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HVAC

BRUSHLESS FAN MOTOR REPLACEMENT, RESIDENTIAL

SWHC038-01

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MEASURE NAME

Brushless Fan Motor Replacement, Residential

STATEWIDE MEASURE ID

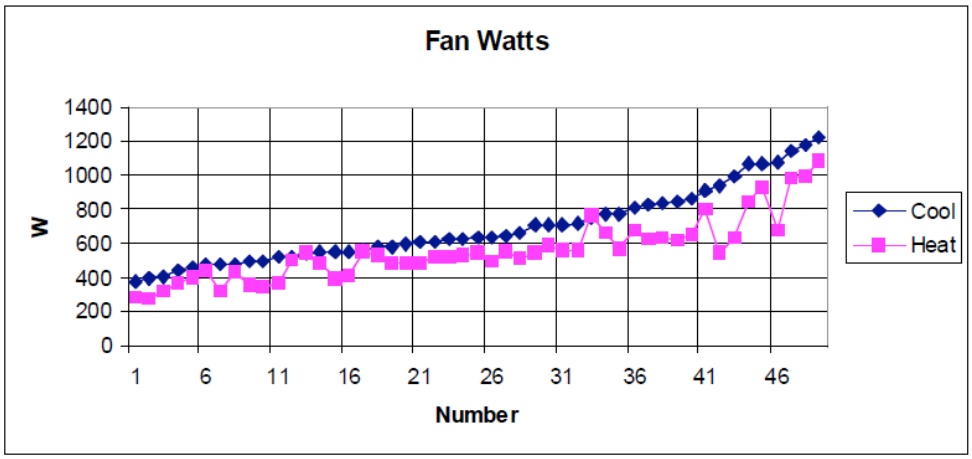
SWHC038-01

TECHNOLOGY SUMMARY

A brushless fan motor (BFM) has several advantages over a permanent split capacitor (PSC) motor:

- A PSC motor is typically used at two speeds, a cooling speed (high speed) and a heating speed (low speed).
- Since a BFM has a higher efficiency at its design rating point and is more efficient at lower speeds than the PSC, it reduces fan watt draw and saves energy during both heating and cooling. It is also configured to produce the same airflow as the PSC motor it replaces, so there is no loss in performance.
- In cooling mode, a BFM rejects less heat into the airstream (heat that the air conditioner must remove). However, a BFM applied to a gas furnace produces a small increase in gas consumption since the heat normally rejected by the motor into the airstream must be provided by natural gas.
- The mode of operation at which a furnace fan runs continuously (independent of compressor operation) is becoming more widespread in residences for the purposes of ventilation and/or added filtration. Therefore, more savings can be realized by the BFM because of these longer operating hours.
- Field tests conducted as part of the Fan Watt Draw and Air Flow, Public Interest Energy Research (PIER) for the 2008 California Building Energy Efficiency Standards[1] suggest a median cooling fan power draw of 632 watts for the California New Construction Field Test Furnace Fan Watt Draw – as shown in the figure below. This power draw is considered as the existing baseline power draw.

[1] Wilcox, B., J. Proctor, R. Chitwood, and K. Nittler. 2006. *Fan Watt Draw and Air Flow – 2008 California Building Efficiency Standards. Fan Watt Draw and Air Flow in Cooling and Air Distribution Models.* July 12.



Fan Watt Draw – California New Construction Field Test Furnace Fan Watt Draw

BFM compared to Electronically Commutated Motor (ECM). BFM motors are a subset of ECM motors; compared to an ECM motor the BFM with shut-off time delay has multiple advantages:

