Guide for the Retrofitting of Open Refrigerated Display Cases with Doors

Published November 2012
Updated June 2013

Prepared for:
Better Buildings Alliance
Building Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared by:
Navigant Consulting, Inc.

Photo Courtesy of REMIS America, LLC

Acknowledgments

This work was accomplished with the guidance of Brian Holuj, Jason Koman, and Kristen Taddonio of the U.S. Department of Energy, and through the contributions of many Better Buildings Alliance retail members and representatives of industry. The U.S. Department of Energy wishes to particularly acknowledge the efforts of the following parties for providing technical information and assistance during the development of this document:

DC Engineering

Hill PHOENIX

Hussmann Corporation

REMIS America, LLC and REMIS GmbH

Zero Zone, Inc.

Disclaimer

This report should be viewed as a general guide to best practices and factors for consideration by end users who are planning or evaluating a retrofit operation, rather than a comprehensive and exhaustive set of specific steps to perform when retrofitting display cases. A qualified refrigeration engineer or firm should always be contracted to oversee any retrofit project.

Executive Summary

In early 2012, members of the U.S. Department of Energy's (DOE's) Better Buildings Alliance and its Refrigeration Project Team suggested that DOE focus upon developing a best practices guide that retailers could follow when retrofitting open refrigerated supermarket display cases with transparent doors for energy reduction. In response, DOE set about researching and developing guidelines and suggestions for display case retrofits. This report outlines the results of this investigation, and was developed through collaboration between DOE, the Better Buildings Alliance refrigeration team members, and key members of industry, including technical experts from supermarket refrigeration equipment manufacturing companies.

The report breaks down best practices and guidelines for conducting case retrofits by project stage, from initial planning through project completion and system monitoring. Namely, the guide highlights the following areas of the process:

- Retrofit Planning
- Case Modification and Door Retrofit
- Refrigeration-System Reconfiguration
- System Performance Evaluation
- Monitoring and Follow-Up

This guide also provides background information on display door retrofits and offers specific technical guidance in key areas of the process where sources have suggested that errors may commonly occur. However, due to variations within installed systems, the applicability of sections of this guidance to a given refrigeration system or display case may vary between projects. For this reason, retrofit projects should always be overseen by a qualified refrigeration engineer or contractor.

Nomenclature

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BBA	Better Buildings Alliance
CRE	Commercial Refrigeration Equipment
DOE	U.S. Department of Energy
ECM	Electronically commutated motor
EER	Energy efficiency ratio
EPA	U.S. Environmental Protection Agency
EPR	Electronic pressure regulator
HVAC	Heating, ventilation, and air conditioning
LED	Light-emitting diode
NSF	NSF International (originally National Sanitation Foundation)
OEM	Original equipment manufacturer
PSC	Permanent split capacitor
SPM	Shaded-pole motor
UL	Underwriters Laboratories

Contents

Figures

1.0 Introduction

1.1 The DOE BBA Program

The U.S. Department of Energy's (DOE's) Better Buildings Alliance[1] (BBA) has the mission of transforming the way that commercial buildings use energy. The BBA invites building owners, managers, and operators to work with the DOE's Building Technologies Office and with each other to identify and implement best practices, key decision-making tools, and advanced technologies for significant energy savings in their portfolios.

BBA members represent more than 9 billion square feet of commercial building space, approximately 20% of the total U.S. floor space in their representative sectors. The BBA comprises subgroups focusing on the following areas:

- Retail – Retailers, supermarkets, and restaurants
- Commercial Real Estate – Commercial real estate and hospitality
- Healthcare – Hospitals and healthcare organizations
- Higher Education – Colleges, universities, and other postsecondary institutions

In addition, the Better Buildings Alliance will be expanding to include state, municipal and K-12 buildings during 2013.

All BBA efficiency initiatives are driven by targeted Project Teams composed of BBA members and Building Technologies Office technical experts across all relevant commercial sectors:

- Lighting and Electrical
- Space Conditioning
- Plug and Process Loads
- Refrigeration and Food Service
- Market Transformation

1.2 Project Background and Overview

Meetings during early 2012 with the BBA Refrigeration Project Team included participation from many supermarket, grocery, and convenience retailers (referred to henceforth as "retailers"). One topic that was presented to DOE by numerous retailers as an area of particular interest was that of retrofitting open refrigerated display cases with transparent doors. These procedures convert existing open cases, commonly used in supermarkets, multi-line retail stores, and convenience stores, into enclosed merchandising cases through the installation of transparent doors. As open display cases consume more energy than doored cases, while maintaining the same product temperature, retrofits hold the potential to create significant reductions in overall refrigeration energy consumption.

---

[1] Additional information on the DOE BBA program can be found at: https://www1.eere.energy.gov/buildings/commercial/bba.html

However, members expressed concern regarding the uniformity and quality of the outcomes of case retrofit projects. Namely, the retailers stated that the impact on system performance has the potential to vary considerably from installation to installation due to the lack of consistent methods for evaluating hardware selection, system design, and installer competency. A poorly performed door retrofit operation, especially one in which the impacts on the refrigeration system (including the compressor rack, refrigerant piping, condensers, and other hardware) are not taken into account, can yield energy savings far below those originally anticipated by the end user at the beginning of the retrofit process.

In response to these concerns, team members suggested that DOE develop a document highlighting best practices to serve as standardized guidance that could be followed by any retailer who wishes to undertake a case retrofit project. In early 2012, based upon this member input, DOE began research and development of this guide. The guide was developed in collaboration with BBA retail members, as well as with technical experts from refrigeration contractors and manufacturers of display cases, display doors, and retrofit kits.

