EFFECT OF NIGHT BLINDS ON OPEN INTEGRAL DISPLAY CABINETS

D Datta, R Watkins and S A Tassou

Department of Mechanical Engineering, Brunel University, Uxbridge, UB8 3PH, England
E-mail: Savvas.Tassou@brunel.ac.ukT

ABSTRACT

The impact of night blinds on the product temperature performance and electrical energy consumption of an integral open multi-deck cabinet is investigated in this paper. The cabinet was tested at various environmental conditions to establish the impact of ambient temperature on the effectiveness of the blind in reducing the energy consumption of the cabinet during night-time operation. The cabinet was tested over a range of temperatures between 20 °C and 35 °C at a constant moisture content. The results indicate that the use of night blinds could produce energy savings of between 10% and 22% calculated on the basis of a 24 hour period of operation with the blind lowered for 12 hours out of the 24 hours. These energy savings lead to pay-back periods of between 2 and 4 years. The savings reduced with increasing ambient temperature due to the increase in the impact of infiltration and conduction across the blind at higher temperatures.

INTRODUCTION

Open Vertical Display cabinets are commonly used in supermarkets and smaller convenience stores and bakeries. Their popularity lies in the ease of access to the products by the customers which promotes sales. For this reason retailers prefer open to glass door cabinets. Open display cabinets have much higher loads than glass door cabinets with infiltration of warm air in the cabinet accounting for most of the refrigeration load (Faramarzi, 1999). The use of blinds when the retail outlets are not trading can reduce the heat transfer due to radiation and convection into the cabinet reducing the power consumption and improving product temperature performance.

Axell and Fahlen (1998) reported savings of up to 30% when a night blind was used on a supermarket display cabinet which took part in a competition in Sweden to promote energy efficient commercial refrigeration. The design of this cabinet used special guides for the night blind which helped to minimise infiltration load when the blind was lowered. They also observed that night blinds in most other cabinets did not achieve high energy saving due to air infiltration at the edges of the blind.

Faramarzi et.al. (1999) carried out experimental investigations on the use of a night blind on a supermarket cabinet equipped with a thermostatic expansion valve and a compressor with variable speed drive. Three operating schedules were investigated at the same environmental condition of 23.9 °C as follows:
a) 24 hour operation without blind; b) 24 hour operation with the blind lowered for 6 hours, and c) blind lowered for the whole 24 hour period. The authors reported savings of 9% for the second schedule and 36% for the third schedule of operation compared to operation without a blind. The use of the blind also led to a 4% and 11% reduction in the product temperature for the second and third schedule respectively. The authors also reported that during part load operation there was a reduction

in the compressor and variable speed drive efficiency which led to a reduction in the overall savings that could be achieved.
Clodic and Pan (2002) reported on the design of an innovative open type medium temperature display cabinet in which they considered automatic night curtain among various other features such as heat exchanger shelves, two controlled air curtains and defrosting without raising air temperature. The authors found that during day-time operation without the blind the total heat load on the cabinet was 4.46 kW. Of this, 78.9% was due to infiltration, 11.6% due to radiation and 9.5% due to conduction. During night-time operation with the automatically controlled air curtain the heat load reduced to 1.35 kW. Of this, 45.2% was due to conduction, 22.5% due to infiltration and 7% due to radiation. They concluded that the use of the night blind reduced the load on the cabinet by a factor of 3.

In a study to investigate the influence of ambient conditions, customer frequency and other operating patterns on the energy consumption of two Swedish supermarkets, Axell and Fahlen (2002) determined that the use of night blinds reduced the cooling demand by 55%. They also observed that the mean value of the measured food temperatures reduced by 3.2 K during night-time operation compared to day-time operation. The conclusion was that significant energy savings in a supermarket could be achieved by installing more efficient display cabinets with a lower degree of infiltration.

This paper reports on the results of investigations to establish the effectiveness of night-blinds on integral open display cabinets over a wide range of ambient conditions. The main motivation of the work was the fact that users of night blinds on integral cabinets in small retail outlets reported that their use did not seem to produce the energy savings specified by the suppliers of the blinds. out of 24-hour operation. The results obtained and the conclusions drawn are presented in the following sections.

LABORATORY INVESTIGATIONS

The investigations were carried out in an integral vertical display cabinet in an environmental test chamber in the laboratory. The cabinet is shown in Figure 1 and its specifications listed in Table 1.

