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Article

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Energy saving in six doors walk-in cooler

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Abstract

Two Identical six doors walk-in coolers are installed with the fixed speed compressor and the digital scroll compressor. Both compressors have almost the same cooling capacity of 8 kW at the evaporating temperature of $-6.7\text{ }^{\circ}\text{C}$ and the ambient temperature of $32\text{ }^{\circ}\text{C}$. The heating loads from the envelope, the water bottles, and the air change during the door closing and opening of both coolers are the same. The temperature of the room in front of the cooler doors is controlled at $25\text{ }^{\circ}\text{C}$. They are set to have a similar average room temperature and a similar cool down. Both units are run 24 h per day for 30 days during which the ambient temperature and the power consumption are recorded. The results show that for Thailand weather, yearly saving is 20% for the digital scroll as compared with the fixed speed compressor.

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Keywords: Energy saving; Walk-in cooler; Fixed-speed compressor; Digital scroll compressor

1. Introduction

Under the framework of Thailand energy efficiency plan during 2015–2036 to reduce energy intensity by 30 percent in 2036 compared to 2010. The Ministry of Energy of the Kingdom of Thailand takes an effort to raise the high energy performance standard and to improve the efficiency of energy usage of each sector. The results of researches the High Energy Performance Standard (HEPS), such as industry fan by Tantakitti et al. [1], hair dryer by Pattana et al. [2], motorcycle tire by Wiratkasem et al. [3] etc., are in process to announce by the ministerial regulations. In order to achieve energy efficiency in the service sector especially in convenience stores, which currently have a large number of stores in almost every community of the country. This will lead to cost reduction and increased competitiveness.

In Thailand, there are presently more than 10,000 units of a walk-in cooler installed in convenience stores. Most of them use a fixed speed, about 3 kW motor, hermetic scroll compressor and more than 50% of these coolers have 6 doors. In the cases that the heating load and the ambient temperature are varied, it is well known that the variable refrigerant flow compressors (VRF) such as a digital scroll compressor consume less electric energy than

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Nomenclature

AT	Ambient temperature
ET	Evaporating temperature
RGT	Return gas temperature

the fixed speed one. To determine the energy saving between each type of compressors, one should use the testing standards for the walk-in cooler. There are more than 10 countries that have the testing standards and regulations, but in only a few countries such as Australian Standard [4] (AS1731.14:2003), Standards Council of Canada [5] (CSA C657-15) and AHRI Standard [6] (AHRI1251:2014), the Minimum Energy Performance (MEP) are enforced for a walk-in cooler. Unfortunately, there is no testing facility in Thailand. So, the face-to-face testing is selected to find the performance and electric energy saving among these two types of compressor.

2. Experimental setup

2.1. Testing facility

To find the performance and electric energy savings among the coolers installed with the two types of compressors are determined by the face-to-face comparison. All coolers are operated at the same condition and time. The facility setups are as follow:

- Two identical six doors walk-in coolers, each is installed with the fixed speed compressor and the digital scroll compressor air-cool condensing units as shown in Fig. 1.
- Each door is equipped with pneumatic cylinder which controlled by PLC to be able to open and close door on demand as shown in Fig. 2(a).
- The temperature of a room in front of cooler is controlled at 25 °C as temperature of most stores.
- The condensing units for each type of compressors are chosen to have a similar rated cooling capacity as shown in Table 1.
- Each cooler is equipped with two evaporators of the same model.
- 2880 and 2400 of 600 cc water bottles are stored on the shelves and the floor inside each cooler respectively as shown in Fig. 2(b).
- The temperature inside the cooler is set at 3 °C and control within ± 1 °C range.
- The coolers are set to defrost every 4 h.
- The cool down time of all coolers is set to be almost the same to eliminate the advantages and the disadvantages of each type of compressors.
- The room temperature, the water temperature, the ambient temperature and the electric energy consumption are recorded every minute for 30 days.

Table 1. Details of the testing compressors.

