Figure 1: An open display case (a) was replaced by a new doored display case (b) at Store 1.

Doored Display Cases

They Save Energy, Don't Lose Sales

By Brian A. Fricke, Ph.D., Member ASHRAE; and **Bryan R. Becker, Ph.D., P.E.,** Fellow ASHRAE

The continual operation of supermarket refrigeration equipment accounts for approximately 50% of the total electrical energy consumption of a typical supermarket.[1] Glass-doored refrigerated display cases save energy, but do they lose sales?

Infiltration accounts for more than 70% of the refrigeration load in open refrigerated display cases.[2] Other contributions to the refrigeration load are minor in comparison and include radiation and conduction heat gain, as well as heat gain from lighting, fans, defrost and anti-sweat heaters. Therefore, reducing infiltration into open display cases will lead to a significant reduction in the overall refrigeration load, reducing overall energy consumption.

One technique to reduce infiltration is to use glass-doored refrigerated display cases. Under controlled laboratory conditions, Faramarzi, et al., found that installing glass doors on an open vertical refrigerated display case reduced the refrigeration load by 68%, resulting in an 87% reduction in compressor power demand.[3] A significant reduction in national annual energy use could be realized if the nation's supermarkets adopted the use of glass-doored refrigerated display cases.

In addition to the infiltration energy savings, glass-doored refrigerated display cases offer several other advantages. Due to the reduced refrigeration load of glass-doored cases, the medium temperature compressor rack size can be reduced by about 15%. Glass-doored cases improve food safety by reducing the wide variations in product temperatures that are observed in open cases. Doors also reduce

A technical paper based on Research Project 1402 will be published in the *2011 ASHRAE Transactions*.

About the Authors

Brian A. Fricke, Ph.D., is an assistant professor in mechanical engineering, and **Bryan R. Becker, Ph.D., P.E.,** is a professor in mechanical engineering at the University of Missouri-Kansas City.

cold air spillage into shopping aisles, resulting in increased shopper comfort, which may translate into increased sales. Furthermore, doors prevent partial cooling and dehumidification of the store by the refrigeration system, allowing the HVAC system, which operates at a higher evaporator temperature and COP, to cool and dehumidify the store more efficiently.

However, in spite of these advantages, the fear of a possible reduction in product sales prevents supermarket owners from implementing glass-doored cases.[4] Unfortunately, the available information regarding the merchandising productivity of display cases is vague and anecdotal.

A clear need exists to compare a typical open refrigerated display case to a typical glass-doored refrigerated display case. The objectives of this project were to quantify the differences in overall energy consumption and food product sales for each case type under actual operating conditions.

Test Plan

For ASHRAE/ARTI Research Project 1402,[5] two supermarkets were identified as test sites: one received a new doored refrigerated display case lineup and the other received a new open refrigerated display case lineup. The two selected test sites were large public supermarkets with footprints of approximately 25,000 ft^2 (2300 m^2), located in the Midwestern United States. The two supermarkets were similarly situated to ensure that climate, weather, time-of-year and economic conditions of the shoppers were comparable.

A "before and after" comparison of product sales was performed in each of the two stores. An existing display case lineup was identified in each store, and the sales data of the products from that display case lineup were collected for a period of approximately two months. The existing display case lineup in each store was then replaced with a new display case lineup. Each new case lineup was then stocked with the same products, in the same location within the new case, as they appeared in the old case lineup. The sales data of these products from each new display case lineup were then collected for a period of approximately two months. A comparison between sales data was made before and after installation of the new display case lineups to determine the effect that new case lineups had on product sales.

In addition, the energy use of each new display case lineup was monitored. Therefore, comparisons could be made between the energy use of a new open display case lineup versus that of a new doored display case lineup.

Display Cases and Products Studied

At Store 1, dairy products, including yogurt, prepackaged cheese, butter, and sour cream, were studied. The dairy products initially resided in a 44 ft (13.4 m) open, multideck case lineup, shown in *Figure 1a*. During the test period, the sales of dairy products were monitored for a period of two months in the original case lineup. This case was replaced with a new, medium temperature, 20-doored case lineup, nominally 48 ft (14.6 m) in length, shown in *Figure 1b*. After installation of the new case, the sales of the selected dairy products were monitored for a period of two months.

The energy consumption of a 10-doored portion of the new 20-doored case lineup was measured for a period of two months. This 10-doored portion of the case lineup was nominally 24 ft (7.3 m) in length, and contained refrigeration and electrical circuitry that was separate from the remaining 10 doors of the lineup. This was done so that a comparison of energy use could be made with the similarly sized 24 ft (7.3 m) open case lineup installed in Store 2.

