Research Journal of Applied Sciences, Engineering and Technology 6(23): 4370-4374, 2013
DOI:10.19026/rjaset.6.3438
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: January 23, 2013 Accepted: February 25, 2013 Published: December 15, 2013

**Research Article**

# One New Type Vertical Open Display Cabinet and Its Thermostatic Performances

Wen-ji Song and Zi-ping Feng
Key Laboratory of Renewable Energy and Gas Hydrate, Guangzhou
Institute of Energy Conversion, Chinese Academy of Sciences, China

**Abstract:** Vertical Open Display Cabinets (VODC) are widely used in supermarkets for food or drink sales under an adaptive temperature. In this study, one new type VODC which developed based on ice-slurry technology and central refrigeration was established and its thermostatic performances was experimental studied and compared with a conventional one which chilled by refrigerating R22 directly. The experimental results show that it has good refrigerating effects and few temperature fluctuations. It can basically satisfy food fresh-keeping demands. This new type VODC can operate at high efficiency and save money for the users, indirectly protect our living environment.

**Keywords:** Display cabinet, experimental study, thermostatic performance

## INTRODUCTION

Display cabinets are very important equipments in supermarkets and convenience stores. They can not only store various foods, but also attract customers` attention for products promotion.

Display cabinets use a large of electricity energy to refrigeration, about 50% of total energy consumption because of its open structure (Sweetser, 2000; Ke-zhi *et al.*, 2007), to a large extent, due to cold air spillage from the cabinets to supermarket indoor environment. There has been a lot of energy saving technologies and control methods applied to display cabinets. By decreasing the temperature fluctuation inside display cabinet (Gray *et al*., 2008), decreasing cycles between frosting and defrosting (Ke-zhi *et al*., 2009), improving efficiency of main components (Tahir and Bansal, 2005), energy consumption has been cut down evidently.

According to inside cabinet temperature, the display cabinets could be simply classified to three kinds: deep cold cabinet (about -18°C), freezing cabinet (-10~0°C) and chill cabinet (above 0°C). In China, supermarkets adopt numerous Vertical Open Display Cabinets (VODC) with 2~10°C for cooled products merchandising. Part of energy consumption of this type VODC is used for keeping products` temperature from surrounding environment temperature; another part of energy is losses in frosting and defrosting because its evaporating temperature is lower than 0°C.

In this study, one new type of VODC developed based on ice-slurry technique and central refrigeration is established, experimented and compared with a conventional one which chilled by refrigerating fluid directly. The purpose of this study is to undertake a feasible investigation on whether the new type VODC could satisfy chill storage and save energy or not. To date there has not been any investigation about this and thus the optimized parameters need include frozen water flow rate and forced-air curtain flow rate.

**Vertical display cabinet based on ice-slurry storage system:** The principle of this new type VODC is shown in Fig. 1. During the night supermarket closing, the refrigerator generates cold energy and chills tap water into ice slurry by ice-making unit. Slurry-like ice is pumped and stored in ice tank. During the day supermarket opening, chill water (0~1°C) is sucked out from bottom of ice tank and pumped to VODC, passes thorough the evaporator coils located at the back of display cabinet and absorbs heat and then flows back to ice tank from the top.

Ice-making unit produces a flow of super cooled water (about -2°C) and disturbed physically in order to generate ice crystals and then obtains slurry-like ice, which is a patented product of Senyo®. Ice slurry is pumped into ice storage tank and stratification occurs because of buoyancy between ice crystal and water. Water at bottom of the tank is circulated until ice storage process finishes. When VODC works, high temperature water absorbed heat in evaporator is sprayed directly to ice from the top of ice tank, ice melts and cold thermal releases.

This new VODC has some advantages. Using chill water (0~1°C) as secondary refrigerant instead of refrigerating fluid can overcome the frosting and

**Corresponding Author:** Wen-ji Song, Key Laboratory of Renewable Energy and Gas Hydrate, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China, Tel.: 86-20-8705 9478

