Calculated Energy Savings for Disabling Anti-Sweat Door Heat on Glass Display Case Doors

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LEGAL NOTICE

ABBREVIATIONS AND ACRONYMS

ASTM	American Society for Testing and Materials
CT	circuit transducer
F	Fahrenheit
HP	horsepower
kWh	Kilowatt-hours
NOAA	National Oceanic Atmospheric Administration
PET	polyethylene terephthalate
ROI	return on investment
RH	relative humidity
TMY	typical meteorological year

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EXECUTIVE SUMMARY

A grocery store customer within PG&E territory installed Anti-fog film on the inside glass of a five-door frozen food display case and the door anti-sweat heat was disabled on the doors of the display case. PECI analyzed actual energy consumption for three weeks before and three weeks after the door heat was turned off to determine the avoided energy use from reduced load on the compressor and reduced door heater energy use during the post retrofit period. Energy data was metered at the doors and at the condensing unit serving the case to capture savings directly from the reduction in door heat power and to capture the reduction in load on the condensing unit. The pre and post metered data was also used to calculate estimated annual energy savings. Table 1 below displays the results from the avoided energy use calculations, as well as the estimated annual savings.

AVOIDED KWH (SAVINGS)	Annual kWh (SAVINGS)
173.0	3,128

TABLE 1: SUMMARY OF AVOIDED ENERGY USE RESULTS

As a result of this study, PECI supports that there are savings at both the door and the compressor for turning off the door heater on a frozen food case. However, PECI feels that additional testing needs to be pursued to verify the Anti-fog product's performance at different conditions in the absence of door heat.

PROJECT GOAL

Determine if there are energy savings, and if so how much, if the anti-sweat door heater is disconnected on a frozen food case at a grocery store.

PROJECT DESCRIPTION

The project monitored energy consumption on a 5-door frozen food case for three weeks before and three weeks after anti-fog window film was installed on the interior door panes and the anti-sweat door heater was disconnected.

PROJECT FINDINGS/RESULTS

PECI supports that there are savings at both the door and the compressor for turning off the door heater on a frozen food case.

PROJECT RECOMMENDATIONS

PECI advises that additional testing be pursued to verify the Anti-fog product's performance at difference conditions in the absence of door heat.

BACKGROUND

When the warm, humid air of a grocery store's floor space contacts the cold glass of a display case, the water vapor in the warm air condenses and forms a fog on the glass. Door heaters prevent this condensation by raising the temperature of the outer glass surface above the dew point. This heat is not always necessary depending on the temperature and the humidity levels in the store; however, the default setting is for door heaters to run all the time.

There are a variety of controls available that monitor ambient dew point and/or condensation on the doors and turn the door heaters on and off as needed. While these controls reduce the direct electrical energy demand from the heaters by reducing their run time and also reduce the amount of heat the refrigeration system needs to reject, they can be expensive. Anti-fog film is an alternative to installing controls.

EMERGING TECHNOLOGY/PRODUCT

Anti-fog film is a 0.1 mm thick polyethylene terephthalate (PET) sheet with adhesive that is applied to the interior of refrigerated case doors. The Anti-fog film Product Datasheet is attached to the end of this report as an appendix for reference. The Anti-fog film distributor, Anti-fog Systems, Inc., describes the film by stating "Anti-fog is hydrophobic, so it attracts the water, and sheets it out invisibly on the coated surface resulting in a clear, fog-free surface."[1] In this study the door heaters were disabled when the film was installed, but the frame heater remained in use.

SITE DESCRIPTION

One small grocery store, approximately 2,500 square feet, located in San Jose, California, was recruited for this short study. The store's operating hours are from 6am to 10pm daily. The display case that received the retrofit is a Zero Zone five-door frozen food case that is in good condition, with intact gaskets, auto closers and triple-pane glass doors. The condensing unit that is serving the frozen food case has a two horsepower compressor and runs on R404a refrigerant. Table 2 and Table 3 below provide details of the frozen food display case and condensing unit compressor.

