Proven Energy-Saving Technologies for Commercial Properties

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Chapter 10. High-Performance Refrigeration Cases

10.1 Description

Grocery stores use a significant amount of refrigeration equipment, including compressors, condensers, display cases, walk-in coolers, and walk-in freezers. This equipment accounts for about 60% of grocery store electricity consumption. Because of this high electricity demand, a typical grocery store's average energy costs are higher than almost all other building types at $4/ft^2 (Bendewald 2013).

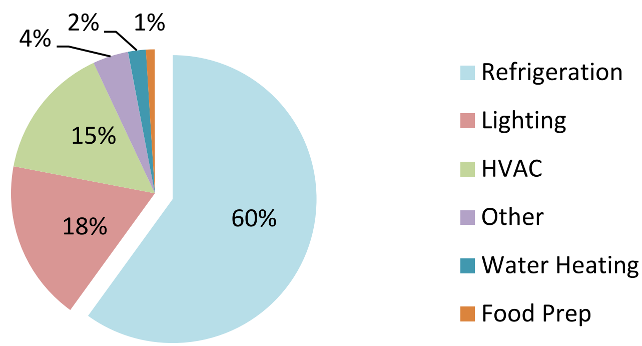

Figure 36. Electricity consumption by end use in a typical grocery store

(Source: Bendewald 2013)

Several technologies can be applied to refrigerator display cases to improve their energy performance, including:

- LEDs
- Electronically commutated motors (ECMs) for evaporator fans
- Anti-sweat heater controls
- Permanent doors on open dairy, deli, and beverage cases
- Night curtains for meat and produce open cases.

Although the information contained in this chapter pertains specifically to refrigerated display cases, many of these EEMs can also be applied to walk-in coolers and freezers.

Energy savings from high-performance refrigerator display cases vary depending on the temperature of the cases. Because low-temperature (LT) cases have a larger cooling load, any EEM that reduces the heat produced inside the cases, such as turning off anti-sweat heaters or reducing lighting and motor power, saves more energy than similar EEMs applied to medium-temperature (MT) cases. Additionally, replacing shaded pole (SP) motors with ECMs will result in greater energy savings than replacing permanent split capacitor (PSC) motors with ECMs. Table 24 shows typical costs and savings[39] for EEMs on refrigerated display cases. The data are presented per linear foot of display case.

[39] The cost savings are based on national average rates of $0.112/kWh, and $0.8/therm.

Table 24. High-Performance Refrigeration Cases Typical Annual Energy and Cost Savings

		Decrease Anti-Sweat Heater Usage		Close Open Cases		EC Motors		LED Fixtures	
Parameter Name	**Unit**	**MT Cases**	**LT Cases**	**Night Curtain**	**Permanent Door**	**Compared to PSC Motors**	**Compared to SP Motors**	**MT Cases**	**LT Cases**
Electricity saved	kWh/ft	57	206	315	1,708	33	189	112	190
Gas saved	therms/ft	0	0	0	0	0	0	0	0
Reduction in EUI	kBtu/ft^2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Utility bill savings	$/ft	$6	$23	$35	$191	$4	$21	$13	$21
Typical capital cost	$/ft	$25	$25	$30	$0 (NC) $600 (retrofit)[40]	$20	$46	$63	$63
Typical simple payback	years	3.9	1.1	0.9	0 (NC) 3.1 (retrofit)[40]	5.4	2.2	5	3
Capital cost 5-year payback	$/ft	$32	$115	$176	$956	$18	$106	63	106
Target incentive	$/ft	N/A	N/A	N/A	N/A	$1.5	N/A	N/A	N/A

Sources: (Tobin, 2006); (Friedrich, 2011) (Navigant Consulting, 2013)

[40] The "permanent door" column shows two typical capital costs and paybacks because the costs are different for new construction or retrofit projects when adding doors to MT open display cases. The two numbers in these fields are for new construction and retrofit applications, respectively.

10.2 Components of High-Performance Refrigeration Cases

Figure 37 illustrates three strategies for reducing energy consumption of refrigerated display cases: anti-sweat heater controls, ECMs, and LEDs.