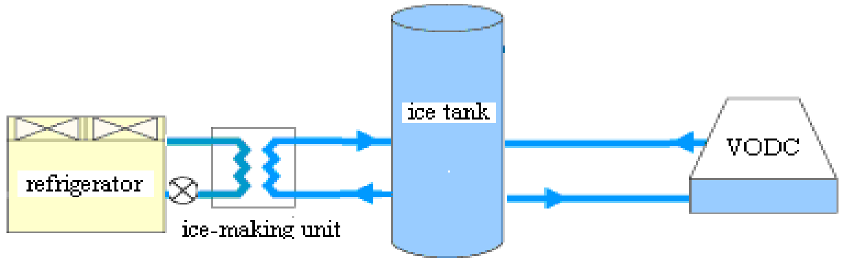



Fig. 1: Schematic diagram for ice slurry VODC with central refrigeration

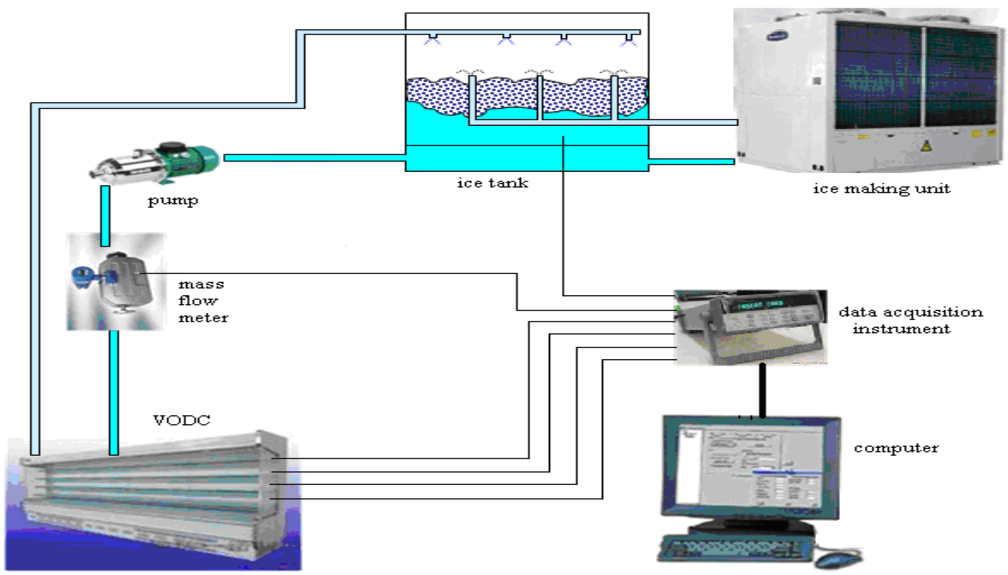



Fig. 2: Test set for feasibility study on VODC

defrosting problems completely, which can cut down energy consumption for refrigerating and avoid products temperature fluctuation. Furthermore, ice-slurry storage system can benefit from the Time-of-Use (TOU) electricity price, save running cost for the user.

## EXPERIMENTAL SETUP AND PROCEDURE

**Experiment apparatus:** The test setup system consists of three main parts, the ice making cycle, the VODC cycle and the measuring system, as shown in Fig. 2. The ice making cycle, which includes conventional refrigerating machine (normal refrigerating output = 5000 W), ice making unit (normal ice production = 180 kg/h) and ice storage tank (H = 1200 mm, W = 860 mm, Length = 1000 mm), generates ice in order to storage cold thermal using cheap electricity during night. The VODC cycle, which includes VODC machine (H = 1400 mm, W = 850 mm, Length = 1600 mm, Model SCLG4-2000C of Jinniu Co. Ltd.), ice tank and circulating pump (WILO Co. Ltd. MH1404, max output = 8 t/h), releases cold thermal in order to keep products in VODC low temperature.

The measuring system can measure mass flow rate of chill water, flow rate of chill air from air curtain and temperature in different position. Instruments used are list in Table 1.

In order to test and verify this new type VODC, some modifications were done based on the conventional VODC after contrast experiments. First of all, compressor-condenser unit was removed and evaporator was replaced because the cooling media is chill water instead of refrigerant. The new matching evaporator needs bigger pipe diameter and heat exchange area than before. Then, one ice storage tank was added and pump provided circulating chill water for VODC from ice tank bottom, as shown in Fig. 3. At last, adjusting devices were installed in order to adjust air flow rate and chill water flow rate.

