INTEGRATION OF DEMAND RESPONSE INTO TITLE 20 FOR ANTI-SWEAT HEATERS ON GLASS DOORS OF LOW-TEMPERATURE REACH-IN DISPLAY CASES

Phase1: Demand Response Potential

DR 09.05.02 Report

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ABBREVIATIONS AND ACRONYMS

ASH	Anti-sweat heaters
DP	Dew Point
DR	Demand Response
EE	Energy Efficiency
EER	Energy Efficiency Ratio (Btu/hour/watts)
EFLH	Equivalent Full Load Hours (hours/year)
Title 20	California's Appliance Efficiency Regulations
LT	Low-Temperature
SCE	Southern California Edison
SCT	Saturated Condensing Temperature, (^{o}F)
TTC	Technology Test Centers

EXECUTIVE SUMMARY

The specific focus of this project is to establish and quantify demand response (DR) potential for anti-sweat heaters on glass doors of low-temperature reach-in refrigerated display cases. The entire analysis and recommendations made in this project rely on findings from prior research conducted at Southern California Edison's (SCEs) Technology Test Centers (TTC). This project seeks to evaluate the potential for DR utilizing anti-sweat heaters which could be to be incorporated into the California Appliance Efficiency Regulations, Title 20. Currently, there are no demand response regulations for anti-sweat heaters in Title 20, Federal regulations, or ENERGY STAR programs. Title 20 only regulates anti-sweat heaters on glass doors of walk-ins, and not on glass doors of reach-in refrigerated display cases.

Low-temperature reach-in refrigerated display cases are commonly found in grocery stores. These cases are equipped with anti-sweat heaters to prevent condensation on the glass doors. Absent any control mechanisms, the anti-sweat heaters on conventional glass doors require about 200 watts per door at all times. Most of the time, however, the temperature and humidity inside grocery stores do not necessitate continuously running heaters at full load. Therefore, the connected electrical power to these heaters can be lowered according to the indoor conditions of the grocery stores.

The results of this project indicate that the only practical and reasonable demand response strategy for anti-sweat heaters on conventional glass doors, without any control mechanism, is to reduce the power supplied to them from 100% to 60%. The basis for this conservative strategy is the typical indoor conditions (temperature and humidity) observed in grocery stores, and the empirical data that provides the target power level for these heaters according to indoor conditions in grocery stores. As a result, it is anticipated that the proposed DR strategy has the potential to reduce demand by 99 watts per door. Extending this finding to the potential market size in SCE service territory and California by assuming different market acceptance levels, the demand reductions are anticipated to range between 52 kW and 2,607 kW, and between 128 kW and 6,413 kW, respectively.

Although the proposed DR strategy yields power reductions, it is highly recommended to evaluate the cost effectiveness of this strategy relative to prominent energy efficiency solutions. Currently, rebate programs offer incentives for using controllers on anti-sweat heaters and using a new generation of glass doors that require low power. This is recommended because these two energy efficiency measures provide long-term benefits whereas reducing the power for certain periods of time provides short-term benefits. Additionally, the magnitude of the savings realized by using these two energy efficiency measures are far greater than the savings realized using the proposed DR strategy. From a DR cost effectiveness stance, it is also recommended to focus on grocery stores that are equipped with energy management systems and interfaces that offer two-way communication. Nonetheless, if the proposed DR strategy is to be pursued, field or laboratory assessments will provide improvement areas for the proposed strategy.

INTRODUCTION

This project seeks to validate and establish demand response (DR) potential for anti-sweat heaters (ASH). It is part of a multi-phase effort to evaluate the potential for DR to be incorporated into the California Appliance Efficiency Regulations (Title 20) for a series of 13 commercial and residential appliance categories from refrigerated display cases to anti-sweat heaters.

This project aligns well with the objective of Southern California Edison's (SCE) SmartConnect^{TM} by fostering and accelerating the availability of DR-ready appliances in the market place. Furthermore, this project supports the California Public Utilities Commission goal of zero net energy for residential new construction by 2020 and commercial new construction by 2030.

Phase 1 of this potential three-phase effort addresses the DR potential for anti-sweat heaters; if Phase 1 yields encouraging results, Phase 2 will demonstrate DR capabilities and strategies for anti-sweat heaters; and if the demonstration is successful, Phase 3 will develop a Title 20 Codes and Standards Enhancement initiative to incorporate DR requirements for anti-sweat heaters.

Phase 1 is the focus of this project and establishes DR potential for anti-sweat heaters. This phase entails assessing the demand reduction associated with anti-sweat heaters, the population statewide and within SCE service territory, and the market/consumer acceptability of DR strategies associated with anti-sweat heaters.

