**Work Paper SCE13HC011**

**Revision 1**

**Southern California Edison Company**

**Air Filter Alarm**

# At-a-Glance Summary

|  |  |
| --- | --- |
| ****Applicable Measure Codes:**** | AC-98098 |
| **Measure Description:** | Air filter alarm which signals upon high system pressure (e.g., dirty filter). Energy savings are due to forced air unit (FAU) system operating at near design system pressure. |
| **Base Case Description:** | Source: Forced air unit (FAU) and air distribution system without Air Filter Alarm. |
| **Energy Impact Common Units:** | Sensor |
| **Energy Savings :** | Refer to Excel Calculation Attachment |
| **Gross Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Measure Incremental Cost ($/unit):** | Refer to Excel Calculation Attachment |
| **Effective Useful Life (years):** | Source: Manufacturer’s warranty documentation / 5 Years |
| **Measure Application Type:** | Retrofit Add-on (REA) |
| **Net-to-Gross Ratios:** | Source: “DEER2011\_NTGR\_2012-05-16.xls” – 0.55 |
| **Important Comments:** | 1. Energy savings on measured are estimated based on projected incremental static pressure in air filters. 2. **This work paper document does not contain a data set in conformance with the 4/1/14 CPUC Ex Ante Database Specification; SCE will provide that data set separately.** |

# Document Revision History

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Workpaper and Revision # | Tech. Revision | MM/DD/YY | Author/Affiliation | Summary of Changes |
| SCE13HC011.0 | No | 04/19/2012 | Margaret Pigman / PL Energy | -Original work paper draft for 2013-2014 program cycle.  -Updated version of 2010-2012 work paper WPSCREHC0012. |
| SCE13HC011.1 | No | 3/14/2014 | Andres Fergadiotti/SCE | -New WP template  - Work paper updated for the reporting period, effective 7/1/14 – 12/31/14. |

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This work paper details the values used to forecast the impacts of installing an air filter alarm to reduce residential space conditioning energy usage. Since homeowners are very likely to change all air filters in their homes at the same time, it is assumed that only one air filter alarm per home is needed.

An air filter alarm is attached to the blower side of a forced air unit (FAU) air filter. As dirt accumulates on the air filter, more pressure, and therefore energy, is required to move air through the filter. Once excessive dust and particulate buildup begins obstructing the air filter, air is forced through the alarm, which emits a tone that notifies the homeowner to change or clean the filter. This will reduce the amount of time an FAU is operated with a dirty filter, and therefore, lower fan energy consumption for both the heating and cooling seasons.

Table 1 Measure Names

|  |  |
| --- | --- |
| Solution Code | Measure name |
| AC-98098 | Air Filter Alarm Controls |

Measure requires that baseline FAU system is not equipped with air filter alarm controls and/or pressure sensor indicating air pressure drop or high pressure across air filter.

## 1.2 Technical Description

The measure is intended to save energy by operating distribution fan in the Forced Air Unit at a lower system (static) pressure or operating distribution fan near the system design (static) pressure. Air filtration systems are used in forced-air heating, ventilating, and air-conditioning (HVAC) systems to protect occupants and to provide adequate indoor air quality, but they influence HVAC energy consumption – where the power draw by the fan is proportional to the pressure increase across the fan and the airflow rate.

## 1.3 Measure Application Type

This measure if offered through the Financial Support / Giveaway delivery method. It is an REA measure as it is an add-on to a standard forced air unit.

## 1.4 Measure and Base Case Cost Effectiveness Data

### 1.4.1 DEER Measure and Base Case Analysis

Table 2 DEER Difference Summary

|  |  |
| --- | --- |
| DEER Difference Summary Table | |
| Modified DEER Methodology | No |
| Scaled DEER Measure | No |
| DEER Building Prototypes Used | No |
| Deviation from DEER | DEER does not contain this type of measure. |
| DEER Version | N/A |
| DEER Run ID and Measure Name (Sample) | N/A |

**Net to Gross**

The NTG value was obtained from the “DEER2011\_NTGR\_2012-05-16.xls” on the DEER website as required by Version 5 of the California Public Utilities Commission (CPUC) Energy Efficiency Policy Manual [351]. The relevant NTGR for this measure is shown in Table 3 below.

Table 3 Net-to-Gross Ratio

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NTGR\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID | NTG\* |
| Res-Default>2 | All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years | Res | Any | All | 0.55 |

\*Denotes that the column is taken from the DEER NTG Table.