In order to investigate the influence of air curtain velocity on the performance of the VODC, the velocity measuring points are located at the air curtain inlet. Temperatures are measured by K-thermocouples. The thermocouples are located at the air curtain inlet, chill water supple inlet and inside VODC. There are five shelves in the VODC. For each shelf, six thermocouples were adopted and three were located at shelf surface nearly outer margin and three at back wall nearly mid-

Table 1: Instruments list

| Name | Model | Range | Accuracy |
|---|---|---|---|
| Coriolis mass flow meter | ZLJC7 | 0~7 t/h | ±0.25% |
| Thermal bulb-type anemoscope | BJ-QDF-2B | 0.05~5 m/s | ±5% |
| Thermal couple | K type | -40~375°C | ±0.50°C |
| Data logging instrument | HP34970A | / | |

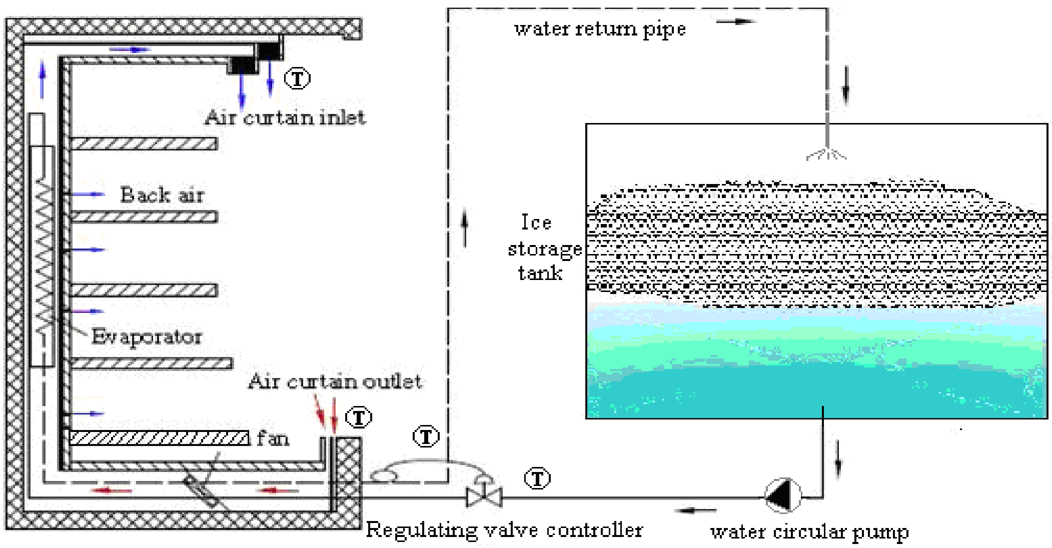



Fig. 3: Schematic view of new type VODC in this study

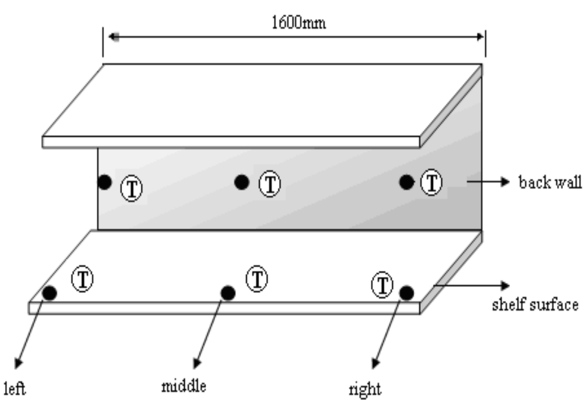



Fig. 4: Front view for part of cabinet of VODC

height, as shown in Fig. 4. The mean temperature was regards as the characteristic temperature of the shelf. Ts1in stands for the temperature on back wall of top shelf and Ts5out stands for the temperature on outer margin of bottom shelf.

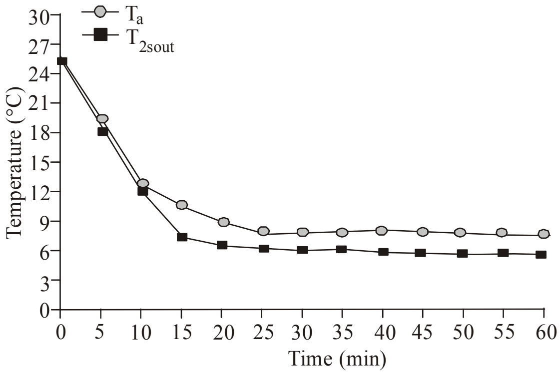
**Experimental procedures:** The conventional VODC (refrigerating system) system and the new type VODC (chill water system) were stared up when the environment temperature and relative humidity reach a steady state. There are two type measurements in the experiments including transient measure and steady measure. Each experiment was kept less than 2 h.

