LOW GWP REFRIGERANT FOR BUSES AND TRAINS AIR CONDITIONING

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1. INTRODUCTION

Due to increased pressure to address the issue of global warming, the European Commission through the MAC directive has effectively banned the use of R-134a refrigerant in air conditioning in new car platforms in EU countries starting January 1, 2011. The F-gas regulation is expected to be reviewed and its potential extension to other Transportation systems cannot be ruled out.
Honeywell embarked upon a research program to identify fourth generation fluorocarbon chemistry that would incorporate the desired environmental properties, that is, low global warming potential (GWP) with respect to climate change, while maintaining desirable properties and high performance characteristics. Meeting the requirements outlined in the MAC directive requires GWP less than 150. Honeywell identified HFO-1234yf as a new low global warming refrigerant (GWP=4) which has been selected by the auto-industry as a global sustainable solution for automotive air conditioning. HFO-1234yf has properties similar to R134a; it can be a potential candidate to replace R134a in many other applications, including public transport systems, such as buses, coaches and trains.
Another low GWP molecule HFO1234ze (E) has been identified and is currently commercialized by Honeywell for foam, aerosol and refrigeration applications. It is a highly energy efficient HFO molecule, with a GWP of only 6. Both of these new molecules, either as a pure substance or as a blend are a part of the fourth generation fluorocarbon technology that Honeywell is developing and investigating.
Although today's legislation does not apply to trains and buses, trias are in progress to identify HFO based technology, to lower the environmental impact of public transport vehicles.
Several bench and field trials are in progress. Results are encouraging; indicating that HFO based technology can potentially replace existing refrigerants with little or no modification to existing AC systems.

2. HYDRO-FLUORO-OLEFIN PLATFORM

Honeywell's HFO technology can offer a significant reduction in carbon footprint of refrigeration and air conditioning, because of the low GWP associated with the new fluids and also because of their efficiency. These fluids have excellent environmental properties with positive impact on the environment and can satisfy today and potential future legislations.
These new high performance fluids, whilst containing fluorine, are also by their chemical structure classified as olefins,-- that is an unsaturated chemical compound containing at least one carbon-to-carbon double bond.
HFO-1234ze(E), HFO-1234yf, and other new HFO chemistries under development and commercialisation by Honeywell are part of the fourth generation fluorocarbon technology being developed and investigated by Honeywell.

2.1 Environmental

HFO-1234yf and HFO-1234ze(E) atmospheric chemistry has been evaluated experimentally [1,2]. HFO-1234yf and HFO-1234ze (E) have no ozone depletion potential. Atmospheric lifetime was determined to be 11 and 18 days respectively versus R-134a at 14 years. Global warming potential based on a 100 year time horizon was determined to be 4 and 6 respectively versus R-134a at 1430.

2.2 Materials Compatibility

a) Thermal Stability

HFO-1234yf and HFO-1234ze (E) have been evaluated for thermal stability per ASHRAE Standard -97 Tests were conducted with refrigerant and either polyalkylene glycol (PAG) or polyolester (POE) lubricant under extreme conditions of moisture and temperature. Visual examination of the sealed tube showed no change in the appearance (fig. 1) of the refrigerant and oil. Results of the analysis of the oil show very low acidity values. In addition, gas chromatography and molecular weight measurements of the refrigerant performed before and after tests show no change in the purity of the material. One can conclude from this evaluation that 1234yf and 1234ze (E) are very stable with oils used in these applications.

b) Plastics and Elastomers Compatibility

HFO-1234yf and HFO-1234ze (E) have been evaluated for compatibility with typical commonly used plastics and elastomers, in sealed tubes containing refrigerant and lubricant. Plastics were then inspected for weight change after 24 hours and physical appearance. Elastomers were evaluated for linear swell, weight gain and hardness using a durometer. The results of specific plastics and elastomers that were tested show HFO-1234yf and HFO-1234ze(E) having similar behavior with plastics and elastomers compared to R134a, indicating that many materials in use in current air conditioning systems may be compatible with these new refrigerants.

