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REFRIGERATION

EC MOTOR RETROFIT FOR A WALK-IN COOLER OR FREEZER SWCR004-01

CONTENTS

MEASURE NAME

EC Motor Retrofit for a Walk-In Cooler or Freezer

STATEWIDE MEASURE ID

SWCR004-01

TECHNOLOGY SUMMARY

Evaporator fan motors are found within refrigerated display cases and walk-in freezers/coolers. This measure pertains to the replacement of shaded pole (SHP) and permanent split capacitor (PSC) evaporator fan motors with new electronically commutated permanent magnet motors (ECMs) in walk-in freezers/coolers.

High-efficiency motors with lower energy (heat) losses reduce both electrical energy consumption of the evaporator fans and the internal cooling load required by the cases. EC motors operate efficiently over a wide range of speeds and optimize airflow while minimizing energy use and waste heat.

According to a commercial refrigeration study conducted for the U.S. Department of Energy (DOE),[1] typical SHP fan motor efficiencies are 15% to 23%, typical PSC fan motor efficiencies are 40% to 70%, and typical ECM fan motor efficiencies are 71% to 83% for rated shaft output between 6 W and 373 W (1/125 hp to 1/2 hp). Therefore, replacing the evaporator fan SHP and PSC motors with ECM motors will reduce the evaporator fan energy consumption and the refrigeration cooling load for cooling the heat rejected by the motors, and result in electrical energy savings.

MEASURE CASE DESCRIPTION

The measure case is a new electronically commutated permanent magnet motor (ECM) for a walk-in cooler or freezer. The measure offerings are specified below:

BASE CASE DESCRIPTION

The base case is defined as the existing shaded pole (SHP) or permanent split capacitor (PSC) evaporator fan motor for a walk-in cooler or freezer.

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[1] Arthur D. Little, Inc. 1996. *Energy Savings Potential for Commercial Refrigeration Equipment.* Prepared for Building Equipment Division Office of Building Technologies U.S. Department of Energy. Efficiencies inferred from Table 5-2, Page 5-8.

CODE REQUIREMENTS

Applicable state and federal codes are summarized in Table 1. The California Appliance Efficiency Regulations (Title 20) stipulates the efficiency of evaporator fans in newly constructed walk-in coolers and freezers manufactured on or after January 1, 2009. Specifically, evaporator fan motors with less than one horsepower and less than 460 volts must use electronically commutated motors (ECM, brushless direct current motors) or 3-phase motors. [2]

Table 1. Applicable State and Federal Codes and Standards

Code	Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2014)	Section 1605.1(a)(4)(E)(1)	January 2019
CA Building Energy Efficiency Standards – Title 24	None.	n/a
Federal Standards	None.	n/a

NORMALIZING UNIT

Each (per motor)

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
Accelerated replacement (AR)	DnDeemDI	Com
Accelerated replacement (AR)	DnDeemed	Com

Eligible Products

All products must meet the requirements in the Measure Case Description.

[2] California Energy Commission (CEC). 2019. *2019 Appliance Efficiency Regulations*. CEC-140-2019-002.

The evaporator fan motor shaft output is typically rated between 6 W and 373 W (1/125 hp to 1/2 hp).

Requirements for accelerated replacement of walk-in cooler evaporator fan motors are:

- The existing motor system must be fully functional with no signs of replacement in the 12 months following the project application date.
- Pre-inspection of existing equipment is required.

Eligible Building Types

This measure is applicable in any existing commercial building type 2008 and older. This is based on the assumption that walk-in equipment is at least as new as the building.

Eligible Climate Zones

This measure is applicable in all California climate zones.

Required Documentation for Installations

Preponderance of evidence (POE) must be documented. Notably, programs shall document if measure was replaced as a direct result of information, recommendations, and support provided by the Program Administrator, and programs shall require the collection and submission of documentation to ensure proper conformance to eligibility and implementation requirements. The following are the types of information that will be required for all projects:

- Customer/site information
- Specifications of existing equipment
- Proof that existing fan motor is still operating as intended
- Existing fan motor nameplate data with manufacturer date to confirm remaining useful life
- Replacement motor nameplate information

To document POE, the provided Preponderance of evidence (POE) survey[3], or similar, should be completed.