TECHNOLOGY DESCRIPTION

Low-temperature reach-in refrigerated display cases, Figure 1, can be found in small, medium, and large size grocery stores. They are used to merchandise frozen foods and ice cream. The air temperatures inside LT reach-in display cases can range from -5^{o}F to -24^{o}F. Due to cold case temperatures and the moisture content of the surrounding air, condensation becomes a problem in the operation of LT reach-in refrigerated display cases.

The temperature at which condensation occurs, which is known as dew point (DP), depends on the amount of moisture in the air in the surrounding environment. Condensation takes place when moist air contacts a cold surface with a temperature below the DP air temperature.

Condensation on a cold exterior surface of glass doors and doorframe is referred to as *sweating*. The exterior surfaces that are not well insulated or sealed are particularly vulnerable to the accumulation of condensation from the moisture in the surrounding air. Figure 1 illustrates sweating on the exterior glass surface (left picture) and exterior surface of the doorframe (right picture).

FIGURE 1. SWEATING ON THE EXTERIOR GLASS SURFACE (LEFT) AND THE DOORFRAME (RIGHT)

Further, as the moisture condenses and freezes on the interior surface of the glass doors it becomes opaque thus blocking visibility through the door with a surface of *fog* (see Figure 2). Fogging on the interior surface of the glass doors is mainly due to shoppers opening and closing the doors. As the glass doors are opened, the surrounding air circulates across the face of the glass doors and into the case while the cold air of the case spills out onto the floor. When the glass doors are closed, the surrounding air that is trapped inside the case begins to cool and the moisture it contains condenses and freezes on all surfaces.

FIGURE 2. FOGGING ON THE GLASS SURFACE

The problems with condensation are summarized below:

- Sweating and fogging that blocks shoppers' visibility through the display case, thus possibly affecting store sales
- Condensation dripping on the floor that can be a slip hazard to shopper traffic

- If the surface temperature of the case is very cold in a location where sweating occurs, a local build up of ice can occur. If ice forms on door seals additional problems can develop:
  - Build up of ice on door seals can render the seals rigid and no longer pliable, thus no longer effective at sealing the doors. This problem quickly compounds to more ice and more leakage across the door seal mating surfaces.
  - If condensate on or around the door seals freezes it can cause the door seals to become rigid and frozen to the mating surfaces of the case and door. The seals then become vulnerable to ripping and tearing when the doors are opened.

In order to minimize the problem of the cold surface temperatures that cause condensation to form on glass doors of LT reach-in display cases, ASH or sometimes referred to as anti-condensate heaters are used. ASH are electric resistance heaters that add heat in localized areas to keep the surface temperature above that which would allow condensation to occur. A portion of the electric connected load of ASH becomes the cooling load of the case. This load is ultimately removed by the compressor to maintain target product temperatures.

The conventional or standard glass doors used on LT reach-in display cases require three sets of heaters:

- Case mullion heaters – located inside the case to keep the doors from freezing shut (green in Figure 3)
- Doorframe heaters – located in the doorframe to keep the doors from freezing shut and provide some heat to the glass (red in Figure 3)
- Glass heaters – located on the glass itself to raise its surface temperature and prevent condensation (blue in Figure 3)

FIGURE 3. TYPICAL ANTI-SWEAT HEATERS LOCATION FOR LOW-TEMPERATURE REACH-IN DISPLAY CASES

The structure of the components that make up the interface between the doors and the display case is illustrated in Figure 4. The interface is referred to as a mullion and serves to separate the opening of the display case into sections that can be covered with practical sized doors.

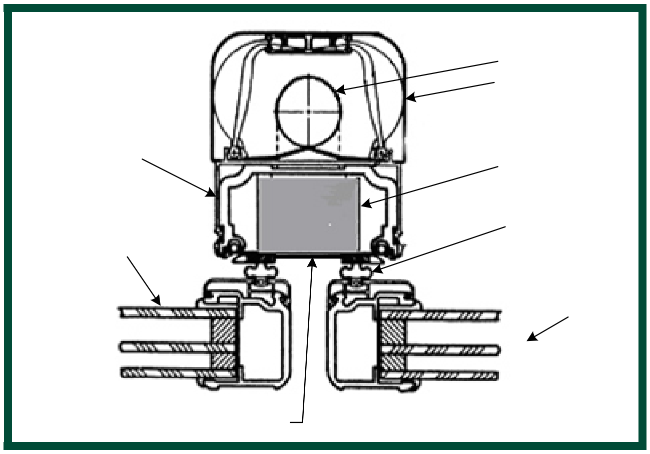

FIGURE 4. TOP VIEW OF MULLION AND DOORS

The mullion is the perimeter frame around the face of the display case where the doors close up against the display case. It divides the open face area of the case into separate openings that are each the size of a mating door. The vertical mullions between doors offer a convenient place for mounting internal lighting fixtures and their respective power supplies. Note, the lamp ballast mounted in the mullion channel. In addition to being conveniently close to the lamp, any heat given off by the ballast supplements that of the ASH in the mullion. Close to the door mating surface and behind an access panel are the heating elements of the mullion heaters (see Figure 5). The mullion heaters (white wire shown in Figure 5) help keep condensation off of the door gasket mating surface of the mullion. They also help keep the door gaskets dry and pliable while the doors are closed.