All the experiments can be divided into three parts. Firstly, compare tests were done between conventional VODC and new type VODC. Secondly, the influence of chill water flow rate on performance of new type VODC was conducted and one optimal flow rate was obtained. Thirdly, the influence of air curtain flow rate was carried out and one optimal air curtain flow rate was obtained.

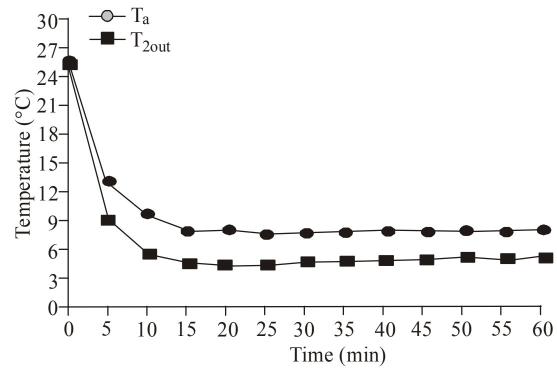
## RESULTS AND DISCUSSION

**Contrast experiments without products inside:** For this two types VODC in this study, transient characteristics during cooling process can express its temperature preservation ability. Without products inside, Ta (temperature of air curtain inlet) and T2sout show same tendency along time, as shown in Fig. 5 in which Ta stands for the air temperature at air curtain inlet and Tw stands for the water temperature at evaporator inlet. The new type VODC can achieve the same cooling effect. It can be deduced that the range of temperature fluctuation inside VODC is acceptable with products inside, because the products should be pre-cooling before placed onto the shelves.

**Influence of chill water flow rate and air curtain velocity:** Temperature difference between evaporator inlet and outlet represent heat transfer ability of evaporator, which is determined by chill water flow rate and air curtain flow velocity. Increasing chill water flow rate can exchange much more evaporator heat to VODC and meanwhile increase circulation pump consumption. So, there exists an optimal flow rate. As

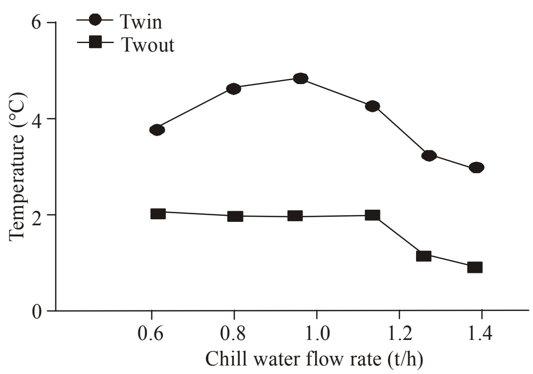



(a) New type VODC at Tw = 1.5°C

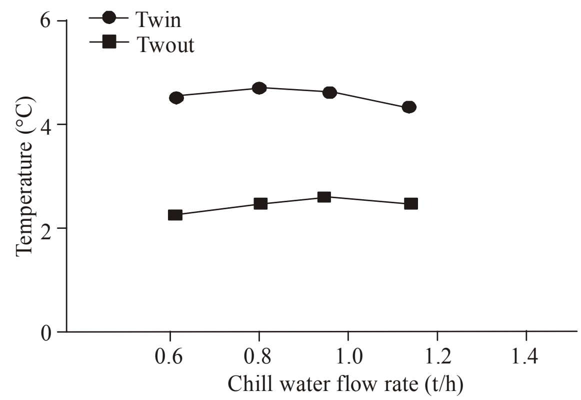



(b) Conventional VODC

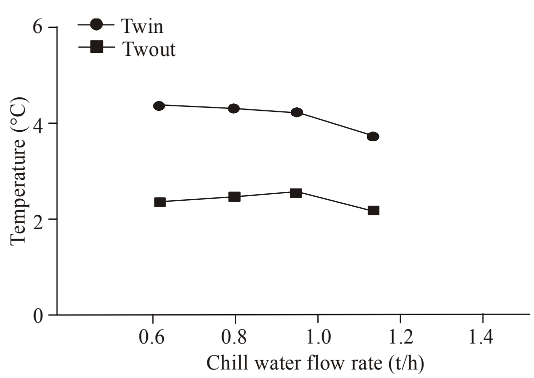
Fig. 5: Temperature response versus time at air velocity 1.2 m/s without products inside




(a) Air curtain flow velocity at 1.2 m/s




(b) Air curtain flow velocity at 1.0 m/s




(c) Air curtain flow velocity at 0.8 m/s

Fig. 6: Temperature difference between chill water inlet and outlet

shown in Fig. 6a, the value is 1.0 t/h at air curtain flow velocity 1.2 m/s and it is independent to chill water inlet temperature.

