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A Supermarket Eco-Efficientization

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Abstract This article proposes to design and analyse from an energy and ecological efficiency point of view a refrigeration application in the commercial area, related to the cooling consumers in a supermarket.
The fields of use of the cooling agent are various, from commercial refrigeration equipment up to naval refrigeration equipment, etc.
The present paper aims at dimensioning a refrigeration plant with mechanical vapour compression in one step and choosing the optimal solution from an ecological point of view (GWP-TEWI) and energy efficiency COP.
The selected refrigerant is R448 because of its higher C.O.P., lower electricity consumption and lower GWP being in line with EU legislation. Compared to other refrigerants (R404a, R449a) it has the lowest GWP and the highest COP. The composition of R448 is a mixture of ecological halogenated freons R134a, R125, R32a, R1234ze and R1234yf. To simulate and compare refrigerants thermodynamic proprieties The National Institute of Standards and Technology (NIST) - Refprop version 8.0, 2007 was used.
In the project, modern design methods were applied using specialized softwares.
The refrigerant recommended in the Commercial Cooling System is R448 a. This agent was chosen because it is part of the ecological refrigerant category, being recommended on average for cooling and for low energy consumption. The composition of this agent is a mixture of ecological halogenated freons R134a, R125, R32a, R1234ze and R1234yf.

1 Introduction

This refrigerant is a halogenated derivate from saturated hydrocarbons, methane, ethane blended with different contend of flour, olefyne and hydrogen. These components do not burn, do not constitute explosive mixtures if they enter in reaction with the air, they are not poisonous and do not have any smell, if they do not exceed 20%.

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.

The fields of use of the cooling agent are various, from commercial refrigeration equipment up to naval refrigeration equipment.

The refrigerant recommended in the Commercial Cooling System is R448 a. This agent was chosen because it is part of the ecological refrigerant category, being recommended on average for cooling and for low energy consumption. From the point of view of compression, this agent is a mixture of ecological halogenated freons R134a, R125, R32a, R1234ze and R1234yf.

2 Refrigerants analysis

Three refrigerants are proposed for analysis: R404a, R448a and R449a as can be seen in Table 1 and Table 2 for both freezing (and refrigeration [1,2,3].

Cooling capacities (Φ) and parameter conditions are:

Φ refrigeration = 35.36 kW

Θ_0/ Θ_c -10/36°C ;

Φ freezing = 16.3 kW

Θ_0/ Θ_c -20/36°C (where : Θ_0/ Θ_c is evaporation temperature/condensing temperature).

2.1 R404a Refrigerant

It is an azeotrope mixture of halogenated refrigerants having R143a, R125 and R134a composition with concentrations (44/52/4)%. It has a GWP of 3940, ODP = 0. In terms of physic-chemical characteristics, the following are mentioned:

- boiling temperature: -47°C
- critical temperature: 73°C
- critical pressure: 37.4 bar
- condensing temperature at 26 bar: 55°C
- cooling capacity: 99% (in operating mode -35/+40°C)
- COP = 98% (in operating mode -35/+40°C)
- liquid density at 30°C : 1.091 kg/dm3

From the point of view of the R404a safety prescriptions, they fall into class A1 (non-flammable refrigerants that are not substantially harmful) - SR EN-378

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2.2 R448A Refrigerant

It is a zeotropic blend, designed to replace R22 and R404a in new systems and to retrofit existing installations. It has component R32, R125, R134a, R1234ze and R1234yf with concentrations of (26/26/21/7/20)%. It has a GWP = 1270 and ODP = 0.

In terms of physic-chemical characteristics it mentions:

- boiling temperature: -45.9°C
- critical temperature: 83.7°C
- critical pressure: 46.6 bar
- liquid density at 25°C: 1092.3 kg/m^3
- glide : 5K

From the point of view of the safety instructions, it is part of the A1 flammability class.

2.3 R449A Refrigerant

It is a low GWP hydrofluoroolefin 1282 designed to replace R404a, R507 and R407a, has an energy efficiency of 8-12% better than R404a and R507.

It has component R32, R125, R134a and R1234yf in concentrations of (24.3 / 24.7 / 25.7 / 25.3)%.

Physico-chemical characteristics:

- boiling temperature: -46°C
- critical pressure: 44.47 bar
- critical temperature: 81.5 °C
- liquid density at 21.1°C: 1113.3 kg/m^3
- glide 5K.