PROGRAM EXCLUSIONS

This measure cannot be used in conjunction with the Evaporative Fan Controller for Walk-in Coolers and Freezers.

The measure excludes motors greater than 1/2 horsepower.

[3] SWCR004 POE Survey.docx

DATA COLLECTION REQUIREMENTS

This workpaper revision is based on the finding that most existing evaporative fan motors in walk-in coolers and freezers are suitable for ECM upgrade as a cost-effective energy efficiency measure, and that the classes of existing motor that are targeted by the baseline tend to be limited to a maximum rating of 1/2 horsepower. Research that finds motor replacements in other components of walk-in coolers and freezers to be cost-effective, or that documents a different range of sizes in baseline equipment, would merit consideration of another revision. However, at this time, the only anticipated driver for revision is price fluctuations, for which no timeline can now be established.

To improve quality of cost-effectiveness calculations, programs implementing this measure should collect data on actual costs for materials and labor. The highest quality data collection would provide also associated motor sizes (nominal W) and a table of material and labor costs for each size of motor being installed.

USE CATEGORY

Commercial refrigeration (ComRefrig)

ELECTRIC SAVINGS (kWH)

The building energy simulation tool DOE-2.2R was used to derive the annual energy impacts because this measure is weather-sensitive.

Assumptions

The following assumptions were established for the savings calculations of the energy (and demand) impacts of the walk-in cooler/freezer ECM motor retrofit:

- *This measure applies to fixtures with single and multiplex compressor systems.* The DEER2020 "Grocery" prototype building models were generated with multiplex refrigeration systems for the reach-in refrigerated display cases. Single-compressor systems are less efficient than multiplex-compressor systems. According to the 2004-2005 DEER Update Study,[4] single-compressor systems were typically designed prior to 1980. To be conservative, it is assumed that the generated energy savings are applicable to display cases with single-compressor systems.
- *This measure applies to fixtures located inside a space that has space heating and space cooling.* Since the heat gain to a display case primarily depends upon the temperature maintained for the display case and the surrounding space temperature, it is assumed that the building types would not have significant impact on the energy savings. Thus, the resulting savings for the Grocery Store building is applied to all other applicable building types.

[4] Itron, Inc. 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report.* Prepared for Southern California Edison.

Base Case and Measure Case Model Simulations

The building energy simulation engine DOE-2.2R (via MASControl3) was used to derive base case and measure case unit energy consumption. The model is summarized as follows:

- The DEER2020 prototype template files for Grocery buildings were updated to accept input parameters describing evaporator fan input power for refrigerated walk-in cases. Copies of the MASControl3 workbooks were created to describe Measure, Technology, and Parameter definitions.
- MASControl3 generates a list of all applicable building instances as combinations of HVAC types, representative year building vintages, and altitude and weather (climate zone), consistent with DEER2020 methodology.
- The list of building instances to simulate was filtered to include only Grocery building type and only vintage 2003, the most recent vintage for which DEER2020 models by default have "standard" (as opposed to high efficiency) evaporator fan motors in walk-in refrigeration cases. Please note that with the Grocery prototypes update task performed by SCE did not require any updates to DEER2020 models before vintage 2015.
- Simulations were generated for the run list using the most recent weather files distributed with DEER2020 (same as DEER2014 CZ2010 weather data files
- The DEER building prototypes specify multiplex-compressor systems as the refrigeration type
- The walk-in evaporator fan input power levels provided in the D03-202 DEER measure definition (built into the Grocery model source code) were used to specify the base case models for the SHP motor baseline. Note that DOE-2.2R models the evaporator fan power via a kW per CFM factor. Because the simulation engine does not require the model to separately describe the fan mechanical efficiency nor head/pressure requirements (and the DEER models do not further document the assumptions behind these particular default levels), it is not possible to infer a motor efficiency corresponding to the default DEER values, nor the motor type. Thus the assignment of the default power levels to the SHP motor type is an assumption, although power levels seem reasonable and consistent with this motor type, based on comparison with anecdotal refrigerated case model specifications described in the references.
- For ECM motor case and the PSC motor base case, the fan input power is multiplied by a ratio of motor efficiency (relative to SHP motors) that is specific to the type of equipment (refrigerator or freezer) by referring to curves for typical motor efficiency as a function of size and technology, and the sizes for refrigerator and freezer fan motors in prototypical equipment. These efficiency curves and typical sizes are documented in the attached workbook[5] and are based on a 1996 DOE report.[6]

