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Experimental performance evaluation of a vapour compression refrigerating plant when replacing R22 with alternative refrigerants

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ABSTRACT

This paper presents the results of an experimental analysis comparing the performance of a vapour compression refrigerating unit operating with R22, and its performance in comparison to a new HFC fluid, substituting the former according to Regulation No 2037/2000.

In particular, the plant working efficiency was first tested with R22 and then with three new HFC fluids: R417A, R422A and R422D. The investigation verified that despite the case of substitution and the advantage of being able to continue to use mineral oil as a lubricant in the compressor, the performance with the new tested fluids did not result as efficient as when using R22.

1. Introduction

Regulation No 2037/2000 of the European Parliament and Council, 29 June 2000 on substances depleting the ozone layer provides, among others, that no manufacturer or importer may place on the market or use hydrochlorofluorocarbons after 31 December 2009 [1].

Among all the fluids that can replace the HCFCs there are the HFCs. The HCFCs replacement (hydrochlorofluorocarbons) with HFC synthetic fluid refrigerants (hydrofluorocarbons), does not have damaging actions on the ozone layer, because they do not contain chlorine, yet they introduce other problems. Indeed, the HFCs contribute to the global warming of our planet both as a direct effect (refrigerant released into the atmosphere) and as an indirect effect (carbon dioxide released by the electric plants used to produce energy to keep refrigeration units running).

Firstly, the leakages in the systems should be minimized and then it would be best to choose a type of HFC producing the minimum amount of greenhouse gases, since HFCs have a large direct greenhouse effect.

The HCFC most widely used in refrigeration and air conditioning plants was R22. Its ban imposes the need to resort to alternative solutions which go from the redesigning of systems that run on natural fluids to that of continuing to use the same plants with substitute fluids that do not harm the ozone layer (ODP = 0), with low or zero GWP and able to operate efficiently in the existing plants running on R22 without having to revert to laborious refitting operations requiring a change in lubricating oil and components in the refrigeration plant.

The first case, being the use of natural fluids, is the safest option from an environmental point of view, in that it would mean using fluids that are present in the environment and of which even their long term effects are known.

The most commonly used natural fluid is ammonia (NH_3) which has excellent thermo-fluid-dynamic properties, but its flammability and toxicity (ASHRAE classification, B2 security group) poses a problem. It would be the best replacement for R22 in all of its applications (freezing processes, industrial refrigerated storage) where the presence of adequate safety measures and the running of the plants is entrusted to qualified staff who would measure up to any eventual criticism.

Other natural fluids having excellent thermodynamic and thermophysical properties are hydrocarbons such as propane (HC290), butane (HC600), isobutene (HC600a) and propylene (HC1270). They have the inconvenience of being highly flammable (ASHRAE classification, A3 security) and are only used today where a small amount of refrigerant is necessary (e.g. domestic refrigerators) which even in the case of a leakage would not create a safety problem.

Most of the domestic refrigerators sold in Europe today use isobutene, propane or a mixture of the two. The largest quantity used in these refrigerators is barely 60 g which in the case of a leakage would not be dangerous.

Finally, another natural fluid which over the last few years has been brought back into use and which is under the scrutiny of

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Nomenclature

ST	storage tank with heat exchanger
COP	coefficient of performance
CO	compressor
AC	air condenser
DA	data acquisition
EV	evaporator
LI	liquid indicator
DF	dryer filter
F	flow meter
HG	heat generator
n	polytrophic coefficient
P	pressure gauge
Poc	cooling power (kW)
CP	circulation pump
RF	regulation flow valve
AT	aspiration tank
Rcp	compression ratio
LR	liquid receiver
MI	moisture indicator
T	thermometer gauge
Tev	evaporation temperature (°C)
Tec	compressor exit temperature (°C)
TE	thermostatic expansion valve
MV	three way mixing valve

researchers and the refrigerator company designers is carbon dioxide (CO_2). It is a safe fluid, respecting the environment (ODP = 0, GWP = 1) and therefore ideal in counteracting the impoverishment of the ozone and environmental warming. Unfortunately, its critical low temperature (31.06 °C) imposes the use of a transcritical cycle with the temperature of condensation very close to the critical one, thus resulting in low energy efficiency values for the traditional refrigeration plants.