**Installation Rate**

The installation rate (IR) is identified in the calculation attachment. This value is obtained from the support table available in READi. Currently there is no versioning on the installation rate table. To address appropriate selection of the installation rate the date of the workpaper will serve as the last date checked for updated IR values. The installation rate varies by end use, sector, technology, application, and delivery method. The relevant IR values for this measure are shown in Table 4 below.

Table 4 Installation Rate

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

**Spillage Rate**

Spillage rate will also be applied to measures however the values will not be tracked in the workpapers. The spillage rate will be tracked in an external table to be supplied to the Energy Division.

**READi Technology Fields**

To support the development of the ED ex ante tables, select fields from the ex ante database will be identified in the workpaper. For a full set of values associated with the measures in the workpaper refer the Excel calculation template. (In the event that the READi IDs do not support the technology in this workpaper simply indicate “Non-DEER”.)

Table 5 READi Tech IDs

|  |  |
| --- | --- |
| READi Field Name | Values included in this workpaper |
| Measue Case UseCategory | HVAC |
| Measure Case UseSubCats | Non-DEER |
| Measure Case TechGroups | HVAC Technology |
| Measure Case TechTypes | Non-DEER |
| Base Case TechGroups | Non-DEER |
| Base Case TechTypes | Non-DEER |

### 1.4.2 Codes and Standards Analysis

There are no applicable Code and/or Regulations on measure

Table 6 Code Summary

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Dates |
| Title 24 (2013) | N/A | N/A |
| Title 20 (2010) | N/A | N/A |

### 1.4.3 Non-DEER Study Review

None.

### 1.4.4 Measure and Base Case Effective Useful Life

DEER14 update documentation provides EUL and RUL information to be used for the 2015 program cycle extension on [www.deeresources.com](http://www.deeresources.com). The DEER documentation “Summary of EUL-RUL Analysis for the April 2008 Update to DEER” provides the RUL value as a flat 1/3 of the EUL value. The RUL value will only be applied to the first baseline period for retrofit measures that have applicable code that will affect the energy savings. In all other installation types and retrofit with no applicable code that affects the energy savings, the RUL is not applicable to either the first or second baseline period.

The DEER14 update documentation, EUL\_Summary\_10-1-08.xls [213], was consulted. However, this documentation does not contain EUL on the measure. Therefore, manufacturer’s warranty information on “Dirty Air Filter Alarm for HVAC System” was consulted [[[1]](#endnote-1)] to determine EUL identified in following Table 7.

Table 7 DEER14 EUL Value/Methodology

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| READi EUL ID | Market | Enduse | Measure | EUL (Years) | RUL (Years) |
| N/A | Residential | HVAC | Air Filter Alarm | 5 | 1.67 |

# Section 2. Energy Savings & Demand Reduction Calculations

The calculations discussed in this section are based on the following assumptions:

* Air filters collect dirt at a constant rate.
* Increased energy needed to move air through a dirty filter has a linear correlation to the amount of dirt on the air filter surface.
* The FAU in a home operates during both heating and cooling.
* The fan is sized to match the air conditioner tonnage.

## 2.1 Energy Savings Estimation Methodologies

### 2.1.1 Calculating Additional Power Due to Dirty Air Filter

The percentage increase in power requirements due to a dirty air filter was calculated with Equation 1:

Equation 1



where ΔP = percentage increase in power due to dirty air filter,

Pdirty = power consumption with dirty air filter,

Pclean = power consumption with clean air filter.

The power drawn by a fan is described in Equation 2:

Equation 2

P = *IV* cos (ϴ)

where P = power measured in watts,

I = current measured in amps-rms,

V = voltage measured in volts-rms,

cos (ϴ) = power factor of the fan motor.

An Arizona State University study [411] measured the current drawn by a fan pushing air through a clean and a dirt air filter. These values can be used in Equation 2:

* Clean filter: 415 mA of current

Pclean = 0.415 *V* cos(ϴ)

* Dirty filter: 430 mA of current

Pdirty = 0.430 *V* cos(ϴ)

Therefore the percent increase in power from Equation 1 is:



*where the ratio of the terms is assumed to be one.*

Since the voltage and power factor are constants, the difference in the energy consumption between the clean and dirty filters may be expressed as a simple percentage. The dirty air filter consumed 3.61% more energy than the clean air filter. The amount of dirt accumulation on the filter measured is not known, and no pressure drop measurements were taken. Thus, this work paper conservatively assumes that this percent increase occurs at the time the filter would be changed without a filter alarm, i.e., 11 months on average [[[2]](#endnote-2)]. When calculating energy savings, the value used is the average percent increase for the months between a recommended filter change and when an actual filter change occurs.

