Experimental analysis to optimize the performance of air curtains and heat exchangers: application to refrigerated display cases.

Experimental Analysis to Optimize the Performance of Air

Curtains and Heat Exchangers: Application to Refrigerated Display Cases

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Abstract

This chapter reports an overview about experimental studies concerning the thermal performance of air curtains and heat exchangers installed in vertical open refrigerated display cases. The air curtain analysis shows the influence on the thermal performance by varying the width of the discharge air grille and the perforation density of the back panel by a mathematical model. The variation on the perforation density of the back panel and the width of discharge air grille alter significantly the thermal entrainment factor and the energy consumption of the equipment. Focusing the influence of environmental conditions on the performance of the heat exchanger, a second mathematical model was developed to evaluate the total heat load, its partial components and the condensate water mass. This analysis provides valuable information to the design of the air curtain and heat exchanger based on in-store environmental conditions and airflow efficiency.

Chapter Preview

Top

Introduction

In order to preserve food for a longer period, man has developed cooling forms since prehistoric times. The effects of low temperatures on food preservation were already known before 2000 B.C.. The older methods of producing cold made use of natural ice or mixtures of salt and snow. Later, the mechanical refrigeration cycle has emerged consisting essentially of four main components: evaporator, compressor, condenser and expansion device.

With the use of refrigeration machines and the development of new technologies, storing and transporting perishable foods over long distances and for longer periods became possible. Therefore, commerce and distribution of perishable food began to increase. Perishable foods, since production to the final consumer, are maintained and distributed through the system called as cold chain, which is composed of five main links (Rigot, 1991).

- â€¢ Cold production
- â€¢ Cold storage
- â€¢ Refrigerated transport
- â€¢ Cold distribution
- â€¢ Domestic cold.

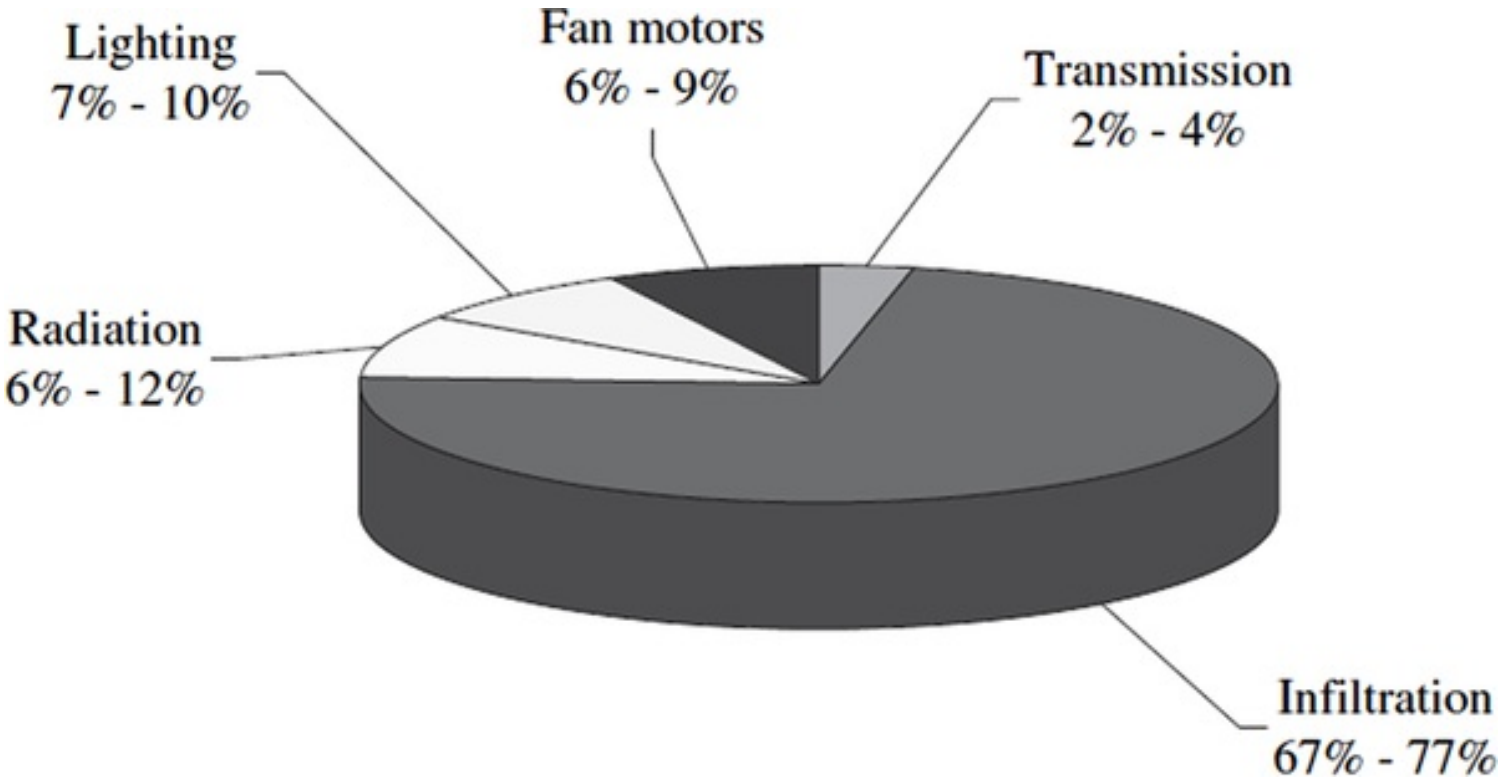
The fourth link in the cold chain, which will be described along this chapter, is commonly referred as commercial refrigeration. Refrigerated and frozen products are separate on the production phase and follow in environments with different temperatures through the storage, transportation and distribution. At the distribution phase, foods are expose for sale at convenience stores, small and large supermarkets through refrigerated equipment of various designs and levels of temperature according to the industry regulations and the growing demand for quality by consumers. The refrigerated or freezing display cases can be open or closed to the external environment.

