THE 2018 RTOC ASSESSMENT REPORT
MOBILE AIR CONDITIONING (CHAPTER 10)

Chap 10 Leading author - Carloandrea Malvicino[1]
Chap 10 Co-authors: Radim Čermák, Jiangping Chen, Dave Godwin, Jürgen Köhler, Samuel Yana Motta

1. INTRODUCTION

The Refrigeration Technical Options Committee (RTOC) under United Nations Environment (UNEP) Montreal Protocol (https://ozone.unep.org/) has released its 2018 Assessment Report in March 2019.

The Chapter 10 of the Report is devoted to the Mobile Air Conditioning system used for road transport vehicles covering the new developments since the RTOC 2014 Report including the evolution related to the vehicle electrification.

Even though railway (train) air conditioning falls within mobile mass transit, because of similarity of technology it is covered in Chapter 6 (Transport Refrigeration).

2. SCENARIO

The majority of new AC equipped passenger cars worldwide uses HFC-134a while HFO-1234yf is rapidly increasing its market share in US and Europe due to the enforcement of regulations. The transition from CFC-12 is complete for new systems, but there are still cars in use especially in Article 5 countries where average age of vehicles is higher than in the other regions of the world.

More than one refrigerant will be used in the coming years for car and light truck air conditioning. HFC-134a will remain largely used worldwide, HFO-1234yf will continue its growth in new models, R-744 is used in a couple of car models and is expected to be re-considered as an option for electrified vehicles when used also with in heat pump function.

The de-carbonization of road transport and its progressive electrification is leading to a very relevant technology change that includes the Mobile Air Conditioning. The vapour compression cycle will remain by far the most used technology but implemented with different configuration where the direct expansion will be in part replaced by liquid cooled systems to allow the electric and battery thermal management.

HFO-1234yf will increase its take rate but the global vehicle air conditioning market will be significantly governed by additional considerations such as safety, costs, regulatory approval, system reliability, heat pump capability (especially for electric driven vehicles) and servicing.

The transition to new and more expensive refrigerants is driven by regulations, so where there are or will be specific regulations, HFO-1234yf will be further diffused, otherwise the old refrigerant HFC-134a) will be kept as main option unless (or until) less expensive solutions will become available.

In this framework, it should be mentioned that there are studies to evaluate the use of less expensive but flammable low GWP refrigerants in Article 5 countries.

---

[1] FCA Italy SpA

Finally, it is unclear whether the bus and heavy duty truck MAC will follow the passenger vehicle evolution or another path, utilizing for example HFO-1234yf or other options (HFO blends, R-744, …).

3. TYPES OF EQUIPMENT AND FUTURE TRENDS

Light duty vehicles use from 0.3 kg to 1.4 kg refrigerant charge, while for buses the charge could be from 8 kg up to 16 kg as a function of the vehicle category (e.g. simple bus, articulated bus). Currently there are approximately 1,000 ktonnes of refrigerant in vehicles considering that there are about 1.3 billion road vehicles circulating (see (https://www.statista.com/statistics/281134/number-of-vehicles-in-use-worldwide/).

Estimating that 75% of circulating vehicles are equipped with MAC, and assuming a yearly renewal rate of 8% (e.g. 100 million units approx.), the refrigerant demand (excluding service) is about 75 ktonnes/year.

HFC-134a is widely used for new equipment as well for retrofits worldwide as replacement of CFCs. In the mid-1990's the evaluation of lower GWP refrigerant started, as an alternative to HFC-134a where several synthetic and natural working fluids (e.g. R-744, R-290) have been evaluated, the HFO-1234yf has been then selected to replace R-134a and reducing the GWP in spite of its (low) flammability and higher cost.

In 2013 OEMs started the transition to lower GWP refrigerants driven mainly by regulations (US light-duty vehicle regulations, European MAC Directive, Japanese regulatory prohibitions). and supported by non-regulatory initiatives (e.g. the Improved Mobile Air Conditioning (I-MAC) SAE Cooperative Research Program CRP) as well as four SAE 1234yf CRPs and the SAE Interior Climate Control Committee).