At Store 1, a 12 ft (3.7 m) open, multideck case lineup merchandising beer and various alcoholic beverages (wine cool-

Figure 2: An open display case (a) was replaced by a new open display case (b) at Store 2.

ers, hard lemonade, etc.) was replaced with a six-doored case lineup (not shown). While beer and alcoholic beverages were not originally intended to be primary products studied at this supermarket, the replacement of the old open beer case lineup with a new doored beer case lineup provided an opportunity to collect beer and alcoholic beverages sales data for an old open case lineup versus a new doored case lineup.

At Store 2, beer and various alcoholic beverages (wine coolers, hard lemonade, etc.) were studied. These products initially resided in an open, multideck case lineup, nominally 24 ft (7.3 m) in length, shown in *Figure 2a* (see Page 19). During the test period, sales of beer and various alcoholic beverages were monitored for two months in the original case lineup. This original open case lineup was then replaced with a new, medium temperature, open, multi-deck case lineup, nominally 24 ft (7.3 m) in length, shown in *Figure 2b* (See Page 19). After installation of the new case, the sales of the selected products and the energy consumption of the new case were monitored for two months.

Summary of Test Configurations

The combination of old and new display case lineups at the two supermarkets resulted in the following four test configurations to be studied:

- Old open dairy case at Store 1;
- New doored dairy case at Store 1;
- Old open beer case at Store 2; and
- New open beer case at Store 2.

Furthermore, an opportunity arose to study the following two additional configurations when a new doored beer case lineup was also installed at Store 1:

- Old open beer case at Store 1; and
- New doored beer case at Store 1.

Analysis of Energy and Sales Data

Energy-related data was collected and analyzed for the two new display case lineups from April 21, 2009 through June 1, 2009. In addition, beer and dairy sales data from both stores were collected and analyzed before and after installation of the new display case lineups for the period Jan. 4, 2009 through June 6, 2009.

Analysis of Energy-Related Data

For the test period from April to June, daily energy consumption of the new open and new doored display case lineups was determined from measured energy-related data using the methodology described in ASHRAE Standard 72, *Method of Testing Commercial Refrigerators and Freezers*, and ARI Standard 1200, *Performance Rating of Commercial Refrigerated Display*

Merchandisers and Storage Cabinets.[6,7] The daily refrigerator load, Q, for the open and doored display case lineups were determined as follows:[6]

$$Q = \frac{m(h_v - h_l)}{(t - t_{dt})} \quad (1)$$

where

m = total refrigerant mass flow for a 24-hour test period
h_v = enthalpy of the refrigerant suction vapor
h_l = enthalpy of the refrigerant liquid
t = length of a test period (24 hours)
t_{dt} = total defrost period during a 24-hour test period

Electrical Energy Consumption	New Doored Display Case (Store 1)	New Open Display Case (Store 2)
Compressors (kWh/day)	11.70	42.20
Lights (kWh/day)	11.93	5.18
Fans (kWh/day)	4.58	5.69
Anti-Sweat Heaters (kWh/day)	15.50	—
Total (kWh/day)	43.72	53.07
Total (kWh/day per ft)	1.71	2.21

Table 1: Mean electrical energy consumption of the new doored and new open display case lineups calculated using ARI Standard 1200.

The mean daily refrigerator load during the 42-day test period for the new open display case lineup was 25,082 Btu/h (7.351 kW), which is significantly greater than that of the new doored display case lineup that was found to be 7,027 Btu/h (2.059 kW).

Based on the techniques given in ARI Standard 1200, the daily compressor energy consumption (CEC) for the new open and new doored display case lineups was estimated as follows:

$$\mathrm{CEC} = Q(t - t_{dt}) / (1{,}000 \times \mathrm{EER}) \quad (2)$$

where

Q = refrigerator load of the display case lineup
EER = energy efficiency ratio

As shown in *Table 1*, the average compressor energy consumption during the 42-day test period for the open display case lineup was estimated to be 42.20 kWh/day while for the