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[1] What will Anti-Fog Do For You? Anti-Fog Systems, Inc.: Refrigeration Application. antifogsystems.com. Retrieved May 14,2013 from http://antifogsystems.com/what-can-we-do-for-you/

Case Make	Case Model	Year Built	# of Doors	Heater Amps (Frames and Doors)	Gasket Conditions	Auto Closer Presence	Door Details	Case Product Type	Fan Motor Amps
Zero Zone	5RVZC30R	Jun-05	5	8.73	Good	Working	Anthony 101B: 3-pane heated reflective glass	frozen food and ice cream	1.5

Table 2: Test Site Case Details

Compressor	Compressor HP	Refrigerant
Tecumseh AVI82RT	2	R404a

Table 3: Test Site Condensing Unit Details

Technical Approach

Sub-metered Interval Data

Sub-metered interval data was collected from the main power feed to the condensing unit and the five-door display case using Dent ELITEpro SP™ Energy Loggers with appropriate current circuit transducers (CTs) borrowed from the Pacific Energy Center. For the display case, the Dent ELITEpro SP™ was attached to the case circuit connected to the display case motors, frame heaters and door heaters. Case motor energy was not expected to change during this study, so the difference in energy use pre and post retrofit reflects only the change in door heater energy. The data was collected at 1 minute intervals and then summed into daily intervals. No other energy efficiency projects took place at the site during the pre and post monitoring periods.

Monitoring Period

The monitoring period was limited to approximately three weeks pre and three weeks post implementation due to budget and time constraints. The pre period was February 26, 2013 to March 17, 2013 and the post period was March 19, 2013 to April 9, 2013. Installation of the Anti-fog film and disconnection of the door heaters took place March 18, 2013.

Weather Data

National Oceanic Atmospheric Administration (NOAA) hourly Quality Controlled Local Climatological Data from the closest weather station is used in the regression model for the condensing unit. For this test site, PECI used San Jose, California weather data. Specifically, dry-bulb temperature data was used because the condensing unit monitored is air cooled.

AVOIDED ENERGY USE

The avoided energy use method for the condensing unit involved the creation of a baseline regression using baseline energy and dry-bulb data monitored prior to implementation of the energy efficient measure. Then, the actual outside air temperatures recorded during the post period following the conclusion of energy efficiency implementation are used in the regression derived from baseline data to create an adjusted baseline for the condensing unit. The adjusted baseline is a prediction of how the unit would have operated if the energy efficient change was not implemented. The difference between the adjusted baseline and measured post-installation energy use is the avoided energy use, or the closest attempt to "measure" energy savings (Equation 1).

Avoided Energy = Adjusted Baseline – Post Installation Energy Use

EQUATION 1: AVOIDED ENERGY

Calculating the avoided energy use for the doors did not involve building a regression with weather data. This is because the reduction in power uses was a constant value during the pre-monitoring period while the door heaters were on, and another constant value for the entire post-monitoring period while they were turned off. To calculate the avoided energy use of the doors, the post energy use is subtracted from the actual pre-energy use. Because a regression was not built to calculate the door savings, there is not a confidence interval for the savings.

RESULTS

The calculated avoided energy for the condensing unit and doors are shown in Table 4, below, along with the confidence interval calculated at an 80% confidence level for the condensing unit. An 80% confidence level is used because it is the minimum industry accepted level and PECI feels it is appropriate for the short duration of data collected.

	Post monitoring period (# of days)	Avoided Savings (kWh)	Confidence Interval
Condensing Unit	22	16.71	± 4.48
Doors	22	156.3	N/A

TABLE 4: AVOIDED ENERGY USE

NORMALIZED ANNUAL SAVINGS

Normalized savings are calculated using separate regressions for the baseline and post-installation periods. Each regression is then driven with a common dataset, such as TMY temperature data. As the regressions are driven with TMY (typical meteorological year) data, less than 1 year of data can be used to estimate annual savings. Normalized energy savings was used to calculate the estimated annual energy savings at the condensing unit. The savings resulting from disconnecting the door heaters is a constant load reduction that does not change, so to annualize this savings the daily kWh reduction is simply multiplied by 365 days to determine the annual consumption reduction.

First, for the condensing unit, two regression models are built, one using the pre and one using the post condition metered data to correlate daily condensing unit energy to average daily dry bulb temperature from the closest NOAA station. The same NOAA weather station data from the avoided energy analysis is used. The pre and post energy use correlated to dry-bulb for the condensing unit is illustrated in Figure 1: kWh vs. Dry Bulb.

