WPSCGREHC161128A

**Revision 01**

**SoCalGas**

**Customer Programs Department**

**Efficient Fan Controller for Residential Furnaces**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | TBD (See EAD tables for the measure codes) |
| **Measure Description** | Efficient fan control devices delay the furnace fan cycle by a predetermined period which will ensue in a heating cycle reduction time. When added to HVAC units, the automated fan controller extends blower runtime, thus dispersing additional heat trapped in the furnace, ducts, and other surfaces into the conditioned spaces. |
| **Base Case Description** | Ducted gas furnace with heating fan cycling off not more than two minutes after the burner shuts off. |
| **Units** | Each |
| **Energy Savings** | -Efficient Fan Controller: SCG (Sfm- CZ9: 9.33 Therm, -18.20 Kwh) |
| **Full Measure Cost ($/unit)** | -Efficient Fan Controller (Sfm- CZ9: $121.70 per unit) |
| **Incremental Measure Cost ($/unit)** | -Efficient Fan Controller (Sfm- CZ9: $121.70 per unit) |
| **Effective Useful Life** | 5 years (1/3 EUL for HV-ResAC) DEER READI 2.4.7 |
| **Measure Installation Type** | Retrofit Add-on (REA) |
| **Net-to-Gross Ratio** | ET-Default: 0.85 |
| **Important Comments** | This work paper has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 00 | 11/28/2016 | Eli Caudill/Mary Hinkle/CLEAResult | Original Release |
| 01 | 5/31/2018 | Carlos Pineda(SCG) | * Normalize savings to “Each” savings instead of “Therm/Cap” * Change cost to “per unit” value * Fixed grammatical mistakes, template update |

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# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This work paper outlines the retrofit add-on of an efficient fan controller (EFC) device onto a residential single-family, multi-family or double-wide mobile home gas furnace. This controller enables the blower to continue operating for a predetermine period beyond manufacturer settings to allow further dispersion of residual heat into the conditioned space. This device will extend the blower an additional 1.5 minutes, currently units operate the fan approximately 2 minutes after the furnace shuts off per manufacturer settings, with the EFC the fan run time will be 3.5 minutes.

Table : Base, Standard and Measure Cases

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Installation of efficient fan controller to extend the fan run time. |
| Existing Condition | Ducted natural gas furnace without a built-in fan delay. |
| Code/Standard | N/A |
| Industry Standard Practice | Indoor fan runtime can be determined using fixed values, temperature probes, or proprietary algorithms. |

Table : Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
| TBD |  |  |  | Efficient Fan Controller for Furnace |

1. **Eligibility Requirements:** 
   1. This measure applies only to ducted gas furnaces.
   2. Current gas furnace system cannot have a working built-in delay that cycles the fan for more than two minutes after the burner shuts off.
   3. Customer must have a furnace powered by a California IOU provided natural gas.
2. **Implementation Requirements:**
   1. This work paper allows the installation of any device, capable of controlling the air handler fan through a built-in logic controller to extend the blower run time 1.5 minutes beyond manufacturer settings.
   2. This measure can be installed in single family, multi-family, and double-wide mobile homes in all California climate zones.
   3. The technology must be identified as being capable of controlling fan delay times during heating cycles. This technology is not applicable to systems with central air handler fans set to continuous operation.
   4. This measure shall be set and commissioned by a trained contractor
   5. Heating applications, if the device can be programmed by the installer, it must be installed and set to run the indoor air handler fan for a period of 1.5 minutes after the fan ceases to operate per manufacturer settings or 3.5 minutes after the burner ceases to operate.
   6. The EFC fan run extension will only apply when the furnace burner runs for 4 minutes or longer.

