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PROPYLENE REFRIGERANT FOR COMMERCIAL APPLICATIONS

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ABSTRACT

Driven by global HFC phase down, hydrocarbons are the most sustainable refrigerants for new light commercial applications. They have very high thermodynamic efficiency and ultra low GWP which already meets the requirements of all global regulations. Due to flammability, the application of hydrocarbons in commercial plug in systems is restricted to charge limit of 150g per circuit. With recent modification of the safety standard IEC 60335-2-89, it is supposed that hydrocarbons will be used also for larger plug-in systems with charges allowed up to 500g. Excepting isobutene and propane, which are widely used gases in light commercial refrigeration; another hydrocarbon, propylene, can be applied for commercial systems, especially for those which are requiring high capacity and efficiency. This paper shows the performance study of application the propylene in a light commercial compressor.

Keywords: Refrigeration, Hydrocarbons, Compressors, Propylene

1. INTRODUCTION

The light commercial refrigeration market, recently fully dominated with Hydrofluorcarbons (HFCs) refrigerants R134a and R404A is moving forward to eco friendly technologies. Legacy HFCs, non toxic – non flammable, must be phased out because of their high impact on global warming. Their use is not anymore sustainable in the future considering the alarming increase of Earth's temperature in last decades. The European Union, with application of F-Gas directive" in 2014, initiated push for conversion of HFCs with high value of Global Warming Potential (GWP) to other more eco-friendly alternatives with significantly lower impact on climate change. The plan to reduce direct emissions from refrigeration and air conditioning installations about 80% in 2030 is very ambitious but not impossible with the currently available technology of natural refrigerants. From January 2020, the HFCs refrigerants with GWP> 2500 are banned for use in refrigerators and freezers for commercial use. The next step, a ban on HFCs with GWP > 150 in plug in commercial refrigeration units, will enter into force in 2022. Another driver to replace HFC technologies are regulations focused on minimum efficiency of refrigeration units, Ecodesign 2019/2024 regulation and Eco labeling 2019/2018 regulations must be respected. Therefore, many manufacturers are looking for solutions which comply with not just only HFC gas regulation but solutions which are also highly efficient and have acceptable cost. So, from long term perspective they represent the best scenario. Analyzing options which are commercially available, Hydrocarbons will be the best alternative for light commercial refrigeration units with cooling capacity up to 5kW.
The most applicable hydrocarbon in light commercial refrigeration segment is propane R290. There are already millions of installations in the world, widely used in chest freezers, bottle coolers, professional kitchen equipment, and food retail self-contained units mainly driven by variable speed technology still limited to 150g of refrigerant charge. The barrier of safety charge limit for flammable refrigerants was removed by modification of standard IEC 60335-2-89 in 2019 as edition 3 which rasises charge limit for HCs up to 500g. This is a very important step which will allow HCs increase the market share and become the preferred solution after standard

will be adopted by CENELEC and harmonized with related European directives. The increase of charge limit will open doors for systems requiring higher charges above 150g like Ice makers, and larger multidoor retail refrigerators and freezers.
Hydrocarbons are also successfully used in ultra low freezers. If propane is used in 1st stage; another hydrocarbon, ethane. is used in 2nd stage. Together with application of variable speed technology for both stages, superior efficiency can be achieved.
For larger systems requiring larger refrigerant charges, like remote systems or cold rooms, new chemical blends belonging to lower flammability group A2L (R455A R454C), may be used.

Table 1. Future perspective of refrigerants x applications

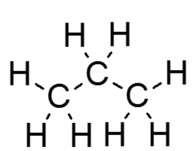
Type of application	Future dominant refrigerant
Bottle coolers	R600a/R290
Chest freezers	R600a/R290
Professional Kitchen	R290
Food retail - self contained	R290
Food retail - remote systems	R744
Ice makers	R290
Ice cream makers	R290
Cold rooms	R290 / Low GWP A2L
Blast chillers	R290 / Low GWP A2L
ULT cascade freezers	R290 / R170

2. PROPYLENE AS AN ALTERNATIVE TO HFCS AND PROPANE

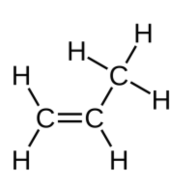
Propane has been successfully used in light commercial refrigeration systems for a long time. Many systems operating with R404A were converted to R290 technology; however compressor displacement had to be adjusted due to lower volumetric refrigeration effect. The cooling performance problem of R290 can be overcome by using another hydrocarbon refrigerant, Propylene R1270. Propylene is also a highly flammable refrigerant belonging to safety group A3 as R290. It has double bond and comparing to Propane, has naturally pungent smell so the potential leakage can be detected by user or service. Propylene has higher pressures than propane, but lower than R404A/R452A; so the motor compressor shall be optimized for the specific load.