FIGURE 5. MULLION WITH DOORS AND MULLION ACCESS COVER REMOVED SHOWING WIRING FOR LIGHTS (BLUE) AND MULLION HEATER WIRE (WHITE)

The heat in each door consists of door frame heaters and a door glass heater. The heating elements for each of these components are separate but are typically fed through a single electrical connector at the bottom edge of the doorframe (see Figure 6 and Figure 7).

Doorframe heaters help keep condensate from forming on the perimeter of the doorframe. Heat from the doorframe also complements the mullion heaters in helping to keep the door gaskets dry and pliable while the doors are closed.

The glass of the doors is typically made up of several layers of glass separated by inert gas-filled chambers between each layer. This is done to improve the insulation across the doors by improving the thermal isolation from inside to outside the case. The inside surface of the exterior layer of glass is typically coated with a very thin layer of transparent, electrically conductive material that heats up when electric current is applied. This is referred to as glass heat and is the primary source of ASH for the surface of the glass.

FIGURE 6. DOORFRAME EDGE SHOWING DOOR HEATER RECEPTACLE AND CONNECTIONS

FIGURE 7. DOORFRAME MATING PLUG WHICH PROVIDES POWER TO DOOR HEATERS

Absent any control mechanisms for ASH, these heaters operate at full power 100% of the time. Typically the ASH controllers modulate the amount of heat supplied to the heaters as a function of indoor humidity or the amount of moisture detected on the surface of the glass. In addition, although the conventional or standard glass doors require three sets of heaters (mullion, glass and doorframe), the new generations of glass doors require either mullion heat only or mullion and glass heat.

Overall, there are at least four possible scenarios for ASH on LT reach-in glass doors. These four scenarios are outlined below. The only scenario that could potentially provide demand reductions is scenario 1. In scenario 2, the power supplied to ASH is controlled and optimized according to indoor environment humidity conditions. In scenario 3, special glass doors with low-powered ASH are used. In scenario 4, these low-powered ASH glass doors are controlled and further optimized according to indoor environment humidity conditions. As a result, in scenarios 2, 3 and 4 where the ASH heat requirements are already optimized, additional demand reductions would be insignificant and not be feasible. Therefore, the focus of this report is on ASH on conventional glass doors that are not equipped with any control mechanism (scenario 1). Possible scenarios:

1. ASH on standard or conventional glass doors without controller
2. ASH on standard or conventional glass doors with controller
3. ASH on new generation glass doors that require low heat without controller
4. ASH on new generation glass doors that require low heat with controller

CURRENT ENERGY CODE REQUIREMENTS

Display cases have remained unregulated appliances in the United States (US) because of the difficulty in addressing the wide variety of components and configurations present in this product type. However, in January 2009, the US Department of Energy (DOE) published energy standards for 38 display case equipment classes, which becomes effective for case manufacturers on or after January 1, 2012.[1] These energy consumption standards are based on the total refrigerated volume for closed cases and the total display area for open cases, due to the significant impact of open area on energy consumption. No DR capabilities are included in this standard.

ENERGY STAR programs do not address display cases. Title 20 standards, however, address only the ASH of the glass doors of walk-ins, and not the ASH of glass doors for reach-in display cases.[2]

DEMAND PROFILE AND ENERGY CONSUMPTION

This section discusses both the direct and indirect or interactive effects of using ASH on LT reach-in display cases. Direct effect is simply the connected electric load of ASH. The interactive or indirect effect of ASH is the portion of the connected electric load of ASH that becomes the cooling load of the display case, which ultimately has to be removed by the compressors. Therefore, it is imperative to consider both direct and interactive effects of ASH.

DIRECT EFFECTS OF ASH

According to the 2004-2005 Database for Energy Efficient Resources (DEER), the ASH connected electrical load for a conventional or standard glass door is 214 watts.[3] The Gas Research Institute (GRI) reported total ASH connected electric load of 574 watts for a LT reach-in display case equipped with three conventional or standard glass doors.[4] This is equivalent to ASH connected electric load of 191 watts (574 watts ÷ 3 doors) per door. Similarly, laboratory testing has shown a total of 544 watts of ASH connected electric load for a LT reach-in display case equipped with three conventional glass doors.[5] This is equivalent to ASH connected electric load of 181 watts (544 ÷ 3 doors) per door.