The steps to determine motor efficiency ratios for refrigerator and freezer equipment include the following. First, reference sizes for evaporator fan motors in refrigerator and freezer cases were drawn from the prototypical model specifications provided in the table below. Next, tables of nominal motor output power (eg. rated in HP) vs. input power (rated in W) were recorded from table 5-2[7], and the

[5] SWCR004-01- fan motor setup calcs.xlsx

[6] Arthur D. Little, Inc. 1996. *Energy Savings Potential for Commercial Refrigeration Equipment.* Prepared for Building Equipment Division Office of Building Technologies U.S. Department of Energy. Pages 28-38.

[7] Ibid., p. 5-8.

equivalent motor efficiency computed for each entry. For shaded pole motors, input power data was available only to a maximum output rating of 1/30 HP; to establish an efficiency for 1/20 HP shaded pole motors, the efficiency was extrapolated by logarithmic regression fit. For each walk-in case type at its reference motor sizes and for each of PSC and ECM motor types, these power input ratios were multiplied by the fan power per flow levels assumed for SHP motors to determine fan power per flow levels to use for the applicable technology runs.

Table 2 Reference Sizes for Evaporative Fan Motors from Prototypical Model Specification[8]

	Walk-In Freezer	Walk-In Cooler
Typical evaporator fan	Shaded pole (1/40 HP)	Shaded Pole (1/20 HP)
SHP efficiency at typical size	22.2%	25.2%
PSC efficiency at typical size	47.6%	52.9%
ECM efficiency at typical size	74.1%	75.5%
PSC power input ratio relative to SHP	0.467	0.477
ECM power input ratio relative to SHP	0.300	0.334
SHP fan power per flow	0.169 W/CFM	0.169 W/CFM
PSC fan power per flow	0.07887 W/CFM	0.08069 W/CFM
ECM fan power per flow	0.05070 W/CFM	0.05648 W/CFM

These power per flow values are entered in technology definitions in the modified Technology Workbook[9] and communicated by MASControl3 to the models via the user-defined parameters corresponding to the individual walk-in cases in the Grocery model, as in the table below. The modified DEER model source file 'GroRfg2.inp' is required and should be copied to overwrite the file IncFiles/GroRfg2.inp distributed with MASControl3. Note that the technology definitions are organized via the modified measure definition workbook[10] into meaningful baseline and measure case technology. The methodology described above is implemented via technology and measure IDs labeled "draft2".

System U-name	SUPPLY-KW/FLOW keyword set by parameter:
Sys_A_RfgWFrz_C	FanKwCfmFreezer
Sys_A_RfgWClr_C	FanKwCfmCooler

[8] Ibid., p. 4-66.

[9] TechData_NonResLtgPlugs.xlsm. Attached within "SWCR004-01 - MAScontrol3 setup and DOE2 models.zip"

[10] DEER_NonRes_Measures.xlsm

To normalize the energy savings per unit fan, a number of fan motors subject to the measure must be determined consistent with the equipment modeled in the building energy simulations. In DOE-2.2R models for walk-in refrigerated cases, the number of fans is never explicitly entered, and the DEER2020 documentation does not specify the number of fans. Instead, for this workpaper, the method selected to determine the number of fan motors is to consider the shaded pole baseline equipment and assumptions, and for each refrigerated case, presume that the number of fans is equal to the total walk-in case fan power input divided by the power input for a motor of the typical size as described above. The total input fan power can be determined from the evaporator fan power per flow (as discussed above) and air flow rate, which is entered as an input to the model.