### 2.1.2 Calculating Percentage of Annual Operating Hours with Dirty Air Filter

In addition to the assumption dirt collects on a filter at a constant rate, the following information is considered to determine annual operating hours with a dirty air filter.

* A two month recommended change interval; based on an average of industry suggestions shown in the Air Filter Change Interval attachment and
* An 11 month actual change interval; based on an informal survey of homeowners shown in the attachment [B].

Both of these points are shown in Figure 1.

**Annual Operating Hours with Dirty Filter**

1

2

3

4

5

6

7

8

9

10

11

12

**Months**

**Dirt Accumulation**

Recommended   
Filter Change

Dirt   
Accumulation

Actual  
Filter Change

0

Hours Operating  
w/Dirty Filter

Figure 1 Illustration of Dirty Filter Operational Hours

If dirt build-up on an air filter progresses in a linear fashion over time, as shown in Figure 1, then the total energy consumption increase over time is:

Equation 3



### 2.1.3 Calculating Annual Operating Hours

The next step is to calculate the number of hours that a FAU operates per year. The DEER measure RE-HV-ResHP-13p0S-8p1H contains average kW and kWh data for using a 13 SEER/8.1 HSPF heat pump in each climate zone for single and multi-family residential buildings [49]. Average operating hours in each climate zone and building type were determined by dividing average kWh by average kW. Using information on the distribution of single and multi-family homes from the RASS [195], Version 2010, a weighted average of operating hours was found for each climate zone. The results are shown in Table 8 below.

Table 8 Annual FAU Operating Hours by Climate Zone

|  |  |
| --- | --- |
| Climate Zone | Annual Operating Hours |
| 6 | 6,146 |
| 8 | 2,153 |
| 9 | 2,582 |
| 10 | 2,135 |
| 13 | 2,817 |
| 14 | 2,509 |
| 15 | 1,927 |
| 16 | 5,458 |

### 2.1.4 Calculating Energy Savings

The annual energy savings may be derived using Equation 3 and a standard motor power draw calculation to arrive at Equation 4:

Equation 4



*where*,

kWhsavings = annual energy savings per FAU,

P = power blower motor (kW),

ΔP = percentage increase in power due to dirty air filter,

hweighted = annual operating hours of blower motor,

Mlf = Motor Load Factor, and

R = percentage installed (installation rate).

The following values are used to calculate energy savings:

* Mlf = 85% motor load factor
* R = 47% air filter alarm installation rate [412]
* hweighted annual operating hours of blower motor; see Table 8

The maximum percentage increase in power due to a dirty air filter was estimated in Section 2.1.1 as 3.61%. However, some increased energy consumption occurs between the time a clean filter is installed and the recommended replacement time.

Table 9 summarizes the linear increase over the 11 months average air filter replacement interval. The average power increase from months three through eleven, 2.30%, is used as a conservative value for ΔP.

Table 9 Increased Power Use Over Time

|  |  |
| --- | --- |
| Month | % Increase in Power  Due to Dirty Filter |
| 0 | 0.00 |
| 1 | 0.33 |
| 2 | 0.66 |
| 3 | 0.98 |
| 4 | 1.31 |
| 5 | 1.64 |
| 6 | 1.97 |
| 7 | 2.30 |
| 8 | 2.63 |
| 9 | 2.95 |
| 10 | 3.28 |
| 11 | 3.61 |

The blower motor power was calculated using following equation:

Equation 5



Average system tonnage for each climate zone was found using DEER measure RE-HV-ResHP-13p0S-8p1H. The CFM per ton and Watts per CFM figures are average values for residential furnace fans. For more information see attachment [B]. The results are summarized in Table 10 below.

Table 10 Blower Motor Power

|  |  |  |  |
| --- | --- | --- | --- |
| **Climate**  **Zone** | **Cooling**  **Tons** | **CFM (at 400 CFM/Ton )** | **P kW (at 0.51 W/CFM)** |
| 6 | 2.62 | 1,048 | 0.53 |
| 8 | 2.39 | 957 | 0.49 |
| 9 | 2.76 | 1,105 | 0.56 |
| 10 | 3.31 | 1,323 | 0.67 |
| 13 | 3.10 | 1,237 | 0.63 |
| 14 | 3.73 | 1,491 | 0.76 |
| 15 | 4.13 | 1,651 | 0.84 |
| 16 | 2.70 | 1,078 | 0.55 |

The annual energy savings for Climate Zone 6 using Equation 4 are estimated as:

P = 0.53 kW

ΔP = 2.30%,

hweighted = 6,146 hours,

Mlf = 85%, and

R = 47%.