Additional data was extracted from two leading U.S. display case manufacturers' catalogs, namely Hill Phoenix[6] and Hussmann.[7] The results are summarized in Table 1. As shown in Table 1, the ASH connected electric load ranges between 188 and 216 watts per door, which is in close agreement with the three cited references above. Note that all the referenced display cases in Table 1 are equipped with conventional or standard glass doors.

TABLE 1. ASH POWER DEMAND FOR LOW-TEMPERATURE REACH-IN GLASS DOOR DISPLAY CASES FROM TWO LEADING U.S. MANUFACTURERS' CATALOG

MODEL NUMBER	DISPLAY CASE DESCRIPTION	TOTAL ASH POWER (WATTS)	ASH POWER PER DOOR (WATTS / DOOR)
ORZ[6]	Glass Door Reach-In Frozen Food/Ice Cream Merchandiser (3-door)	637	212
ORZH[6]	High Glass Door Reach-In Frozen Food/Ice Cream Merchandiser (3-door)	648	216
ONRZ[6]	Narrow Glass Door Reach-In Frozen Food/Ice Cream Merchandiser (3-door)	637	212
ONRZH[6]	High Narrow Glass Door Reach-In Frozen Food/Ice Cream Merchandiser (3-door)	648	216
NRC[7]	Reach-In Ice Cream Merchandiser (3-door)	565	188
NRCV[7]	Reach-In Ice Cream Merchandiser, Vertical Lighting (3-door)	636	212

As indicated earlier, ASH stays on full load around the clock minus any control mechanism. Based on this assertion, the annual operation hours of ASH is 8,760 (365 days/year x 24 hours/day). Accordingly, the annual energy usage of ASH is estimated by simply multiplying power demand by annual hours of operation. Table 2 summarizes electric demand per door from all five cited sources and the corresponding annual electric energy usage per door. Table 2 also shows the arithmetic average value for demand and energy usage.

TABLE 2. SUMMARY OF ASH ELECTRIC DEMAND AND ANNUAL ELECTRIC ENERGY USAGE PER DOOR

DATA SOURCE	ELECTRIC DEMAND (WATTS / DOOR)	ANNUAL ELECTRIC ENERGY (KWH / DOOR / YR)
DEER 2004-2005[3]	214	1,875
GRI[4]	191	1,673
Laboratory Testing[5]	181	1,586
Hill Phoenix (ORZ and ONRZ)[6]	212	1,857
Hill Phoenix (ORZH and ONRZH)[6]	216	1,892
Hussmann (NRC)[7]	188	1,647
Hussmann (NRCV)[7]	212	1,857
Arithmetic Average	**202**	**1,770**

INDIRECT OR INTERACTIVE EFFECTS OF ASH

Laboratory testing revealed that about 35% of the sensible heat generated by the ASH ends up as a cooling load inside a LT reach-in display case.[5] Using 202 watts (or 0.202 kW) per door as the connected electric power of ASH and assuming that ASH are on 100% of the time, the contribution of ASH to the total cooling load of the case is about 241 Btu/hr per door. Equation 1 shows the formula for calculating the cooling load contribution per door from ASH.

EQUATION 1. COOLING LOAD CONTRIBUTION FROM ASH

$$Q_{ASH} = 35\% \times kW_{ASH} \times ASH\ ON\% \times (3{,}413\ Btu/hr/kW)$$

$$= 35\% \times (0.202\ kW/door) \times 100\% \times (3{,}413\ Btu/hr/kW)$$

$$= 241\ Btu/hr/door$$

This additional cooling load of 241 Btu/hr per door, however, needs to be removed by the LT compressors. To estimate the compressor power and energy required to remove this load, the compressor energy efficiency ratio (EER) and equivalent full load hours (EFLH) of operation are needed. Since both EER and EFLH are weather-dependent factors, they vary according to saturated condensing temperature (SCT) or climate zone. Table 3 summarizes EER and EFLH as a function of climate zone or the representative SCT.[8] As shown in Table 3, the average EER for LT compressors is 5.26 Btu/hr/watts and EFLH is 5,696.