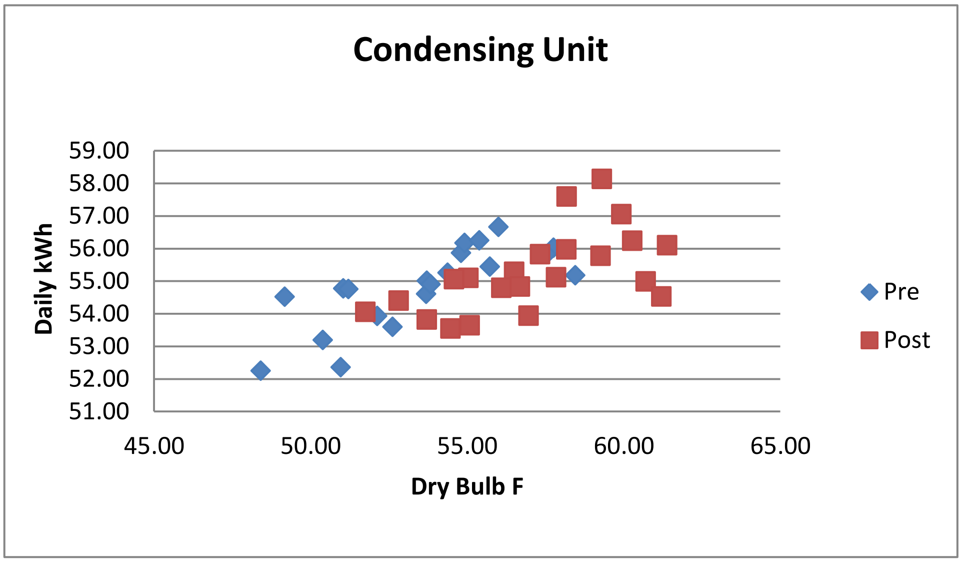

FIGURE 1: KWH VS. DRY BULB

Next, the two regression models built on the short term metered data are then driven with TMY daily average temperature values to calculate normalized annual electrical energy use for pre-installation and for post-installation periods. The difference between the post-installation annual energy use and the pre-installation annual energy use is the normalized energy savings (Equation 2).

Annual Normalized kWh Pre Installation – Annual Normlized kWh Post Installation = Annual Normalized kWh Savings

EQUATION 2: ANNUAL NORMALIZED KWH SAVINGS

Table 5 shows the calculated normalized annual energy savings values for the condensing unit and the confidence interval calculated at an 80% confidence level. While the normalized annual energy savings values are provided for the condensing unit, these values are not accurate estimates of annual savings as the regression which they were based on only covered a small range of ambient conditions. The maximum temperature experienced during the monitoring period was below 65 F degrees, whereas the maximum expected temperature during the full year is 75 F degrees, nearly 10 F degrees warmer. Previous research has shown capturing the full range of temperature is critical for the accuracy of annual savings for weather dependent systems.[2] Figure 2 displays the temperature range covered by the metering period in comparison to the temperature range in a typical year for the grocery store monitored.

	Calculated Annual Savings	Confidence Interval
Condensing Unit	535 kWh	± 31.91 kWh
Door	2,593 kWh	N/A
Total Expected Savings	3,128 kWh	± 31.91 kWh