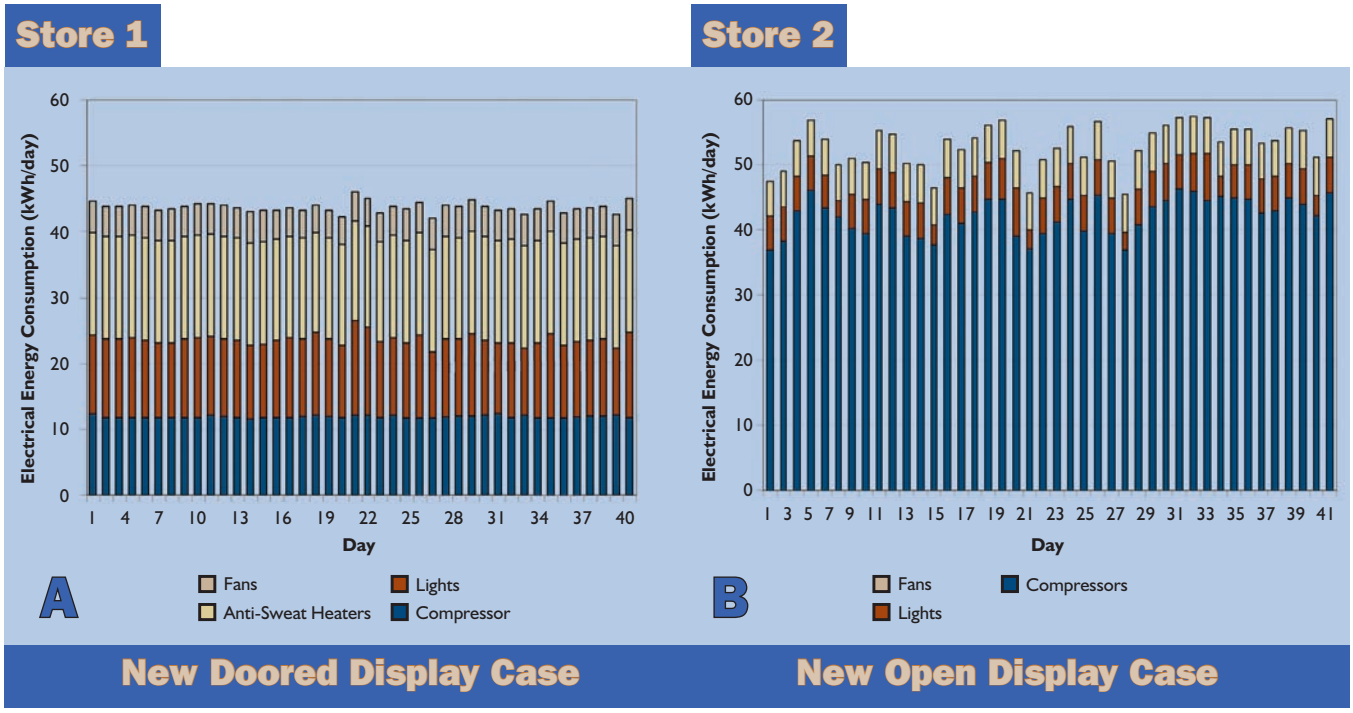

Figure 3: Daily electrical energy consumption, showing the components of the electrical load for the period 21 April 2009 through 1 June 2009, for (a) the new doored refrigerated display case lineup and (b) the new open refrigerated display case lineup in Stores 1 and 2.

doored display case lineup, the average compressor energy consumption was estimated to be 11.70 kWh/day.

The mean auxiliary electrical energy consumption, which includes fans, lighting, and anti-sweat heaters, for the open and doored display case lineups are summarized in *Table 1* (See Page 21). The mean auxiliary electrical power consumption of the doored case lineup was greater than that of the open case. The lighting, fans and anti-sweat heaters of the doored case consumed an average of 32 kWh/day. The mean auxiliary electrical power consumption of the open case, which consisted only of lighting and fan loads, was found to be 10.9 kWh/day.

Per unit length of case lineup, the total electrical energy consumption of the open display case lineup was found to be 2.21 kWh/day·ft (7.25 kWh/day·m) while the total electrical energy consumption of the doored display case lineup was found to be 1.71 kWh/day per foot (5.61 kWh/day per meter) as shown in *Table 1*. This is based upon the 25.56 ft (7.79 m) length of the 10-door lineup and the 24 ft (7.3 m) length of the open case lineup. Therefore, per unit length of case, the open display case lineup consumed approximately 1.3 times more energy than the doored display case lineup.