Cabinet Description	
External l x w x h:	1285 x 730 x 1855 mm
Intended temperature classification:	H (+10/+1°C) with ± 1°C tolerance
Refrigeration System	
System Type:	Direct expansion/R-404A
Refrigerant:	R-404 A
Expansion valve:	Capillary Tube
Test Conditions	
Test room climate class:	3 (+25°C 60 %RH)
Defrost type:	Electrical with additional heater for the condensate
Defrost termination temperature:	+12°C
Defrost termination maximum time:	35 mins
Defrost setting:	6 times / 24 h
Night covers:	Yes
Number of shelves:	4 + the base
Total display volume:	640 lts

Table 1:- Cabinet Features and Settings

The cabinet was loaded according to EN441 conditions (BS EN441, 1995). M-packs which composed of 30% cellulose and 70% water and salt were used at the positions where product temperature needed to be measured as seen in Figure 2. The rest of the cabinet was loaded with water containers to provide the thermal load.

Tests were carried out at ambient air temperatures between 20°C and 35°C at constant moisture content of 11.0 g/kg (dry air). Air velocity of 0.2 m/s was maintained across the face of the cabinet during the tests. Each test duration was 24 hours. The evaporator coil air off temperature set point which controls the operation of the cabinet was set at 0°C for all tests.

Prior to every test the cabinet was allowed to operate for at least 8 hours to reach steady state conditions. Each test started with the night blind pulled down for 12 hours followed by 12 hours of no night cover. The parameters monitored were the product temperature, air on to the evaporator coil and air off the coil and refrigerant temperature after each component along with the ambient temperature and relative humidity. A power analyser was used to monitor and log the power consumption over the 24-hour test period.

Figure 1: Multideck display cabinet

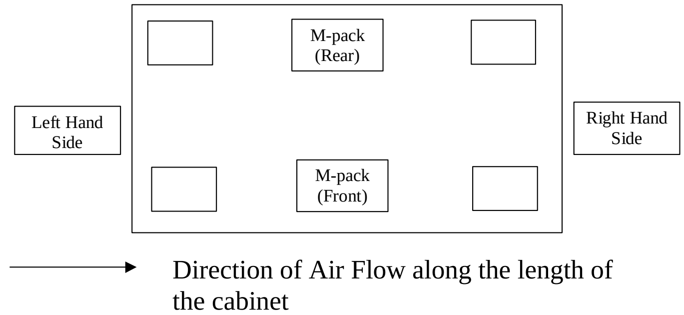


Figure 2: Plan view of the cabinet showing M-pack positions for temperature measurement

RESULTS AND ANALYSIS

Figure 3 shows the compressor power consumption for ambient temperature of $20^{o}C$. It can be seen that the power consumption of the compressor together with evaporator fans and lights is around 1.25 kW. When the condensate heater comes on to evaporate the condensate after each defrost cycle, the power consumption increases to 2.25 kW. It can also be observed that during night-time operation the compressor is able to meet the load and cycles on and off frequently. During day-time operation, the power consumption of the compressor increases by around 100 W due to the higher evaporating temperature arising from increased air infiltration and higher evaporator coil air-on temperatures. It can also be seen that the cycling rate of the compressor is a lot less frequent. Also, the condensate heater stays on almost continuously to evaporate the increased amounts of water arising for much higher infiltration rates, resulting in a significant increase in the energy consumption of the system.

The product temperatures at the ambient temperature of $20^{o}C$ are shown in Figure 4. It can be seen that during night-time operation product temperatures are maintained below $4^{o}C$

whilst during day-time operation without the blind the product temperatures on the top shelf increase to a maximum of 9°C.

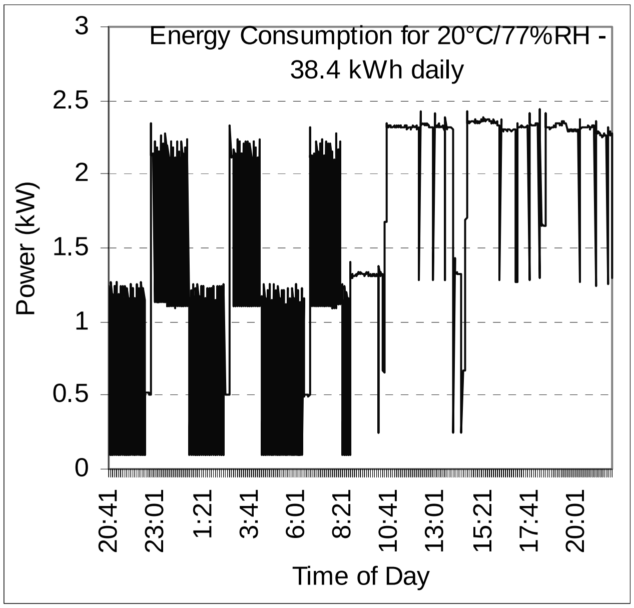


Figure 3: Power Consumption at 20°C and 77% RH with the use of blind for 12 hours followed by no blind for 12 hours