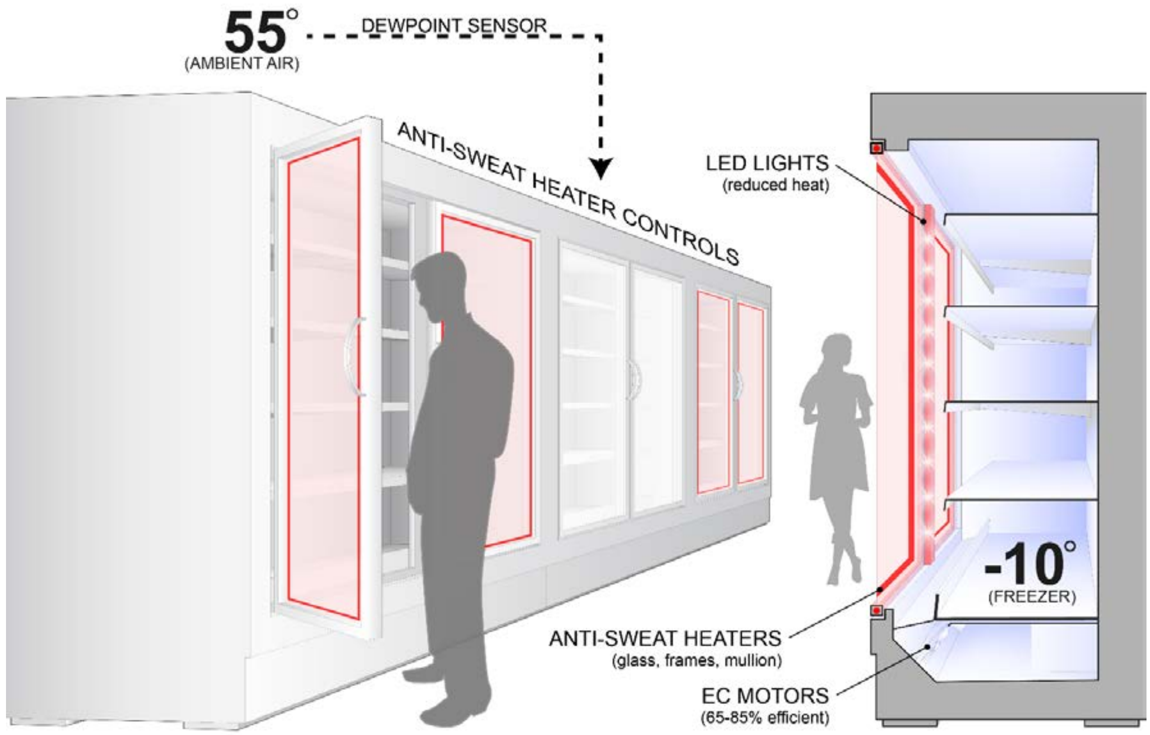

Figure 37. Components in high-performance display cases

(Courtesy Jason Sippel, Energy Center of Wisconsin)

10.2.1 Anti-Sweat Heater Controls

Anti-sweat heaters ensure that case doors remain fog and frost free. This allows customers to see the products, prevents puddles in front of the doors, stops the doors from freezing shut, and prevents moisture from forming inside the frame. Anti-sweat heaters help maintain sales, ensure safety, and reduce the need for door replacements. They are typically installed in the door and frame for LT cases and in the frame for MT cases. Most anti-sweat heaters operate 100% of the time, regardless of whether they are needed, resulting in unnecessary electricity consumption by the heaters and additional heating of the display cases that must be cooled by the refrigeration equipment.

The two approaches to reducing the energy used by anti-sweat heaters are: (1) installing anti-sweat heater controls; and (2) replacing doors with low-energy doors. Anti-sweat heater controls modulate the door anti-sweat heater power based on need. The frame anti-sweat heater typically does not modulate. Preventing the heaters from running all the time reduces the amount of energy powering the heater, but also allows the refrigeration system to work less because less heat is transferred to the case. Figure 37 shows anti-sweat heaters controlled using a dew point sensor, but these can also be controlled using relative humidity and conductivity sensors. Humidity-based controls measure the relative humidity in the air just outside the display case, and conductivity-based controls measure the ambient dew point relative to the temperature of the inner glass pane. These controls reduce anti-sweat heater energy use in MT cases by approximately 74% and by 46% for LT cases (Bendewald 2013). On average, conductivity-based controls using a dew point sensor typically reduce anti-sweat heater energy by 15% more than humidity based controls (SAG 2014). Although anti-sweat heater controls may be available based on relative humidity, dew point control provides better control and is the direction the industry is headed.