TABLE 3. REPRESENTATIVE AND AVERAGE LOW-TEMPERATURE COMPRESSORS' ENERGY EFFICIENCY RATIO AND HOURS OF OPERATION AS A FUNCTION OF SATURATED CONDENSING TEMPERATURE

CLIMATE ZONE	REPRESENTATIVE DRY BULB TEMP. (°F)	SATURATED CONDENSING TEMP. (°F)	ENERGY EFFICIENCY RATIO (BTU / HR / WATTS)	EQUIVALENT FULL LOAD HOURS OF OPERATION (HRS / YEAR)
1	69	79	7.74	5,477
2	96	106	4.98	5,517
3	89	99	5.57	5,609
4	88	98	5.67	5,744
5	83	93	6.14	5,625
6	92	102	5.31	5,819
7	83	93	6.14	5,880
8	89	99	5.57	5,855
9	94	104	5.14	5,796
10	100	110	4.67	5,734
11	104	114	4.37	5,528
12	100	110	4.67	5,615
13	101	111	4.59	5,744
14	108	118	4.08	5,681
15	111	121	3.88	6,269
16	89	99	5.57	5,240
Arithmetic Average			**5.26**	**5,696**

Subsequently, compressor power and annual energy usage due to additional cooling load imposed by ASH are calculated using Equation 2 and Equation 3, respectively. As outlined below, the LT compressors require 0.045 kW/door and 256 kWh/door/year to remove the additional cooling load of 241 Btu/hr per door.

EQUATION 2. COMPRESSOR POWER FOR REMOVING COOLING LOAD DUE TO ASH

$$kW_{compressor} = (\text{Cooling Load Contribution from ASH}) \div (EER_{compressor} \times 1{,}000)$$

$$= (241\ \text{Btu/hr/door}) \div (5.26\ \text{Btu/hr/watts} \times 1{,}000\ \text{watts/kW})$$

$$= 0.045\ \text{kW/door}$$

EQUATION 3. ANNUAL COMPRESSOR ENERGY FOR REMOVING COOLING LOAD DUE TO ASH

$$kWh_{compressor} = kW_{compressor} \times EFLH$$

$$= (0.045\ \text{kW/door}) \times (5{,}696\ \text{hours/year})$$

$$= 256\ \text{kWh/door/year}$$

Overall, taking into account both direct and indirect effects, ASH require 0.247 kW or 247 watts per door. This power demand translates to 2,026 kWh per door, annually. Table 4 summarizes the results.

TABLE 4. OVERALL DEMAND AND ANNUAL ENERGY USAGE PER DOOR FOR ASH

	ELECTRIC DEMAND (KW / DOOR)	ANNUAL ELECTRIC ENERGY (KWH / DOOR / YR)
Direct Effects	0.202	1,770
Indirect Effects	0.045	256
Total	**0.247**	**2,026**

MARKET SIZE

To estimate the number of supermarkets and grocery stores in SCE service territory and statewide, the information in the Commercial End-Use Survey (CEUS)[9] report was used.[10] Note that the information in CEUS was only for SCE, PG&E, SDG&E, and SMUD, and it did not include other municipal utilities in California.

While CEUS divided the total number of supermarkets and grocery stores into three main categories according to their annual energy consumption (Table 5), it did not provide the actual number of stores for each category in the report. Nonetheless, CEUS provided the number of stores in each of the three size categories that was planned to be sampled, which serves as a proxy for the actual distribution (Table 5). For example, it was estimated that the small size grocery stores comprise about 27% of the total grocery stores. For medium and large size grocery stores, the distribution was estimated to be about 47% and 26% of the total grocery stores, respectively.

TABLE 5 GROCERY STORES SIZE CLASSIFICATION AND BREAKDOWN ACCORDING TO ANNUAL ENERGY CONSUMPTION

GROCERY STORE SIZE CATEGORIES	ANNUAL ENERGY CONSUMPTION (KWH / YEAR)	AVERAGE DISTRIBUTION (% OF TOTAL)
Small Size	Less than 190,000	27%
Medium Size	Between 190,000 and 1,600,000	47%
Large Size	Greater than 1,600,000	26%

Table 6 summarizes the total number of stores in SCE, PG&E, SDG&E, and SMUD, as well as the number of stores according to their size classification for these service territories. Table 6 also shows the total number of stores for each of the three size classifications that can be used as a proxy for the actual number of stores statewide.

TABLE 6. TOTAL MARKET SIZE, AND MARKET SIZE FOR SMALL, MEDIUM, AND LARGE SIZE GROCERY STORES

SERVICE TERRITORY	TOTAL GROCERY STORES	SMALL SIZE (27% OF TOTAL)	MEDIUM SIZE (47% OF TOTAL)	LARGE SIZE (26% OF TOTAL)
SCE	**10,760**	**2,905**	**5,057**	**2,798**
PG&E	12,293	3,319	5,778	3,196
SDG&E	2,632	711	1,237	684
SMUD	825	223	388	215
Total	**26,510**	**7,158**	**12,460**	**6,893**

Typically, small size grocery stores have one or two self-contained LT reach-in display cases.[11] Therefore, the focus and attention is given to medium and large size grocery stores.