Table 3. Calculation of denominator used to normalize energy savings

	Freezer	Cooler	Source
Evaporator air flow	5700 cfm	5938 cfm	DEER models
Input power to evaporator fans per unit flow, with SHP motors	0.169 W/cfm	0.169 W/cfm	DEER models
Fans total input power	963.3 W	1003.4 W	Line 1 × Line 2
Input power for typical sized motor	90.0 W (1/40 hp output)	146.6 W (1/20 hp output)	"SWCR004-01- fan motor setup calcs.xlsx", based on A. D. Little (1996)
Number of fan motors	11	7	Line 3 / Line 4

Electric Energy Savings

Total energy savings were calculated as the difference between the modeled total energy consumption of the base case and measure case models, as shown below. The unit energy savings (UES, kWh/motor) was calculated by dividing the total energy savings by the number of motors per freezer/cooler.[11,12] Values of parameters in Equation 1 are provided in Table 4.

Equation 1. Annual ECM Motor Retrofit Electric Energy Savings Calculation

$$ES_{Total\ Line-Up} = EC_{Base} - EC_{Measure}$$

$$UES_{Motor} = \frac{ES_{Total\ Line-Up}}{Motors}$$

where:

$ES_{Total\ Line\text{-}Up} =$	*Total energy savings for the entire line-up (kWh)*
$EC =$	*Modeled energy consumption of the base case and measure case units (kWh)*
$UES_{Motor} =$	*Unit energy savings per motor (kWh/motor)*
$Motors =$	*Number of motors per freezer/cooler*

Table 4. ECM Motor Retrofit Electric Energy Savings Parameters

Parameter	Base Case Model	Measure Case Model	Source
Modeled energy consumption and demand	*Varies by climate zone*		Southern California Edison (SCE). 2019. "SWCR004-01 - MAScontrol3 setup and DOE2 models.zip"
Motors per freezer/cooler	11 / 7	11 / 7	Calculation above

PEAK DEMAND REDUCTION (KW)

Peak demand was calculated as the average of the electrical power draw between 4:00 p.m. to 9:00 p.m. in conformance with the Database for Energy Efficiency Resources (DEER) peak definition.[13] Unit peak demand reduction (kW/motor) was calculated as the difference between the base case and measure case total peak demand reduction, divided by the total number of motors of the walk-in freezer/cooler case.

[11] Southern California Edison (SCE). 2019. "SWCR004-01 Energy analysis.xlsx"

[12] Southern California Edison (SCE). 2019. "SWCR004-01 - MAScontrol3 setup and DOE2 models.zip."

[13] California Public Utilities Commission (CPUC). 2018. *Resolution E-4952. Approval of the Database for Energy-Efficient Resources updates for 2020 and revised version 2019 in Compliance with D.15-10-028, D.16-08-019, and Resolution E-4818.* Ordering Paragraph 1.

GAS SAVINGS (THERMS)

There are no therms savings from this measure.

LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration. The RUL is only applicable to the first baseline period for a retrofit measure with an applicable code baseline.

The methodology to calculate the RUL conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends "one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values."[14] This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.[15] Further, as per Resolution E-4807, the California Public Utilities Commission (CPUC) revised Add-on Equipment (AOE) measures so that the EUL of the measure is equal to the lower of the RUL of the modified system or equipment or the EUL of the add-on component." [16]

The EUL and RUL specified for ECM motor retrofits of display cases are presented in Table 5. The EUL is associated with the lifetime of a high efficiency evaporative fan motor. This EUL value was recommended for the PY2001 programs by the IOUs in response to Ordering Paragraph 8 of Decision 00-07-017.[17] The adopted value was then incorporated into the 2005 and subsequent versions of DEER.[18]

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[14] California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.

[15] KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

[16] California Public Utilities Commission (CPUC). 2016. *Resolution E-4807*. December 16. Page 13.

[17] California Measurement Advisory Committee (CALMAC). 2000. *Public Workshops on PY2001 Energy Efficiency Programs.* Pp 8 – 9, Appendix C2. September 25.

[18] Itron, Inc. 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report*. Prepared for Southern California Edison. Table 11-2.

