible for the suitability of their products.

SAE J2670 and SAE J639 provide additional information regarding safety.

5.2 Pressure and temperature ranges

The minimum reference design requirements for pressure and temperature boundaries for the MAC system are defined in Annex B.

The manufacturer may establish more demanding values than these limits.

5.3 System layout

5.3.1 Recommendations for the routing and circuit connections in the engine compartment of the vehicle

The package of the refrigerant system and the routing of the piping shall not interfere with the ground clearance. The refrigerant system shall be designed to minimize the risk of impact with the ground or loose objects.

Service ports shall be located for ease in attaching service hoses and shall be oriented to allow safe access.

The design of R-1234yf systems shall consider potential impingement of leaked refrigerant and oil on hot surfaces.

5.3.2 Routing and circuit connections in vehicle cabin

In vehicles, the evaporator as part of the HVAC is located inside the passenger compartment. The piping and other components of the refrigerant system remain outside it or are additionally integrated into the HVAC. Furthermore, some vehicles have a second HVAC installed with the piping routing inside the vehicle interior space.

With R-134a refrigerant systems, in respect to the cabin safety perspective, no restrictions apply for arrangement and positioning of junction points, components and piping.

With R-1234yf and R-744 refrigerant systems, connections shall

— be located outside the passenger compartment and outside the cabin air flow path

or

— ensure design-intent leak tightness and follow service and repair leakage recommendations for safety if the connections are inside the cabin or air flow path.

5.4 Pressure and temperature limitation strategies

5.4.1 Overpressure strategy

The system shall be designed to ensure that the pressure does not exceed the maximum pressure. If a pressure relief device is used, it shall vent to a location to minimize risk.

5.4.2 Overtemperature strategy

The system shall be designed to ensure that the refrigerant temperature does not exceed the maximum refrigerant temperature.

6 Component level requirements

6.1 General requirements

6.1.1 Burst pressure

New components (those components not previously subjected to fatigue stresses) shall have an ultimate burst pressure not less than two times the maximum pressure as described in Annex B for high/low pressure sides of the refrigerant system.

For R-744, components on the high pressure side of the refrigerant system which may be subject to tensile strength reduction as a consequence of temperature and pressure (i.e. compressor outlet chamber, gas cooler, and connecting piping between these components) shall be tested as follows.

— The components shall be exposed to the appropriate system operating conditions to simulate the specified refrigerant system life (temperature, pressure, pressure cycling, vibration, corrosion, etc.) in correlation of vehicle usage.

— The burst pressure shall not be less than 1,5 times the maximum pressure as described in Annex B when tested at every component operating temperature after exposure to simulated system operating conditions.

6.1.2 Materials

The materials of the components forming the refrigerant system in the vehicle shall be suitable for the maximum operating temperature and pressure ranges over vehicle lifetime. The operation environment in a vehicle shall be considered, e.g. vehicle speed, mechanical load, vibrations, abrasion by particles, corrosive environment such as road salt and salt water spray, or air borne substances.

For components applied in the vehicle interior or within the airflow stream to the vehicle cabin interior for which a corrosion-related failure may cause a hazardous concentration in the passenger compartment, the material selection shall ensure that no sudden accelerated leakage rate occurs.

Further, an adequate material resistance is required against chemical reaction and physical attacks from the refrigerant and lubricants under continuous operation, which may alter the temperature/pressure performance of the refrigerant with shifting refrigerant charges as well as emptied condition when charge is fully depleted.

Material selection shall consider that properties can change due to mechanical, chemical, thermal impact due to production process and further to storage of the component.

For components assembled from different materials or components made of different materials connected by physical contact to other components, galvanic corrosion may occur if the components are exposed to a wet environment since contaminated water acts as an electrolyte. Factors such as surface area ratio of the anode and cathode, types of materials, and operating conditions (temperature, humidity, salinity, etc.) will affect galvanic corrosion.

Non-metallic materials such as rubber, plastics and elastomers shall fulfil the mechanical, thermal, chemical, and physical requirements against refrigerant/oil mixture and shall not create products that are a fire hazard. The electrical properties for those materials in respect to galvanic corrosion shall be considered.