This report is a general guide to best practices and factors for consideration by end users who are planning or evaluating a retrofit operation, and provides the reader direction towards the more detailed analysis needed to successfully undertake a given retrofit project.

2.0 Background on Refrigerated Display Case Retrofits

In the past years, retailers faced with tight operating budgets have sought means of reducing their energy expenditures through increasing the energy efficiency of their refrigerated display cases and associated systems. Generally, the largest consumption of refrigeration system energy in supermarket settings is attributed to open display cases, such as traditional meat and dairy cases, which are subject to much higher heat loads than cases with transparent display doors. One method of decreasing this energy consumption that has become increasingly popular is the practice of retrofitting open display cases with transparent doors. In this situation, an existing open case is fitted with display doors, and is made to function similarly to a case which is designed and shipped from the factory with doors installed. Retailers perform these retrofits to gain benefits including greatly reduced refrigeration energy expenditure, potential savings on building heating, ventilation, and air conditioning (HVAC) energy expenditures, and increased shopper comfort levels.

Past laboratory studies and DOE analyses have shown that for medium-temperature, remote-condensing open refrigerated display cases, infiltration loads comprise 70-80% of the total case heat loads. For comparison, in display cases manufactured with vertical transparent display doors and operating in a similar configuration, the infiltration accounts for only roughly 10% of the heat load that must be removed from the display case. According to discussions between DOE and experts, a properly retrofitted display case can offer energy performance very similar to that of a case designed and shipped from the factory for use with doors. Thus, the implementation of doors on cases, coupled with proper system-level changes, can result in a significant reduction in system energy usage.

Additionally, retrofits require a substantially smaller investment than would be needed to completely replace existing open display cases with new doored cases. Sources consulted in the preparation of this guide told DOE that case door retrofits, including installation and labor, can cost on the order of half the installed cost of replacing existing open display cases with new doored cases.

In addition to the installation of doors on open cases, the case retrofit process allows store owners the opportunity to make additional concurrent changes to the cases, including lighting and fan upgrades, to improve their energy performance through additional capital investments at that time.

3.0 Retrofit Planning

Sources consulted during the development of this guide agreed that proper planning before the commencement of any retrofit activity is one of the keys to a successful case retrofit project. They suggested that all building owners wishing to engage in a retrofit project consult a qualified refrigeration engineer or firm, preferably one with experience in designing, implementing, and operating systems incorporating open case retrofits. Contributing parties also stressed the importance of full system and building energy and electrical modeling in preparation for case retrofits. The following guidelines list suggested areas of consideration to be taken into account in planning for a retrofit operation.

3.1 Documentation of Existing System Characteristics

The first step in planning a retrofit project should be the documentation of existing as-built characteristics. This will be imperative in both providing inputs to required design analyses, as well as in cataloging changes to the system during and after the retrofit installation. The contractor supervising the project should review existing drawings in order to gauge the impact on the installed equipment. A survey of the refrigeration system should be taken, including the compressor rack, controls, expansion valves, piping, and condensers, to quantify the existing condition of the equipment and any differences between the as-built layout and the original system designer's plans. Moreover, the condition of the display cases and refrigeration system should be evaluated. If equipment is approaching the end of its service lifetime or is in poor condition, the contractor may advise complete replacement of the equipment.

In many instances, the chosen vendor for the retrofit kit or display doors and frames will provide a form with step-by-step instructions on the necessary measurements and information that should be provided in order to ensure that the new doors and other parts fit properly with the existing case. This will typically involve documentation of the case makes and models, as well as measurements of critical inside and outside dimensions and features present on the cases.

3.2 Reconfigured System Analysis

3.2.1 Case Heat Load Modeling

The installation of doors on previously open cases will result in a large decrease in the heat load (on the order of 50-80%) that must be removed from those cases by the refrigeration system. The magnitude of the refrigeration load is the driving factor in the sizing and configuration of the compressor rack and other refrigeration components and, by extension, determines the energy expenditure of the system. As many BBA members have noted, reduction of the load on the cases themselves is only one factor in energy reduction and proper system performance. The refrigeration system must be adjusted as well, or else the imbalance between the refrigeration load and the capacity steps and other operating parameters of the refrigeration system will lead to inefficient, suboptimal performance. For example, during excessive compressor cycling caused by such a mismatch, much more energy is used starting the compressors than is used operating in the steady state, which greatly increases system energy consumption. Thus, it is imperative that proper modeling of the post-retrofit refrigeration loads be performed in order to facilitate accurate modifications to the rest of the system.

Modeling of the as-designed cases post-retrofit should be carried out by a qualified refrigeration engineer and should, to the extent possible, take into account factors such as shopper traffic and climatic variations throughout the year. The result of this modeling should be an estimate of case load in Btuh/ft for the affected cases, which can be used as the basis for comparison to the available capacity of the refrigeration system.

3.2.2 Lighting Modification

Store owners may consider using the retrofit project as an opportunity to consider upgrading existing T8 fluorescent lighting fixtures installed in the cases to light-emitting diode (LED) fixtures. These fixtures have the potential to reduce lighting energy consumption by a factor on the order of 70%, while maintaining the level of product illumination needed for proper merchandising and product display. Moreover, lighting power reduction in turn serves the secondary benefit of reducing the heat load into the case (as the lighting energy is dissipated as heat), which in turn reduces the refrigeration load and thus the refrigeration system energy consumption. LED lighting is available from a wide variety of vendors, and is often specified and supplied with the doors and frames by the door manufacturer or retrofit kit supplier. Since display doors can often be easily specified to include integrated lighting, a case retrofit is an ideal time to consider a lighting upgrade. When considering replacement of the case lighting, operators and system designers should take into account the product being displayed and the placement within the store, amongst other factors, in order to select the proper lighting power and color profile. The DOE BBA has released a specification on LED lighting for refrigerated display cases, available at http://www1.eere.energy.gov/buildings/alliances/refrigerated_case_lighting.html.