To estimate the number of LT reach-in glass doors in medium and large size grocery stores, the data gathered from reviewing the refrigeration schedule, past[12] and current projects[13], as well as the survey[14] of several grocery stores was used. The data revealed that a typical medium size grocery store has on average about 35 LT reach-in glass doors. The number of LT reach-in glass doors in a typical large store ranges between 65 and 100, or on the average about 80 doors.

According to an Evaluation, Monitoring, and Verification (EM&V) report[15], 41% of the grocery stores have a mechanism to cycle and control ASH of LT reach-in glass doors. In addition, about 32% of the grocery stores use a new generation of glass doors that requires low to no ASH. However, this report does not clarify the percentage of the grocery stores that have both a new generation of glass doors and a mechanism to control ASH power. Therefore, to take a conservative approach for estimating the number of standard or conventional LT reach-in glass doors without any ASH controllers in SCE service territory and statewide, these percentages are applied independently. Subsequently, Equation 4 is used to estimate the number of standard or conventional LT reach-in glass doors without ASH control in SCE service territory and statewide. Table 7 summarizes results for SCE service territory, and Table 8 summarizes the results for the entire State of California.

EQUATION 4. NUMBER OF CONVENTIONAL REACH-IN GLASS DOORS WITHOUT ASH CONTROL

No. of Glass Doors without ASH Control = No. of Stores x No. of Glass Doors per Store x % of Stores with ASH Control x % of Stores with New Generation of Glass doors

TABLE 7. NUMBER OF STANDARD OR CONVENTIONAL LOW-TEMPERATURE REACH-IN GLASS DOORS WITHOUT ASH CONTROL IN SCE SERVICE TERRITORY BY MARKET SIZE AND TOTAL

	MEDIUM SIZE	LARGE SIZE	TOTAL
Number of LT Reach-In Glass Doors per Grocery Store	35	80	n/a
Number of Grocery Stores	5,057	2,798	7,855
Total Number of LT Reach-In Glass Doors	*176,995*	*223,840*	*400,835*
Percentage of Grocery Stores with ASH Control	41%	41%	n/a
Percentage of Grocery Stores with New Generation of Glass Doors	32%	32%	n/a
Total Number of Standard or Conventional LT Reach-in Glass Doors without ASH Control	**23,222**	**29,368**	**52,590**

TABLE 8. NUMBER OF STANDARD OR CONVENTIONAL LOW-TEMPERATURE REACH-IN GLASS DOORS WITHOUT ASH CONTROL IN CALIFORNIA BY MARKET SIZE AND TOTAL

	MEDIUM SIZE	LARGE SIZE	TOTAL
Number of LT Reach-In Glass Doors per Grocery Store	35	80	n/a
Number of Grocery Stores	12,460	6,893	19,353
Total Number of LT Reach-In Glass Doors	*436,100*	*551,440*	*987,540*
Percentage of Grocery Stores with ASH Control	41%	41%	n/a
Percentage of Grocery Stores with New Generation of Glass Doors	32%	32%	n/a
Total Number of Standard or Conventional LT Reach-in Glass Doors without ASH Control	**57,216**	**72,349**	**129,565**

MARKET BARRIERS

Reducing the ASH power of LT reach-in display cases can be associated with several risks that threaten potential sales, increased maintenance cost, and customer safety. These risks should be considered as primary market barriers.

It is important to refer back to the primary function of ASH to better understand the market barriers of DR strategies in this application. The primary function of ASH is to minimize the condensation problem that is common for LT reach-in display cases. Since grocery stores operate at low profit margins, fogging and sweating that blocks shoppers' visibility through the glass doors can be associated with the risk of significant loss of revenue and profit. Condensation can also result in slippery walk ways and be a cause of injuries. In addition, ice build up on the surfaces of the case could cause the door assembly to freeze, which can be associated with the increased cost of maintenance, and perhaps loss of sales. Thus, the fundamental market barrier for any DR strategy for ASH is the uncertainty associated with the ability to minimize and eliminate the condensation problems.

DEMAND RESPONSE STRATEGIES AND POTENTIAL

The following equation is used to determine the DR potential for this strategy.

EQUATION 5. DEMAND RESPONSE POTENTIAL

$$DR_{potential} = (kW_{reduction}/unit) \times (\text{Market Size}) \times (\text{Market Acceptance})$$

Focusing on ASH for standard or conventional glass doors that are not equipped with any control mechanism, the only practical and reasonable DR strategy is to reduce the power supplied to the ASH to a level that does not cause condensation problems on the glass doors. In the following sections, this strategy and the rational for selecting this strategy is explained. Additionally, in the following sections the demand reduction benefits for using this strategy are quantified.