Detail	Fixed speed	Digital scroll
Compressor type	Scroll-hermetic	Scroll-hermetic
Refrigerant	R404A	R404A
Receiver volume (kg)	4.4	6.3
Rated condition ET/AT/RGT (°C)	−6.7/32/18.3	−6.7/32/18.3
Voltage, frequency	AC 3Ø380 V @50 Hz.	AC 3Ø380 V @50 Hz.
Capacity (kW)	7.8	8.3
COP (W/W)	2.29	2.47
Rated load ampere (A)	7.5	7.7
Total fan motor power input (W)	116 (AC)	246 (AC)

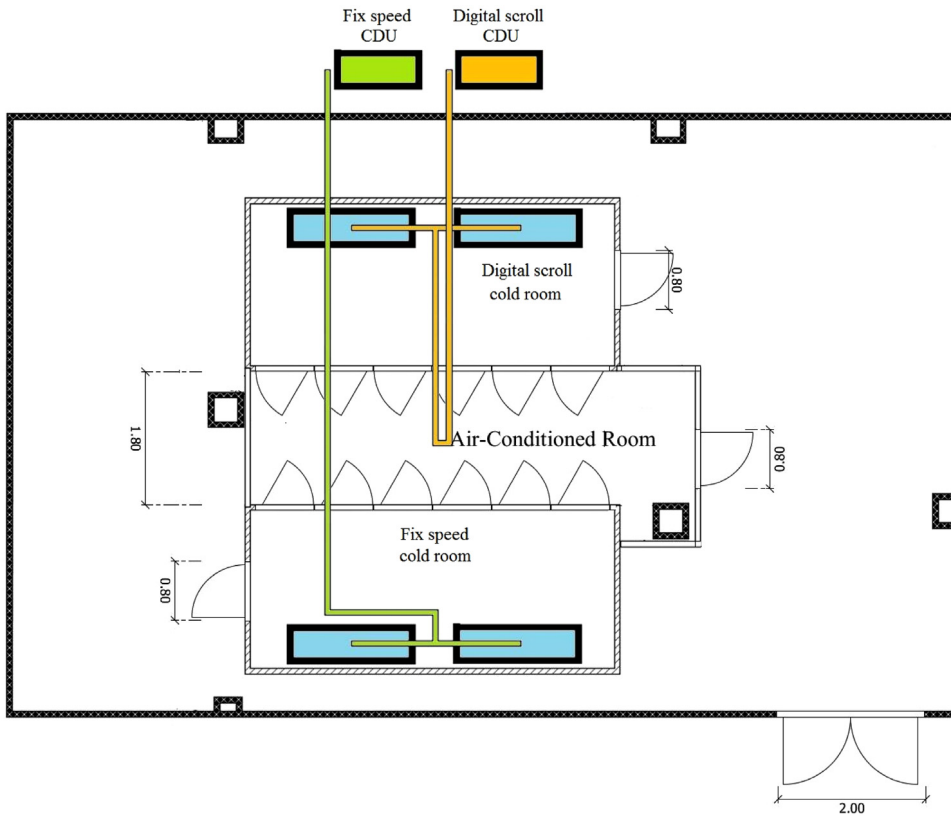


Fig. 1. Floor plan of the testing facility.

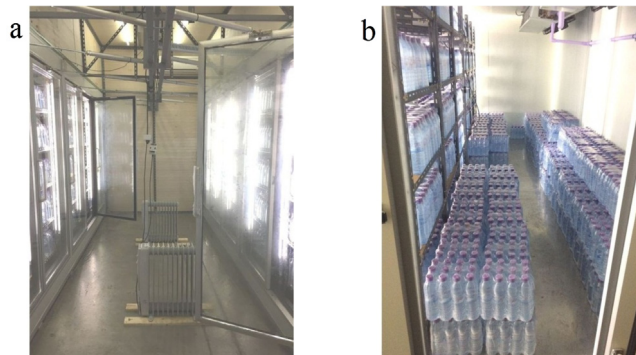


Fig. 2. (a) Pneumatic cylinder on each door; (b) Water bottles on the shelves and the floor inside each cooler.

2.2. Variable heat load conditions

From the survey data of typical convenience store that have 6 doors walk-in cooler, about 1200 bottles containing a variety of drinks are loaded everyday into a cooler around 1:00 PM. In addition, the customer traffic and drink sales vary depending on the time of the day, to mimic the real-life scenarios, the test conditions are selected as follow.

- At 13:00, 1200 of 600 cc water bottles in the cooler are replaced with new ones every day.
- The frequency of the door opening is based on the time of the day.

From 00:00 to 06:59, 1 door is opened every hour.
 From 07:00 to 08:59, 1 door is opened every 4 min.
 From 09:00 to 10:59, 1 door is opened every 3 min.
 From 11:00 to 20:59, 1 door is opened every 1 min.
 From 21:00 to 23:59, 1 door is opened every 3 min.

- Whenever the door is opened, it has to be left open for 45 s.