Generally, refrigerated display cases are designed to operate in supermarkets that have ambient air conditioning. The global industry considers climatic condition of 25 Â°C with 60% of relative humidity (climate class n.Âº 3 (ISO 23953-2, 2005) as the standard to certify this type of equipment - critical summer condition).

Refrigerated display cases can be classified based on several criteria, however the standard ISO 23953-1 (2005) divides them into vertical, semi-vertical, horizontal and combined; which may be open or closed to the store environment; for self-service or not. The specifications of each display case type are: (1) Vertical refrigerated display cases with multiple shelves have height exceeding 1.5 m. Semi-vertical refrigerated display cases are whose overall height does not exceed 1.5 m and the display opening may be vertical or inclined. Horizontal refrigerated display cases have horizontal display opening on its top. Open refrigerated display cases (ORDC) are those that access to the products takes place in a direct way without the need of opening doors or lids. Closed refrigerated display cases (CRDC) has the access to the products by opening of a door or lid. Combined refrigerated display cases are those that combine at least two of the above characteristic. Each type of display case has its characteristic operating temperature, from preserving ice cream, frozen foods, fresh meat, dairy/deli to fruits/vegetables.

The ORDC are more sensible to changes in environmental conditions. According to Faramarzi (1999) and Gaspar *et al.* (2011a), the ambient air infiltration load corresponds to 67%-81% of the total thermal load of this type of display case. This is due to the low efficiency of the air curtain, which forms a physical barrier between the internal and the external environment. The relative contribution of each heat load in an ORDC is shown in Figure 1.

Figure 1. Heat load contributions



The energy consumption reduction due to infiltration depends directly of the cool airflow inside the ORDC. In the case of CRDC, infiltration is proportional to the frequency of door opening by the consumers and the accumulated time for product replacement.

Key Terms in this Chapter

Thermal Load: Amount of heat (sensible and latent) energy to be removed from an inner environment by the refrigeration equipment to maintain that environment at the design temperature when worst case external temperature is being experienced.

Open Refrigerated Display Case: Refrigerated display cases are classified by standard ISO 23953-1 (2005) into vertical, semi-vertical, horizontal and combined; which may be open or closed to the store environment; for self-service or not. The specifications of each display case type are: (1) Vertical refrigerated display cases with multiple shelves have height exceeding 1.5 m; (2) Semi-vertical refrigerated display cases are whose overall height does not exceed 1.5 m and the display opening may be vertical or inclined; (3) Horizontal refrigerated display cases have horizontal display opening on its top. Open refrigerated display cases (ORDC) are those that access to the products takes place in a direct way without the need of opening doors or lids. Closed refrigerated display cases (CRDC) has the access to the products by opening of a door or lid; (4) Combined refrigerated display cases are those that combine at least two of the above characteristic. Each type of display case has its characteristic operating temperature, from preserving ice cream, frozen foods, fresh meat, dairy/deli to fruits/vegetables.

Thermal Entrainment Factor: Dimensionless temperatures or enthalpies difference that quantifies the aero-thermodynamics blockage provided by an air curtain. This parameter varies from 0, which corresponds to no entrainment (unreachable condition) to 1, which corresponds to unblocked passage and entrainment of air between the two contiguous environments.

Heat Exchanger: Piece of equipment built for efficient heat transfer from one medium to another.

Testing Standard: The testing standard of performance characteristics of refrigerated display cases is performed according to ISO standard ISO 23953:2005.

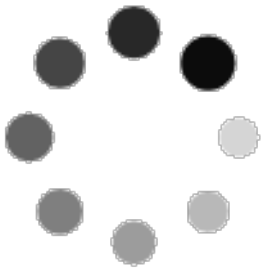
Food Safety: Food safety refers to the conditions and practices that preserve the quality of food to prevent contamination and foodborne illnesses. Ensuring the food temperature below the prescribed limits will promote their safety.

Frost Formation: Frost formation occurs when humid air encounters a surface whose temperature is less than the freezing temperature of water (273 K), and is less than the dew point temperature, so that water vapour goes from a gaseous to a solid state. As the frost layer increases in the evaporator surface, the cooling capacity of refrigeration is depleted due to the extra thermal resistance to the heat transfer process and also because it increases the air pressure drop, thereby substantially reducing the fan-supplied airflow rate.

Air Curtain: The Air Movement and Control Association International Inc. (AMCA International) defines air curtain as a controlled stream of air moving across the height and width of an opening with sufficient velocity and volume to reduce the infiltration or transfer of air from one side of the opening to the other and/or to inhibit insects, dust or debris from passing through.

Energy Consumption: The energy consumption of open refrigerated display cases is dependent on ambient air conditions (temperature, humidity and direction and magnitude of velocity), which will influence the heat transfer rate of the evaporator, air curtain efficiency and defrost system operation.

Complete Chapter List



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