Additionally, operators could consider the use of case occupancy sensors or other lighting controls, in conjunction with LED lighting (these technologies are not compatible with fluorescent lighting), which offer the potential to further reduce energy expenditures on product lighting. DOE suggests that the refrigeration engineer or firm planning the retrofit evaluate the cost and payback period for the use of LED lighting and lighting controls in the given application as part of the planning for the project and present that information to the building owner to facilitate an informed decision.

3.2.3 Fan Power Adjustment

Due to the marked decrease in case heat load from infiltration, the case fan motor configuration may need to be adjusted to ensure proper airflow. Modeling performed prior to the beginning of the retrofit could include analysis of the required case airflow before and after the addition of doors. In some cases, the lack of need for a functioning air curtain after the installation of the doors may allow for the reduction of fan power to levels needed to maintain even product temperature. If a reduction in fan power is found to be warranted, adjustments to the discharge plenum may be required as well. The refrigeration engineer should consult with the case manufacturer or retrofit kit supplier, should this step be needed, in order to ensure that the correct replacement parts are procured.

Industry experts suggested that one relatively simple method for reducing fan power is to reduce the pitch of the evaporator fan blades used in the cases. A suggested guideline provided to DOE was to aim for the goal of achieving a 350-foot-per-minute discharge air velocity as measured at the maximum discharge point of the honeycomb on an empty case. Selecting the proper fan blade pitch to meet the necessary airflow requirement without requiring excess power from the fan motor can reduce fan energy consumption with no further changes required. Necessary calculations should be performed in order to ensure that sufficient airflow is maintained.

Additionally, many building owners use case retrofits as an opportunity to upgrade their evaporator fan motors to high-efficiency motors, including permanent split capacitor (PSC) motors or electronically commutated motors (ECMs), which can reduce fan motor energy consumption on the order of 40% and 70%, respectively, when compared to shaded-pole motors (SPMs). Additionally, since fan motor energy is dissipated as heat inside the case, reducing the motor energy consumption reduces the refrigeration load and, in turn, the energy consumption of the refrigeration system. The system designer or refrigeration engineer coordinating the retrofit project may wish to evaluate the cost and payback period for the use of ECM fan motors as part of the planning for the project and present that information to the building owner to facilitate an informed decision.

3.2.4 Anti-Condensate Heaters

The need for anti-condensate ("anti-sweat") heaters on the new display doors will depend on the make and model of door used, the case configuration, and the ambient conditions within the store. Many door manufacturers currently sell medium-temperature products that utilize only frame heaters or no heaters at all. However, it is important to prevent condensate formation and the customer safety issues that condensation can cause; thus, the need for anti-sweat heaters should be analyzed based upon the anticipated operating conditions of the case and the anticipated ambient condition fluctuations within the store. For example, stores operating in areas with long durations of high-temperature, high-humidity weather may be more prone to condensation issues. Should anti-condensate heaters be required, consider the use of anti-sweat heater controls to mitigate excess energy use by the heaters.

3.2.5 Electrical Modeling

Modeling of the case and building electrical systems should be performed in anticipation of the case retrofit project, in order to ensure that the power supplies and components remain properly sized for the system after the modifications are made. Analyses should be conducted by a qualified refrigeration engineer and should encompass the entirety of the electrical system serving the cases, fans and lighting, compressor rack, condensers, and other components of the refrigeration system. Particular attention should be paid to existing system components, such as circuit breakers, which may prove to be improperly sized when matched with the electrical loads of the upgraded cases and refrigeration system. System designers should work with the retrofit kit supplier to understand the electrical characteristics of the system, including peak load, fuse dimensions, cable dimensions, and power factor, and should account for those characteristics during the planning of the retrofit.

3.2.6 Building HVAC Modeling

Open refrigerated display cases remove large amounts of heat from the surrounding store space as cold, dehumidified air escapes the case through infiltration. This results in a net increase in the building heating load during the heating season and a net decrease in the building cooling load during the cooling season. The addition of doors onto these open cases greatly reduces the level of infiltration and thus changes the associated impacts on HVAC loads.

In commercial retail buildings, the HVAC system is generally sized, designed, and/or configured to account for the interaction with the refrigeration equipment. The large change in heat load on the HVAC equipment due to the installation of doors on open cases will require a reassessment of the HVAC system configuration to ensure continued optimal performance. In planning for the retrofit operation, the engineer coordinating the analysis should re-evaluate the performance of the HVAC equipment, taking into account the contribution of the retrofitted cases on the system. If major changes to the system are warranted, a qualified HVAC contractor should be consulted.

3.3 Equipment Procurement

In selecting a retrofit kit and doors, users should take into account a variety of factors, both functional and aesthetic. One major consideration is the type and size of doors and the impact that those doors will have on aisle widths and shopper traffic. Additional factors to be considered include the desired product temperature, door hinge opening angle, door width, and glass types, gas fills, and glazing treatments (such as anti-reflective coatings). These factors should be taken into account during system design and their impact on the store layout and operation should be analyzed. Sources consulted during the development of this guide also pointed out that operators should ensure that doors are certified to American National Standards Institute (ANSI) 297.1 as well as Underwriters Laboratories (UL) and NSF International (NSF) requirements for their applications.