The possibility of using carbon dioxide is linked to the development of plant technology that would be able to increase its energy efficiency, which today is still quite modest.

It is foreseen that there is a good chance of using (CO_2) in air conditioning systems used for heating and producing hot water.

There are already numerous publications, both theoretical and experimental, relating to the substitution of R22 in existing plants and on the subsequent results of its substitution [2–10].

Refrigerant fluids have recently been put forward by the chemical industry that are a mixture of HFC with a small quantity of HC added guaranteeing its miscibility with the mineral oils in use in the plants running on HCFC. This makes the substitution of the HCFC fluids being used in existing systems economical and easy.

The aim of this work is to experimentally verify the validity of R22 being substituted by this new miscible of HFC with a small quantity of HC added.

Test comparing these new fluids' performance with R22's were carried through an experimental facility at the Cold Energy Technology Laboratory, Department of Environmental Research, University of Palermo.

The results obtained from the evaluations and calculations of the data permitted a comparison between the use of R22 and the alternative mixtures and to verify if its substitution can have negative outcomes in terms of energy efficiency and on the respect of nature.

2. Experimental apparatus

Fig. 1 shows the experimental vapour-compression refrigeration plant. Essentially, it consists of a vapour-compression plant having a four cylinder semi-hermetic reciprocating compressor with a volumetric flow of 32.54 m^3/h. The fluid condensation is accomplished by transferring heat to the outside through a condenser consisting of a finned heat exchanger.

The refrigerant load consists of a water–ethylene glycol mixture (10% in mass) being continuously heated by a gas boiler and then sent to an evaporator.

The test apparatus is set in two loops: the first includes the refrigerating equipment consisting in a semi-hermetic

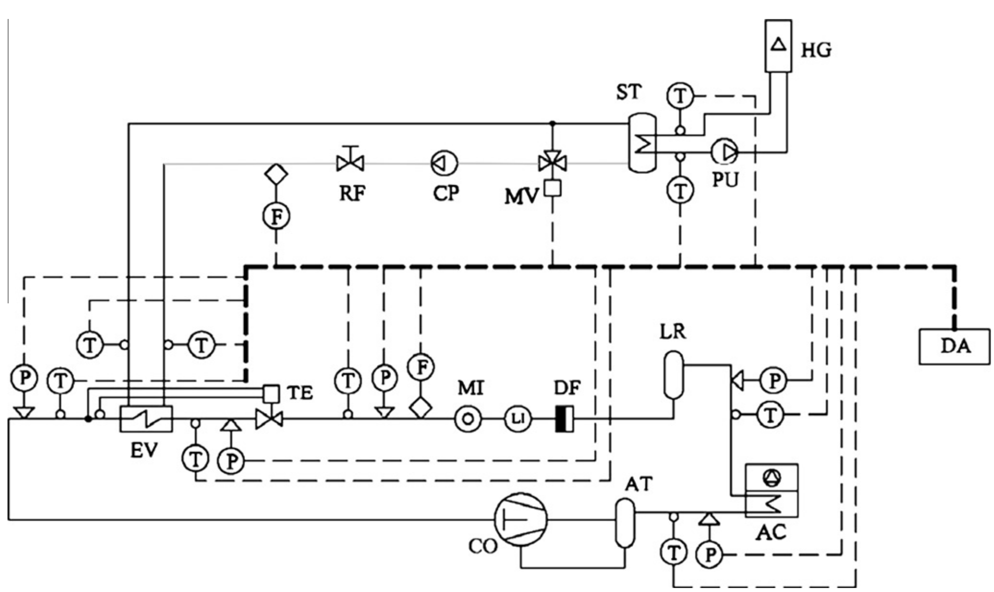

Fig. 1. Layout of the test setup.