Table 2. Basic characteristics of Propylene and Propane

Refrigerant	Safety Group	GWP	Boilng temp (°C)	Critical temp (°C)	LFL (kg/m3)
Propane R290	A3	3	-42	96.7	0.038
Propylene R1270	A3	2	-48	91.1	0.046



Propane, C_3H_8



Propylene, C_3H_6

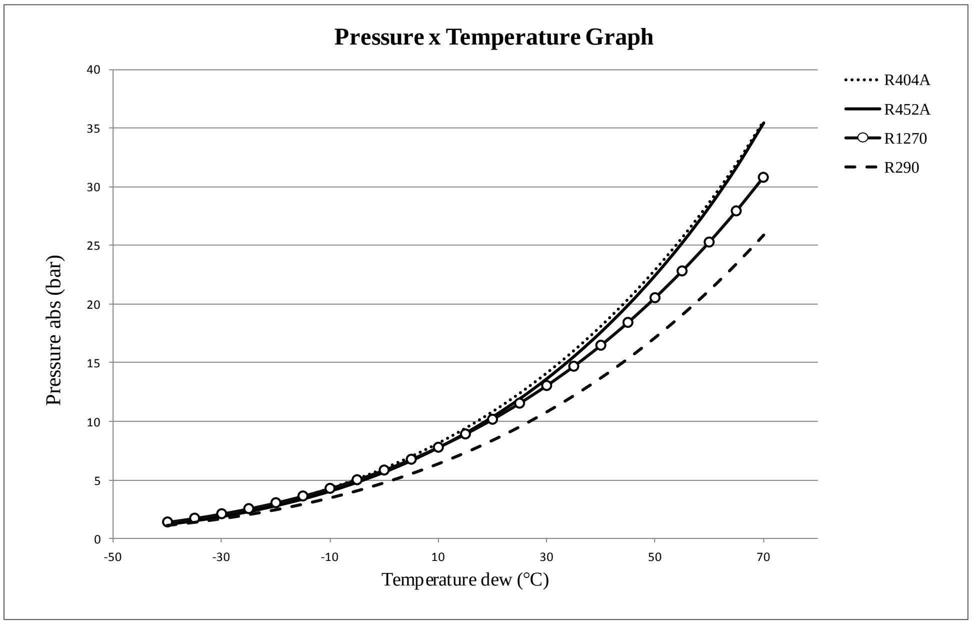


Figure 1: Pressure x Temperature graph

Performance

Based on theoretical thermodynamic analysis, propylene has higher volumetric refrigeration effect than propane, allows achieving a similar cooling capacity as R404A with the same displacement. While propane requires increasing of displacement about 15%, a compressor with propylene can keep the same displacement as a R404A compressor. This is advantage mainly in frame breakers where enlarge of displacement is costly often requiring more robust platform. Thermodynamic efficiency of propylene is very similar to propane however the end compression temperature is higher, propane and R452A has very similar end compression temperature to R404A.

Table 3. Theoretical thermodynamic projection of propylene compressor

Conditions EN12900 MBP: -10/45 °C, no subcooling, suction temperature 20°C, without internal superheating

Parameter / Refrigerant	R404A	R452A	R290	R1270
Evaporation pressure Dew (Bar)	4.31	4.00	3.45	4.28
Condensing pressure Dew (Bar)	20.4	19.9	15.3	18.4
Pressure ratio	4.7	5.0	4.4	4.3
Pressure difference	16.14	15.88	11.89	14.15
Pump displacement size (relative to R404A)	1	1.06	1.15	0.96
Discharge temperature (°C)	78.5	78.8	79.5	86.3
COP PV Ideal Cycle relative to R404A	1	-1.7%	10.5%	8.7%

3. RESULTS AND DISCUSSIONS

Actual calorimeter measurements of hermetic reciprocating commercial refrigeration compressors are showing the expected benefits of propylene in cooling capacity, while capacity with propane is much lower. The capacity with propylene is quite close to R404A. Compressor efficiency is higher than theoretical projection, very good results were obtained mainly at medium back pressure (MBP) operation field where compressor efficiency is much higher than R404A/R452A, following efficiency curve of propane.