3. Results

3.1. Cool down and electric consumption

Fig. 3 shows an example of the data obtained from all coolers which are operated at the same time in 24-h period (e.g. between 13:00 on April 1st and 12:59 on April 2nd). The ambient temperatures varied from 25–35 °C, while the temperatures outside the cooler (warehouse), in the control room in front of cooler (store), and inside the cooler are 30, 25 and 3 °C respectively. It can be seen that the cooling time is about 2.5 h (from 13:00–15:30). The spikes of the temperature inside the cooler in each graphs correspond to the defrost process. So, it can be assumed both units are adequately comparable. Daily electric consumptions are 44.1 and 34.0 kWh for the fixed speed compressor and the digital scroll compressor, respectively. The digital scroll compressor consumed less electric energy than the fixed speed compressor.

3.2. The relation between the electric energy consumption and the ambient temperature

The relation between the electric energy consumption and the ambient temperature is analyzed by plotting the energy consumption against the ambient temperature from the experiment period of 30 days, as shown in Fig. 4(a) and (b) for the fixed speed compressor and the digital scroll compressors, respectively. The data points appear scattered due to the variation of hourly load, so they are separated into two periods: 21:00–10:59 (low variation load) and 11:00–20:59 (high variation load). The data points in each period are then subjected to the linear regression analysis and as shown in Fig. 4. The relations between the electric energy consumption (y , kWh) and the ambient temperature (x , °C) for the fixed speed compressor are:

For fixed speed compressor, low variation load;

$$y = 0.0247x + 0.7082 \quad (1)$$

For fixed speed compressor, high variation load;

$$y = 0.1667x - 2.6877 \quad (2)$$

During the low variation load period, the increase in the ambient temperature causes the slight increase in the electric energy consumption. On the other hand, during the high variation load period, the rise in the ambient temperature results in a much higher electric energy consumption (slope is higher for the high load as compared to the low load). These results are in line with the theory.

The results for a digital scroll compressor are shown in Fig. 4(b) and the relations are analyzed to be:

For digital scroll compressor, low variation load;

$$y = 0.0187x + 0.5591 \quad (3)$$

For digital scroll compressor, high variation load;

$$y = 0.1306x - 2.0179 \quad (4)$$

3.3. Yearly electric energy consumption and saving

The relations between the electric energy consumption and the ambient temperature are then used to estimate the yearly electric energy consumption. The ambient temperature was selected from the Typical Meteorological