STRATEGY: REDUCE ASH POWER FROM 100% TO 60%

STRATEGY DESCRIPTION

As its name implies, this strategy reduces the electrical power to the ASH. To determine the acceptable power reduction level for ASH, two issues need to be addressed: (1) indoor temperature and humidity levels inside grocery stores, and (2) minimum ASH power for that particular indoor temperature and humidity levels.

The field-monitored data from a previously conducted project by SCE's TTC was used to establish average and typical indoor dry bulb (DB) and relative humidity (RH) inside the grocery stores. Figure 8 depicts the hourly monitored DB temperature and RH inside a supermarket located in Thousand Oaks, California, which is classified as climate zone 9. The average monthly DB temperature and RH are also shown in Figure 8. Based on the presented field data, it seems to be reasonable and appropriate to consider an average indoor DB temperature of 72^{o}F and an average indoor RH of 45% for this grocery store. It is worthwhile to point out that the indoor DB temperature did not vary significantly and remained relatively constant. While the variations in indoor RH were to some extent significant and exceeded 45% level in some instances, the monthly average indoor RH did not exceed 45%. This is an important observation because it underscores the fact that there might be instances where reducing the ASH power may perhaps cause condensation on glass doors, hence may not be a desirable option.

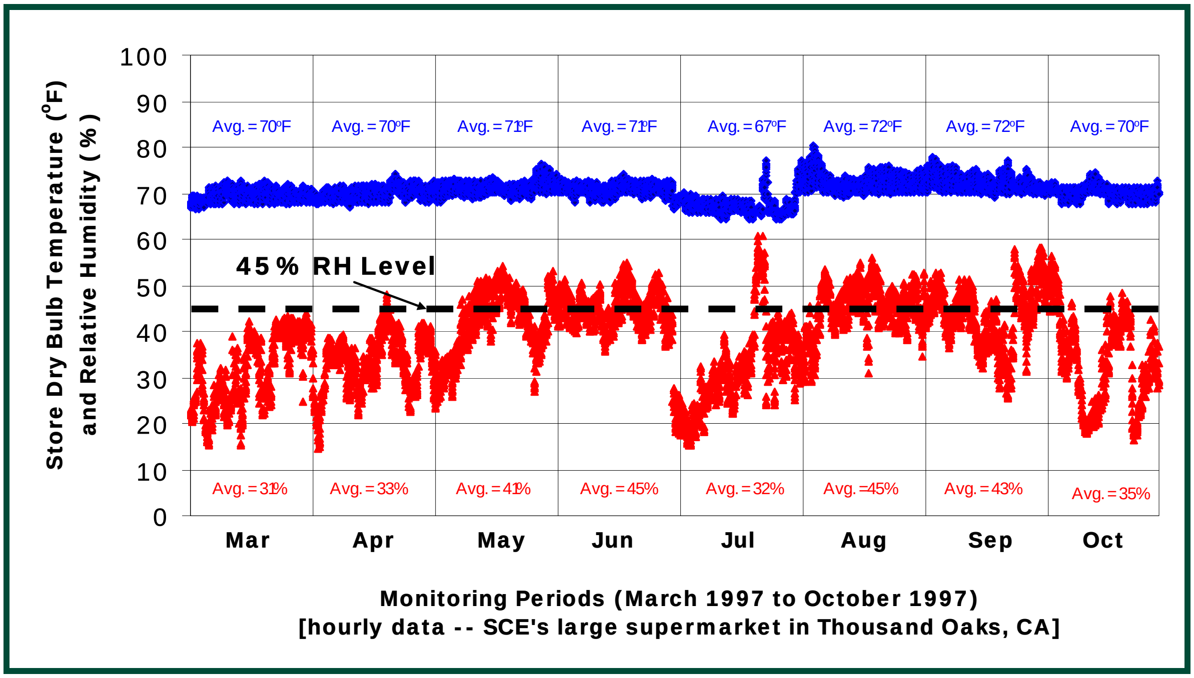

FIGURE 8. INDOOR DRY BULB TEMPERATURE AND RELATIVE HUMIDITY AT A SUPERMARKET IN THOUSAND OAKS, CA

SCE's TTC laboratory test data revealed that when the indoor DB temperature was 75°F and RH was 45% (equivalent to a DP temperature of 52.2°F), providing 83 watts of ASH power per door was sufficient to prevent condensation.[5] In other words, when the indoor DB was 75°F and RH was 45%, there was no need to run the ASH at full power of 181 watts per door. In fact, the temperature of the exterior of the glass door was 66°F and the doorframe temperature was 64°F, which both were above the indoor DP temperature of 52.2°F. The interior glass temperature at 24°F was below the indoor DP temperature of 52.2°F. As a result, a fogging effect was observed on the interior surface of the glass. It took about 48 seconds to clear the fog on the interior glass surface when only 83 watts per door was supplied to ASH. Under the scenario where 181 watts per door was supplied to ASH, it took about 38 seconds to clear the fog on the interior glass surface. The fogging effect on the interior surface of the glass, however, is inevitable even at low humidity levels of 35%.