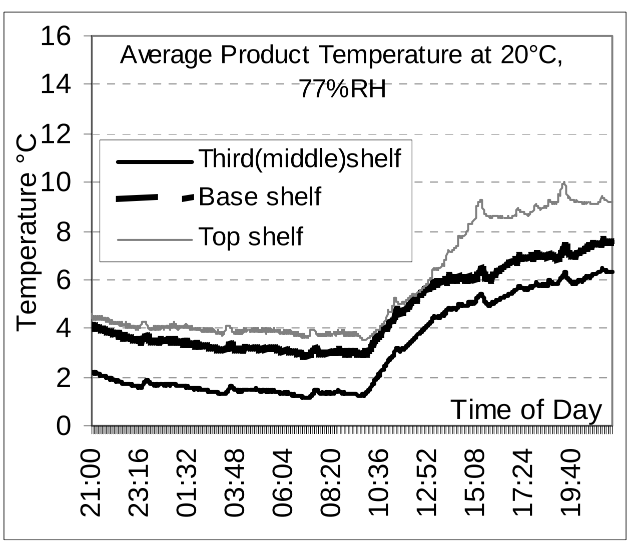
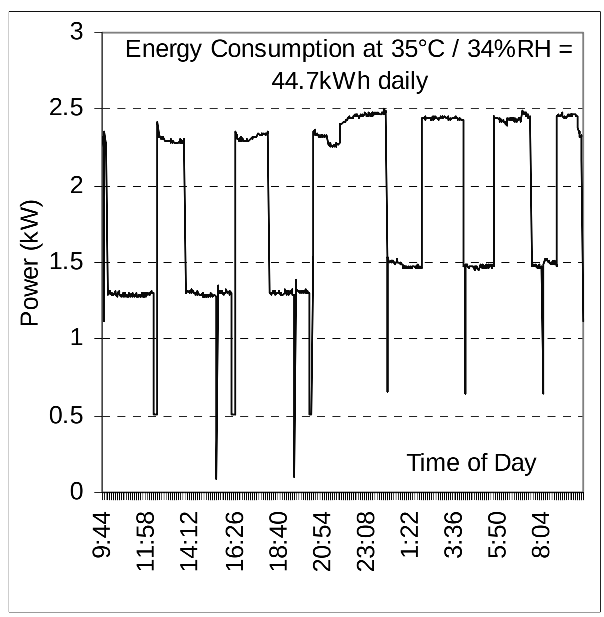


Figure 4: Product Temperature at various points at 20°C and 77% RH with the use of blind for 12 hours followed by no blind for 12 hours

Figure 5 shows the electrical power consumption of the cabinet at the ambient temperature of 35 °C. It can be seen that at this temperature, even during night-time operation, the compressor runs continuously without cycling off apart from during the defrost cycle.

Figure 6 shows a comparison between the electrical energy consumption of the cabinet over a 12 hour period with and without a night blind and with the condensate heater in operation. It can be seen that without the blind the energy consumption stays fairly constant at around 25 kWh even though one would expect the energy consumption to increase with temperature. This is due to the complex interaction between the amount of water vapour in the infiltration air, rates of condensation and frost formation on coil and energy requirement of the condensate heater to evaporate the condensate. When the blind is used, the energy consumption of the cabinet increases almost linearly with ambient temperature.

Figure 5: Power Consumption at 35°C and 34%RH with the use of blind for 12 hours



followed by no blind for 12 hours

Figure 7 depicts the energy consumption of the cabinet with and without a blind over a 12 hour period without the condensate heater in operation. This is a better reflection of the effectiveness of the blind as the results are not distorted by the energy consumption of the condensate heater.