The annual energy savings are shown in Table 11 for each climate zone. Note that since the FAU runtime and air-conditioning sizing is on a per home basis, the annual energy savings is per home. The detailed calculations are provided in the attachment [B].

Table 11 Annual Energy Savings by Climate Zone.

|  |  |
| --- | --- |
| Climate Zone | Annual Energy Savings  (kWh per Home) |
| 6 | 15.08 |
| 8 | 4.83 |
| 9 | 6.68 |
| 10 | 6.62 |
| 13 | 8.18 |
| 14 | 8.76 |
| 15 | 7.46 |
| 16 | 13.79 |

## 2.2 Demand Reduction Estimation Methodologies

Demand reduction estimation methodologies were calculated using following equation:

Equation 6



*where*,

kWreduced = demand reduction per FAU,

P = power of blower motor,

ΔP = fractional increase in power due to dirty air filter, and

R = fraction of air filter alarms installed (installation rate).

The demand reduction is estimated for Climate Zone 6 using Equation 6 as follows:



Table 12 Demand Reduction by Climate Zone.

|  |  |
| --- | --- |
| Climate Zone | Peak Demand Reduction  (kW) |
| 6 | 0.00289 |
| 8 | 0.00264 |
| 9 | 0.00305 |
| 10 | 0.00365 |
| 13 | 0.00342 |
| 14 | 0.00411 |
| 15 | 0.00455 |
| 16 | 0.00297 |

For full details, see the attachment [B].

# Section 3. Load Shapes

The difference between the base case load shape and the measure load shape would be the most appropriate load shape; however, only end-use profiles are available. Therefore, the closest load shape chosen for this measure is the Reduce\_Cooling\_Load-Ret load shape. See Table 13 for a list of all Building Types and Load Shapes. See the KEMA report [31] for a more thorough discussion regarding the load shapes for this measure.

Table 13 Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| Building Type | E3 Alt. Building Type | Load Shape |
| Residential Single Family | RES | Reduce\_Cooling\_Load-Ret |
| Residential Multi-Family | RES | Reduce\_Cooling\_Load-Ret |
| Residential Mobile Home – Double-Wide | RES | Reduce\_Cooling\_Load-Ret |

# Section 4. Base Case & Measure Costs

## 4.1 Base Case Cost

The assumed base case has no air filter alarm. Therefore the base case cost is zero.

## 4.2 Measure Case Cost

This work paper assumes that only one air filter alarm is installed per home and that the homeowner will change the FAU filter (or all FAU filters) at the same time. Additionally, this work paper assumes that the homeowner installs the air filter alarm.

Per Measure Case Cost documentation, only two providers were found of air filter alarms. The average cost found was $3.06. Refer to attachment [B].

## 4.3 Gross and Incremental Measure Cost

### 4.3.1 Gross Measure Cost

The Gross Measure Cost is the same as the Measure Case Cost shown in Section 4.2.

### 4.3.2 Incremental Measure Cost

The Incremental Measure Cost is the same as the Measure Case Cost shown in Section 4.2.

# Attachments

1. 
2. 

# Appendix A – SCE/ED Application Types

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SCE Program Type | ED Application Type | 1st Baseline Savings | 2nd Baseline Savings | 1st Baseline Cost | 2nd Baseline Cost | 1st Baseline Life | 2nd Baseline Life |
| New | New Construction (Nc) | Above Code/Standard | N/A | Incremental Cost | N/A | EUL | 0 |
| Replace on Burnout (ROB) | Replace on Burnout (Rob)/Normal Replacement (NR) | Above Code/Standard | N/A | Incremental Cost | N/A | EUL | 0 |
| Retrofit (RET) | Early Replacement (ER) | Above Cust. Existing | Above Code/Standard | Full Cost | Incremental Cost | RUL | EUL-RUL |
| Retrofit – First Baseline Only (REF) | Early Replacement RUL (ErRul) | Above Cust. Existing | N/A | Full Cost | N/A | EUL | 0 |
| Retrofit Add-on (REA) | N/A | Above Cust. Existing | N/A | Full Cost | N/A | EUL | 0 |

# References



[351]

[213]

[49]

[31]

[195]

[411]

[412]

1. [] <http://www.techmall.com/Dirty-Air-Filter-Alarm-for-HVAC-System-05058-p/56508.htm> [↑](#endnote-ref-1)
2. [] Attachment 2 – General Calculations & Cost.xlsx. [↑](#endnote-ref-2)