6.2 Piping and connecting technology

6.2.1 General information

The piping and connecting technology of the refrigerant system shall be designed in such a way that under normal use, occupants or persons directly adjacent to the vehicle cannot be exposed to leakage resulting in an inadmissibly high concentration of refrigerant and oil aerosols and/or projection of fluid or fragments.

Piping and attached components shall be designed to minimize mis-assembly, causing hazards.

6.2.2 Tightness requirements

The tightness requirements shall be fulfilled during assembly and service. The values for components inside the passenger compartment shall not exceed corrosion leak rates as defined in SAE J2772.

6.2.3 Design requirements for piping

If piping cannot be common for different refrigerants, the pipes shall be marked for the specific refrigerant usage unless there is mechanical differentiation to avoid unintentional cross-usage.

Low pressure pipes shall be marked as such if attachment to high pressure components can occur.

6.2.4 Design requirements at connection

For R-744, connection joint technology must leak before sudden separation if the fastener becomes loose or is loosened intentionally to provide warning that the system is under pressure.

Sealing elements of the connection technology shall be protected during transport and shall not be easily damaged during assembly. Sealing elements shall be serviceable and shall not be reused after disassembly of the connection technology.

Connection technologies intended for re-use shall allow safe and reliable re-assembly at least 10 times.

6.2.5 Hose and crimps

Service parts used as replacement in the system must meet the OEM requirements for leakage and reliability.

Crimping in the field shall not be allowed for R-744.

Crimping in the field may be allowed for R-1234yf provided that it meets the requirements of SAE J2064.

6.3 Compressor

6.3.1 Failure mode

Compressor assemblies shall be designed to incorporate devices that will cut off transmission of power to the compressor in the event of the compressor suffering catastrophic internal failure. Such devices shall be equipped on the compressor pulley or compressor itself or implemented in vehicle software.

This shall be demonstrated by means of worst case destructive testing (as determined by OEM and supplier); the housing(s) wall may crack or permanently deform or lose pressure during this test.

Safety features of the compressor shall function throughout the range of component operating temperatures (as agreed upon between OEM and compressor manufacturer).

In systems equipped with a pressure relief valve (PRV), the system shall have means to limit the compressor operation before a pressure relief device will vent refrigerant, in order to prevent discharge of refrigerant during operation.

6.3.2 Electrical compressor

The compressor electrical circuits, both compressor-side and vehicle-side, shall be designed to prevent user contact with hazardous voltage ($>$ 60 V DC).

In the event of an electrical short, the electrical circuit (compressor-side and vehicle-side) shall be designed to prevent the occurrence of a hazardous thermal event.

The electrical circuit for powering the compressor (compressor-side and vehicle-side) shall be designed to prevent the occurrence of electrical conductivity leakages.

6.3.3 Lubricants

Proper lubricant shall be selected to ensure compatibility between refrigerant, lubricant, and system components and adequate lubricity of the compressor. Specific oils have been developed for each refrigerant (R-1234yf, R-744, R-134a). It is critical that the correct oil be used with each refrigerant because improper lubricant selection may result in breakdown of A/C components and/or premature failure of the A/C system.

For electrical compressors, a qualified oil may be required to maintain a certain level of isolation resistance. A significant reduction in the isolation resistance may result in electrical leakage or a shutdown of the high-voltage system.

If such an oil is required, care shall be taken to prevent contamination with other oil types that would result in a significant reduction in isolation resistance.

Compressor lubricant lifetime shall meet or exceed the targeted vehicle lifetime.

Lubricant manufacturer's material safety data sheets (MSDS) shall be consulted to obtain recommended handling instructions specific to the lubricant.

6.4 Evaporator

6.4.1 Design requirements for R-134a evaporators

Evaporator design for R-134a shall comply with SAE J639.

6.4.2 Design requirements for R-1234yf and R-744 evaporators

Evaporator design for R-1234yf and R-744 shall comply with the design criteria and certification for OEM MAC systems/components and service replacements as defined in SAE J2842.

6.5 Condenser/gas cooler

No specific requirements.

6.6 Receiver and accumulator

The combined accumulator with internal heat exchanger must fulfil the design intent leak tightness.