High-performance refrigeration display cases have either no-energy doors or low-energy doors with anti-sweat heater controls. Installing low- or no-energy doors on MT and LT cases significantly reduces or completely eliminates the need for anti-sweat heaters on the glass. The frame heat is reduced but not eliminated, ensuring the gaskets remain malleable and condensation does not form on the framing.

In humid climates, using a desiccant dehumidifier to reduce store relative humidity can also reduce the need for long anti-sweat heater runtimes.

10.2.2 Electronically Commutated Evaporator Fan Motors

ECMs use less electrical energy than either PSC or SP motors. In general ECMs are 65%–80% efficient compared to 50%–60% for PSC and 18% for SP motors (Wellington 2014). They also save cooling energy because they reduce the amount of waste heat that is added to the refrigerator case. Improved evaporator fan motors provide significant savings because they never turn off for MT cases and turn off only during defrost cycles (approximately 1 hour per day) for LT cases.

10.2.3 Light-Emitting Diodes

LED fixtures are particularly well suited for refrigerated display cases because they produce less heat than typical fluorescent lights, thus reducing the refrigeration load. Also, unlike fluorescent lights, LED performance does not degrade in cold environments. LED fixtures can be controlled using an occupancy sensor. Although most refrigerated display case lighting is programmed to turn off when the store closes, occupancy sensors can also shut off refrigerator display case lighting when the store has low occupancy and activate it when a shopper approaches the refrigerated aisles.

> While participating in the CBP program, the DeCA Lackland project team learned that when LED fixtures replace fluorescent lights in display cases in a retrofit situation, the anti-sweat heaters have to work harder because less heat is created by the lights. Overall energy savings still increase.

10.2.4 Doors or Night Curtains on Open Cases

Certain types of display cases are often left open to the warm store environment. This results in significant infiltration heat gains, increasing energy consumption. Closing open cases with night curtains or by installing doors saves considerable energy. Night curtains can either manually or automatically cover open cases when the store is closed. Automatic night curtains have a higher first cost but manual night curtains must be pulled down manually once the store closes, which is an added operational cost. Also, manual night curtains are less likely to be closed for most a store’s nonoperating hours. Night curtains reduce refrigeration load by approximately 12% and compressor power consumption by 9% (Bendewald 2013). Figure 38 depicts the benefits of night curtains. With a night curtain in place, cool refrigerated air recirculates in the case instead of escaping into the warm environment. When deploying night curtains, the defrost frequency and duration should be reduced.

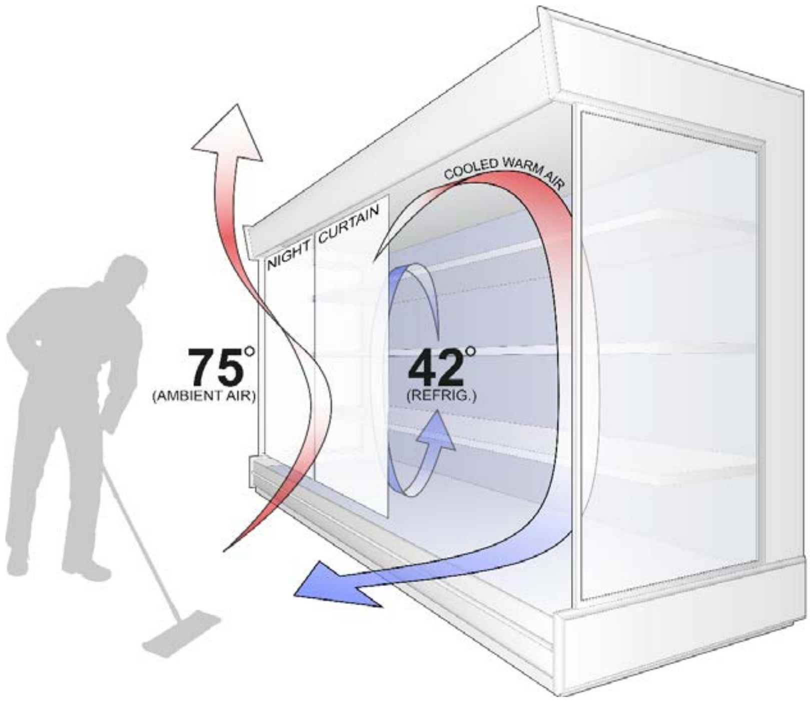

Figure 38. Night curtains keep cool air in the case.