**1.2 Technical Description**

Efficiency fan controller(EFC) devices delay the fan cycle time for ducted furnaces for a predetermined period beyond manufacturer settings. This work paper allows for the installation of any device with built-in logic, capable of controlling the air handler fan run time. EFC devices can delay fan cycle time for split system air conditioners or ducted furnaces, however this workpaper only reflects a furnace case. When added to HVAC units, the efficient fan controller extends blower runtime, thus dispersing additional heat trapped in the furnace, ducts, and other surfaces into the conditioned space. In effect the cycles per year will be reduced, this will enable the furnace to consume less natural gas, thus providing energy savings.

## 1.3 Installation Types and Delivery Mechanisms

Table : Installation Type Descriptions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Retrofit Add-on (REA) | Above Customer Existing | N/A | EUL | N/A |

A delivery mechanism is a delivery method paired with an incentive method. Delivery mechanisms are used by programs to obtain program participation and energy savings.

Table : Incentive Method Descriptions

|  |  |
| --- | --- |
| **Delivery Method** | **Description** |
| Financial Support | The program motivates customers, through financial incentives such as rebates or low interest loans, to implement energy efficient measures or projects. |

Table : Delivery Method Descriptions

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Direct Install | The program implements energy efficiency measures for qualifying customers, at no cost to the customer. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

Table : DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Workpaper?** |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | Yes, with modifications; see below |
| DEER Version | DEER, 2014, DEER 2015, READI v2.4.7 |
| Reason for Deviation from DEER | Packaged Variable Volume Variable Temperature HVAC system was changed to Package Single Zone to reflect a typical residential building with a single zone |
| DEER Measure IDs Used | N/A |

**Net-to-Gross Ratio**

The NTG values were obtained using the DEER READI tool. The relevant NTG values for the measures in this work paper are in the table below.

Table : NTGR ID

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| ET-Default | Emerging Technologies approved by ED through work paper review | Any | Any | Any | 0.85 |

**Spillage Rate**

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

**Installation Rate**

The IR values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in the table below.

Table : GSIA ID

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

**Effective and Remaining Useful Life**

The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for an RET measure with an applicable code baseline. The relevant EUL and RUL values for the measures in this work paper are in the table below.

Table : EUL ID

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| HV-ResAC | High Efficiency Air Conditioner (package and split systems) | Res | HVAC | 15 | 5 |

### 1.4.2 Codes and Standards Analysis

There are currently no federal, state, or regional codes that impact efficient fan controllers for residential Furnace. However, federal standards and California Title 20 require a residential furnace to have an AFUE (Annual Fuel Utilization Efficiency) of at least 78%. This efficiency rating was used to establish the baseline furnace for this measure.

Table : Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | Section 110.2 Tables 110.2-A,B,E,J | N/A |
| Title 20 (2017) | Section 1605.1 Tables C-3; E-6 | N/A |

## 1.5 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information

ET13SCG0004 HVAC Fan Stop Delay Heating Savings Assessment report presents results for a tested residential furnace in a laboratory setting. The testing included the installation of a commercially available automated fan controller. A test was performed to determine the amount of heat delivered from the furnace while the fan was running under a baseline test condition of allowing the furnace fan to run for two minutes after shutting off the burner. The automated fan controller was then installed, allowing the fan to run longer than the baseline two-minute period after the burner shut off. A test was then performed to determine the amount of heat delivered from the furnace while the fan was running, also including the extended fan run time due to the installation of the efficient fan control device. Tests were run with fan run times extended for an additional 1.5 and 2 minutes. The test results showed that residual heat from the furnace remained after the blower fan stopped under baseline conditions. A fraction of this remaining heat was delivered from the furnace due to the extended fan run time. The full report can be viewed in the attached file “ET13SCG0004 HVAC Fan Stop Delay Heating Savings Assessment” [[[1]](#endnote-1)].

