

Experimental study of the performance of single-band air curtains for a multi-deck refrigerated display cabinet

Yun-Guang Chen *, Xiu-Ling Yuan

Department of Refrigeration and Cryogenic Engineering, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an 710049, PR China

Received 22 March 2004; accepted 6 August 2004

Abstract

Experiments were conducted to study the effects of several important factors on the performance of a refrigerated display cabinet, including ambient air temperature, indoor relative humidity, ambient air flow, air supply velocity, air flow from perforated back panels and night covers. Both inside temperature distribution and heat load were investigated. Furthermore, the thermal entrainment factor is correlated with Reynolds number and Richardson number. The results show the thermal entrainment tends to increase with increasing momentum force but decrease when the gravitational force is dominant.

© 2004 Elsevier Ltd. All rights reserved.

Keywords: Air curtains; Refrigerated display cabinets; Experimental study

1. Introduction

In recent years open-type refrigerated display cabinets are widely used in supermarkets and grocery stores because of good display effects and allowing customers free access to food inside the cabinets. Recirculated air curtains provide enough cooling capacity for chilled food as well as an artificial barrier between the store environment and the chilled display area.

The performance of refrigerated display cabinets is affected by many factors, which include the dimensions of the air supply and return grilles, the width and length of the air jet, the velocity and temperature of the air jets and the temperature, humidity and air flow velocity of the ambient environment.

To date, most researches on refrigerated display cabinets focused on CFD simulation and experimental studies mainly concentrated on the effects of air supply

velocity and initial turbulent intensity. Howell, Van, and Smith (1976) investigated heat and moisture transfer through recirculated plane air curtains, and their results showed the total heat transfer across an air curtain is directly proportional to the discharged air velocity and the temperature difference across the air curtain. The latent heat load makes up a significant portion of the total (about 40–50%). Van and Howell (1976) studied the effect of the initial turbulent intensity on the development of an air jet and found that the length of the developing region and thickness of the jet is strongly affected by the amount of initial turbulent intensity. However, the air curtains studied were used as air doors and different in velocities and dimensions from those used in display cabinets. Howell (1993) found that energy saving for most refrigerated display cabinets would be up to 20–30% when the ambient relative humidity decreased from 55% to 35%. Field and Loth (2001) used the particle image velocimetry (PIV) techniques to study the entrainment characteristics of air curtains. They observed the flow features of air curtains with Reynolds numbers ranging from 1500 to 8500. Navaz, Faramarzi,

* Corresponding author. Fax: +86 29 2668725.

E-mail address: yunguang_chen@eyou.com (Y.-G. Chen).

Nomenclature

A	area (m^2)
b	width of initial air jets (m)
g	gravitational acceleration (ms^{-2})
Gr	Grashof number
i	enthalpy (kJ kg^{-1})
i_{fg}	enthalpy of vaporization (kJ kg^{-1})
$\dot{m}$	mass flow rate (kg s^{-1})
Q_{lat}	latent heat transfer (kW)
Q_{sen}	sensible heat transfer (kW)
Q_{tot}	total heat transfer (kW)
Ri	Richardson number
Re	Reynolds number
u	velocity (ms^{-1})

W	humidity ratio (kg kg^{-1})
-----	--

Greek symbols

α	thermal entrainment factor
μ	dynamic viscosity ($\text{kg m}^{-1} \text{s}^{-1}$)
ρ	density (kg m^{-3})

Subscripts

a	dry air
amb	ambient
r	return air
s	supply air

Gharib, Dabiri, and Modarress (2002) combined computational and experimental methods to study the air entrainment of air curtains at different discharge temperature and velocities. However, both Field and Loth (2001) and Navaz et al. (2002) did not take the effects of ambient environment into account. Few experimental researches giving comprehensive details on the performance of refrigerated display cabinets have been published. In addition, most experimental investigations evaluated the performance based on official standards so that variable working conditions were seldom reported.

The purpose of this paper is to investigate the effects of some important factors on the temperature distribution and cooling load of a multi-deck refrigerated display cabinet, such as ambient temperature and humidity, discharge air velocity, night covers and air flow from perforated back panels. The work involves field tests and theoretical analyses and the results of the present paper are of great significance to the optimum design of display cabinets and energy management of supermarkets.

2. Experimental testing

2.1. Experimental apparatus

The dimensions of the vertical display cabinet in the present study are 2.4m in length, 1.1m in width and 2.2m in height. It has five shelves and its opening height is about 1.7m. The refrigeration system uses remote condenser-compressor units. All the tests were conducted in a controlled environment room, which can be utilized to simulate various indoor conditions. Independent refrigeration and electric heating systems as well as humidification and dehumidification systems were employed to provide the desired ambient temperature and relative humidity. Variable-voltage speed con-

trollers were installed to adjust the horizontal air speed of indoor environment.

Fig. 1 shows the sensor locations for temperature measurements. S and R represent supplied and returned air, and L1–L6 are the five shelves and the bottom board, respectively. Temperatures inside the cabinet were measured at three vertical cross-sections along the cabinet length and at each shelf temperatures on the front, center and rear parts were all measured. At the air supply and return grille the relative humidity and air curtain velocity were also measured.

For the refrigeration system some important parameters were measured, such as refrigerant mass flow rate as well as pressure and temperature at both the inlet of the expansion valve and the outlet of the evaporator, through which the cooling capacity can be acquired.

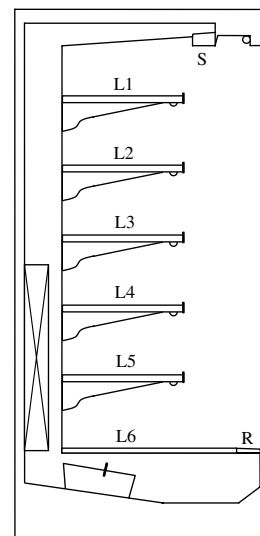


Fig. 1. Schematic diagram of a multi-deck refrigerated display cabinet.

Download English Version:

<https://daneshyari.com/en/article/10278632>

Download Persian Version:

<https://daneshyari.com/article/10278632>

[Daneshyari.com](https://daneshyari.com)