3.4 Merchandise Preservation and Retrofit Coordination

One important factor to consider during the retrofit operation will be provisions to preserve the existing perishable inventory that is currently housed in the cases to be modified. During some retrofit operations, the merchandise may be able to remain in the case during the duration of the retrofit; thus, no steps will need to be taken beyond covering the merchandise. In other instances, this inventory will need to be moved to another case, a walk-in cooler, or another refrigerated space with the capacity and capability to hold and preserve the merchandise throughout the duration of time when the cases are out of operation.

Therefore, when planning the retrofit, the operator should account for the time and staff capacity needed to move the product if necessary, and should also budget for the refrigerated space needed to store the merchandise. Incoming inventory shipment schedules may need to be altered in order to allow room to accommodate the product removed from the cases being retrofitted. Additionally, individual store owners or operators should take into account their specific store operating hours and customer traffic patterns to minimize sales disruptions during the retrofit.

4.0 Case Modification and Door Retrofit

With the initial evaluation, system modeling, and equipment procurement complete, the next step in the retrofit process is to proceed with the action of physically retrofitting the cases. Work should be performed by a qualified contractor with experience in performing case retrofits and refrigeration system reconfigurations. All equipment should be installed per the guidance of the door manufacturer, retrofit kit provider, or other applicable equipment supplier.

4.1 Case Preparation

In preparation for the installation of doors and other work performed as part of the retrofit, merchandise housed in the affected cases should be removed and transferred to other cases, walk-in coolers, or other refrigerated storage spaces in a manner so as to mitigate product loss as discussed per section 3.4. Electrical supply to the affected cases and systems should be interrupted per the instructions of the supervising engineer so as to ensure a safe working environment. Refrigerant valves should be closed, or the refrigerant supply to the case otherwise interrupted to lower the potential for refrigerant leakage should the sealed system components accidentally be punctured.

4.2 Display Door Installation

Display door installation should be performed in accordance with the instructions provided by the door manufacturer, retrofit kit provider, or case original equipment manufacturer (OEM). Installation generally begins with the removal of the existing bumpers, sheet metal façade, and other exterior components on the front of the case and canopy. Doors will be coupled to the case frame using mounts or brackets intended for compatible use with the given case model, following the instructions of the retrofit kit or door provider.

Gasketing and sealing of the retrofit doors and frame to the existing case structure is a function of the retrofit kit design and should have been taken into account by the retrofit kit or door designer. Gasketing materials and types can vary widely in style and design based upon the style and make of door selected. When using doors with gasketing, special care should be taken to ensure that proper materials are used to create a full seal between the retrofit doors and the body of the case. Open cases, by design, include provisions to account for the presence of some "spill air"— that is, refrigerated air that leaves the case interior and enters the ambient environment. This is not needed in a doored case, where a full seal and absolute minimization of infiltration is desired. If steps are not taken to create an airtight seal between the door and case body, a significant amount of infiltration could still occur, reducing the energy savings potential of the retrofit. Installers should take care to ensure that the retrofit kit is properly matched to the existing equipment and should follow all instructions given by the kit provider regarding the mounting of the doors on the case structure.

Additionally, DOE suggests that all display doors selected be designed to swing or slide closed if not locked open for stocking, in order to avoid instances of case doors being left open, leading to excessive energy usage and possible product loss. Doors that are designed to swing closed may need to be adjusted to ensure that they close by themselves from a position of being only a few inches open in order to prevent them from being inadvertently left ajar.

If the initial system analysis and design concluded that the use of anti-condensate heaters was warranted in the specific application, the heaters included in the door and frame package should be connected to the electrical supply by an electrician. The power level should, if possible, be adjusted to the level suggested by design calculations. If anti-condensate heater controllers have been specified in the work plan, the controllers should be installed, configured, and calibrated according to the manufacturer's instructions.

4.3 Lighting Modification

Generally, the installation of retrofit display doors will also involve changes to the lighting system. While retailers sometimes may wish to keep existing shelf and/or canopy lighting, in many instances store owners choose to replace the lighting to fit the new configuration with the doors in place. Most retrofit door sets, with the exception of some single-pane doors and "frameless" doors, will come paired with a frame, and lighting is usually located in the mullion of the frame and supplied by the door manufacturer. Some retrofits may incorporate shelf or canopy lighting as well as mullion lighting.

New lighting should be tied into the existing case wiring harness by a qualified technician, and the supervising refrigeration engineer should perform the necessary calculations to ensure that the existing case electrical system is adequate to properly power the new lighting.

4.4 Fan Adjustment

If the retrofit plan calls for the upgrade of existing SPMs to ECMs or PSC motors, the existing SPMs should be disconnected at their terminals and removed from the case. If the existing fan blades are to be reused, they should be removed from the motor shafts, cleaned, inspected for damage (e.g., nicks, bent blades), and retained. The electrical connections should be checked for integrity and for compatibility with the new ECMs, and the hole pattern on the existing fan blades should also be checked for compatibility. The motors and accompanying fan blades should be installed by a qualified technician.

If the initial calculations determined that a reduction in case airflow and fan power was warranted, the fan motors and/or blades should be replaced or adjusted in accordance with the results of the prior analysis and the instructions of the equipment manufacturers.

4.5 Defrost Adjustment

In open cases, defrost systems are generally designed and configured so that defrost periods occur repeatedly throughout the day. Experts consulted in the preparation of this guide stated that, after the installation of doors on the cases, the number of defrost periods can generally be reduced to between one and three per day, and that these can generally be timed to coincide with periods of low door opening and shopping traffic. The need for defrost periods should be examined during the planning portion of the retrofit operation, and changes to the defrost schedule should be implemented after the installation of doors, taking into account any information provided by the case manufacturer or retrofit kit provider.