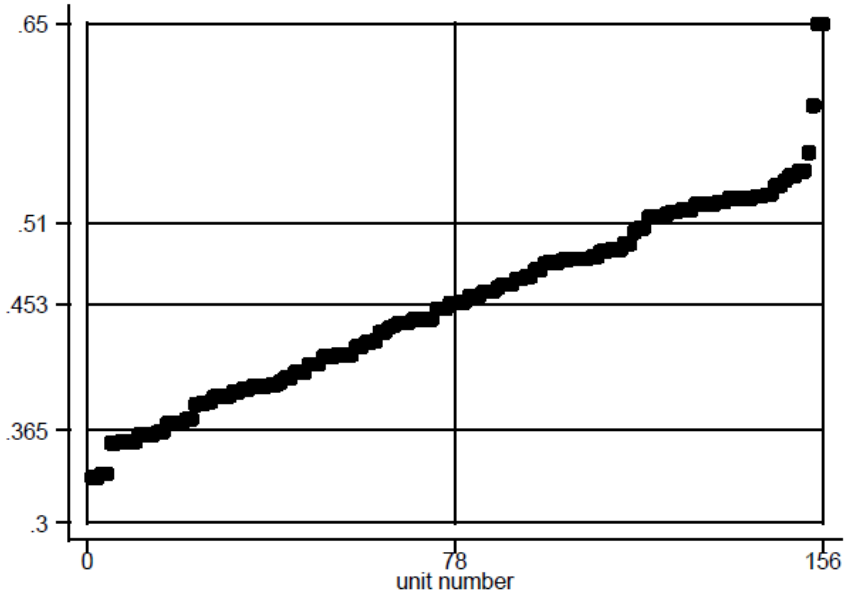
- Unlike an ECM motor, the BFM motor does not require a separate speed controller.
- Unlike an ECM motor, the BFM motor is available for retrofitting in existing furnaces.
- An ECM motor is controlled to attempt to produce a given airflow regardless of the amount of power required; on the other hand, a BFM motor is controlled to produce the same airflow as the PSC it replaces, resulting in significantly higher energy and peak savings. Modeling conducted by the Lawrence Berkeley National Laboratory (LBNL)[2] indicates that an ECM motor controlled to produce a given airflow will increase watt draw on units with restrictive duct systems.
- A U.S. Department of Energy (DOE) report[3] projected a savings of 75% (three times the savings of an ECM) for a Brushless Motor that was tuned to the capacity of the air conditioner and furnace.
- A BFM motor costs less than an ECM motor.

[2] Franco, V., J. Lutz, A. Lekov. 2008. "Furnace Blower Electricity: National and Regional Savings Potential." Proceedings of the 2008 ACEEE Summer Study on Energy Efficiency in Buildings, 2-93. Washington, DC: American Council for an Energy Efficient Economy (ACEEE).

[3] Arthur D. Little, Inc. 1999. *Opportunities for Energy Savings in the Residential and Commercial Sectors with High-Efficiency Electric Motors.* Prepared for the U.S. Department of Energy (DOE). Reference 35495-14. December 1.

Fan Watt Draw and Air Flow in Cooling and Air Distribution Models - 2008 California Building Energy Standards (Wilcox, Proctor, and Chitwood; 2008).[4] This study manufacturers data for 156 model numbers with PSC motors that had the airflow and blower fan watt draw listed at high speed and 0.50 IWC external static pressure. The median power draw for these units was 453 watts per 1,000 cfm, as shown in the figure below. The median power draw is substantially higher than the default 365 watts per 1,000 cfm. The median power draw is also lower than the typical field measured power draw (510 watts per 1,000 cfm).

The field data show higher external static pressures around 0.80 IWC. For the 146 units with manufacturer data, for 0.80 IWC at high speed, the median is 496 watts per 1,000 cfm, close to the field measured 510 watts per 1,000 cfm.



High Speed PSC Air Handler/Furnace Power at 0.50 IWC External Static

MEASURE CASE DESCRIPTION

The measure case is defined as a central brushless fan motor (BFM, or DC Motor) specifically configured as a drop-in retrofit for a standard permanent split capacitor (PSC) residential fan (blower) motor serving a central HVAC system. For this measure, a BFM is compared to a PSC as if they were both installed on identical systems (duct and furnace) at the same CFM and external static pressure.

This measure is applicable in all residential building types that use central air-cooled direct expansion (DX) cooling and/or furnace HVAC equipment.

[4] Wilcox, B., J. Proctor, R. Chitwood, and K. Nittler. 2006. *Fan Watt Draw and Air Flow – 2008 California Building Efficiency Standards. Fan Watt Draw and Air Flow in Cooling and Air Distribution Models.* July 12.

Measure Case Specification

Statewide Measure Offering ID	Measure Offering Description
SWHC038A	Central brushless fan motors (BFM or DC Motor)

BASE CASE DESCRIPTION

The base case is defined as a permanent split capacitor (PSC) residential fan motor serving a HVAC system for which fan performance (watts/cfm) varies between existing condition and code/standard.