6.7 Service ports

The service ports are connected to lines, which must be fastened or rigid, so that coupling/decoupling of the service and production coupler does not permanently deform the piping.

Service port(s) described in SAE J639 shall be used on the high and/or low side of the system to avoid the possibility that refrigerants could be mixed in service.

6.8 Control devices

Sensing devices attached to any part of the refrigeration system and in direct contact with the refrigerant shall be designed to prevent unexpected separation and/or release of refrigerant as defined in SAE J639.

7 Design requirements for service and manufacturing

R-134a service equipment according to SAE J2788.

R-1234yf service equipment according to SAE J2843.

R-744 service equipment according to SAE J2771.

Technicians shall be trained in recommended practices as described in SAE J2845 for R-744 and R-1234yf.

Annex A
(normative)

Relevant input values for the risk assessment of refrigerants R-134a, R-1234yf and R-744

A.1 Refrigerant safety classification

Toxicity, flammability classification and proper refrigerant-related definitions can be found in the latest version of ANSI/ASHRAE 34.

A.2 Refrigerant thermodynamic properties

Standard properties of MAC refrigerants are presented in Table A.1.

Table A.1 — MAC refrigerant thermodynamic properties

Properties	R-134a	R-1234yf	R-744
Boiling point, T_b	−26 °C	−29 °C	−78,5 °C
Critical point, T_c	102 °C	95 °C	31 °C
P_{vap}, MPa (25 °C)	0,665	0,677	6,4
P_{vap}, MPa (80 °C)	2,63	2,44	11,1 with a charge of 260 g/dm^3
Liquid density, kg/m^3 (25 °C)	1 207	1 094	711
Vapour density, kg/m^3 (25 °C)	32,4	37,6	243

A.3 Refrigerant toxicity data

Toxicity limits for MAC refrigerants are presented in Tables A.2 and A.3.

Table A.2 — R-134a and R-1234yf toxicity data

Parameters	R-134a	R-1234yf
Acute lethality	LOEL 567 000 ppm	LOEL > 400 000 ppm
Cardiac sensitization	NOEL 50 000 ppm LOEL 75 000 ppm	NOEL > 120 000 ppm
4-week subchronic toxicity	NOEL > 50 000 ppm	NOEL > 50 000 ppm
13-week subchronic toxicity	NOEL 50 000 ppm	NOEL 50 000 ppm
Genetic toxicity	Ames not active Chromosome aberration not active Micronucleus (mouse) not active	Ames slight activity in two strains Chromosome aberration not active Micronucleus (mouse and rat) not active Unscheduled DNA synthesis not active
Developmental toxicity	Rat NOAEL 300 000 ppm Rabbit NOAEL 2 500 ppm	Rat NOAEL 50 000 ppm Rabbit NOAEL 4 000 ppm
Reproductive toxicity 2-generation	NOEL 50 000 ppm (1 h exposure), or ~8 300 ppm (6 h exposure)	NOEL 15 000 ppm (6 h exposure)
Occupational Exposure Limit (OEL)	1 000 ppm	500 ppm (AIHA WEEL value)
Acute toxicity exposure limit	50 000 ppm	100 000 ppm

Table A.3 — R-744 health limits

Parameters	R-744
Acute lethality (LC50)	Approximately 400 000 ppm[a]
Anaesthetic effect (ppm)	40 000 (30 minutes)[b]
Cardiac sens. No effect level (ppm)	Not tested/not expected
Occupational Exposure Limit (OEL)	5 000 ppm (8-hour TWA) 40 000 (IDLH)
28-day NOAEL (ppm)	No data#
90-day NOAEL (ppm)	No data#
Developmental toxicity NOAEL (ppm)	No data#
Genotoxicity	No data#
Carcinogenicity	No data#
Acute exposure limit	40 000 ppm (ATEL 30-min TWA)[c] 55 000 ppm (5-min TWA) 90 000 ppm (peak)

NOTE Standard tests for these endpoints have not been conducted. In subchronic studies that have been conducted, reports of effects are variable and not consistent.

[a] Study exposure was for 3 h rather than 4 h. Animal mortality was 21 %.