4.6 Case Temperature Adjustment

The installation of display doors on a previously open case will generally mean that a lower discharge air temperature will be needed in order to maintain the product temperatures necessary for merchandising and food safety. Industry experts stated that discharge air temperatures can often be raised on the order of 4°F while maintaining the desired product temperature. Adjustments to the discharge air temperature and saturated evaporator temperature should be made in accordance with the guidance of the case manufacturer, retrofit kit provider, and other equipment suppliers.

4.7 Example Installation Photos

This section contains photographs and explanations documenting selected steps of an example retrofit project. The narrative and graphics are for illustrative purposes only and are not intended to provide an exhaustive description of how to perform a retrofit. Additionally, these images provide an example of one type and instance of retrofit methodology. This should not be interpreted as an endorsement of any single company or methodology on behalf of DOE, and steps implemented in a specific retrofit project will vary based on the vendor and project specifics.

All photos in this section were provided courtesy of REMIS America, LLC.

Figure 1: De-merchandising and removal of bottom racks

The bottom shelf of the case is de-merchandised to allow for access to the expansion valves, and the bottom racks are removed to make way for the installation of new custom bottom racks. The rest of the product is able to be left in place during the retrofit in this particular instance.

Figure 2: Covering of product and layout of new bottom rail

The product is covered to protect it from any debris that may be produced during installation of the hardware. A new bottom rail, which will fit under the door frames, is laid into place.

Figure 3: Fitting and placement of door frames

The upper canopy of the case has been removed, as have the stock T8 fluorescent lighting fixtures. The wiring harness has been exposed. The door frames are placed and checked for fit. Where necessary to ensure a proper fit, spacers are put into place.

Figure 4: Installation of door frames

The door frames and new face plates are screwed into the body of the existing case.

Figure 5: Wiring of new lighting fixtures

The new LED lighting fixtures, which are integrated into the door frames, are wired into place using the existing case wiring harness. The wiring harness is tucked away under the top inside cover of the case, and the cover is secured.

Figure 6: Replacement of top canopy

The existing top canopy of the case is replaced, preserving the visual appearance of the case.

Figure 7: Gasket installation

Gasketing material is cut to length and pressed into the inside of the door frames to ensure a tight fit between the doors and frames when the doors are closed.

Figure 8: Hanging the doors

The doors are set into place on the bottom hinge brackets of the door frames. The top hinges are set and screwed into place, mounting the door to the frame body. Later, each door is checked for proper fit and closure and fine adjustments are made to ensure that all doors close properly. Additionally, a lockout mechanism, used to hold the door open when it is being stocked, is attached.

Figure 9: Expansion valve adjustment

A refrigeration technician makes the necessary changes to the expansion valve to allow the case to run a higher evaporator temperature. This is needed due to the reduced case heat load after installation of the doors. This may involve simple adjustment of the valve or replacement of it completely. This step may be performed before or after installation of the doors; this image shows it being performed after the frames are installed but before the doors are hung. Adjustments to the rack and other aspects of the refrigeration system, as discussed in section 5.0, may yield for further increases in performance.

Figure 10: Example of finished display with retrofit doors in place

5.0 Refrigeration-System Reconfiguration

If performed properly, retrofits of open cases with glass doors will lead to sizeable reductions in infiltration loads, reducing overall case heat loads by 50-80% as compared to the original open case performance, according to laboratory studies and experts interviewed during the development of this guide. Additional system improvements performed concurrently, such as upgrading fan motors, installing higher-efficiency lighting, and raising case saturated evaporator temperatures can further reduce the heat load from the refrigerated display case.

In light of these substantial reductions in refrigeration load, it is imperative that the refrigeration system configuration be reevaluated to match system operation to the load profile. According to experts interviewed, improper reconfiguration of refrigeration systems is the predominant cause of case retrofit projects not delivering the expected results. The following sections outline guidance for properly reconfiguring refrigeration systems after retrofitting open cases with doors.

5.1 Load-Profile Evaluation

The first step in properly reconfiguring the refrigeration system should consist of a thorough analysis of the load profile for the retrofit cases. Ideally, such system analysis would have been performed as part of the initial engineering assessment in the preplanning phase of the retrofit (see section 3.0).

Perform a detailed analysis that accounts for periods of maximum customer traffic and adverse ambient conditions. Maximum heat load estimates will be necessary to ensure that the reconfigured refrigeration system is still capable of delivering the needed cooling capacity under the most extreme conditions that it will encounter so as to ensure product freshness and food safety.

5.2 Refrigerant Reclamation

When working with the sealed refrigeration system, it is imperative that refrigerant leaks be prevented. Before any work requiring opening of the sealed system, or which could result in accidental puncture of the system, is performed, refrigerant should be evacuated from the affected portions of the system or systems per the applicable federal, state, and other regulations. Refrigerant evacuated from the system should be retained or recycled per the appropriate guidelines.

5.3 Compressor Rack and Control Configuration

Proper modification of the compressor rack and adjustment of refrigeration-system controls constitutes one of the most significant and important aspects of the retrofit process. Installation of doors on open cases, which are traditionally the largest contributors to the refrigeration system heat load, will result in markedly different operating conditions for the compressor rack serving those cases. Failure to properly configure the rack to best match the case load profile will result in a mismatch between the load steps of the rack and the actual loads from the cases, resulting in excessive compressor cycling. This mode of operation is much less efficient than the higher duty cycle operation typically observed when the refrigeration system is well matched to the load. Moreover, the added stress of starting and stopping the moving components through many additional cycles can lead to excessive wear and tear on the compressor rack, resulting in shortened operational life and additional repair costs.