Table 5. Effective Useful Life and Remaining Useful Life

Parameter	Walk-in Freezer Evaporator Fan ECM Motor	Walk-in Cooler Evaporator Fan ECM Motor r	Source
EUL (yrs) – host high efficiency evaporative fan motor	15.0	15.0	California Measurement Advisory Committee (CALMAC). 2000. *Public Workshops on PY2001 Energy Efficiency Programs.* September 25.Pp 8 – 9 and Appendix C2. Itron, Inc. 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report*. Prepared for Southern California Edison. Table 11-2.
RUL (yrs)	5.0	5.0	

BASE CASE MATERIAL COST ($/UNIT)

Cost data was gathered from online list prices of two distributors[19]. This data was grouped by size range (two ranges, based on hp or Watts) and by motor type (ECM, permanent split or shaded pole). The small size motors serve the freezers and the larger size serve the coolers. The average cost per fan was calculated for each motor type serving freezers and coolers. In the gathered data, the cost for permanent split capacitor motors serving the freezers was not available. Hence, interpolation was used to calculate this cost.

Since the base case cost is the cost of code/ industry standard equipment and the code requires ECM motors, the base case cost will be same as measure case cost.

MEASURE CASE MATERIAL COST ($/UNIT)

Same approach as above. The ECM cost is the measure cost.

LABOR COST ($/UNIT)

The average labor cost per motor installation was estimating using RSMeans.[20] From RSMeans, 2019 quarter 3, the labor cost for Los Angeles areas for installing a motor <=3/4 Hp is $119.16. Because the evaporator fan motors are small (1/20 and 1/40HP) and they are bundled in the evaporator coil, it is assumed that (3) of these evaporator coil motors could be installed in the same time as a typical standalone small electric motor. Hence, the labor cost for installing an evaporator fan motor is estimated at $39.72.

[19] 2019 -2020 Johnstone Supply catalog and Grainger, included in SWCR004-01 Cost analysis.xlsx (SCE, 2019).

[20] Gordian. 2019. *RSMeans Online*. Electrical Costs.

NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. These NTG values are based upon the average of all NTG ratios for all evaluated 2006 – 2008 commercial, industrial, and agriculture programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. This sector average NTG ("default NTG") is applicable to all energy efficiency measures that have been offered through commercial sector programs for more than two years and for which impact evaluation results are not available.

Table 6. Net-to-Gross Ratios

Parameter	Walk-in Freezer ECM Motor	Walk-in Cooler ECM Motor	Source
NTG – Commercial	0.60	0.60	Itron, Inc. 2011. *DEER Database 2011 Update Documentation*. Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3.

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. This GSIA rate is the current "default" rate specified for measures for which an alternative GSIA has not been estimated and approved.

Table 7. Gross Savings Installation Adjustment Rate

Parameter	Walk-in Freezer ECM Motor	Walk-in Cooler ECM Motor	Source
GSIA	1.0	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31.

NON-ENERGY IMPACTS

Non-energy impacts for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based. DEER 2005 does not address the replacement of SHP and PSC evaporator fan motors with new ECM motors in walk-in coolers and freezers. DEER does include measure D03-202 which addresses the replacement of SHP fan motors with PSC fan motors on walk-in coolers/freezers for vintages before 2005. This differs from the measures of this work paper.

A summary of differences from DEER is provided in Table 8.

Table 8. DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	Yes
Scaled DEER measure	No
DEER Base Case	No
DEER Measure Case	No
DEER Building Types	Yes
DEER Operating Hours	No
DEER eQUEST Prototypes	Yes
DEER Version	DEER2020
Reason for Deviation from DEER	DEER combines both low- and med-temp display cases. This measure calculates the impacts of low- and med-temp display cases separately.
DEER Measure IDs Used	D02-203
NTG	Source: DEER2020 Update "SupportTable-NTG2020-rev18Sep2018.xlsx". The NTG of 0.60 is associated with NTG ID: *Com-Default>2yrs*
GSIA	Source: DEER, READI. The value of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER2014. DEER2020 Update "SupportTable-EUL2020.xlsx", EUL_ID The EUL of 15 years is associated with EUL ID: *GrocWlkIn-WEvapFanMtr.*

REVISION HISTORY

Table 9. Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	03/31/2018	Jennifer Holmes Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: PGECOREF109 Revision 6 (November 8, 2016) SCE13RN011 Revision 2 (February 3, 2016) PGE3PREF123 Revision 1 (November 17, 2015) Consensus reached among Cal TF members.
	11/18/2019	Solaris-Technical, LLC.	Draft updated with DEER2020 models and recent costs