(Courtesy Jason Sippel, Energy Center of Wisconsin)

A more permanent solution that greatly reduces energy use is to install doors on open cases. Although this is more cost intensive than manual night curtains, doors are more effective because the open cases are closed at all times, except when a customer opens them or they are being stocked. Adding doors to open cases reduces the refrigeration load on the case by approximately 65%, which lowers power consumption of the compressor by 87% (Bendewald 2013). Door retrofits add cost to a project; however, new closed cases are typically similar in price to open cases such that there is no cost premium.

10.3 Real-World Considerations

10.3.1 Anti-Sweat Heater Control

Anti-sweat heater controls can increase the amount of time required for fog to fade off the doors when doors are opened. However, when implemented properly, these controls can ensure that fog is mitigated and energy savings realized. Savings from anti-sweat heaters also vary based on climate. In dry areas, such as Colorado, anti-sweat heater controls have greater savings because the relative humidity is naturally lower in the store. In humid regions, savings are lower.

10.3.2 Night Curtain and Permanent Doors

Beyond energy savings, permanent doors on open cases contribute to occupant comfort by preventing cold air from spilling into the aisles. This EEM also reduces the temperature variation in open cases, resulting in higher product quality and uniformity. Concern that closed cases will minimize impulse purchases and negatively influence sales is the main reason given for not installing doors on open cases. Supermarkets have very low profit margins, so much so that often store owners reject any EEM that might negatively influence sales, even if it has an acceptable payback period. Although utility cost savings associated with energy directly add to a supermarket's profit, more store owners are likely to choose night curtains over doors, so cases remain open while customers are in the store.

The refrigeration design team for DeCA Lackland concluded that adding doors to open display cases makes the store look cleaner and more organized and that the retrofitted open cases resemble new display cases. This design team has also worked with supermarket managers who did not want to install doors because of the concern about sales. Stores such as Whole Foods Market tend to be more concerned about adding doors to their open cases, because their product displays are part of the shopping experience and are designed to entice shoppers to buy products they may not have on their shopping lists. However, Whole Foods Market, a Commercial Building Partner, is also putting doors on previously open refrigerated cases.

A recent study tested the assumption that cases with doors reduce sales. In this study, two large supermarkets located in the midwestern United States received new display cases. One store received a new display case with doors that replaced an old open case. The second store received a new open display case that replaced an old open display case. The same products were kept in the new display cases and they were arranged in the same manner. Sales increased by 27% in the store with the new case with doors and 29% in the store with the new open case. Both stores saw a significant increase in sales, but an insignificant difference based on whether the case was open or closed (Becker 2010).

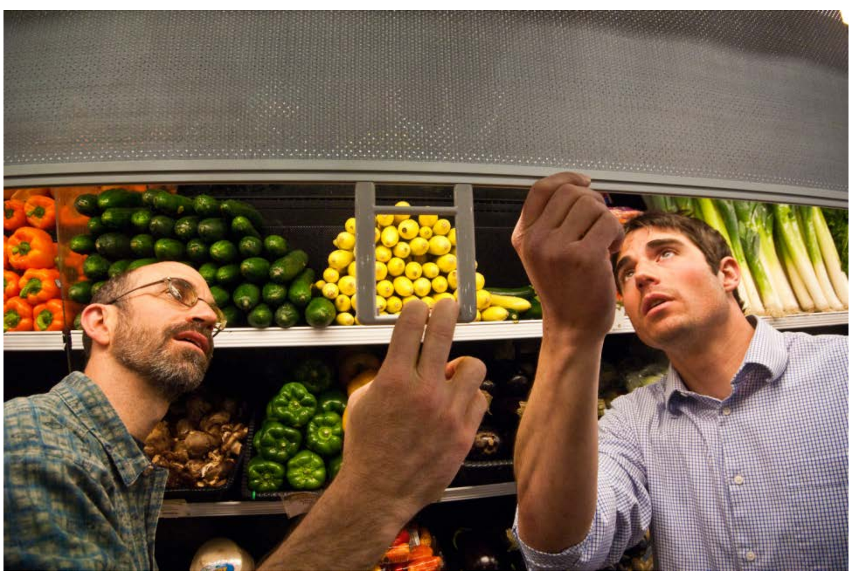

Figure 39. Night curtains cover a refrigerated produce case

(Pat Corkery, NREL)