In addition to performing any necessary modifications to the compressor rack and controls to accommodate the new refrigeration load, the refrigeration contractor should take this opportunity to thoroughly inspect the rack and related equipment for any existing damage or wear and perform the necessary maintenance or repairs to ensure peak performance. Standard maintenance checks of the compressors, in accordance with the recommendations of the compressor manufacturer, should be performed.

The contractor coordinating the retrofit operation should examine the following areas related to the compressor rack and refrigeration-system controls.

5.3.1 Compressor Rack Configuration

In many cases, the decreased load on the compressor rack due to the addition of display doors to open cases will necessitate physical changes to the rack in order to accommodate the modified refrigerant throughput and characteristics. Results of calculations of the case heat load under various sets of operating conditions, performed prior to case retrofit operations, should be the key driver for changes to the rack configuration.

In many cases, the reduction in peak heat load seen by the rack will be significant enough to warrant the disabling of one or more compressors on the rack. In this instance, care should be taken to ensure that the rack remains configured in a manner so as to provide appropriate capacity modulation in order to mitigate excessive compressor cycling and product temperature fluctuations. For example, on a rack with differently sized parallel compressors, it may be desirable to disable the larger compressors first, while leaving the smaller ones in place to allow for more granularity in load control. Load steps should be compared against anticipated heat load increments, and further compressor changes may be required if the disparity is significant.

In addition to potential reconfiguration of the compressors themselves, additional modifications may need to be made to the following rack components to ensure optimal performance:

1) **Oil return:** Attention should be paid to the suction risers in ensuring proper oil return. If the risers are not properly sized, the rate of lubricant return may be insufficient and damage to the compressors could occur. In many cases, the existing risers will be sufficient. However, the engineer overseeing the project should verify that this is the case in order to maintain proper performance. If warranted, changes to the risers should be made based on the type of system, depending on whether it is a split-tube design, features a siphon in the riser, or uses an oil separation system. After the retrofit, the operator or contractor should observe oil levels in the separator, reservoir, and/or crankcase to ensure that proper oil return is occurring.

2) **Refrigerant charge:** Charge level should be checked at the receiver and adjusted to ensure agreement between the level of charge and the system’s needs after the retrofit.

3) **Receivers:** Standard maintenance checks should be performed.

5.3.2 Controls and Calibration

After the necessary physical alterations to the compressor rack are made, existing control systems should be recalibrated to ensure proper performance. Additionally, building owners could use the retrofit project as an opportunity to upgrade existing controls with more advanced systems. Controls that should be examined by the refrigeration engineer or firm responsible for the retrofit include:

1) Variable-frequency drive systems
2) Cylinder unloading
3) Building energy management systems
4) Defrost control systems
5) Other control systems and schemes

5.3.3 Hot Gas Defrost

If the rack is equipped with the capacity to accommodate hot gas defrosting of coils, the solenoid valve on the main liquid line or the discharge differential valves should be evaluated for compatibility with the new system operating parameters and replaced if necessary.

5.3.4 Heat Reclaim

If the rack contains the capacity to perform heat reclaim, calculations should be performed to evaluate the new heat output of the rack when operating in conjunction with the newly retrofitted cases. With reduced heat output, the existing heat reclaim coil could potentially prove to be oversized. If changes to the compressors have been made, this is likely.

5.4 Refrigerant Piping and Expansion Valves

The significant decrease in refrigeration load due to the addition of doors on cases has the potential to affect many components of the refrigeration system, including the refrigerant line runs and the case expansion valves. Generally, experts who provided input for this guide stated that liquid and suction lines will both remain appropriate in size to serve the retrofitted cases. However, some sources stated that attention should be paid to the suction riser (the line running from the evaporator coil outlet to the shared suction line on top of the lineup) in order to ensure adequate refrigerant velocity and thus proper oil return. The engineer coordinating the case retrofit should conduct sufficiently detailed system modeling and flow calculations to ensure that the line sizes utilized will be capable of properly returning a sufficient capacity of refrigerant and lubricant while maintaining the desired properties. Minimum American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) design considerations, including a minimum suction line velocity of 500 feet per minute and a minimum suction riser velocity of 1000 feet per minute, should be followed.

Expansion valves attached to each individual coil in the display cases serve the critical function of controlling coil superheat, and will require changes to accommodate the markedly different refrigerant flow properties precipitated by the change in the case configuration during the retrofit. For expansion valves with removable internal cartridges, a compatible cartridge properly sized for the new refrigerant flow level may be available. In other instances, expansion valves will need to be replaced altogether. During system analysis and modeling, the engineer supervising the retrofit should analyze the anticipated heat loads and refrigerant flow conditions, and choose properly sized valves for each display case accordingly. Industry experts stated that expansion valves will likely need to be reduced one or two sizes to provide for proper superheat control at reduced refrigerant flow rates and increased evaporator temperatures. The suggested superheat recommended to DOE was 4-7 degrees; however, the case equipment manufacturer's literature should be consulted to verify.

If electronic expansion valves are in place, generally the valves will not need to be altered. However, the valve manufacturer's literature should be reviewed in order to ensure the valves' compatibility with the new system configuration.

Additionally, each case lineup contains a solenoid valve or electronic pressure regulator (EPR) used to control case temperature. Solenoid valves used in either the liquid or suction lines can generally be retained, provided that the sizing of the lines is evaluated as described above to ensure a proper operating pressure across the valve. However, due to the fact that the reduction in load created by the retrofit allows for higher case suction temperatures, an EPR is preferred for optimal performance. Existing EPRs should be checked for proper performance at the new case loads. If possible, the common suction temperature downstream of the EPR should be raised in order to further reduce the power input requirement at the compressor rack.

