



DRAFT INTERNATIONAL STANDARD ISO/DIS 13043

ISO/TC 22

Secretariat: **AFNOR**

Voting begins on:
2010-04-30

Voting terminates on:
2010-09-30

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Road vehicles — Refrigerant systems used in Mobile Air Conditioning systems (MAC) — Safety requirements

Véhicules routiers — Systèmes réfrigérants utilisés dans les systèmes d'air conditionné embarqués (MAC) — Exigences de sécurité

ICS 43.040.60

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Foreword

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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 good 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 thus bans the use of R-134a for new model types, from January 1st 2011 and for all new vehicles from January 1st 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/or to a technician required to service the vehicle. This standard looks 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 a mobile air conditioning 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 standard addresses the use of only R-134a, R-1234yf and R-744 refrigerants in vehicle OEM and aftermarket (non-OEM) supplied components and systems.

From past experience and low GWP refrigerants assessments by car manufacturers and system suppliers, 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 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 HVAC system (heater, blower, air mixing and distribution) or any other component of the vehicle but not related to the refrigerant system will not be covered in this document.

The purpose of this standard is to ensure that end-users and/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 document. 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 R-134a system, this standard applies to any new model type launched one year after the document is published.

For R-1234yf and R-744 systems, this 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.

ISO/DIS 13043

ISO 817, *Refrigerants – Designation and Safety Classification* (currently ISO/DIS 817:2010)

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

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 J2683, *Refrigerant Purity and Container Requirement for Carbon Dioxide (R-744) Used in Mobile 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 under system refrigerant leakage conditions*

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

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

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

SAE J2810 - HFC-134a (R-134a), *Refrigerant Recovery Equipment for Mobile Automotive 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 J2844 - R-1234yf, *New Refrigerant Purity and Container Requirements Used in 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)*

SAE J2851 - R-1234yf, *Refrigerant Recovery Equipment for Mobile Automotive Air-Conditioning Systems*

3 Terms and definitions

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

3.1 vehicle

any vehicle with a combustion engine or / and 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 or/and 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 vehicle it contains mechanical or electric compressor and piping.

NOTE 3 In a 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 (or 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**

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 Heating, Ventilation and Air Conditioning (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 but 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 like 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 fulfill design intent leak tightness and form a closed refrigerant cycle, in which refrigerant can circulate at different pressures. The refrigerant lines make connection between the components. Pressure and temperature sensors sense the refrigerant condition. For performance enhancements an internal heat exchanger can be integrated between 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 of the designated refrigerant charge.

3.3**refrigerant system components**

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 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, ...).

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

3.3.8

expansion device

orifice or regulating valve through which the refrigerant expands to a saturated low pressure vapor 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 parts 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 and / 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 of the refrigerant system in order to not exceed the maximum pressure

3.3.18**pressure sensor, temperature sensor, 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 ports

connections used to service the mobile air conditioning system, that enable the refrigerant circuit to be charged, discharged, evacuated, and pressure checked

3.4

refrigerant system boundary conditions

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 in case that 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 in case that the engine is /was operating high load and the vehicle speed is/ was 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 are changing 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 (CO₂) 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****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. Risks are estimated via the process of risk assessment

4 Safety targets

4.1 General

The purpose of this 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 mobile air conditioning systems using R-134a. Potential hazards may be associated with:

1. 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.
2. 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.
3. 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.
4. An unexpected exposure to an open flame due to ignition of a sufficient refrigerant concentration in the air.
5. An unexpected exposure to refrigerant decomposition products infiltrating the cabin from ignition or thermal decomposition of leaked refrigerant underhood.
6. 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 and/or other road participants.
7. The quality and durability of air conditioning system components over vehicle lifetime shall be considered as this may affect the level of risk.
8. An inappropriate repair or serious failure in service leading to refrigerant system leakage errors with refrigerant quality and quantity.
9. The occurrence of car accidents and vehicle malfunctions which may impact the level of risk associated with the refrigerant system.
10. 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.)"
11. 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 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 risks assessment methodology is described in 4.2. Information supporting the risk assessment for each refrigerant is given in chapters 4.3 to 4.5.