### 1.5.2 Final Report on HVAC Fan Stop Delay Heating Savings Assessment in Residential Applications

1. Lab Evaluation by BR Laboratories, Inc.; February 2014
2. Residential Market
3. Lab evaluation of the automated fan controller was performed in heating mode
4. Data from the report was directly used for this work paper
5. Further research is recommended by the report author

## 1.6 Data Quality and Future Data Needs

1. The controller used for the heating savings study applied different extended fan run times, based on the on-cycle time of the furnace and was only activated after a six-minute furnace on-cycle time. Savings values from the heating savings assessment report were extrapolated for this work paper to account for savings in scenarios with fan run times for shorter furnace on-cycle times and for longer fan run time extensions.
2. Furnace on-cycle times can be controlled by multiple thermostat setting strategies. Only one baseline control approach was considered in the heating savings assessment report for determining potential heating savings.
3. Changes in the residential thermostat marketplace and controls of residential HVAC systems could affect the baseline fan delay for heating. Future savings will be affected by this change in baseline.

# Section 2. Calculation Methodology

### 2.1 Energy Savings

Energy savings and demand reduction were estimated using eQUEST version 3.64.7130 energy modeling software and DEER 2015 prototypes generated by MASControl v3.00.27 [[[2]](#endnote-2)]. All modeling was performed using default DEER hours and the CZ2010 weather files. DEER prototypes were used with some modification (as described below) to develop baseline and measure case energy use and demand estimates for single family, multi-family, and double-wide mobile homes with natural gas furnaces.

DEER prototypes were generated for all climate zones and thermostat options using the code level (C13) case of the “D08-RE-HV-ResAC-45to64kBtuh-15S” Tech ID. The 2003 (03) vintage was selected as an un-weighted representative for the average single or multi-family residence and the 2000 (M00) vintage was selected for double-wide mobile residences.

A modification to the DEER prototypes, similar to the process described in the cooling savings section, involved changing the default system type (SYSTEM:TYPE) from Packaged Variable Volume Temperature (PVVT) to Packaged Single Zone (PSZ), reflecting a typical residential building with a single zone.

Energy savings values were calculated using eQuest to establish the baseline energy consumption, then applying calculations and findings from the “ET13SCG0004 HVAC Fan Stop Delay Heating Savings Assessment”report to determine extended off-cycle time of the furnace, due to increased BTU recovery delivered by the additional fan run time from the automated fan controller. As explained in the ET13SCG004 report, the increased BTU recovered during the additional fan run time leads to a reduction in the annual heating cycles, reduced gas consumption, and an increase in fan energy consumption. Five hourly variables were captured from the eQuest simulations for a year; supply fan energy (kWh), total heat capacity (Btu/hr), heat output of the furnace (Btu/hr), gas consumed by the furnace (Btu/hr), and fraction of hours the fan cycles on.

Regressions of the test data from the ET13SCG004 heating savings assessment report were performed to determine the amount of heat delivered due to standard operation of the furnace and the potential remaining extractable heat at different operating times then the ones represented on the ET13SCG004 report. The percentages of the potential remaining extractable heat and heat delivered due to the extended fan run times were found from the test data, for extended fan run time of 1.5 minutes. These values were used in a regression to calculate the heat added by the extending the fan run time and percentages of heat delivered in addition to the standard operation heat output, for cycles not presented in the ETSCG004 study. The [regression fan-delay file](#Attachments) represents the data analysis and calculations shown in **Table** 2**.** The savings represented in this workpaper are higher than the ones in the ETSCG004 study due to a broader burner operating time cycles.

Table : Data and Regressions from ET13SCG004 Report

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Burner Run Time (min) | 4-5 | 5-6 | 6-7 | 7-8 | 8-9 | 9-10 | 10+ |
|  | Heat output under standard operation (Btu) | 1452 | 1805 | 2225 | 2737 | 3367 | 4140 | 5081 |
|  | Potential heat to be recovered after standard operation (Btu) | 136 | 159 | 173 | 180 | 184 | 188 | 200 |
| % of potential heat added by extending fan run-time | 1.5 Minutes of Extended Fan Run Time | 88.4% | 88.4% | 88.4% | 88.4% | 88.4% | 88.4% | 88.4% |
| Heat added by extending fan run-time (Btu) | 1.5 Minutes of Extended Fan Run Time | 121 | 140 | 153 | 159 | 162 | 166 | 176 |
| % of total additional heat delivered due to extending fan run-time | 1.5 Minutes of Extended Fan Run Time | 8.3% | 7.8% | 6.9% | 5.8% | 4.8% | 4.0% | 3.5% |