5.5 Condensers

Supermarket refrigeration systems generally use separate air-cooled condensers, most often located on the rooftop of the building, to reject heat to the ambient environment. In many cases, excess condenser capacity will already be accounted for by existing control and operation schemes. However, in some instances, removal of excess condenser capacity may be warranted. Additionally, operators in climates experiencing extreme winter cold or high summer temperatures should consider climatic factors when making modifications to their condensers.

5.5.1 Discharge Risers

The discharge riser (the piping from the compressor rack outlet to the condenser) should be evaluated for proper sizing based upon the new system operating parameters. In many cases, the existing sizing will be adequate. However, if the retrofits were significant enough to create a sufficient impact on the given system, the line may need to be resized in order to ensure sufficient lubricant return to the compressor rack.

5.5.2 Winter Control

Some condensers may be equipped with a device, known as winter control, which regulates the head pressure to prevent it from falling below optimal condensing pressure during low ambient temperature conditions. If the condenser has the capacity for winter control and there is a sufficiently significant reduction of case heat load (a figure of 35-40% was suggested as a guideline), the winter control valve should be checked and resized if necessary.

5.5.3 Subcooling

If the condenser features subcooling and the drop in case heat load is sufficient (a figure of 35-40% was suggested as a guideline), the subcooler and the associated expansion valves may need to be resized.

5.6 Unitary Condensing Units

In systems featuring unitary condensing units, with a single display case being served by a dedicated remote condenser, the issue of load reduction is likely to have a more pronounced impact than in multiplex rack systems. This is due to the fact that the single condensing unit operates on demand based solely on the conditions in the case served, and is originally sized to the anticipated load of the case. Whereas a rack system can often be modified in a fairly straightforward manner to accommodate lower case loads (such as through disconnecting a compressor or adjusting existing controls), this may not be possible using the existing equipment in a dedicated remote-condensing unit. If the unit is left to run as is with a case load that is 50% or more lower than that for which it was originally designed, the condensing unit will be grossly oversized, and the result will be frequent compressor cycling. This will result in highly inefficient operation due to the high number of compressor and condenser fan starts and stops, as well as possible shortening of refrigerated product lifetime due to rapid warming and cooling cycles.

In light of the resulting discrepancy between case heat load and condensing unit capacity after a retrofit, one of two measures could be employed in order to bring the two values closer into line. The first of these would be the employment of an electronic suction regulator or similar control device to hold the refrigerant flow so that the condensing unit experiences a reduced impact due to the decrease in load. However, since this step enables the condensing unit to operate in a manner similar to which it did with an open case, this means that the full energy savings will not be realized. Another measure, if feasible based on the physical size and location of the cases, is the consolidation of multiple cases onto single condensing units. In this instance, a unitary condensing unit which originally served a single display case could be reconfigured to serve two cases through re-routing of refrigerant piping and other adjustments. Proper calculations should be carried out in order to ensure that the existing condensing unit is capable of accommodating the peak loads of multiple cases.

5.7 Electrical System

Retrofit operations, by design, have the intended result of significantly changing the electrical demand profiles of the display cases and refrigeration system. Case electrical consumption may be reduced due to changes in lighting and fan power, while a compressor rack reconfigured for retrofitted cases may use, even in peak operation, far less electricity than it previously needed. While this is desirable from an energy efficiency and cost reduction standpoint, care must be taken to ensure that the building electrical system is still correctly sized for the refrigeration equipment per the relevant building and safety codes. For example, existing circuit breakers may be grossly oversized and may not trip even in the case of an overload situation, which could present a serious safety hazard. A qualified engineer or firm should be consulted to ensure that all building codes and electrical safety requirements are met, and that the building electricity supply and connections are properly sized for the new operating profile of the system.

5.8 Relabeling and Recertification Requirements

Display cases and refrigeration systems are generally labeled in a manner that reflects the necessary certification of the equipment, usually UL and NSF for the former and UL for the latter. Changes to the physical composition of the cases by way of component swaps and additions, as well as changes to the case electrical system, would likely require recertification with these bodies. Similarly, any changes to the componentry of the rack may require recertification.

5.9 System Recharging

Any work to the sealed portion of the refrigeration system will have required evacuation of the refrigerant in the system previous to the modifications being performed. Prior to restarting of the system, the refrigeration contractor should ensure that those portions which have been evacuated are properly recharged to the necessary levels using the appropriate refrigerant. Particular attention should be paid to any system modifications, which could result in a change in the needed refrigerant charge. For example, due to the load reductions on the system, each case's evaporator coil may require an increased charge, resulting in a need to add more refrigerant to the entirety of the system before it is returned to service.

6.0 System Performance Evaluation

After the completion of the case retrofits and reconfiguration of the refrigeration system as warranted, it is essential to test the performance of the refrigeration equipment in use.