4. LIGHT DUTY VEHICLES AND ELECTRIFICATION ASPECTS

Usually a vapor compression cycle in combination with a ventilation system is used to provide the passenger compartment cooling. The system also includes a coolant circuit and heat exchanger to use the engine waste heat to heat the cabin. The combination of cooling and heating function ensures the air dehumidification that enhance the fogging prevention function. The worldwide regulation to reducing the GHG emission are driving toward an increasing of vehicle electrification (e.g. the European Union is on its way to fully de-carbonize the light duty vehicles) that will reflect on MAC design and requirements.

The Hybrid Electric Vehicle combines a combustion engine and an electric motor to recuperate the vehicle kinetic energy that is stored in a battery. The electric motor is used to support the conventional engine and to enable the vehicle to travel in pure electric mode. To ensuring the thermal comfort in electric driving mode an electric semi-hermetic compressor is usually implemented.

In case of Plug-in Hybrid Electric Vehicle have usually larger batteries that can be charged also connecting the vehicle to the electric power network (plug-in) enabling the vehicle to drive longer distances (e.g. 50 km) in pure electric mode.

These vehicle together with pure BEV (Battery Electric Vehicles) the MAC system is used also to thermally control the battery especially during charge phases, although in some instances two separate systems may be employed. The system loop integrates a chiller (refrigerant to coolant) or a direct expansion evaporator, either conventional for air-cooling or plate coupled to the battery array for battery thermal management. The refrigerant charge of such a system is usually about 30% to 50% higher than that of a conventional system. The cabin heating is ensured by the engine waste heat or, when in pure electric mode, by an electric heater or a heat pump. The heating and air conditioning function may affect in a relevant way the pure electric range reducing it up to 50% (Denso, 2017, Koehler, 2018; Westerloh, 2019).

5. HEAVY-DUTY TRUCKS

The heavy-duty trucks use a main system based on the same concept which is used in light duty vehicles but with a slightly higher refrigerant charge due to the longer distance from compressor to cabin. Quite often, to ensure comfort while parked, an auxiliary air conditioning system is used. This system is usually quite similar to domestic systems with an external condenser, an internal cooling and ventilation unit and an auxiliary electric compressor. Currently heavy-duty truck MAC systems rely on HFC-134a, although HFO-1234yf is allowed on some classes (e.g., USEPA, 2016a).

6. BUSES AND COACHES

Buses and Coaches are mass transit vehicles that have air-conditioning systems that are larger in size with higher cooling capacity, and larger refrigerant charges than passenger cars. They also operate at ambient temperatures ranging from -30ºC to 50ºC. These systems are typically packaged type roof or rear mounted units with compressors belt driven by the vehicle engine. The predominant refrigerant is HFC-134a with R-407C for high ambient temperature applications in some instances, while R-744 has also been introduced in small volumes in Europe. Typical refrigerant charge sizes have been around 10 kg, which was reduced in recent years by 50% and more, due to the implementation of microchannel condensers.

7. ENERGY EFFICIENCY IN MAC APPLICATIONS

Base on average annual values, HFO-1234yf as well as R-774 systems exhibit efficiencies comparable to HFC-134a for cooling and heating.

To achieve these performance levels, in case of HFO-1234yf, manufacturers use either an IHX or larger degree of sub-cooling while for R-744 appropriate system design (e.g. IHX) and control are required.

8. CONCLUSIONS

Currently, more than one refrigerant is used for car and light truck air conditioning: HFC-134a will remain largely used worldwide, while HFO-1234yf is currently the main option in Europe and North America and the R-744 is currently available on a couple of models

The progressive diffusion of highly electrified vehicles (PHEV and BEV) in Europe, China and North America will lead to the implementation of heat pump function where R-744 will be also reconsidered thank to its properties.

Other low GWP synthetic refrigerants and refrigerant blends (e.g. R-444A, R-445A) have been investigated but do not seem likely to be used in the near future while interest has been shown for R-152a for application in non-article 5 countries thanks ot is lower GWP and cost.

Currently, it cannot be foreseen whether or not all these refrigerants will remain for a long period of time parallel in the market. It is also unclear where bus sector (where currently HCFC-22, HFC-134a, R-407C and R-410A are used) and the heavy-duty truck sector will follow these trends.