While the doored display case lineup had significantly less compressor energy consumption than the open display case lineup, the doored case lineup had a substantial anti-sweat heater energy consumption that the open case lineup did not have. A significant portion of the energy savings gained by reducing the display case infiltration load through the use of doors was offset by the energy requirements of the anti-sweat heaters. However, the energy consumption of the doored case lineup could be substantially reduced by using "no heat" doors and LED lighting. Assuming zero energy consumption for "no heat" doors and 265 W energy consumption for LED lighting, it is estimated that the 10-doored case lineup could consume as little as 20.5 kWh/day or 0.802 kWh/day per foot (2.63 kWh/day per meter).

For the 42-day test period, the total daily electrical energy consumption for the new doored and new open display case lineups in Stores 1 and 2 are shown in *Figures 3a* and *3b*, respectively. The electrical energy consumption of the open display case lineup exhibited significant variation from day-to-day. This variation is mainly attributed to the difference in compressor energy consumption from day-to-day. The electrical energy consumption of the doored display case lineup was relatively consistent from day-to-day, with all of the components of the electrical load remaining fairly constant.

The anti-sweat heaters were the major contributor to the total daily electrical load of the doored refrigerated display case, accounting for 36% of the energy use. The compressors and lights each accounted for 27% of the total daily electrical energy consumption, while fan energy consumption was 10% of the total for the doored display case lineup.

On average, the compressors accounted for approximately 79% of the total daily electrical energy consumption for the open refrigerated display case lineup. Fans accounted for 11% of the total daily electrical energy consumption while lighting consumed 10% of the total for the open display case lineup.

Figure 4 shows the variation in daily electrical energy consumption of the new open and new doored display case lineups versus mean daily indoor relative humidity. As the mean indoor relative humidity increased, the electrical energy consumption

of the open display case lineup increased. The open case lineup consumed approximately 1.25 times as much energy when the indoor relative humidity was 45% as compared to when the indoor relative humidity was 20%. However, for the doored display case lineup, the electrical energy consumption remained relatively constant with increasing mean indoor relative humidity.

Analysis of Sales Data

The mean and standard deviation of the weekly beer sales before and after installation of the new doored and new open display case lineups are summarized in *Table 2*. Recall that both supermarkets received new beer case lineups. Store 1 received a new doored display case lineup that replaced an old open display case lineup. Store 2 received a new open display case lineup that replaced an old open display case lineup.

Table 2 shows the average weekly quantity of beer products sold increased after the installation of both the new doored and new open display case lineups. Beer sales increased by 27% in the new doored display case lineup at Store 1, from 55.4 units per week in the old open case lineup to 70.5 units per week in the new doored case lineup. And, beer sales increased by 29% in the new open display case lineup at Store 2, from 104.4 units per week in the old open case lineup to 134.6 units per week in the new open case lineup. Statistically, it was found that these increases in sales were significant ($\alpha = 0.05$). Since the rate of increase in beer sales was essentially the same for the new doored and new open display case lineups, the data shows that "doored versus open" had no effect on product sales.

The mean and standard deviation of the weekly dairy sales before and after installation of the new doored display case lineup are summarized in *Table 3*. Recall that Store 1 received a new doored dairy case lineup that replaced an old open dairy case lineup while the open dairy case lineup at Store 2 remained the same during the test period.

Table 3 shows that before and after the installation of the new doored display case lineup, the average weekly quantity of dairy products sold remained the same in both supermarkets. Statistically, it was found that there was no significant difference ($\alpha = 0.05$) in dairy product sales in either store before and after installation of the new doored display case lineup in Store 1. Since the rate of dairy sales remained essentially the same in both stores before and after the installation of the new doored display case lineup, the data shows that "doored versus open" had no effect on product sales.

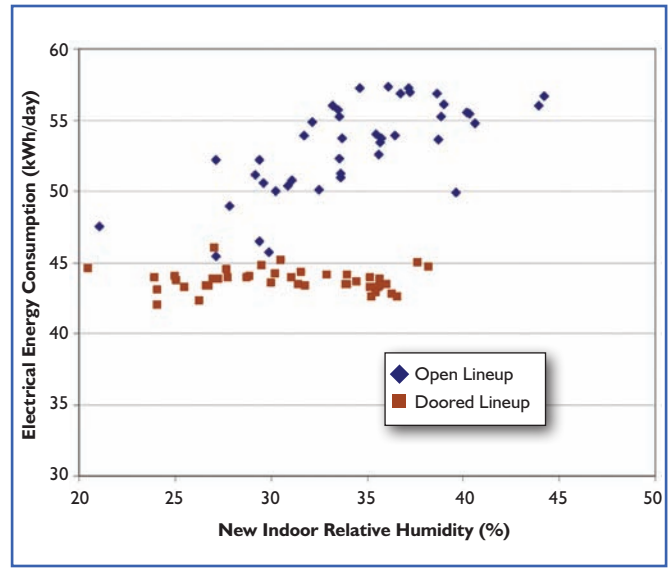

Figure 4: Variation in electrical energy consumption vs. mean indoor relative humidity for the new open and new doored display case lineups.