Savings for fan delay are applied to situations for furnace on-cycle times greater than four minutes. Fan on-cycle times are calculated assuming an average on-cycle time of 3.87 minutes, based on the value provided in ANSI/ASHRAE Standard 103-1993 [[[3]](#endnote-3)]. On-cycle time for the furnace is calculated as below:

Where,

= on-cycle time for each hour (minutes)

= fraction of each hour fan cycles on for heating

= 3.87 minutes

= annual median fraction of hours fans cycle on for heating

The eQuest model relates the amount of heat needed per hour to the (of the cycle. From this the, ( of the furnace was evaluated. This was accomplished by relating the furnace on time to the amount of heating needed per hour, which is also related to the fan ( The ( expression provides an approximate of the annual average furnace on time by taking in account the 3.87 minutes on average time found in ASHRAE.

Sample calculations for the first hour of the year for a double-wide mobile home in CZ16 with a type 5 thermostat with the fan running for an additional 1.5 minutes are shown below:

The off-cycle time () for the furnace is calculated as below:

Sample calculation:

The additional heat delivered during the operation of the automated fan controller, increases the amount of time needed for the thermostat to call for heat again. The increase in furnace off-cycle time () for each hour is assumed to be directly related to the increase in heat delivered. The expression developed, expresses that the heat percent added is also the percent of the time increment for the furnace off period, with reference to the off time with no fan delay.

Sample calculation:

The extended off-cycle times reduces the number of total cycles per hour.

Where,

= total number of on and off cycles of the furnace per hour

60 = minutes per hour

Sample calculation:

The reduction in the total cycles per hour occurs when the fan delay is activated, in effect this will reduce the natural gas consumption, a sample calculation is presented below:

Where,

Measure hourly natural gas consumption (Btu/hr)

= eQuest output of gas consumed by furnace (Btu/hr)

Sample calculation:

The extended fan cycle time leads to an increase in fan energy consumption. The additional fan operation time is determined by calculating the fraction of each hour the fan cycles on for heating in the improved scenario ().

Sample calculation:

If the fan delay is activated during an hour of operation, the electricity consumption of the additional run time () is calculated.

Where,

= Fan Power (kW)

= extended fan run-time per cycle

Sample calculation:

The total electricity consumption in the improved scenario accounts for the extended fan run time and the reduced cycles per hour.

Sample calculation:

Savings values for gas were calculated as the difference between the annual gas consumed by the baseline and improved scenarios. This process is repeated for all 8,760 hours in the year and summed to obtain the total annual energy savings for the EFC unit in each DEER building prototype. The annual energy savings was normalized by heating capacity using actual kBtuh input for each unit examined within each prototype. Results for all zones or systems were simple averages for each building type and orientation. An example of calculations performed for a 1.5-minute extension of fan run time for one building type and one thermostat for one climate zone is provided for reference [[[4]](#endnote-4)].

To find the savings per unit at each climate zone, the file “WPSCGREHC161128A-Rev01-EnergyImpacts\_Res-GasFurnace-AFUE92” was used. The Cap-KBtuh savings found was multiplied by the weighted capacity of furnace input at different climate zones and residential building types “NumUnit”. This product represents the savings per unit at each respective climate zone and IOU. The same product is found for the additional electrical consumption that originates from extending the fan run time.

Savings were then weighted based on thermostat prevalence for each climate zone[[5]](#endnote-5).