With air curtain flow velocity decrease, heat exchange ability of evaporator decreases obviously, as shown in Fig. 6b to c. So, air flow velocity recommended is 1.0~1.2 m/s, otherwise it will have to increasing evaporator capacity to meet cooling load demands.

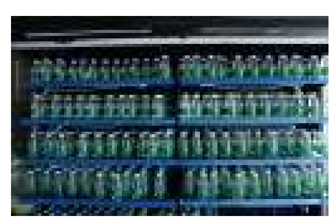


Fig. 7: Picture of new type VODC with products inside

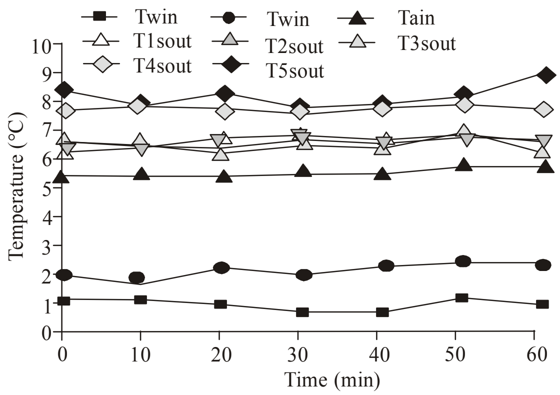



Fig. 8: Temperature distribution inside VODC at the condition of Qw = 1.36 t/h and Va = 1.0 m/s

**Influence of chill water flow rate and air curtain velocity:** At last, one proof experiment was done with bottled water loaded inside VODC, as shown in Fig. 7. Those bottled waters were pre-cooling down to 6°C in cold store.

The test results were shown in Fig. 8. At the condition of chill water flow rate 1.36 t/h and air curtain flow velocity 1.0 m/s, temperature inside VODC is below 8°C and less fluctuation which can basically satisfy chill storage demands limited to GB/T 21001.2-2007 of PRC (The National Refrigeration Standardization Technology Committee (PRC), 2007).

The performance can be promoted further by improving evaporator efficiency to obtain lower air curtain temperature and adopting compound structure for air outlet (such as double-band air curtain structure) in order to decrease the entrainment heat from the ambient.

## CONCLUSION

Based on the experimental results above, such conclusions can be obtained as follows:

- The new type VODC based on ice-slurry storage system can keep temperature well-distributed and meet the demands for products chill storage.
- There exist optimal values for chill water flow rate and air curtain flow velocity. The optimal values are 1.2 t/h and 1.0~1.2 m/s respectively.

## ACKNOWLEDGMENT

This study was supported by the foundation of Major Technologies Program of Guangdong Province, PRC, under the Grants No. 2009A080305002.

## REFERENCES

Gray, I., P. Luscombe, L. Mclean, C.S.P Sarathy, P. Sheagen *et al*., 2008. Improvement of air distribution in refrigerated vertical open front remote supermarket display cases. Int. J. Refrig., 31: 902-910.

Ke-zhi, Y., D. Guo-liang and C. Tian-ji 2007. Simulation of air curtains for vertical display cases with a two-fluid model. Appl. Therm. Eng., 41: 2583-2591.

Ke-zhi, Y., D. Guo-liang, C. Tian-ji, 2009. Experimental investigation on a vertical display cabinet with central air supply. Energ. Convers. Manage., 50: 2257-2265.

Sweetser, R., 2000. Supermarket relative humidity and display-case performance. Heat. Piping Air Condition Eng., 72(2): 38-45.

Tahir, A. and P.K. Bansal, 2005. MEPR versus EEPR valves in open supermarket refrigerated display cabinets. Appl. Therm. Eng., 25: 191-203.

The National Refrigeration Standardization Technology Committee (PRC), 2007. GB/T 21001.2-2007 Refrigerated display cabinets-Part 2: Classification Requirements and Test Conditions. Standards Press of China, Beijing.