TABLE 5: CALCULATED ANNUAL SAVINGS

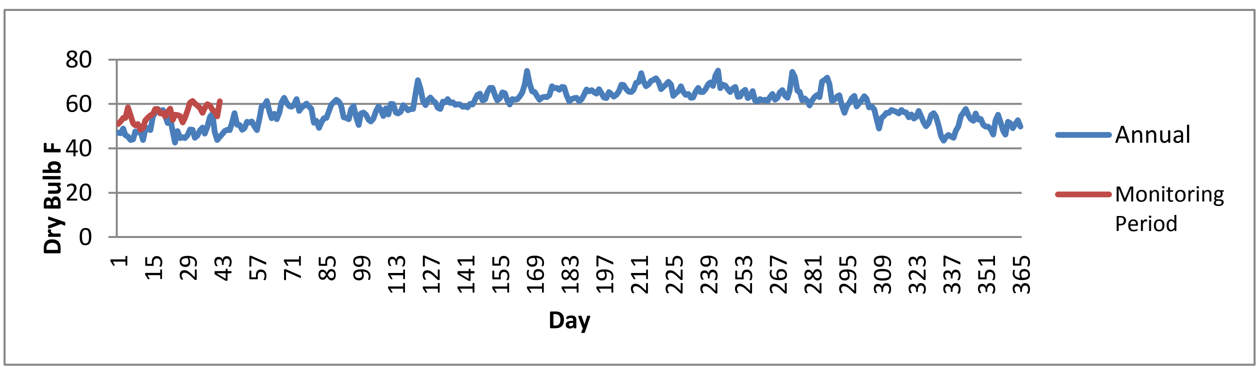

FIGURE 2: DRY BULB RANGE DURING MONITORING PERIOD VS. AVERAGE YEARLY RANGE

[2] Kissock, J.K., Reddy, T.A., Fletcher, D., Claridge, D.E., 1993. The Effect of Short Data Periods on the Annual Prediction Accuracy of Temperature-Dependent regression Models of Commercial Building Energy Use. Joint Solar Engineering Conference, ASME 1993.

Montgomery, D.C, 1991. Design and Analysis of Experiments, Third Edition, John Wiley and Sons, New York.

Effinger, J., Effinger, M., Friedman, H., 2011. Case Studies In Using Interval Data Energy Models For Savings Verification: Lessons from the Grocery Sector. ICEBO conference, 2011.

ROI EVALUATION

An estimated cost for the Anti-fog film product and installation of the product on a refrigerated display is $15 per square foot of display case glass. The five door refrigerated display case in this study has about 66 feet of glass surface to which Anti-fog film was installed. The cost to install the product was approximately $984. Based on an E-19 rate schedule, $0.137/kWh is used to calculate the return on investment (ROI) for this project. Using the calculated annual savings of 3,128 kWh/yr with the confidence interval from Table 5 above, the annual calculated energy saving is approximately $428/yr. Equation 3 below provides a ROI for this project of about 2.3 years.

$$ROI\ (yr) = Project\ Cost\ (\$) \div Annual\ Calculated\ Energy\ Savings\ (\$/yr)$$

EQUATION 3: RETURN ON INVESTMENT (ROI)

RECOMMENDATIONS

The purpose of this study was to evaluate the energy savings for disabling the door heaters on a refrigerated display case when the doors are retrofitted with Anti-fog film. This study was not designed to assess the effectiveness of the Anti-fog film at eliminating condensation from the glass door of the display case with the absence of door heaters. PECI feels that it is important to evaluate the product's effectiveness in order to support the implementation of the product on different door types and in different store conditions.

PECI staff did observe condensation on doors on two of three visits to the store during the post implementation period. Figure 3 below illustrates the display case doors with varying condensation. The photo on the left was taken late morning on March 27th show condensation on all five doors. The photo on the right was taken late morning on June 5th and shows condensation on just the door closest to the produce cases. Elevated relative humidity creates an ideal environment for condensation to form, so PECI recorded the relative humidity outside the display case door and at and entrance of the store to ensure that the relative humidity was not unexpected for a grocery store. Additionally, these readings enabled comparison to the operating conditions referenced in Anti-Fog System LLC: Fridge Film Condensation document found at http://images.katrinacostedio.com/Condensation%2008.21.12.pdf. This document outlines that at 75ºF ambient air temperature and relative humidity level below or equal to 55%, refrigerated glass doors should not have condensation on the outside of the doors when anti-sweat door heaters are turned off.

PECI also noticed bubbles in the Anti-fog film on visits to the store. PECI confirmed the bubbles were an installation issue and covered by the manufacturer's warranty. The recorded data and observations are documented in Table 6 below. Recording this type of data over a longer period of time, with greater frequency and under different dry-bulb and relative humidity conditions may help identify the ideal store conditions for the product.


