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Air-Water Heat-Pump with Low GWP Refrigerant

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Abstract. As a result of the new legislative regulation on an international level regarding the refrigerants, new ecological alternatives which comply with the Global Warming Potential (GWP) guidelines must be found in the following years. This paper is a study case focused on the ecological and energy – efficiency aspects of a water-air heat pump. In this study, comparisons between R134a, MV3T and R1234yf were made. The theoretical study analyzes a one stage refrigeration system that currently works with R 134a. The comparative study of these facilities followed the coefficient of performance of a plant and also the TEWI factor (Total Equivalent Warming Impact – in respect with EN 378-1). Energy efficiency is directly related to global warming and greenhouse gases emissions has focused on water-air heat pump ecological and energy - efficiency study case.

1 Introduction

The theoretical study analyses a one stage refrigeration system that currently works with R 134a. The comparative study of this facility followed the coefficient of performance (COP/EER) and also the TEWI factor (Total Equivalent Warming Impact) – in respect with EN 378-1 [1,2].

Energy efficiency is directly related to global warming and greenhouse gases emissions.
Thermodynamic properties of these simulations were done using software RefProp and Clima Check (CC).

This work is also a study case of the new legislative Regulation UE 517/2014 implementation. Concerning this, ecological alternatives cooling agents with low global warming potential (GWP) must be found in the following years, at an international level. Table 1 presents the properties of the refrigerants.

Table 1. Properties of refrigerant retrofit.

Refrigerant	R134a	MV3T	R1234yf
Critical temperature	101,06	98.06	94.7
Group safety	A1	A1	A2L
Molar mass [kg/kmol]	102	108	114.04
Critical density, kg/m3	511.9	493.06	475.55
GWP	1430	717	4

Similarly to R134a, MV3T is a medium pressure refrigerant with a lower critical temperature and density.

Some of the properties of the refrigerants R1234yf and MV3T in comparison to R134a are listed in Table 1.

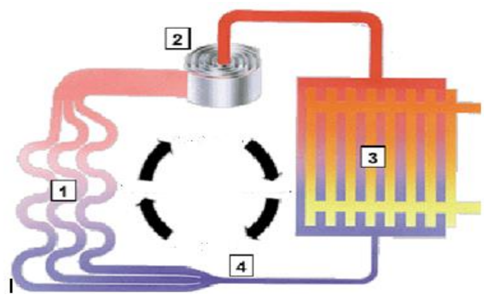

Fig. 1. The circuit of function of PC (1 – Evaporator, 2 – Compressor, 3 – Condenser,4 –Expansion Valve).

2 Ecological Analysis

HFO R1234yf has a GWP of just 4, providing substantially lower direct greenhouse gas emissions than R134a systems. It thus significantly reduces the CO_2 emissions of refrigeration systems [3,4].

The study case has a refrigeration capacity of 1.6kW. The temperature of evaporation for the refrigeration system is 2 °C and condensation temperature is 46.8 °C.

The TEWI factor was determinated taking account of the Standard SR EN 378-1:

$$TEWI= [GWP \times L \times n] + [GWP \times m\ (1-\alpha_{rec})] + [n \times E_{an} \times \beta]$$

Where:
GWP – the global warming potential, CO_2 related
L – Leakage in kilogrammes per year
n – System operating time in years,
m – Refrigerant charge in kilogrammes
α rec - recovery/recycling factor from 0 to 1
E an – energy consumption in kilowatt-hour per year
β - CO2 emission in kilogrammes per kilowatt-hour kg/kWh
GWP x m (1-αrec) - Impact of recovery losses
GWP x L x n - Impact of leakage losses
n x E annual x β - Impact of energy consumption

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To calculate TEWI (Table 2) factor were following assumptions: mass for alternative (R1234yf - 0,72kg, MV3T – 0,75 kg and 0,78 kg) for R134a.
The recovery factor was 0.75.

Operating time of the system was 15 years, and CO2 emission was 0.28 kg / kWh.