10.3.3 Code Requirements

Energy codes are beginning to address refrigerator display cases for the first time. ASHRAE 90.1-2013 requires refrigerator display cases to:

- Install anti-sweat heater control (either humidity or condensation control are acceptable).
- Terminate the defrost cycle in LT cases using a temperature sensor instead of a time limit default.
- Either:
    - Automatically shut off display case lights during nonbusiness hours OR
    - Install motion sensors on each display case that reduces light level by at least 50% after 3 minutes of vacancy.

Refrigerated display case lighting power allowances, evaporator fan type, and night curtains are not discussed in ASHRAE 90.1-2013. However, the maximum daily energy consumption of different types of reach-in refrigerated display cases is specified for the whole case, based on total display area or volume, in Table 6.1.1-13 of 90.1-2013, taken from the Code of Federal Regulations (DOE 2012).

10.4 Financial Incentives

Many state and utility energy efficiency programs provide incentives for retrofitting or replacing commercial refrigeration equipment. Incentives provided by energy efficiency programs include:

New York State Energy Research and Development Authority Existing Facilities Program

- Controls on existing anti-sweat heater—$100/unit
- Night curtains for open coolers—$3/linear ft
- ECMs—$85/motor.

Wisconsin Focus on Energy

- Anti-sweat heater controls—$40/door
- Efficient reach-in case doors—$50 or $100/door for freezers; $10/door for coolers
- LED case lighting—$25/door for LED fixtures only, $35/door for LEDs with occupancy controls
- Night curtains for open coolers—$9/linear ft
- ECMs—$30/motor.

Pacific Gas & Electric Company

- Anti-sweat heater controls—$25/linear ft
- Efficient doors—$100/door
- Night curtains for open coolers—$3.50/linear ft
- ECMs—$35/motor.

10.5 Project Results

10.5.1 Walmart Supercenter Retrofit

Walmart received technical assistance from the CBP program on a retrofit supercenter store in Centennial, Colorado. The goal was to deploy and document strategies to reduce energy consumption by 30% compared to ASHRAE 90.1-2007 code baseline while maintaining customer satisfaction and keeping the store operational during the retrofit work. The retrofit consisted of improvements to lighting, HVAC, refrigeration, and plug loads. This section focuses on the upgrades Walmart made to its refrigeration system (Table 25). Savings are based on comparing calibrated pre- and post-retrofit energy models.

Table 25. Refrigeration System for Centennial Walmart Supercenter

Project	Walmart Supercenter, Centennial, Colorado
Building size	213,000 ft^2
High performance refrigeration cases	Repair and upgrade existing anti-sweat heater control panel. Retrofit existing MT dairy, deli, and beer cases to include glass case doors. Install ECM evaporator fans to walk-in freezers and coolers.
Expected annual energy savings	Anti-sweat controls: 123,500 kWh; 400 therm increase Door retrofit: 68,557 kWh; 12,720 therms EEM evaporator fans: 41,923 kWh Total: 133,980 kWh; 12,320 therms
Expected annual energy cost savings	Anti-sweat controls: $10,300 Door retrofit: $14,174 EEM evaporator fan: $3,141 Total: $27,615
Reduction in EUI (kBtu/ft^2)	4 kBtu/ft^2
Simple payback	3-5 years
Annual carbon emissions avoided	172 metric tons CO_{2e}[41]

10.5.2 Lackland Air Force Base

Lackland Air Force Base near San Antonio, Texas, has embarked on a renovation of its commissary, a supermarket managed by DeCA. The CBP program provided technical assistance to DeCA during the design process to analyze EEMs that could be incorporated into the renovation, which will include replacing the refrigeration system and HVAC equipment that was reaching the end of its life. DeCA chose to fully replace its old display cases with new display cases. Specifically, DeCA incorporated doors on MT display cases, night curtains on open cases, ECMs on evaporator fans, and LED case fixtures. The following are modeled savings estimates.