Table : Example of Thermostat Weighting

|  |  |  |  |
| --- | --- | --- | --- |
| Thermostat Type | Therm Savings/kBtuh | kWh Savings/kBtuh | Thermostat Weighting |
| t1 | 0.3455 | -0.9805 | 0.127968 |
| t2 | 0.1550 | -0.3593 | 0.019999 |
| t3 | 0.1550 | -0.3594 | 0.75 |
| t4 | 0.2431 | -0.6253 | 0.019999 |
| t5 | 0.2431 | -0.6253 | 0.082034 |

Where:

= reported energy savings value (therms/kBtuh or kWh/kBtuh)

W = Weight for a given thermostat

= energy savings value for a given thermostat (therms/kBtuh or kWh/kBtuh)

For a double-wide mobile home in climate zone 16, the calculated heating energy savings for 1.5 minutes of additional run time are 0.19 therms/kBtuh and -0.466 kWh/kBtuh annually.

**Demand Reduction Calculations**

Demand reduction calculations were not performed for heating applications.

# Section 3. Load Shapes

The ideal load shape for net benefits estimates would represent the difference between the base case and measure case. The closest load shapes that are applicable to the measures in this work paper are listed in the table below.

Table : Building Type and Shape Loads

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Residential – Double-Wide Mobile Home | DEER:HVAC\_EFF\_AC | RES |
| Residential – Multi-Family | DEER:HVAC\_EFF\_AC | RES |
| Residential – Single Family | DEER:HVAC\_EFF\_AC | RES |

# Section 4. Costs

## 4.1 Gross Measure Cost

The gross measure cost (GMC) is the measure equipment material costs plus installation labor. Costs were calculated for efficient fan controllers. The measure equipment material cost for efficient fan controllers was determined by reviewing the purchased price for two fan delay controllers tested in the attached “ET13SCG0004 HVAC Fan Stop Delay Heating Savings Assessment”. The price paid was $25 per controller, plus $3.50 for shipping and handling.

**For controllers qualifying to be installed with gas furnaces**,

The measure labor cost was determined from READI v2.3.0. The base labor rate is $67.88 per hour for residential HVAC - Programmable Thermostats. Installation of the fan controller takes 1-2 hours, so the labor cost is estimated at $96.70

GMC = Measure Equipment Cost + Measure Labor Cost

= $25.00 + $96.70

= $121.70 (per Unit)

## 4.2 Base Case Cost

For REA measures, base case cost is not used.

## 4.3 Measure Case Cost

For REA measures, Measure Cost is the same as Gross Measure Cost.

## 4.4 Full and Incremental Measure Cost

Table : Full and Incremental Measure Cost Equations for Heating Applications Utilizing Efficient Fan Controllers

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| REA | $25.00 + $96.70 = $121.70 per-Unit | $25.00 + $96.70 = $121.70 per-Unit | N/A |

# 

# Referenced Attachments

1. Annual Heating Energy Savings

2. Heating Savings Results

3. Regression Fan Delay

4. Savings Template

5. ET13SCG0004 HVAC Fan Stop Delay Heating Savings Assessment

6. EnergyImpacts\_Res-GasFurnace-AFUE92

# References

1. Final Report On HVAC Fan Stop Delay Heating Savings Assessment In Residential Applications, BR Laboratories, INC, February 2014 - Attachment [↑](#endnote-ref-1)
2. James J. Hirsch & Associates. (2014, October 31). *MASControl 3.00.27.* Retrieved from deeresources.com: http://www.deeresources.com/files/DEER2015/download/SetupMASControlX32\_3\_00\_27.msi [↑](#endnote-ref-2)
3. ASHRAE Standard 103-1993, Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnace and Boilers, ANSI/ASHRAE, (1993) [↑](#endnote-ref-3)
4. Annual Heating Energy Savings Example\_DMO.xls [↑](#endnote-ref-4)
5. SavedHeatingResults.xls - Attachment [↑](#endnote-ref-5)