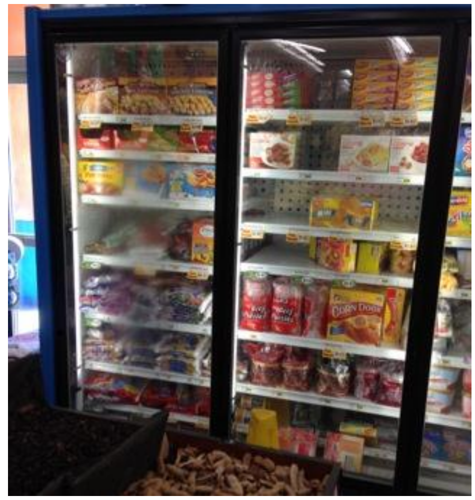

FIGURE 3: DOORS WITH CONDENSATION

Date	Dry-bulb ºF in Front of Case	RH % in Front of Case	Store Entrance Dry-bulb ºF	Store Entrance RH %	Dry-bulb ºF of Display Case Glass	Observation Notes
4/3/13	65.5	42.0	68.5	50.0	44.9	Condensation on door closest to produce case. Some visible bubbles in the film at the bottom of doors. Time of recording:3:30 pm.
4/10/13	72.9	32.8	80.8	30.2	40.2	Time of recording: 2:45 pm. No condensation on doors. More small bubbles in film, all over the doors.

TABLE 6: RELATIVE HUMIDITY (RH) AND CONDENSATION OBSERVATIONS

The dry-bulb and relative humidity readings that PECI recorded were typical for a grocery store. Table 7 below provides average dry-bulb and relative humidity conditions for grocery store conditions across the United States. This information was taken from the ASHREA 2010 Refrigeration Handbook and is based on observation from over 2000 sites[3].

[3] ASHRAE, Inc. (2010). Chapter 15: Retail Food Store Refrigeration and Equipment. *2010 ASHRAE Handbook: Refrigeration, I-P Edition,* 15.3.

Season	Dry-bulb Temperature ºF	Relative Humidity %
Winter	69	36
Spring	70	50
Summer	71	56
Fall	70	50

TABLE 7: AVERAGE STORE CONDITIONS IN UNITES STATES

CONCLUSION

PECI monitored energy consumption on a case and condensing unit where Anti-fog film was installed on the display case doors and the door anti-sweat heat was disabled. Avoided energy savings and normalized annual savings estimates were calculated. PECI recommends that an evaluation that captures ambient store conditions, similar to Table 6, along with the type of door, placement of the Anti-fog film (inside glass, outside glass or both sides) at a more regular interval, would provide helpful data to identify ideal conditions for the installation of the Anti-fog product.

APPENDIX

Anti-Fog film Datasheet

Anti-Fog SYSTEMS LLC

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Valox* HPNGFF Film Product Datasheet

Description

Valox* HPNGFF film is a one-side coated anti-fog PET film. With an adhesive backing it is an excellent candidate for use in display case refrigeration units such as those found in grocery and convenience stores. It offers long-term anti-fog performance, abrasion resistance, impact resistance, and good optical clarity. HPNGFF film also provides chemical resistance and anti-static properties.
Typical applications include: Refrigerated cases, Instrument lenses & display panels, Mirrors, Windows and Auto-Glass.

Typical Property Values◆

Property	ASTM Test Method	Units (USCS)	Value	Units (metric)	Value
Mechanical					
Elongation at Break MD	ASTM D882A	ft-lb	150	N-m	203
Elongation at Break TD	ASTM D882A	ft-lb	100	N-m	135
Yield (nominal)		in2/lb	5,000	M2/kg	7
Yield Strength MD	ASTM D882A	PSI	14,000	Kg/m2	9,842,000
Yield Strength TD	ASTM D882A	PSI	14,000	Kg/m2	9,842,000
Thermal					
Shrinkage MD (190C)		%	<2.5		
Shrinkage TD (190C)		%	<1.0		
Physical					
Thickness (Gauge)			400		
Pencil Hardness	ASTM D3363	-	F		
Taber Abrasion	ASTM D1044	delta Haze	6-10		
Optical					
Light Transmission	ASTM D1003	%	>88		
Haze	ASTM D1003	%	<0.5		
Adhesive properties					
180 degree peel on glass		oz	50 - 100	kg	1.4 -2.8

◆ These are typical properties and are not intended for specification purposes. If minimum certifiable properties are required, please contact your local SABIC Innovative Plastics representative or the SABIC Innovative Plastics Quality Services Department.
Reported Values are Based on 400 gauge thickness unless otherwise noted.

Valox*

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