[41] Greenhouse gas reductions are given in terms of CO_2e. For electricity, 0.000692 metric tons CO_2e/kWh are assumed to be avoided. For natural gas, 0.006418 metric tons CO_2e/therm are assumed to be avoided. Further, no refrigerant leakage contribution is assumed.

Table 26. Case Doors for Lackland Air Force Base Commissary Renovation

Project	Commissary renovation
Building size	123,710 ft^2
Project description	DeCa Lackland is an existing building in San Antonio, Texas. The goal was to upgrade the building to achieve 30% energy savings above ASHRAE 90.1 2007 minimum requirements.
EEM description	Includes case doors on MT dairy, deli, and beverage display cases, manual night curtains on all remaining open cases, ECM evaporator fans, and LED fixtures.
Expected annual energy savings	Case doors: 247,522 kWh Night curtains: 80,550 kWh ECM evaporator fans: 179,172 kWh LED fixtures:138,282 Total: 645,533 kWh
Expected annual energy cost savings	Case doors: $15,346 Night curtains: $4,995 ECM evaporator fans: $11,109 LED fixtures: $8,573 Total: $40,023
EEM cost	Case doors: $12,600 Night curtains: $13,750 ECM evaporator fans: $38,200 LED fixtures: $68,100 Total cost:$132,650
Reduction in EUI (kBtu/ft^2)	17.8 kBtu/ft^2
Simple payback	3.3 years
Annual carbon emissions avoided	446.7 metric tons CO_{2e}[41]

10.6 Modeling High-Performance Refrigerated Display Cases

Energy modeling of refrigerated display cases can be challenging. Without detailed refrigeration case technical specifications, many of the important inputs are difficult to know. Typically, power is determined per door in a closed case and per linear foot of refrigerated display case in an open case. Inputs are fairly standard depending on case types.

An additional complexity is that refrigerated display cases interact with the HVAC system of the space they occupy. Although refrigerated display cases can help HVAC systems by reducing their cooling loads, they do so at a lower efficiency. Whether or not refrigeration EEMs are considered, display cases and their interactions with the HVAC system must be modeled accurately. Guidance for modeling display cases in EnergyPlus is provided in Appendix B.

10.6.1 OpenStudio Guidance

Refrigerated display cases are fully supported in OpenStudio, along with a full set of objects to describe a complete refrigeration system in great detail. A default object is available to help start modeling cases, though it does not incorporate high-performance features. The EnergyPlus guidance in Appendix B can then be followed to adjusting the detailed inputs to simulate more efficient equipment.

10.7 Ensuring Performance

10.7.1 Installation

The display case manufacturer (for new construction) or the refrigeration technician (for retrofit applications) is responsible to ensure the performance of EEMs that reduce energy use in refrigerated display cases

10.7.1.1 New Construction

The display case manufacturer provides energy efficiency options such as LED fixtures, ECMs, anti-sweat heater controls, doors, and night curtains in new products. The display case is shipped as a single unit.

10.7.1.2 Existing Buildings

The refrigeration technician needs to:

- Adjust the expansion valve in the case of a door retrofit to allow for higher evaporator temperature and maintain the proper case and product operating temperatures.
- Define the basis for controlling an anti-sweat heater—relative humidity or dew point temperature—that determines the set point and controller output (Royal 2013).
- Identify sensor placement and determine whether (and how) they will be monitored for failure.
    - If an anti-sweat heater is controlled by a dew point sensor, place the sensor outside the case.
    - Place the dew point sensor near the top of the case, so cold air from the case does not affect the reading.
    - Avoid placing the sensor in a wet or dirty area, and keep it away from a heat source or direct path of HVAC returns.
    - Place the door frame temperature sensor in the bottom horizontal section of the door frame in the center door in the case, because this is typically the coldest place (Emerson 2010). For maximum savings, each case should have its own anti-sweat heater control with set points adjusted to case temperature.
- Update the design documents to account for any changes.

10.8 Commissioning

See Chapter 1 for information about the general commissioning process.

Refrigerated display case equipment is not commonly commissioned, but this should be included in the project and carried out through the first year of operation.

The commissioning agent or facility manager verifies that the anti-sweat heater controls are functioning properly (taken from Royal 2013):

1. Anti-sweat heater sensors drift and are often out of calibration. Verify the sensors are reading the correct values by using an independent sensor and document the ambient temperature and relative humidity to make sure they are within the design conditions.
2. Turn the heater off using the controller and verify that this did not affect the lights or fans.
3. Verify the controller output matches the output specified in the basis of design at each set point.
4. Confirm that the control strategy removes frost from door by turning the anti-sweat heater on for an hour and checking to see that there is no frost on the door.