[b] R-744 data are for humans (NIOSH IDLH value).

[c] Equivalent to the IDLH (Immediately Dangerous to Life and Health) value established by the US National Institute of Occupational Safety and Health (NIOSH) for 30-min exposure, representing escape impairing effects (narcosis, anaesthesia).

A.4 Refrigerant flammability data

The reference parameters for flammability and decomposition product risk assessment are given in Table A.4.

Table A.4 — R-134a and R-1234yf flammability data

Parameters	R-134a	R-1234yf
Flame limits — ASTM E681-01 at 21 °C	N/A	LFL (vol% in air): 6.2 UFL (vol% in air): 12.3
Minimum ignition energy (mJ)	N/A	> 5 000
Autoignition temperature (°C)	> 743	405
Heat of combustion (kJ/g)	4,2	10,7
Burning velocity (cm/s)	N/A	1,5
Decomposition products	Hydrogen fluoride Carbonyl halides Carbon dioxide	Hydrogen fluoride Carbonyl halides Carbon monoxide Carbon dioxide

Annex B
(normative)

Pressure and temperature reference data

B.1 Pressures

The maximum pressure conditions are reported in Table B.1.

Table B.1 — Maximum pressure conditions

Refrigerant	Maximum pressure, low pressure side (MPa)	Maximum pressure, high pressure side (MPa)
R-134a	Saturation at 54 °C	4,24
R-1234yf	Saturation at 56 °C	4,24
R-744	13,00	17,00

B.2 Ambient

The refrigerant system may be operated at ambient temperatures from –10 °C through +54 °C.

B.3 Component outside temperature

The reference values for component outside temperature are presented in Table B.2.

Table B.2 — Component outside temperature reference values

Vehicle position (most frequent)	Component	Component outside temperature	
		lower (°C)	higher (°C)
Instrument panel (inside)	Evaporator Thermostatic expansion device TXV (if mounted at HVAC)	–40	Instrument panel (inside)
Entrance to engine compartment	Condenser/gascooler	–40	Entrance to engine compartment
Engine compartment (cool)	Accumulator, receiver, expansion device (orifice tube, TXV if not mounted in/at the HVAC), sensors, charge and service ports	–40	Engine compartment (cool)

B.4 Component inside temperature

The reference values for component inside temperature are presented in Tables B.3 and B.4.

Table B.3 — Component inside temperature reference values for R-134a/R-1234yf

R-134a/R-1234 component	Refrigerant temperature/inside component temperature	
	lower (°C)	upper (°C)
Compressor, flexible hoses/piping from compressor, condenser, sensors (upstream of the condenser)	−40	150
Accumulator, receiver, expansion device (orifice tube, TXV), sensors (downstream of the condenser), charge and service ports, evaporator	−40	80

Table B.4 — Component inside temperature reference values for R-744 refrigerant system

R-744 component	Refrigerant temperature/inside component temperature	
	lower (°C)	upper (°C)
Compressor, flexible hoses/piping from compressor, condenser/ gascooler, sensors (upstream of the gascooler)	−40	175
Accumulator, receiver, expansion device, sensors (downstream of the gascooler), charge and service ports, evaporator	−40	80

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[1] ISO 817, *Refrigerants — Designation and safety classification*

[2] SAE J2099, *Standard of Purity for Recycled HFC-134a (R-134a) and HFO-1234yf (R-1234yf) for Use in Mobile Air-conditioning Systems*

[3] SAE J2683, *Refrigerant Purity and Container Requirement for Carbon Dioxide (R-744) Used in Mobile Air-Conditioning Systems*

[4] SAE J2773, *Standard for Refrigerant Risk Analysis for Mobile Air Conditioning Systems*

[5] SAE J2776, *Refrigerant Purity and Container Requirements for New HFC-134a 1,1,1,2 - Tetrafluoroethane Refrigerant Used in Mobile Air-Conditioning Systems*

[6] SAE J2810, HFC-134a (R-134a), *Refrigerant Recovery Equipment for Mobile Automotive Air-Conditioning Systems*

[7] SAE J2844, *R-1234yf, New Refrigerant Purity and Container Requirements Used in Mobile Air-Conditioning Systems*

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