The minimum subsidiary requirements for systems and components safety are described in chapter 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:

1. 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.
2. 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.
3. 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,
4. 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.
5. 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.
6. For fluorinated hydrocarbon refrigerants, determining the potential for, and magnitude of, exposure to hydrogen fluoride (HF) due to refrigerant combustion or thermal decomposition.
7. 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 Mobile Air Conditioning 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
 - Refrigerant and decomposition products toxicity
 - PEL = Permissible Exposure Limit
 - OEL = Occupational Exposure Limit

- ATEL = Acute Toxicity Exposure Limit
- Toxicity Hazard Index (HI) = Estimated Exposure Concentration (ppm) / ATEL (ppm)
- AEGL-2 = Acute Exposure Guideline Level for potential refrigerant decomposition products
- Refrigerant Flammability
 - LFL = Lower Flammability Limit
 - UFL = Upper Flammability Limit
 - MIE = Minimum Ignition Energy
 - Autoignition Temperature
 - Heat of Combustion
 - Burning Velocity
 - Hot surface ignition temperatures
 - Relevant Ignition Source
 - Refrigerant / oil mixture concentration

Refrigerant concentrations shall be determined via modeling 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:

- Exposure to R-1234yf concentration above health limits due to a small or large leak in the passenger compartment. The small leak (corrosion leaks as defined in SAE J2772) is associated with a leak in the MAC system during normal operation whereas the large leak (as defined in SAE J2772) is associated with a piping failure caused by a vehicle collision.
- Exposure to R-1234yf concentration above health limits during vehicle service.
- Ignition event associated with small or large leak in the passenger compartment.
- Ignition event associated with small or large leak in the engine compartment.
- Ignition event due to R-1234yf release during vehicle service.
- Liquid or fragment projection resulting from high pressure system burst.
- 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 will be for each vehicle manufacturer to carry out a risk assessment for R-744 refrigerant system 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

— Refrigerant Toxicity

- ATEL = Acute Toxicity Exposure Limit¹ 5-minute TWA and peak exposure limits as determined from studies in the medical literature.
- PEL = Permissible Exposure Limit.
- OEL = Occupational Exposure Limit.

Refrigerant concentration data 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.

b) Scenarios that shall be considered in the risk assessment

- Exposure to CO₂ concentration above health limits due to a small or large leak in the passenger compartment. The small leak (corrosion leaks as defined in SAE J2772) is associated with a leak in the MAC system during normal operation whereas the large leak (as defined in SAE J2772) is associated with a piping failure caused by a vehicle collision.
- Exposure to CO₂ concentration above health limits during vehicle service.
- Liquid or fragment projection resulting from high pressure system burst.
- Potential startling of the vehicle driver due to rupture of the high pressure system, resulting in a possible accident.

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

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.

5.1.3 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 section 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 gCO₂ /dm³ 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 charge of 250 g CO₂ /dm³ and a temperature of all components of 60°C (140°F) the resultant static system pressure will be 9.3 MPa, at 80°C (176°F) the system pressure will be 10,8 MPa. For example, a refrigerant system for a full size vehicle with a total system internal volume 1,5 dm³ shall contain not more than approx. 375g R-744.

5.1.5 Refrigerant additives

OEMs shall ensure 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 in regards to safety.

5.2 Pressure and temperature ranges

The minimum reference design requirements for pressure and temperatures 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 of attachment of service hoses and shall be oriented to allow safe access.

The design of 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 in 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 2.0 times the maximum pressure as described in Annex B for high / low pressure sides of the refrigerant system.

For R744, 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 has to be considered, such as vehicle speed, mechanical load, vibrations, abrasion by particles, corrosive environment like 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 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, 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 way, that under normal use, occupants or persons directly adjacent to the vehicle cannot be exposed to leakage resulting in 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 R744, 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 Original Equipment Manufacturer's 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 compressor shall function throughout the range of component operating temperatures (as agreed upon between OEM and compressor manufacturer).

In systems equipped with a PRV, the system shall have a mean 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 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 is 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 MSDS shall be consulted to obtain recommended handling instructions specific to 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 fulfill 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 deform permanently 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 ASHRAE 34.

A.2 Refrigerants thermodynamic properties

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

Table A.1 — MAC refrigerants 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)	1207	1094	711
Vapor Density, kg/m ³ (25 °C)	32.4	37.6	243

A.3 Refrigerants 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

	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 Uscheduled 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-hr exposure), or ~8 300 ppm (6-hr exposure)	NOEL 15 000 ppm (6-hr 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

	R744
Acute lethality (LC50)	Approximately 400,000 ppm ^a
Anesthetic 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-minutes TWA) ^c 55 000 ppm (5-minutes TWA) 90 000 ppm (peak)
<p>^a Study exposure was for 3 hours rather than 4 hours. Animal mortality was 21%.</p> <p>^b CO2 data are for humans (NIOSH IDLH value)</p> <p>^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-minutes exposures, representing escape impairing effects (narcosis, anesthesia).</p> <p># Standard tests for these endpoints have not been conducted. In subchronic studies that have been conducted, reports of effects are variable and not consistent.</p>	

A.4 Refrigerants Flammability data

The reference parameters for flammability and decomposition products risk assessment are given in table A.4.

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

	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	> 5000
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	1.46 ^a	4.14
R-1234yf	1.46 ^a	4.14
R-744	13.0	17.0
^a based on saturation pressure of R-134a at 54°C.		

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	Condenser / Gascooler	-40	Entrance to Engine

compartment			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 Table 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