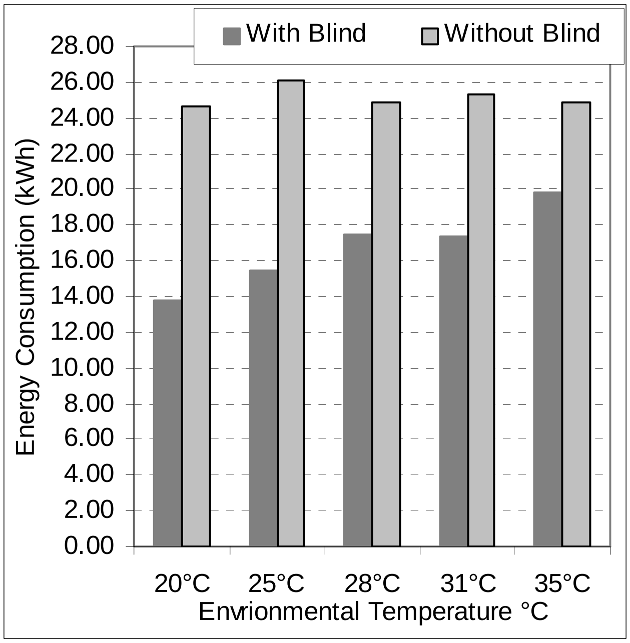


Figure 6: Energy Consumption at various conditions over a 12 hour period with condensate heater in use

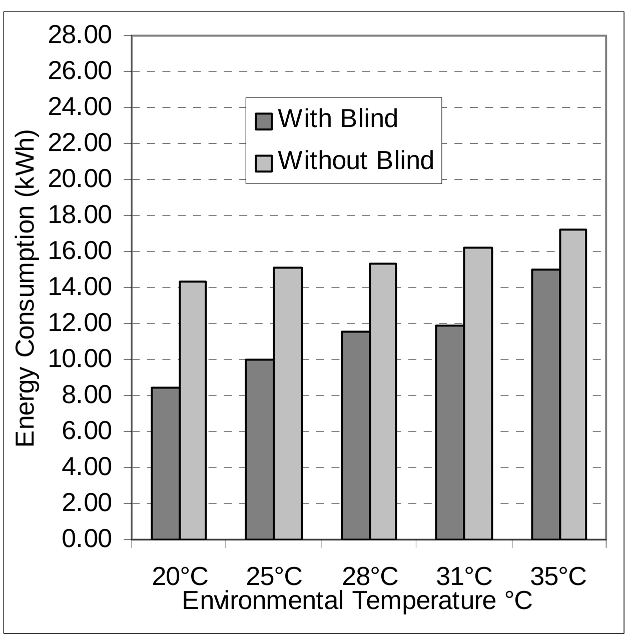


Figure 7: Energy Consumption at various conditions over a 12 hour period without condensate heater in use

It can be seen that the energy consumption of the cabinet both with and without blind increases with ambient temperature. At the ambient temperature of 20^{o}C the use of the blind results in energy savings of 42%. At 35 ^{o}C ambient the savings reduce to 13%. This reduction is due to the increase in the load of the cabinet that requires the compressor to operate continuously without cycling between evaporator coil defrosts.

The effect of night blind on energy savings for a 24 hour period of operation with the blind lowered for 12 out of the 24 hours is summarised in Table 2. It can be seen that at 20^{o}C ambient, energy savings with the condensate heater are 22.1% and reduce to 10% at 35^{o}C. Without the condensate heater energy savings at 20^{o}C are 20.6% and reduce to 6.4% at 35^{o}C. The energy savings with the condensate heater are higher than the case without the condensate heater because of the lower amount of condensate and lower energy required from the heater to evaporate the condensate when the blind was used.

Space Temperature °C	Savings with the use of night blind (%)	
	With Condensate Heater	Without Condensate Heater
20	22.1	20.6
25	20.2	16.9
28	14.9	12.2
31	15.7	13.4
35	10.0	6.4

Table 2: Energy savings arising from the use of blinds

In most commercial cabinets for ease of operation there is a gap of around 25 mm between the edges of the blind and the side walls of the cabinet. To determine the effect of this gap in reducing the effectiveness of the blind when it is lowered, a test was carried out at 25°C and 60% RH with the edges of the blind extended to the side walls providing good sealing between the refrigerated space in the cabinet and the external environment.

The energy consumption of the cabinet over a 12 hour period with the standard blind and extended blind lowered and the condensate heater in operation was 15.5 kWh and 11.7 kWh respectively. For a 24 hour operating cycle with the blind lowered for 12 hours the modification represents energy savings of 9%. The energy savings with the condensate heater not in operation were calculated to be 6%.