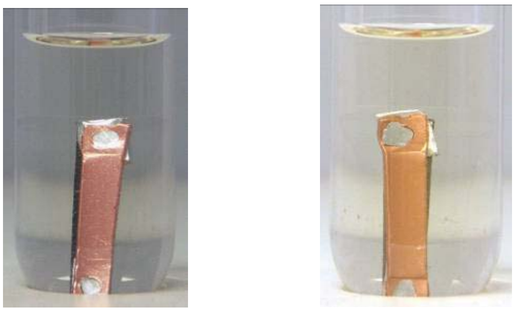

Fig.1: Thermal stability testing HFO-1234yf (left) and HFO-1234ze (E) (right).

2.3 Toxicity

Significant toxicity testing have been completed following OECD guidelines. The toxicity profile for HFO-1234yf and HFO-1234ze(E) are known. Both molecules are REACH registered and safe to use in their respective applications.

2.4 Flammability

A significant amount of work has been published concerning the flammability of HFO-1234yf [3]. The main flammability characteristics, i.e. Flame Limits, Minimum Ignition Energy, Heat of Combustion and Flame Velocity are known. These characteristics, together with testing done by various independent laboratories show that HFO1234yf is very difficult to ignite and when ignited, has a slow and unstable flame. ASHRAE safety classification has been updated to include a new class (2L) in recognition of these mildly flammable refrigerants. HFO-1234ze(E) on the other hand, does not exhibit flame limits at ambient temperatures.

3. BUSES AND COACHES APPLICATIONS

Directive 2006/40/EC relating to emissions from motor vehicles air conditioning systems, provides for a gradual phase-out of refrigerant HFC-134a from mobile air conditioners in passenger cars and in light commercial vehicles. Buses and Coaches are excluded from this directive.

R134a is predominantly the main refrigerant used for buses and coaches. Some buses usually for high ambient region have been designed use refrigerant R407C.

Öko-Recherche [4] carried out a study on behalf of the European Commission to establish the leakage rates of MACs in buses and coaches.

For older buses, the leak rate was established as 2.34kg/year, which is equivalent of 23% of the charge amount. For coaches, the leak rate was reported to be 1.5kg/year. The report also states that with modern buses and coaches, the leak rates can be reduced to 1kg/year or 13% of the refrigerant charge.
The large variation in leakages between various buses and coaches tested was due to the different MAC technologies used, vehicle type and age. Split MACs show almost 3 times higher leakage rates than rooftops MACs.
MACs for these vehicles are characterized by long pipe lengths and a large number of fittings and joints. All of these contribute to the high leak rates reported.
A low GWP refrigerant like HFO-1234yf would reduce the CO2 equivalent emission by 99.6%.
Several bench tests were carried out, using HFO-1234yf with roof top units and carbine modules. The units were first base lined using R134a. The performance and efficiency of these systems were measured with HFO-1234yf. The results were very similar to R134a results, and with further development, HFO-1234yf may possibly be used with little or no modifications to existing systems.
Real life testing with HFO-1234yf system, using validation bus is in progress.