Table 2. Calculation for factor TEWI for retrofit.

	R134a	MV3T	R1234YF
GWP	1430	717	4
L	0.062	0.06	0.057
n	15	15	15
m	0.780	0.750	0.720
ALFA	0.75	0.75	0.75
beta	0.28	0.28	0.28
TEWI [tons of CO2]	8.57	7.73	6.95

3 Energy efficiency analyses

The next part of this article shows some characteristics of the heat-pump (Fig.2)[5].

The advanced technology of the water heater / heat pump (1).

The two-stage radial fan (2) permits the air to be routed through a pipe of up to 10 m in length and 200 mm in diameter. The thermostatic expansion valve and safety devices ensure the possible circulation.

The compressors with oil coolers and waste heat utilisation by cooling the exhaust gases (3).

The evaporator unit has a large surface area giving a cleaning effect (4).

Heat insulation of the storage tank: high insulating value, made of CFC free polystyrene (5). The air connectors permit connection of air inlet/exhaust on site.

Quality 270 litre double enamelled hot water tank (6).

Anode gives increased safety (7).

Helical tube condenser in the double casing ensures efficient heat transfer and the possible safety (8).

Internal plain tube heat exchanger (enamelled) for connecting solar collectors or boilers (9).

Electrical immersion heater (10).

The COP and EER (coefficients of performances) for the HP (air conditioning and refrigeration) systems was calculated with CC and EES software simulations.

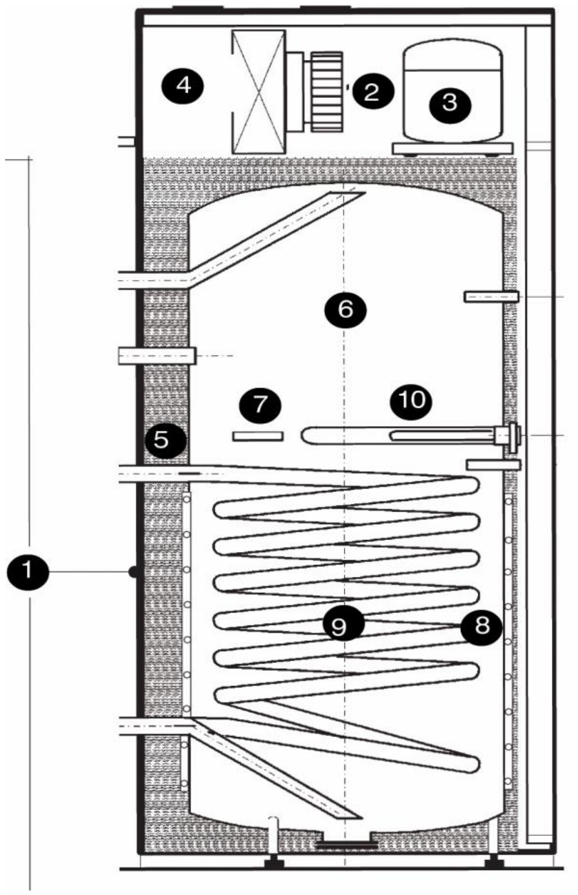

Fig. 2 . Heat pump air-water

Table 3. Efficiency Analysis of refrigerant retrofit**.**

Refrigerant	R134a	MV3T	R1234yf
COP	4.56	4.04	3.95
EER	3.63	3.11	2.93

4 Conclusions

In order to implement the International Legislation, in the future it is necessary to retrofit HFC refrigerant with an ecological refrigerant.

The ecological energy efficiency and thermo-physical properties are the main disadvantages of R 404A.

From an environmental perspective (factor TEWI - Table 2) MV3T [6] and R 1234yf have the advantage of a lower global warming potential (GWP) than R134a [7].

Regarding energy efficiency and yearly consumptions (Table 3) the MV3T has a higher EER and COP than R 1234yf.

Regarding F-Gas Regulation, the optimum alternative for this application is MV3T.

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