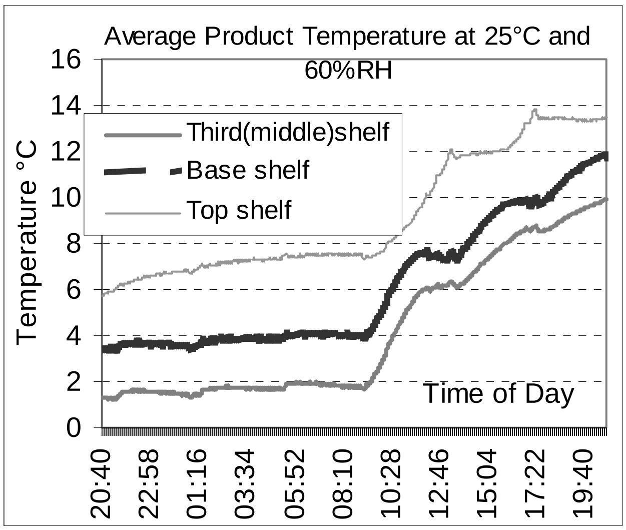


Figure 8: Product Temperature at 25°C and 60%RH with the use of standard blind for 12 hours followed by no blind for 12 hours

A comparison between the product temperatures at the same test conditions with the standard and extended blind is shown in Figures 8 and 9 respectively. It can be seen that with the extended blind, product temperatures during the night are slightly lower. Also the variation in product temperature in the cabinet is much lower with the extended blind compared to the standard blind due to the reduction of ambient air infiltration into the cabinet.

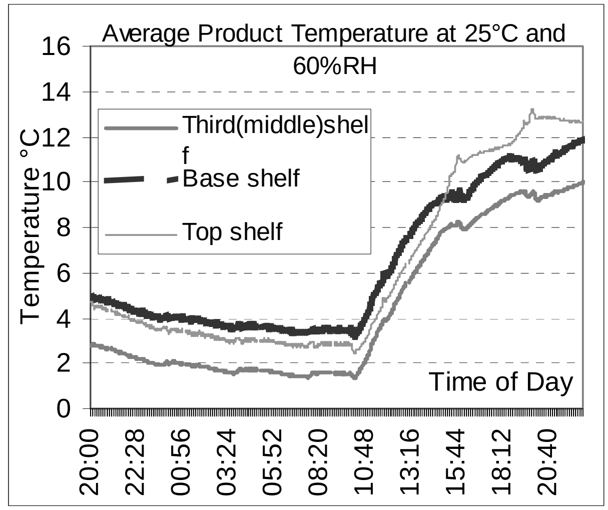


Figure 9: Product Temperature at 25°C and 60%RH with the use of extended blind for 12 hours followed by no blind for 12 hours

CONCLUSIONS

From the investigations carried out the following conclusions can be drawn:

1. The energy savings arising from the use of night blinds in refrigerated display cabinets are a function of the ambient temperature at which the cabinet operates during the night. The savings reduce as the ambient temperature increases.
2. The use of an electric condensate heater to evaporate the condensate resulting from defrosting the evaporator coil increases significantly the energy consumption of the cabinet.
3. The percentage energy savings resulting from the use of night-blinds is influenced by the energy consumption of the condensate heater. The savings increase when the heater is used but the

total energy consumption of the cabinet is also higher.

4. Depending on cabinet operating conditions pay-back periods of between 2 and 4 years can be achieved when night blinds are employed.
5. The use of night blinds reduces product temperatures during the night and improves the product temperature performance of the cabinet during day-time operation.
6. The energy performance of night-blinds can be increased by up to 10% if cabinets and blinds are designed to provide good sealing between the refrigerated space and the ambient air during night-time operation.

ACKNOWLEDGMENTS

The authors acknowledge the support of DEFRA in funding the work carried out in this project under the FoodLink programme, as well as the in-kind contributions from Safeway Stores plc, Greggs plc and Bond Retail Services Ltd.

REFERENCES

Axell M., Fahlen P. O., *Promotion of Energy Efficient Display Cabinets*, Joint International Conference of IIR D1, D2/3. Refrigerated transport storage and retail display, Cambridge, GreatBritain, 1998.

Axell M., Fahlen P. O., *Climatic Influence on Display Cabinet Performance*, Joint International Conference of IIR D1/B1. New Technologies in Commercial Refrigeration, Urbana, Illinois, USA, July 22 and 23, 2002.

Clodic D., Pan X., *Energy Balance, Temperature Dispersion in an Innovative Medium Temperature Open Type Display Case*, Joint International Conference of IIR D1/B1. New Technologies in Commercial Refrigeration, Urbana, Illinois, USA, July 22 and 23, 2002.

Faramarzi R. T., Woodworth-Szieper M. L., *Effects of Low-E Shields on the Performance and Power Use of a Refrigerated Display Case*, ASHRAE Transactions, Vol 105 (1), p533-540, 1999.