Base, Standard, and Measure Cases

Case	Description of Typical Scenario
Measure	Central brushless fan motors (BFM or DC Motor)
Existing Condition	Permanent split capacitor (PSC) residential fan (blower) motors
Code/Standard	Permanent split capacitor (PSC) residential fan (blower) motors
Industry Standard Practice	Permanent split capacitor (PSC) residential fan (blower) motors

CODE REQUIREMENTS

Applicable state and federal codes and standards for fans in Residential HVAC systems are specified below.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20	None	n/a
CA Energy Code/ Building Energy Efficiency Standards – Title 24 (2019), Part 6	Section 150.0(m)13.B	January 1, 2020
Federal Standards	None	n/a

The California 2019 Building Energy Efficiency Standards (Part 6, Title 24)[5] Section 150.0(m) 13.B, specifies the following mandatory requirements for a minimum airflow per tonnage and a minimum fan efficacy, depending on the type of the air handling unit:

> ***Single Zone Central Forced Air Systems.*** *Demonstrate, in every control mode, airflow greater than or equal to 350 CFM per ton of nominal cooling capacity through the return grilles, and an air-handling unit fan efficacy less than or equal to the maximum W/CFM specified in subsections i or ii below. The airflow rate and fan efficacy requirements in this section shall be confirmed by field verification and diagnostic testing in accordance with the procedures given in Reference Residential Appendix RA3.3.*
>
> *i. 0.45 W/CFM for gas furnace air-handling units.*
> *ii. 0.58 W/CFM for air-handling units that are not gas furnaces*

[5] California Energy Commission (CEC). 2018. *2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2018-020-CMF.

Additionally, Section 140.4(c) 3, has prescriptive requirements for fractional HVAC motors for fans as below:

Fractional HVAC Motors for Fans. *HVAC motors for fans that are less than1 hp and 1/12 hp or greater shall be electronically-commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with NEMA Standard MG 1-2006 at full load rating conditions. These motors shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustments for airflow balancing in lieu of a varying motor speed.*
EXCEPTION 1 to Section 140.4(c)3: *Motors in fan-coils and terminal units that operate only when providing heating to the space served.*
EXCEPTION 2 to Section 140.4(c)3: *Motors in space conditioning equipment certified under Section 110.1 or 110.2.*

The space conditioning equipment in which the measure technology is being retrofitted is considered to comply with Section 110.2 – Mandatory Requirements for Space-Conditioning Equipment. Hence, the HVAC fan motors are exempt from the requirements in Section 140.4(c) 3.

NORMALIZING UNIT

Tons of cooling capacity (Cap-tons).

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
Normal replacement (NR)	DnDeemed	Res
Normal replacement (NR)	DnDeemDI	Res
Normal replacement (NR)	UpDeemed	Res

Eligible Products

- The HVAC system must be functional/operable and drawing power.
- The HVAC system shall be capable of delivering a supply air flow rate of at least 350 cfm/ton. The minimum 350 cfm/ton airflow requirement ensures that the refrigerant system can be properly diagnosed and charged as part of a maintenance service. If the system is not delivering 350 cfm/ton upon initial inspection, an assessment should be made to determine if the system will be able to deliver 350 cfm/ton by implementing repairs related to airflow. If it is determined that

the supply fan and duct system in place do not have the capability to deliver at least 350 cfm/ton with or without airflow repairs, the savings in this work paper are invalid.

- Replacement BFM motor capacity and rated voltage shall match that of existing fan motor being replace.
- The replacement brushless fan motor (BFM) motor and motor controls assembly shall be "UL Listed."
- The replacement BFM motor shall have a warranty of at least two years from date of installation.
- The measure shall include HVAC system start-up. During the start-up, the installer shall ensure that system maintain programmed level airflows under both cooling and/or heating and that these are adequate.
- The installation (as applicable) shall comply with all applicable regulations including but not limited to California Building Energy Efficiency Standards (Title-24), California Electrical Code, and NEC, and any applicable local jurisdiction regulations.
- This measure only supports HVAC (evaporator) fan motors with nominal capacities of ½-hp and/or less typically serving HVAC systems with nominal capacities of 3.5 ton (or less).
- The measure applies to units with shaded pole or permanent split capacitor (PSC) motors currently installed. As stated previously, the replacement motor is to be a brushless direct current motor with selectable speed control designed to replace a PSC motor in a residential direct drive fan application.

