Applied Thermal Engineering 41 (2012) 30–35

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Comparison of a R744 cascade refrigeration system with R404A and R22 conventional systems for supermarkets

Alessandro da Silva [a], Enio Pedone Bandarra Filho [b,*], Arthur Heleno Pontes Antunes [b]

[a] Bitzer Compressores Ltda, Av. Joao Paulo Ablas 777, Sao Paulo 06711-250, Brazil
[b] Faculty of Mechanical Engineering, Federal University of Uberlandia, Av. Joao Naves de Avila, 2121, Uberlandia-MG, Brazil

ARTICLE INFO

Article history:
Received 29 April 2011
Accepted 8 December 2011
Available online 30 December 2011

Keywords:
Cascade system
CO_2
Carbon dioxide
R744
Supermarket
R404A
R22

ABSTRACT

The present article focuses on the energy efficiency and climate performance of three different systems used in supermarket applications. The refrigeration systems consist of a cascade cycle (CO_2/HFC-404A) – provide nominal refrigerating capacity – with carbon dioxide for subcritical operation and HFC-404A in the high stage temperature stage (pump circuit for normal refrigeration and direct expansion for deep-freezing), and also HFC-404A and HCFC-22 with direct expansion systems. The cascade system presented a lower refrigerant charge, 47 kg of both fluids, which represents less than a half of the refrigerant charge of the other systems. An important factor is the total GWP in case of leakage, where the impact in the atmosphere of the cascade system operating with CO_2 was much less than the two direct expansion systems.

1. Introduction

Carbon dioxide is a climate-friendly refrigerant because it has a low direct global warming potential with the reference value of 1. Due to its specific thermodynamic properties, including high operating pressure, low critical temperature and low viscosity, CO_2 offers a great potential as a new energy-efficient product. According to Parise and Marques [9], industry is now challenged to produce modern systems with zero leak and minimum refrigerant charge, leading to more compact and efficient heat exchangers. However, Bansal [1] suggests that there is very little information available in the open literature on the fundamental boiling and condensation heat transfer characteristics of CO_2 at low temperatures below −30 °C and −15 °C, respectively. The appropriate optimal design of new heat exchangers may be impeded due to the lack of this information. Furthermore, it will encourage the development of modern systems that will put the refrigeration industry on a more sustainable footing.

Two-stage cascade refrigeration systems are suitable for the supermarket refrigeration industry, where the evaporating temperature of frozen-food cabinets ranges from −30 °C to −50 °C [5].

Refrigerant emissions from the commercial sector are relatively high [10] performed a study in 220 supermarkets in Norway and observed an annual leakage rate of 14% (not including stand-alone equipment). In these conditions, a considerable emission of greenhouse gases to the atmosphere is observed and it reinforces the need to reduce the leakage rate and also search for alternatives fluids.

Considering centralized systems, there are, basically, three possibilities to use the carbon dioxide. It can be used as a secondary refrigerant or it can be employed as a primary refrigerant in the low temperature stage of a cascade system. In all-CO_2 centralized systems with the low temperature stage in cascade and, finally, this refrigerant can be used with separated circuits for LT and MT service, both rejecting heat directly to the environment.

Casson [2] evaluated the COP for medium temperature (MT) and low temperature (LT) for CO_2 systems, with evaporation temperatures between −10 °C and −35 °C, respectively. This author observed that the COP decreases with the increase of the external air temperature, obtaining a COP of 5.2 for MT and 2.5 for LT, when the ambient temperature was 0 °C, and 1.5 and 0.8, respectively, for higher ambient temperature, 30 °C.

Girotto et al. [6] evaluated the efficiency of a centralized all-CO_2 system with 120 kW of capacity and compared it with a direct expansion R404A system. The authors concluded that, for medium temperature applications, the efficiency was still somewhat lower if compared to the R404A system. For medium temperature

* Corresponding author. Tel.: +55 34 32394022; fax: +55 34 32394206.
E-mail addresses: alessandro.silva@bitzer.com.br (A. da Silva), bandarra@mecanica.ufu.br (E.P. Bandarra Filho), arthur.h.p.antunes@gmail.com (A.H.P. Antunes).

1359-4311/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2011.12.019