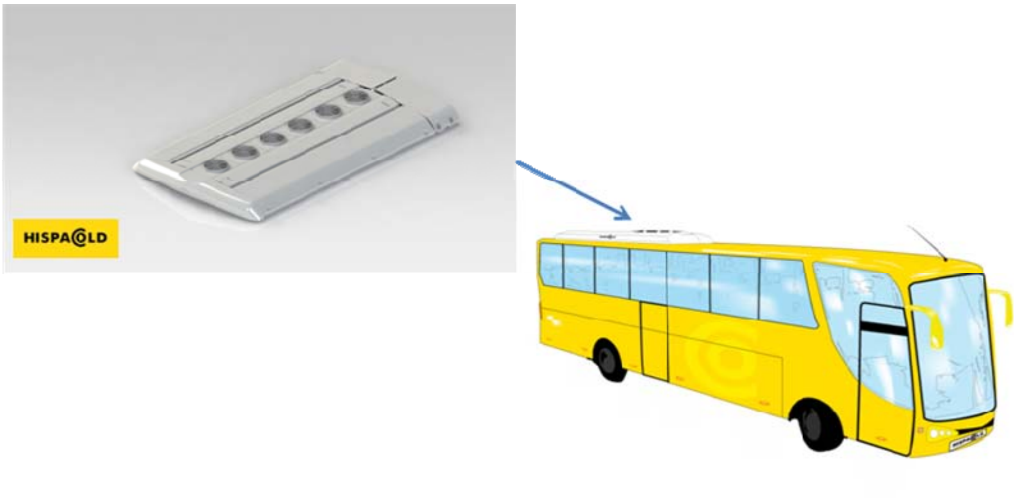

Fig. 2: Hispacold Roof top module tested with HFO-1234yf

4. RAIL APPLICATIONS

Rail vehicles range from high speed trains, regional trains, trams and metro-cars. Each train is made up of several vehicles individually air conditioned.
There are several types of air conditioning systems: compact roof, compact under floor, split and compact central. The refrigerant capacity varies from 20 to 40kW, with refrigerant charges varying from 10 to 30kg. The main refrigerant used is also R134a, but some systems are designed for R407C. Although rail air conditioning systems experience a high level of vibration, their leak rates are relatively low compared to that of buses, and are around 5 to 8%. This is due to the fact that Rail AC systems are of the sealed unit type using hermetic electrical compressors.
HFO-1234yf and a HFO blend have been bench tested on such AC units. Results suggest that both refrigerants may be useful in rail application or have the potential to reduce the environmental impact of these applications.
Fig (3) shows a Train Air conditioning module developed by MERAK (5) based on HFO-1234yf. Two such modules are being used on a Spanish train and field trials are in progress.

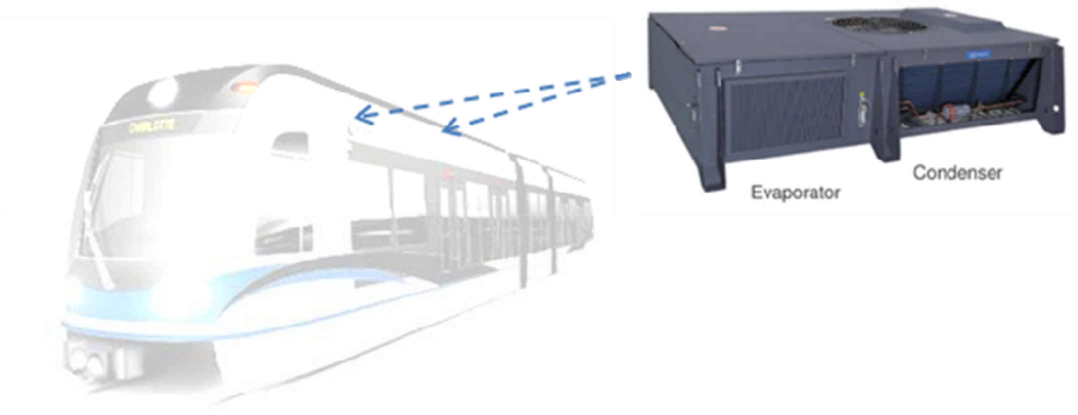

Fig. (3): MERAK AC module, operating with HFO-1234yf.

5. CONCLUSION.

There are various types of public Transport air conditioning systems used in buses and trains. These systems vary by their architecture, layout and capacity. They are very different from systems used in passenger cars.
HFO-1234yf, and Honeywell's new HFO technology, show promise for use in buses and trains air conditioning systems.
Field trials are currently in progress on buses and trains to confirm the potential of these new fluids for these public transport applications.

References

[1] Nielsen, O.J. et al., 2007 "Atmospheric Chemistry of CF3CF=CH2", Chemical Physics Letters, vol. 439, p. 18-22.

[2] Sondergaard, R., Nielson, D. J., Hurley, M. D., Wallington, T. J., and Singh, R., Atmospheric chemistry of trans-CF3CH=CHF: Kinetics of the gas-phase reactions with Cl atoms, OH radicals, and O3, Chemical and Physics Letters 443(2007), Elsevler Press, pp 199 – 204.

[3]_SAE International,"Industry Evaluation of low global warming potential refrigerant HFO-1234yf" final report SAE CRP-1234. 2009

[4] Öko-Recherche, Establishment of Leakage Rates of Mobile Air Conditioners in Heavy Duty Vehicles-Part 2-Buses and Coaches, European Commission (DG Environment) 2007.

[5] MERAK press release, 20 september 2010