Beer Sales Statistics	New Doored Display Case Lineup (Store 1)	New Open Display Case Lineup (Store 2)
Mean Weekly Quantity Sold, Pre-Installation	55.4	104.4
Standard Deviation of Weekly Quantity Sold, Pre-Installation	10.6	9.26
Mean Weekly Quantity Sold, Post-Installation	70.5	134.6
Standard Deviation of Weekly Quantity Sold, Post-Installation	11.1	26.7
Percentage Increase	27%	29%

Table 2: Summary of weekly beer sales during pre-installation and post-installation of the new doored and new open display case lineup.

Dairy Sales Statistics	New Doored Display Case Lineup (Store 1)	Old Open Display Case Lineup (Control) (Store 2)
Mean Weekly Quantity Sold, Pre-Installation	639.4	3,864
Standard Deviation of Weekly Quantity Sold, Pre-Installation	41.3	403.6
Mean Weekly Quantity Sold, Post-Installation	621.5	3,846
Standard Deviation of Weekly Quantity Sold, Post-Installation	152.2	464.5
Percentage Increase	–2.8%	–0.47%

Table 3: Summary of weekly dairy sales during pre-installation and post-installation of the new doored display case lineup.

Advertisement formerly in this space.

Conclusion

This project compared a typical open refrigerated display case lineup to a typical glass-doored refrigerated display case lineup with the aim of quantifying the differences in overall energy consumption and food product sales for each case type.

Two supermarkets were identified as test sites: one received a new doored refrigerated display case lineup and the other received a new open refrigerated display case lineup. Product sales before and after installation of each new display case lineup were analyzed and the energy use of each new display case lineup was monitored.

Per unit length of case lineup, the open display case lineup consumed approximately 1.3 times more energy than the doored display case lineup. While the doored display case lineup had significantly less compressor energy consumption than the open display case lineup, the doored case lineup had a substantial anti-sweat heater energy consumption that the open case lineup did not have.

It was found that as the mean indoor relative humidity increased, the electrical energy consumption of the open display case lineup increased. However, for the doored display case lineup, the electrical energy consumption remained relatively constant regardless of changes in mean indoor relative humidity.

Beer sales increased by 27% after installation of the new doored display case lineup at Store 1 and increased by 29% after installation of the new open display case lineup at Store 2. Since the rate of increase in beer sales was essentially the same for the new doored and new open display case lineups, the data shows that "doored versus open" had no effect on product sales.

Before and after the installation of the new doored display case lineup in Store 1, the average weekly quantity of dairy products sold remained the same in Store 1 and Store 2 (control). Since the rate of dairy sales remained essentially the same in both stores before and after the installation of the new doored display case lineup, the data shows that "doored versus open" had no effect on product sales.

References

1. Westphalen, D., R.A. Zogg, A.F. Varone, and M.A. Foran. 1996. "Energy Savings Potential for Commercial Refrigeration Equipment." Washington, D.C.: Building Equipment Division, Office of Building Technologies, U.S. Department of Energy.

2. Faramarzi, R. 1999. "Efficient display case refrigeration." *ASHRAE Journal* 41(11):46–54.

3. Faramarzi, R.T., B.A. Coburn, and R. Sarhadian. 2002. "Performance and energy impact of installing glass doors on an open vertical deli/dairy display case." *ASHRAE Transactions* 108(1):673–679.

4. Walker, D.H., R.T. Faramarzi, and V.D. Baxter. 2004. "Investigation of Energy-Efficient Display Cases." Oak Ridge, Tenn.: Oak Ridge National Laboratory.

5. Fricke, B., B. Becker. 2009. "Final Report of RP-1402: Comparison of Vertical Display Cases: Energy and Productivity Impacts of Glass Doors Versus Open Vertical Display Cases." www.ashrae.org/research.

6. ANSI/ASHRAE Standard 72-2005, *Method of Testing Commercial Refrigerators and Freezers*.

7. ANSI/ARI Standard 1200-2006, *Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets*.