Also R449a is part of the A1 flammability class

Fig. 1. R449A

Fig. 2. Glide chart

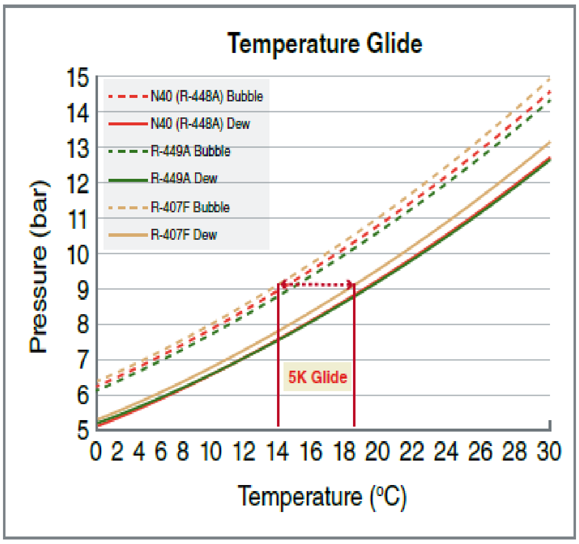

Table 1. Comparative table refrig-- chilled conditions

Parameter	Refrigerant type		
	R 404a	R 448a	R 449a
P_0 [bar]	3,90	3,50	3.22
P_c [bar]	16,06	13,70	17,30
∏[Pc/P0]	4,11	3,91	5.37
Θ_0[0°C]	-10	-10	-10
Θ_c[0°C]	36	36	36
m[kg/s]	0,298	0,224	0.23
P_k[kW]	9,53	9,72	10.30
COP	3,77	3.70	3.50
ODP	0	0	0
GWP	3940	1273	1282

Table 2. Comparative table freezing conditions

Parameter	Refrigerant type		
	R 404a	R 448	R 449
P_0 [bar]	1,45	2,4	2.25
P_c [bar]	16,065	13,7	17,3
∏[P_c/P_0]	11,048	5,71	7,68

Θ_0[0°C]	-20	-20	-20
Θ_c[0°C]	36	36	36
mm[kg/s]	0,16	0,105	0.116
P_k[kW]	8,16	4,83	6,48
COP	2,083	3,5	2,63
ODP	0	0	0
GWP	3940	1273	1282

Following the analysis of the thermodynamic parameters (tables 1 and 2), the R-448a refrigerant was chosen due to the higher COP, the lower energy consumption and the greening of a smaller GWP [4,5,6].

3 TEWI calculation

TEWI Total equivalent warming impact (TEWI), is a way of assessing global warming by combining the direct contribution of refrigerant emissions to the atmosphere with an indirect contribution of carbon dioxide emissions resulting from the need to consume energy for the refrigeration system.

TEWI is designed to calculate the total contribution to the global warming of the refrigerated process as shown in Table 3 below.

It measures both the direct effect of global warming of the refrigerant (its emissions) and the indirect contribution of the power required for the normal operation of the refrigerant system. It is valid only for comparison of alternative systems or refrigerant options for application in a location [9,10,11,12].

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

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

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

Table 3. TEWI calculation

Values for	R404A	R448A	R449A
GWP	3784	1273	1282
L	2,304	2,408	2,416
n	15	15	15
m	35.3	30,1	30,2
a	0,75	0,75	0,75
β	0,287	0,287	0,287
GWP*L*n	130775,04	45980,76	46459,68
GWP*M(1-a)	27244,8	9579,325	9679,1
E annual*n*β	296980,425	296980,425	296980,425
TEWI [tones of CO_2]	455,00	352,54	353,12

4 Conclusions

The present paper aimed at dimensioning a refrigeration plant with mechanical vapour compression in one step and choosing the optimal solution from an ecological point of view (GWP-TEWI) and energy efficiency COP.

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 .

The refrigerant we have chosen was R448 because it has a higher C.O.P. (for refrig-chilled conditions), lower electricity consumption and lower GWP being in line with EU legislation. Compared to other refrigerants (R404a, R449a) it has the lowest GWP.

In the project, modern design methods were applied using the D - COOLSELECTOR and B software [13,14,15,16,17].

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