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# Oil type influence on the optimal charge and performance of a propane chiller

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ABSTRACT

The paper presents the experimental results of a charge optimization study of a water-to-water chiller with two different oils: Mineral and POE. The employed chiller is a prototype which works with propane as refrigerant and provides for a cooling capacity of approximately 16 kW. A complete charge optimization study was performed for two different oils: mineral ISO-VG 68 and POE ISO-VG 22. The study covered a wide range of variation of condensation temperatures, all around the typical operating conditions for AC applications. The obtained performance and compressor efficiencies are studied and discussed to explain the observed differences due to the oil type. The main conclusions are that the optimal charge is strongly different, depending on the solubility of the refrigerant into the oil, and that the POE oil seems to lead to better unit performance.

# L’influence du type d’huile sur la charge optimale et la performance d’un refroidisseur au propane

*Mots clés* : Propane ; Refroidisseur d’eau ; Huile ; Système frigorifique ; Frigorigène ; Charge

## 1. Introduction

Nowadays the search of new refrigerant fluids to replace the traditional synthetic refrigerants has resulted in a renewed interest in the use of natural fluids, among themselves hydrocarbons, which are considered an important alternative due to the excellent thermodynamic properties, null ODP a very low GWP, or good compatibility with most common plastics and metals already present in refrigeration systems (Granryd, 2001; Palm, 2008).

Historically, hydrocarbons (HCs) were among the first fluids to be employed as refrigerant, but due to their flammability their use was abandoned in favor of inert fluids such as clorofluorocarbons (CFCs). Propane (R290) and several other Hydrocarbons (HCs) have been recently commercialized and clearly demonstrated as alternative refrigerants for refrigeration and heat pump and A/C applications.

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**Nomenclature**

| | |
|---|---|
| BPHE | Brazed Plate Heat Exchanger |
| COP | Coefficient of Performance (-) |
| $c_p$ | Specific Heat ($\mathrm{J\ kg^{-1} K^{-1}}$) |
| $\dot{E}$ | Power input (W) |
| $h$ | Enthalpy |
| HE | Heat exchanger |
| MO | Mineral Oil |
| $\dot{m}$ | Mass flow rate ($\mathrm{kg\ s^{-1}}$) |
| PHE | Plate heat exchanger |
| POE | Polyolester oil |
| $\dot{Q}$ | Capacity (W) |
| $\dot{V}$ | Compressor Swept Volume ($\mathrm{m^3\ s^{-1}}$) |

*Greek*

| | |
|---|---|
| $\Delta h$ | Enthalpy difference ($\mathrm{J\ kg^{-1}}$) |
| $\eta$ | Compressor Efficiency (%) |
| $n_\nu$ | Compressor Volumetric Efficiency (%) |
| $\mu$ | Dynamic Viscosity (Pa s) |
| $\varrho$ | Density ($\mathrm{kg\ m^{-3}}$) |

*Subscripts*

| | |
|---|---|
| *c* | Condenser |
| *e* | Evaporator |
| *in* | Inlet |
| *is* | Isentropic |
| *m* | Mixture Refrigerant-Oil |
| *o* | Oil |
| *out* | Outlet |
| *r* | Refrigerant |
| *w* | Water |

Different studies have shown that propane offers very good performance in terms of COP, and also good compatibility with current materials employed in Refrigeration and AC equipment (Castro et al., 2005; Corberan et al., 2008a; Fernando et al., 2004).

The only real factor against application of hydrocarbon refrigerants in refrigeration and air conditioning equipment is the safety concern in handling relatively large amounts of flammable fluids. Isobutane has already been extensively used as refrigerant in domestic refrigerators in millions of dwellings for some years now and no major safety problem has arisen so far due to its very low charge and this type of systems presents quasi-zero leakage.

Propane has also been proposed as refrigerant in air conditioning and heat pump systems. Due to its higher refrigerant charge these systems has to work with secondary fluids and must comply a number of restrictions in the place they are installed (Corberan et al., 2008b).

Due to their flammability, one of the most important challenges in the design of refrigeration equipment for HCs becomes the minimization of the refrigerant charge, or in other words, to reach the highest possible ratios of specific cooling capacity (kW per kg of refrigerant charge). This objective can be accomplished by using compact HEs, BPHE when the heat sink/source fluid is a liquid, or microchannel when the fluid is air, and reducing at maximum the piping and auxiliary components volume, especially at the parts of the system where the refrigerant is in liquid state. A very important issue is to design the system when possible without liquid receiver at the condenser outlet, and when that is not possible, then, designing the system to employ a receiver with the minimum volume.

The absence of a liquid receiver in the refrigerant circuit makes the unit performance sensitive to the amount of refrigerant charge and also to the outdoor conditions. Optimization of this kind of units requires the analysis of the optimal charge at the different operating conditions in which the unit has to operate (Martínez Galván, 2007).

Other important aspect in the relationship between unit performance and charge inventory is the selection of compressor lubricating oil. The oil selection is a critical point concerning the design of a refrigeration system. The refrigerant should be soluble enough to ensure proper oil circulation through the system; also it should not reduce the viscosity of the mixture allowing efficient compressor lubrication. It is known that propane has good mutual solubility with mineral and polyolester (POE) oils (Fernando et al., 2003), so both oils can be used in propane units but the oil selection influences the unit performance by different ways: compressor performance, heat transfer performance in the heat exchangers and charge inventory, due to the amount of refrigerant dissolved in the oil.

From the previous statements, the following questions arise: What is the optimum charge of a unit working with propane without liquid receiver?, Is this optimum dependent on the operating conditions?, Which is the influence of the oil on the unit performance?, And, which is the influence of the oil on the charge inventory?.

The research presented in this paper tries to give some answers to the posed questions.

## 2. Experimental setup and evaluation procedure

Experimental unit was studied in a test rig for water-to-water chillers. The test rig allows establishing different working conditions and evaluating the effects of the refrigerant charge on the unit performance. The test rig consists of two hydraulic loops that simulate the load on the heat source-side and heat sink-side of the chiller. Each water loop is equipped with a secondary plate heat exchanger (PHE) (1), a centrifugal pump (2), by-pass valves (3), an inertia tank (4), expansion chamber (5), pressure release valves and pressure gauges.

The experimental unit was a water-to-water chiller featured with a Scroll compressor (A), BPHE evaporator and condenser (B, C), thermostatic expansion valve (D). Fig. 1 shows the design of the test rig.

For the measurement of the water flows, two Coriolis mass flow meters with an intrinsic error of 0.05% were used (a). The water temperature difference in the brazed plate heat exchangers was measured with calibrated PT-100 type