Overall, this laboratory test finding suggested that when the indoor DB temperature was 75°F and RH was 45%, which is similar to average DB temperature and RH inside a typical grocery store, the power supplied to ASH can be reduced by 54% while preventing condensation on the glass doors. That is, ASH only required 46% of full power to prevent condensation under ambient conditions of 75°F DB and 45% RH. This indicates a reduction from 181 watts per door to 83 watts per door.

Based on the foregoing discussions, the ASH power can be reduced from 100% to 46% since the typical DB temperature and RH inside the grocery stores are 72°F and 45%, respectively. To take a conservative approach, based on our engineering experience, instead of using 46%, 60% will be used as an acceptable power level for ASH in this strategy. Accordingly, the strategy is to reduce the ASH power from 100% to 60% to ensure that there are no condensation problems on the glass doors.

TECHNICAL DEMAND REDUCTION

Reducing the ASH power from 100% to 60% not only reduces the connected electrical power of ASH but it also reduces the cooling load requirements, and thereby compressor power. Reducing the ASH power from 100% to 60% means that the ASH requires 121 (202 x 60%) watts per door instead of 202 watts per door. In other words, the direct effect of reducing ASH power from 100% to 60% is a demand reduction of 81 (202 – 121) watts per door or 0.081 kW per door.

Reducing the ASH power demand by 81 watts per door reduces the cooling load of the case by 97 Btu/hr/door (refer to Equation 1 for calculation methodology). This reduction in total cooling load in turn reduces the compressor power requirement by 0.018 kW per door (refer to Equation 2 for calculation methodology). Overall, coupling both direct and indirect impacts, 0.099 kW per door is the anticipated demand reduction for this DR strategy.

MARKET ACCEPTANCE

The uncertainty associated with potential adverse impacts of reduced ASH on the sales and revenue can affect market acceptance. Therefore, the primary barrier for this strategy is the skepticism about ASH's ability to prevent condensation at 60% power level. Since there is a great deal of unknowns associated with estimating a market acceptance level, market acceptance levels of 1%, 5%, 10%, 20%,and 50% are used for the purpose of this evaluation.

DEMAND RESPONSE POTENTIAL

Table 9 summarizes the results for various market acceptance levels in SCE service territory and statewide, respectively.

TABLE 9. DEMAND RESPONSE POTENTIAL FOR VARIOUS MARKET ACCEPTANCE LEVELS IN SCE SERVICE TERRITORY AND STATEWIDE

			DR POTENTIAL (KW)				
DEMAND REDUCTION (KW / DOOR)	MARKET SIZE (POPULATION)		AT 1% MARKET ACCEPTANCE	AT 5% MARKET ACCEPTANCE	AT 10% MARKET ACCEPTANCE	AT 20% MARKET ACCEPTANCE	AT 50% MARKET ACCEPTANCE
0.099	SCE	52,590	52	261	521	1,043	2,607
	CA	129,565	128	641	1,283	2,565	6,413

RESULTS

The results indicate that the only practical and reasonable DR strategy for ASH on conventional glass doors without any control mechanism is to reduce the power supplied to them from 100% to 60%. The basis for this conservative strategy is the typical indoor conditions (DB and RH) observed in grocery stores and the empirical data that supported the need for reducing ASH power under those typical indoor conditions. As a result, it is anticipated that this DR strategy has the potential to reduce the demand by 0.099 kW per door. Extending this finding to the potential market size in SCE service territory and statewide by assuming different market acceptance levels, the demand reductions are anticipated to range between 52 kW and 2,607 kW, and between 128 kW and 6,413 kW, respectively.

RECOMMENDATIONS

It is recommended to evaluate the cost effectiveness of this DR strategy relative to the current measures in energy efficiency rebate programs. Such evaluation will enhance the understanding about the value of this DR strategy. Currently, rebate programs offer incentives for using ASH controller and new generation of glass doors that require low ASH power. It is important to note that these two energy efficiency measures (ASH controller and new generation glass doors) provide long-term benefits, whereas this DR strategy reduces partially the power for short periods of time. In addition, the magnitude of demand reduction and energy savings realized by using these two energy efficiency measures are far greater than the savings realized using the proposed DR strategy.

Considering DR cost effectiveness, it is also recommended to focus on grocery stores that are equipped with energy management systems and a two-way communication interface. If the proposed DR strategy is to be pursued, however, field or laboratory assessments will provide improvement areas for the proposed DR strategy.

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