The commissioning agent or facility manager verifies that doors and night curtains are working properly.

1. Check that the doors close and seal properly.
2. Ensure that night curtains were installed where specified and are not damaged.
3. Inspect the interior of a refrigerated display case for ice formation as its presence could indicate air leakage (Royal 2013).

10.8.1 Controls Programming

The commissioning agent or contractor is responsible to program the anti-sweat heater controls.

- Program the anti-sweat heater with respect to the store's design dry bulb temperature and relative humidity. If the design dry bulb temperature or relative humidity changes, recalibrate the anti-sweat heaters.
- Anti-sweat heaters can be controlled via:
    - **Relative humidity controller.** If the relative humidity of the air outside the display case is low, the need for anti-sweat heaters is diminished. Relative humidity sensors measure the relative humidity and turn the anti-sweat heaters down or off at low relative humidity. Typically the anti-sweat heaters are programmed to run at maximum power when the relative humidity exceeds 55% and turn off when the relative humidity is below 35%. When the relative humidity is between these values, it should modulate on and off proportionately to the relative humidity (Coburn 2000). These relative humidity set points should be evaluated and tested for each anti-sweat heater application.
    - **Condensate controller.** If the case door temperature is below the dew point of the store, condensation will occur. A dew point sensor measures the dew point of the surrounding air and a temperature sensor measures the temperature of the door frame. Condensate controllers are programmed to ensure the case door is constantly hotter than the dew point. To determine the appropriate offset between the door temperature and the dew point, experimentation should be done. The lower the offset, the higher the energy savings. Begin with a low offset and increase the offset until good performance is achieved (CPC 2005).

10.8.2 Operation

Maintenance staff is responsible to:

- Clean and calibrate humidity or dew point temperature sensors that control anti-sweat heaters.
- Check the display cases for proper door operation and sealing.
- Keep all door gaskets clean and functional.
- Check the case temperature settings.
- Check the refrigerant charge regularly.
- Clean the fan blades annually.
- Clean the condenser and evaporator coils.
- Put night curtains down when the store closes.

10.8.3 Occupant Behavior

Few occupant behaviors affect the performance of high-performance refrigerated display cases. Becker (2010) demonstrated that doors on refrigerator display cases did not significantly impact product sales.

10.9 Measurement and Verification

Measuring and verifying achieved energy savings are integral to reducing energy use in buildings. (See Chapter 1 for information about the general M&V process.) Because refrigerated display cases are relatively isolated from other building systems, an isolated metering approach is often used to verify refrigerator display case energy savings. However, because these cases can affect HVAC energy consumption, a more accurate, but more expensive, approach would also include whole-building calibrated simulation.

10.9.1 Recommended Monitoring Points

Developing an M&V plan for refrigerator display cases involves specifying measurements at the most disaggregated level allowed for in the budget. For example, if multiple display cases are of the same type, only a few need to be metered. Understanding the energy consumption of high-performance display cases involves evaporator and condenser fans, display lighting, anti-sweat heater, and compressor power. Because refrigerated display cases are typically on their own electrical circuits, the circuits associated with the above end uses may be monitored to simplify the process.

10.9.2 Inexpensive, but Less Accurate, Approach

This approach involves continuously measuring electrical current throughout the M&V period by installing current transducers on electrical circuits serving display cases. The voltage and power factor of these circuits should be spot checked during installation, and occasionally thereafter, to confirm their values. Electric power and energy may then be calculated from the measured current, as well as spot (one-time) measurements of voltage and power factor.

10.9.3 More Complex and Expensive, but Accurate Approach

This approach involves continously measuring real electrical power permanently by installing power meters on individual electrical circuits serving display cases. This method is more costly and more accurate, because it accounts for the full waveforms of the electrical power. Real power meters should meet the following criteria:

- Sampling interval of 30 seconds
- Designed for the type of circuit to be metered (e.g., 208 Volt, 20 amp, 60 Hertz)
- Ability to accurately meter loads; rated to meet the load per phase (e.g., 0–3600 Watts)
- Internal clock that timestamps each data point
- UL listing
- Compatibility with the BAS.