Before long-term merchandising use of the system is initiated, the following system characteristics should be inspected and verified:

1) **Leak testing:** All refrigerant line runs affected or modified during the retrofit project and related work should be tested for leaks using a micron gauge and following standard refrigeration system inspection practices. U.S. Environmental Protection Agency (EPA) guidelines should be followed and used to direct this process.
2) **Suction line superheat:** Values should be measured at appropriate points in the suction line and compared to design specification values. Proper adjustments should be made to ensure alignment with desired values specified in the system design.
3) **Discharge air temperature and return air temperature:** Measurements of air temperature in each case at the discharge and return air grilles should be taken and compared to the desired design values. Depending on the desired performance effect, discharge and return air temperatures may be higher, possibly on the order of 4-5°F, after the retrofit, while maintaining the same internal product temperature. These values should be measured over a period of 24 hours in order to gain a complete picture of the system operation.
4) **Defrost operation:** Defrost settings configured for open display cases will likely have been adjusted in retrofitted cases due to the large reduction in infiltrated air and associated moisture. Care should be taken to ensure that reconfigured defrost systems are operating as intended.
5) **Controls:** Control settings and programming should be reviewed to ensure that field configuration aligns with design intent.
6) **Compressor operation:** Compressor cycling times and frequency should be measured in order to ensure that excessive compressor cycling is not occurring due to reduced system loads. In many instances, modern control systems incorporate the capability to record system operating characteristics such as compressor duty cycle and run time. In lieu of this, timers and counters can be installed on each compressor for data-gathering purposes.
7) **Liquid line subcooling:** Values should be measured at appropriate points in the liquid line and compared to design specification values.
8) **Expansion valve settings:** Expansion valves should be inspected to ensure that the settings are appropriate for the refrigerant flow rates and properties necessary to maintain proper temperature in the reconfigured cases.
9) **Condenser operation:** Measurements of condenser temperature should be taken and compared to design value. Correct operation of condenser controls should be verified based on standard maintenance protocols.

10) **Refrigerant charge levels:** System charge levels should be measured in accordance with standard maintenance procedures and compared against calculated required values for the reconfigured system.

11) **Electrical loads:** System electrical loads should be measured at peak operation to ensure that the electrical connections and safety devices such as circuit breakers remain properly sized for the reconfigured refrigeration system.

12) **Anti-sweat heater operation:** If anti-condensate heaters were installed with the display doors, their operation, along with that of any anti-sweat heater controls used, should be checked before long-term operation commences to ensure that they are set to the appropriate power level for the store's range of ambient conditions.

13) **Lubricant return:** Refrigerant piping originally designed for open cases, which require a higher refrigerant throughput, may have been reconfigured to match the new case heat loads. Lubricant return rates and sump oil levels should be checked by visual inspection using installed sight glasses to ensure that the compressors are receiving the needed lubricant flow.

14) **System alarms:** Appropriate alarms should be programmed into the refrigeration-system controls to modify system performance in light of detected issues and to alert building staff of problems as they occur.

Additionally, design plans should be compared to as-built drawings and revised for future use if the field installation required changes not initially reflected in the design drawings.

After the system has been deemed to be operating satisfactorily, products previously removed from the affected cases during the retrofit can be loaded back into those cases, and the cases may be returned to merchandising duty.

7.0 Monitoring and Follow-Up

As a retailer's prime motivation for retrofitting open display cases with doors is generally the desire to save energy, it is essential that the upgraded refrigeration system and display cases be monitored after the initial completion of the retrofit activities. Building engineering staff or the refrigeration service contractor should be retained to monitor performance and collect data. This is essential in ensuring that the system is performing at the optimum level across the possible variety of climatic conditions and shopper volumes to which it will be exposed.

The most fundamental way to gauge system performance from an energy standpoint is to monitor refrigeration system energy consumption. Metered electricity consumption data should be collected regularly, if possible on a per-refrigeration-system basis. Data should be compared against existing benchmark data, as well as against projected energy consumption as calculated during the initial work-up to the retrofit project. Comparisons should, if at all possible, take into consideration factors including climate (comparing the same month across two years, correlating refrigeration energy data to ambient temperature, for example) and shopper traffic.

Additional monitoring should include regular evaluation of physical system characteristics such as the following:

1) Discharge air temperature and return air temperature
2) Defrost operation
3) Suction line superheat
4) Liquid line subcooling
5) Condenser operating temperatures
6) Refrigerant charge levels
7) Anti-sweat heater operation
8) Lubricant return

Discrepancies in metered system electricity consumption or the presence of system operating characteristics, including those listed above, outside of the desired range would serve as grounds for reevaluation of system configuration. In this instance, a qualified refrigeration engineer or firm should be contracted to diagnose the system issue and readjust settings so as to achieve optimum performance and maximal electricity savings.

8.0 Sources

1) United States Department of Energy. *Building Technologies Program: Commercial Building Energy Alliances*. March 30, 2012. Accessed April 13, 2012. < http://www1.eere.energy.gov/buildings/alliances/index.html>
2) "Commercial Refrigeration Swing Door Retrofit Survey Form". Anthony International, Copyright 2010.
3) PECI EnergySmart Grocer, "Vertical Refrigerated Case, Medium Temperature: Open to Closed (Retrofit)". Work Paper PECIREF_PGE604, Revision 0. July 1, 2011.
4) Faramarzi, R.T. 1999. "Efficient Display Case Refrigeration". *ASHRAE J.*, vol. 41, no. 11: pp. 46-54.
5) Faramarzi, R.T., Coburn, B.A., Sarhadian, R. 2002. "Performance and Energy Impact of Installing Glass Doors on an Open Vertical Deli/Dairy Display Case". *ASHRAE Trans.,* vol. 108, no. 1: pp. 673-679.
6) Fricke, B., Becker, B. 2010. "Energy Use of Doored and Open Vertical Refrigerated Display Cases". *International Refrigeration and Air Conditioning Conference*. Paper 1154.
7) United States Department of Energy. *Building Technologies Program: Commercial Refrigeration Equipment (CRE)*. February 21, 2012. Accessed April 13, 2012. <http://www1.eere.energy.gov/buildings/appliance_standards/commercial/refrigeration_equipment.html>
8) "Energy Savings Potential and R&D Opportunities for Commercial Refrigeration". Navigant Consulting, Inc., 2009.