Eligible Building Types and Vintages

This measure is applicable for all residential buildings (single family, multifamily, and double-wide mobile homes) and all vintages.

Eligible Climate Zones

This measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

None.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

HVAC

ELECTRIC SAVINGS (KWH)

MASControl3 does not have a measure for BFM. Hence, an existing measure "RE-HV-ResAC-lt45kBtuh-14S" for Residential HVAC was replicated and modified as follows: [6] [7]

- A MeasureID was created with three new TechIDs in the PreTechID, StdTechID and MsrTechID fields.
- A new global parameter "SupplyMtrClass" for "SUPPLY-MTR-CLASS" has been added.
- The following values were assigned for the for the parameter and TechIDs.

TechID	TechID description	SUPPLY-MTR-CLASS	Motor Technology*	FAN-EIR-FPLR	SUPPLY-KW/FLOW (kW/cfm)	Source
StdTechID	Standard	High Eff	PSC	TwoSpeedFan	0.000580	California 2019 Building Energy Efficiency Standards (Part 6, Title 24)[8] for Air-Handling Units that are not Gas Furnaces.
MsrTechID	Measure	Prem Eff	ECM	Variable Speed Drive FPLR	0.000257	Average of the fan kW/cfm from DEER measure RE-HV-ResAC-lt45kBtuh for SEER 14 to SEER 21

* Expected motor Technology at indicated (kW/CFM) performance characteristics.

Parameter Description	
SUPPLY-KW/FLOW	Design full-load power of the supply fan per unit of supply air flow rate.
SUPPLY-MTR-CLASS	Motor class
FAN-EIR-FPLR	Takes the U-name of a linear, quadratic, or cubic curve that gives the ratio of fan electric energy to full-load fan electric energy, as a function of part-load ratio.

To determine the measure case Supply kW/cfm, MASControl3 measure RE-HV-ResAC-lt45kBtuh for SEER 14 to SEER 21 were reviewed; the W/cfm ranges from 0.233 to 0.294 with the average being 0.257. This average value was used for the measure case.

In TechData workbook, a file required for adding/ modifying measure to MASControl3, the cooling EIR was calculated excluding fan efficiency to maintain the rated SEER. This separation was required since DOE23 cooling EIR includes only compressor and outdoor unit and does not include indoor fan. Since, this

[6] Southern California Edison (SCE). 2019. "SWHC038-01 MC3 and eQuest files.zip."

[7] Southern California Edison (SCE). 2019. "SWHC038-01-Energy Impact Calcs.xlsx."

[8] California Energy Commission (CEC). 2018. *2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2018-020-CMF.

measure is improving the indoor fan efficiency without impacting the cooling EIR (compressor + outdoor unit performance), cooling EIR for base case was left the same for the measure case.

Batch processing was performed for the three building types defined for the residential sector (single family, multifamily, double-wide mobile homes), all climate zones, and all five residential thermostat options.

The DEER2020 thermostat weights available in ProcessQueriesAndSupportTables.zip[9] were applied for thermostat weighted impacts.

The DEER2020 building weights[10] for vintages were applied to calculate the weighted impacts for "ex" vintage. For ease of implementation, the "old" and "recent" vintages were not considered.

PEAK ELECTRIC DEMAND REDUCTION (KW)

The peak demand reduction for this measure during the 4:00 p.m. to 9:00 p.m. peak period[11] was derived using the same approach summarized in Electric Savings.

GAS SAVINGS (THERMS)

The gas unit energy savings (UES) for this measure was derived using the same approach summarized in Electric Savings. Note the gas UES values are negative and represent a gas *penalty* as a result of this measure installation.

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 May 2, 2013 ED Disposition[12] for Residential HVAC Quality Maintenance [367] specified a EUL of 5 years for the following reason:

"The blower motor is an addition to an existing system. Program rules limit the EUL of maintenance on an existing system to no more than system's RUL. By rule, this is 1/3 of the 15 year EUL for a direct expansion HVAC system, or 5 years."

The EUL for the brushless fan motor measure are presented below. RUL is not applicable for NR measures.

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[9] ProcessQueriesAndSupportTables.zip at http://www.deeresources.com/index.php

[10] California Public Utilities Commission (CPUC), Energy Division. (n.d.) "DEER2020-Building-Weights.xlsx."

[11] California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. O.P. 1.