Adding night curtains or permanent doors to open display cases is a more complicated EEM to quantify, because the energy savings results from reduced refrigeration energy to cool the display cases, as well as reduced HVAC load to condition the space. Thus, an energy model should be used to accurately portray these savings. The accuracy of the energy model would benefit from measuring the compressor and condenser fan power. If measuring both is too expensive, the compressor power more accurately portrays the reduction in refrigerator load.

10.9.4 Guidance for Analysis

Metered data accumulate quickly, and simply collecting data does not provide facility managers the information needed to identify and correct performance issues. A method of managing and analyzing the data is essential to complete the M&V process. (See Chapter 1 for more information about data management for M&V efforts.)

Analyzing the data to verify energy savings involves different approaches for existing and new construction projects.

10.9.4.1 Existing Buildings

For existing buildings, energy performance both before and after installing high-performance refrigerated display cases may be measured explicitly. The energy from both periods is then normalized by factors that affect their performance, such as changes in the number or type of display cases or building occupancy. Changes in building occupancy could be measured using grocery sales. Once normalized, the energy savings from this strategy is determined by taking the difference between energy consumption both before and after the strategy was initiated.

10.9.4.2 New Construction

For new construction projects, the energy savings calculation is less clearly defined, because no measured baseline data are available for comparison. Calculations can be used to approximate the theoretical energy consumption of a baseline case versus the measured case. This calculation would be difficult, because refrigerated display case energy is interactive and clear refrigeration baseline requirements are just beginning to be defined in the ASHRAE 90.1 2013 energy code, which is not yet widely implemented. An energy model, whether a simple spreadsheet or complex whole building approach, would need to be created that reflected a baseline with T8 lights, anti-sweat heaters with no controls, and SP motors. In the baseline case, MT display cases would not have doors or night curtains. Another source of baseline information is any existing facilities or operations that the building owner or tenant has (generally for new construction the occupants will be moving or expanding from existing facilities). The refrigeration energy of these facilities can be monitored before completion of the new construction project, and the monitored data from these facilities can be used to establish the before-upgrade condition for the energy savings calculation.

> Walmart did a major retrofit to its store in Centennial, Colorado, as part of CBP. The retrofit involved adding controls and sensors to turn off or reduce anti-sweat heater power based on dew point temperature. The retrofit also included installing doors on MT refrigerator display cases. These doors included LED lights and anti-sweat heater controls. A calibrated existing building model was created to determine the baseline anti-sweat heater, compressor, and condenser fan power. A proposed model was also created from the adjusted baseline model that implemented the EEMs. Performance was verified on a whole-building and an EEM level.
>
> M&V involved measuring power of the compressor, condenser, and anti-sweat heater circuit. Heater power as a function of space dew point was then determined, and used to verify that controls were working properly. This correlation was also used as an input into an energy model to predict energy savings. Because putting permanent doors on open display cases impacts other systems, the proposed whole-building energy model was used to verify the savings. Modeling inputs were updated with monitored power data from the refrigeration compressors and condensers both before and after the retrofit. Walmart operated 24/7 before and after the retrofit and an annual energy analysis using the same weather data was used. Overall, the refrigeration retrofits alone resulted in $27,615 of annual energy savings, with an expected simple payback of 3-5 years.

The baseline and upgraded system models should be normalized using the same occupancy schedules and typical weather conditions (in the case of whole-building simulation). Once normalized, the energy savings from the refrigeration EEMs are determined by taking the difference between energy consumption of the theoretical baseline and actual system with controls.

10.10 Best Practices for Addressing Operational Problems

If the anti-sweat heater operates at maximum power most of the time, the controls should be checked to see if they can be modulated. If a relative humidity control is used, the anti-sweat heaters should be checked to see if they are programmed to operate in a reduced operation mode when the measured relative humidity is below the design relative humidity. During this reduced operation mode, the anti-sweat heaters should modulate on and off proportionately with respect to the measured relative humidity. If anti-condensate controls are used, the offset between the indoor dew point and the case door temperature should be checked to see if it can be lowered without degrading anti-sweat heater performance (see Section 10.8.1 for more details). If night curtains are installed and compressor power does not decrease at night, they should be checked to ensure they are being used.

10.11 References and Other Resources

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