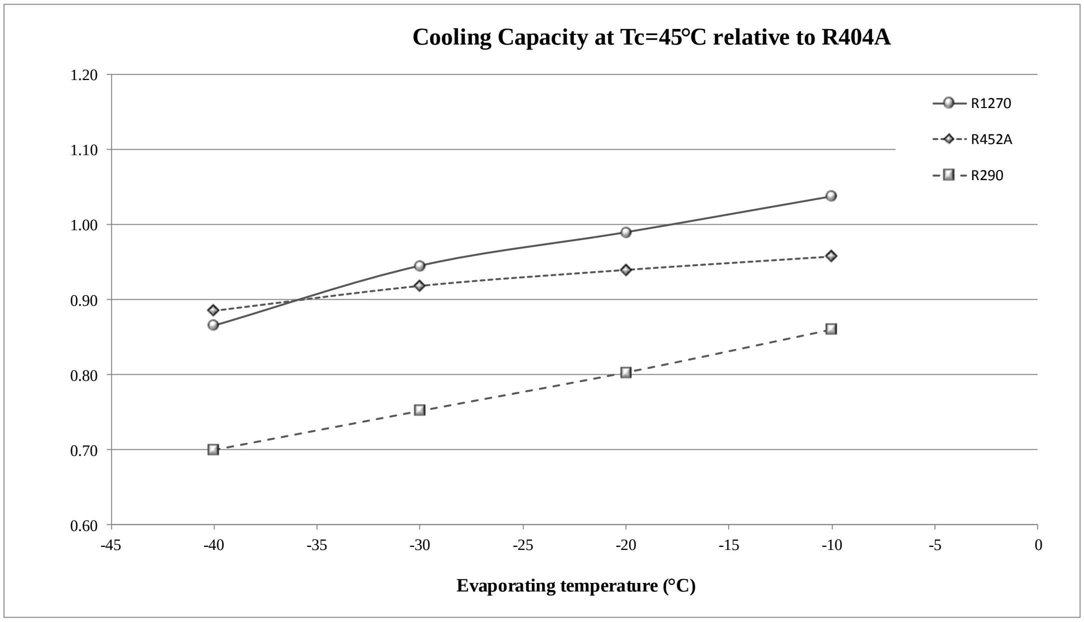


Figure 2: Calorimeter Performance – Capacity at condensing temperature 45°C relative to R404A

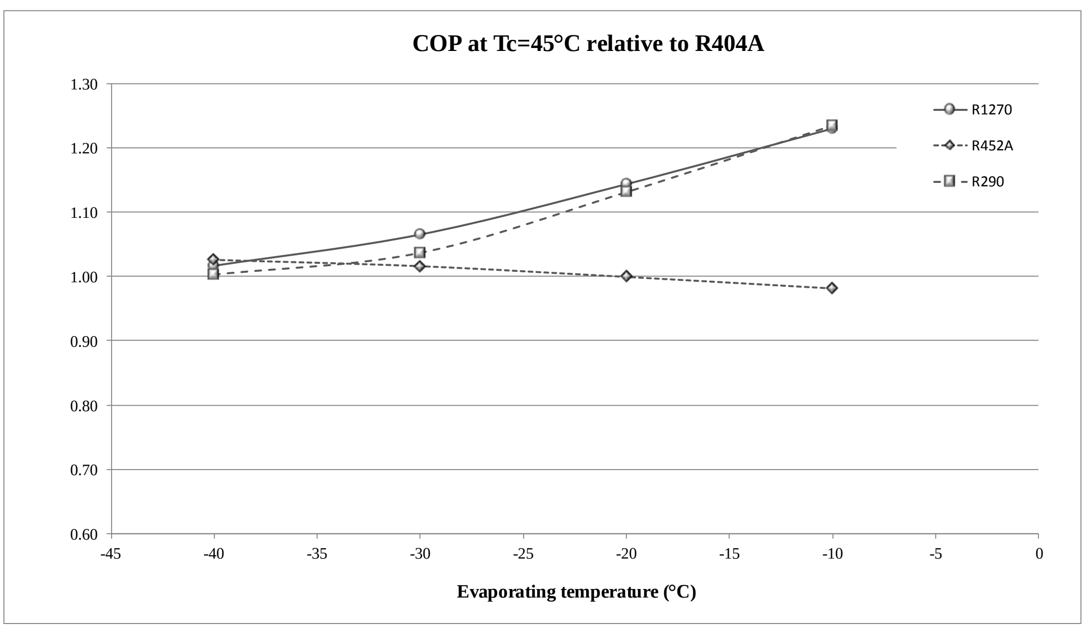


Figure 3: Calorimeter Performance – COP at condensing temperature 45°C relative to R404A

Reliability

Lubricants used with Propane can be applied also with Propylene. Based on a Daniel plot of viscosity-temperature relationship, available for POE oil mixed with propane and propylene, the kinematic viscosity at designed pressure is very similar. Life test at High Load and High Compression Ratio with POE oil showed positive results. However, due to higher end compression temperature of propylene, high compression ratio situations should be avoided in real applications to protect the valve system against carbon deposits.

4. CONCLUSIONS

Propylene can be considered as a perspective future alternative for larger refrigeration systems where propane cannot deliver required cooling capacity. It is an extremely efficient refrigerant, mainly in MBP applications, similarly to propane. Reliability testing results on hermetic reciprocating light commercial compressors with POE oil are very positive. As it is belonging to A3 safety group, all safety features must be followed according to international and local safety standards. Further work will focus on performance evaluation in commercial cold room where natural refrigerant is required together with extended capacity and better efficiency.

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NOMENCLATURE

GWP	Global Warming Potential	*COP*	Coefficient of Performance
MBP	Medium Back Pressure	*POE*	Polyolester

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Refprop 10. Thermodynamic and transport properties of refrigerants and refrigerant mixtures