[12] D2013-ResHVACmaintenance.docx

Effective Useful Life and Remaining Useful Life

Parameter	Value (years)	Source
EUL (yrs) – measure	5	1/3 of 15 years based on May 2, 2013 ED Disposition;

BASE CASE MATERIAL COST ($/UNIT)

Given measure implementation seen by SCE's Programs in previous years, the majority of projects supported replacement and installation of ½-hp motors. Hence, cost documentation below is based on a ½-hp (nominal capacity) motor.

The base case equipment cost for a ½-hp permanent split capacitor (PSC) motor was calculated as the average cost of six PSC motors obtained from the Grainger 2018 online catalog (www.grainger.com). Costs were normalized based on system capacity (tons cooling), using the Database of Energy Efficient Resources (DEER) 2020 residential prototypes average system capacity of 2.4 tons,[13] which corresponds to the typical ½-hp motor sizing.[14]

MEASURE CASE MATERIAL COST ($/UNIT)

The measure case equipment cost for a ½-hp brushless fan motor was based calculated as the average cost of six brushless DC motors obtained from the Grainger 2018 online catalog (www.grainger.com). Costs normalized based on system capacity (tons cooling), using the Database of Energy Efficient Resources (DEER) 2020 residential prototypes average system capacity of 2.4 tons,[15] which corresponds to the typical ½-hp motor sizing.[16]

BASE CASE LABOR COST ($/UNIT)

The base case labor cost for the installation of a blower motor (PSC or DC) based on 2019 RSMeans electrical cost data (line number 233414102080). The labor cost includes contractor overheads and profit margin. Labor cost was then normalized based on system capacity (tons cooling), using the Database of Energy Efficient Resources (DEER) 2020 residential prototypes average system capacity of 2.4 tons,[17] which corresponds to the typical ½-hp motor sizing.[18]

[13] Southern California Edison (SCE). 2019. "SWHC038-01-Energy Impact Calcs.xlsx." See "Energy Impact Calcs" tab.

[14] Southern California Edison (SCE). 2019. "SWHC038-01-Cost Calculations.xlsx."

[15] Southern California Edison (SCE). 2019. "SWHC038-01-Energy Impact Calcs.xlsx." See "Energy Impact Calcs" tab.

[16] Southern California Edison (SCE). 2019. "SWHC038-01-Cost Calculations.xlsx."

[17] Southern California Edison (SCE). 2019. "SWHC038-01-Energy Impact Calcs.xlsx." See "Energy Impact Calcs" tab.

[18] Southern California Edison (SCE). 2019. "SWHC038-01-Cost Calculations.xlsx."

MEASURE CASE LABOR COST ($/UNIT)

The labor cost is expected to be the same for both base case and measure cost. See Base Cases Labor Cost.

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. This NTG values are based upon the average of all NTG ratios for all evaluated 2006 – 2008 residential 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 residential sector programs for more than two years and for which impact evaluation results are not available.

Net-to-Gross Ratios

Parameter	Value	Source
NTG - residential	0.55	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) 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.

Gross Savings Installation Adjustment Rates

Parameter	Value	Source
GSIA	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 inputs and methods from the Database of Energy Efficient Resources (DEER), and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	Yes
Scaled DEER measure	No
DEER Base Case	No

DEER Item	Comment / Used for Workpaper
DEER Measure Case	No
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	Yes, but modified for Base and Measure Case
DEER Version	DEER 2020, READI v2.5.1
Reason for Deviation from DEER	DEER does not have this measure.
DEER Measure IDs Used	N/A
NTG	Source: DEER2019. The NTG of 0.55 is associated with NTG ID: *Res-Default>2yrs*
GSIA	Source: DEER2011. The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER2020. The value of 5 years is associated with EUL ID*: HV-BFMotor*

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	05/14/2019-	Akhilesh Endurthy, Solaris Technical	Updated based on DEER2020/ E-4952. Considered DEER2020 prototypes for SFm, MFm and DMo. Reduced measure kW/cfm based on DEER SplitAC SEER14 And SEER15 measures; and furnace ECM upgrade measure. New Statewide workpaper template Add New Construction (NC) MAT
	06/07/2019	Jennifer Holmes, Cal TF Staff	Revisions for submittal of version 01.
	11/04/2019	Akhilesh Endurthy, Solaris Technical	Updated EUL ID using the new EUL ID provided by DEER team