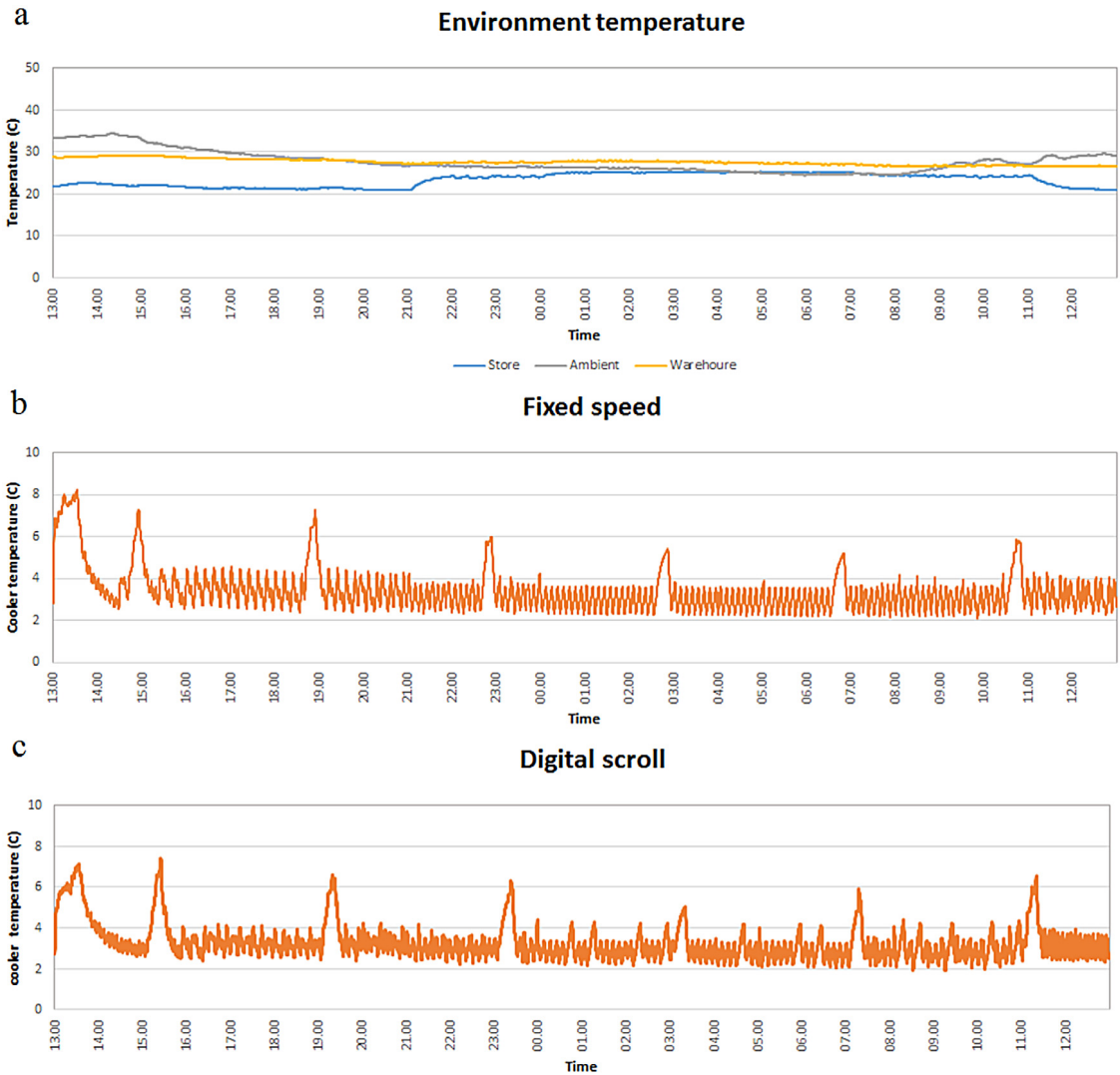


Fig. 3. Temperature of each area (a) environment; (b) fixed speed cooler room; (c) digital scroll cooler room.

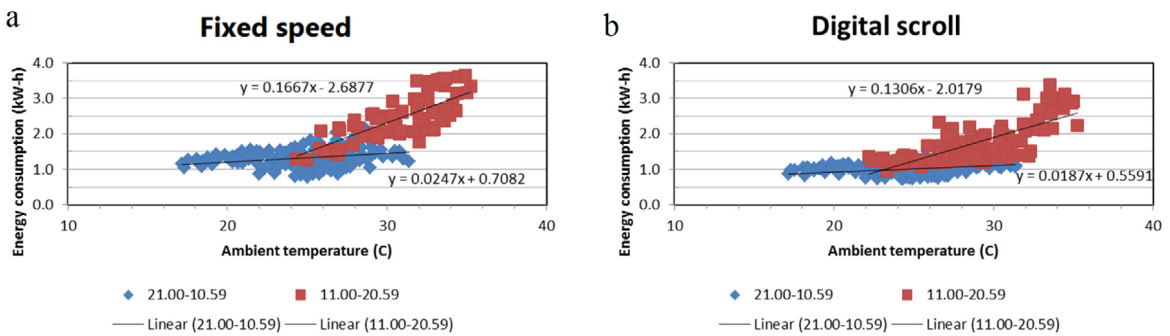


Fig. 4. Energy consumption vs ambient temperature (a) fixed speed compressor; (b) digital scroll compressors.

Years (TMY) data from Meteonorm [7] software. The year-round ambient temperatures are first separated into two periods, low and high variation loads, then binned based on the temperature.

The electric energy consumption (E_y) is calculated by,

$$E_y = \sum (\text{no. of hours}) \cdot y \quad (5)$$

Where, E_y = yearly electric consumption, kWh

y = hourly electric energy consumption at each ambient temperature from Eqs. (1) to (4), kWh.

The yearly electric energy consumptions for each compressor calculated using Eq. (5) are shown in Table 2. The yearly saving is determined using the fixed speed as a comparator. Based on the data and analysis, the digital scroll compressor has more energy saving than fix-speed compressor with 20%.

Table 2. Comparison of yearly electric energy consumption and saving.

Compressor type	Fixed speed	Digital scroll
Yearly electric energy consumption, (kWh)	16,432	13,124
Yearly saving (kWh)	–	3,308
Cost saving (US\$/year) ^a	–	457
Percent saving (%)	–	20

^aBased on electric tariff from Thailand metropolitan electricity authority and 1US\$ = 32 THB.

4. Conclusions

The face-to-face testing of two types of compressors, namely the fixed speed compressor and the digital scroll compressor have been performed in order to compare the electric energy consumptions and identify the best performer for a 6 doors walk-in cooler used in a typical convenience store in Thailand. By apply the bin temperature method, yearly electric energy consumption can be calculated. It is found that the digital scroll compressor consume less electric energy than the fixed speed compressor. From this study, the digital scroll compressor has more energy saving than fix-speed compressor with 20%. The future study should be conducted with inverter compressor which also have high performance when use in the same condition.

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