**Work Paper SCE13PR005**

**Revision 1**

**Southern California Edison Company**

**Air Compressor VSD**

# At-a-Glance Summary

|  |  |
| --- | --- |
| ****Applicable Measure Codes:**** | *PR-50059, PR-34445* |
| **Measure Description:** | Retrofit an existing rotary screw air compressor (using load/unload controls) with a variable speed drive |
| **Base Case Description:** | Rotary screw air compressor using load/unload controls |
| **Energy Impact Common Units:** | Horsepower (hp) |
| **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):** | 13 years |
| **Measure Application Type:** | Retrofit Add-on (REA) |
| **Net-to-Gross Ratios:** | 0.6 (Com-Default>2yrs) |
| **Important Comments:** | **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 |
| SCE13PR005.0 | No | 4/30/2012 | Mike Casey/AESC | Original work paper for 2013-14 program cycle |
| SCE13PR005.1 | No | 4/16/2014 | Jason Wang/SCE | * Template update * Removed PR-60966 due to Title 24 (2013) * Changed PR-34445 from “15 to 50 hp” to “15 to 25 hp” since Title 24 (2013) impacts compressed air systems 25 hp and greater * Work paper updated for reporting period, effective 7/1/14 – 12/31/14. |

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

The measure case is a variable speed drive (VSD) on an existing rotary screw air compressor.

The base case is an existing rotary screw compressor using load/unload controls, with rated capacity ≥ 5 hp and < 25 hp. If the compressed air system includes multiple compressors, the base case compressor operates as a trim compressor.

Table 1 Measure Names

|  |  |
| --- | --- |
| Solution Code | Measure name |
| PR-50059 | 5 up to 15 HP Variable Speed Drive on Air Compressor Control |
| PR-34445 | 15 up to 25 HP Variable Speed Drive on Air Compressor Control |

The existing compressor shall meet the following requirements:

* Must be a rotary screw compressor.
* Must have a horsepower rating ≥ 5 hp and < 25 hp, because compressors 25 hp and greater are ineligible due to Title 24 (2013).
* Must use load/unload controls.
* Must operate in a stand-alone capacity or as a trim compressor, i.e. not base loaded in a multiple compressor system.
* Must be permanently installed; portable compressors are not eligible.

This measure is applicable only to the following building types:

* Agricultural
* Health/Medical - Hospital
* Health/Medical - Clinic
* Manufacturing - Bio/Tech
* Manufacturing - Light Industrial
* Industrial
* Misc - Commercial
* Retail - Single-Story Large
* Transportation - Communication - Utilities

## 1.2 Technical Description

Definition of trim compressor: In systems with multiple compressors, a trim compressor is a compressor that is designated for part-load operation, handling the short-term variable trim load of end uses.

Load/unload controls

Compressors with load/unload controls generally operate in conjunction with one or more storage tanks (receivers). The purpose of a receiver is to store a volume of compressed air for use when it is needed. The compressor fills the receiver, and the compressed air end users use air from the receiver. The loaded compressor fills the receiver until it reaches a certain pre-set pressure (e.g. 110 psig) and then it unloads. As the end users use air from the receiver, the pressure decreases. When the pressure in the receiver reaches a second pre-set pressure (e.g. 100 psig) the unloaded compressor loads again to fill the receiver. Long and/or frequent cycles of unloaded operation reduce the overall efficiency of the compressor by allowing the motor to operate while producing no compressed air. Compressor manufacturers use different strategies for unloading a compressor but, in most cases an unloaded rotary screw compressor will consume 15 to 35 percent of full-load horsepower while delivering no useful work [352].

Variable speed drive controls

A VSD saves energy by varying the motor speed and compressed air output to match the compressed air demand, greatly reducing or eliminating unloaded operation. A VSD controller is given a single discharge pressure set point, and the controls vary the speed of the motor to match this set point. Retrofitting a load/unload compressor that operates fully loaded (i.e. no unloading) with a VSD will not generally result in any savings. In fact, the VSD controller uses a certain amount of power (generally estimated to be 5% of the full load power of the compressor) to operate, so that retrofitting a fully loaded compressor will actually result in increased in energy use.

VSD efficiency varies with manufacturer and size of VSD as well as with the type of motor it is coupled with and the speed of the motor. Motor efficiency also varies with speed and loading. 5% is used here as an average “VSD Efficiency Factor”, which accounts for all of these effects [354]. The energy savings in this work paper are provided on a per compressor horsepower (hp) basis.

## 1.3 Measure Application Type

Note: See Appendix A for a comparison of the application types used by and incorporated into SCE systems versus the application types available in the newest revision of DEER 2014. Appendix A will serve as a translation between the outputs of this workpaper and application types used by READi.

The delivery methods are:

* Financial Support – Down-Stream Incentive – Deemed
* Partnership – Down-Stream Incentive – Deemed

The program/install type is Retrofit Add-On (REA).

## 1.4 Measure and Base Case Cost Effectiveness Data

### 1.4.1 DEER Measure and Base Case Analysis

Compressed air measures are not included in the Database for Energy Efficient Resources (DEER) Version 2014.

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 | DEER14 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\* |
| Com-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Com | Any | Any | 0.6 |
| Ind-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Ind | Any | Any | 0.6 |

\*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 | Compare |
| Measure Case UseSubCats | ManufDryAir |
| Measure Case TechGroups | AirComp |
| Measure Case TechTypes | CA\_Screw |
| Base Case TechGroups | AirComp |
| Base Case TechTypes | CA\_Screw |

### 1.4.2 Codes and Standards Analysis

Title 24 (2013), Section 120.6(e) provides the following requirements for new systems, additions, and alterations of compressed air systems 25 hp or greater:

|  |
| --- |
|  |

Due to Title 24 (2013) requirements, this measure will not be offered for compressor air systems 25 hp or greater.

Table 6 Code Summary

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Dates |
| Title 24 (2013) | Section 120.6(e) Mandatory Requirements for Compressed Air Systems | July 1, 2014 |

### 1.4.3 Non-DEER Study Review

No Non-DEER studies were used in the development of this work paper. One data source used was AIRMaster+, a software tool created by the U.S. Department of Energy to help users analyze energy use and saving opportunities in compressed air systems. It is the standard analysis tool used by the compressed air industry. This work paper’s savings are based on outputs from the AIRMaster+ tool.

### 1.4.4 Measure and Base Case Effective Useful Life

DEER14 update documentation provides EUL and RUL information to be used for the 2013-14 program cycle 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 EUL is taken from program savings documentation from The Connecticut Light and Power Company and The United Illuminating Company [353]. Table 7 below identifies the value/methodology used for the measures in this work paper.

Table 7 DEER14 EUL Value/Methodology

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| READi EUL ID | Market | Enduse | Measure | EUL (Years) | RUL (Years) |
| NonDEER | Non-Residential | Process | Variable Speed Drive on Air Compressor Control | 13 | N/A |

# Section 2. Energy Savings & Demand Reduction Calculations

This measure achieves energy savings and demand reduction by enabling an air compressor to operate more efficiently at part load conditions. Savings do not vary by climate zone or building type.

**AIRMaster+ Runs**

Base Case: Baseline AIRMaster+ runs were performed using several sizes of single stage, lube injected rotary screw compressors using load/unload controls, ranging from 5 hp to 25 hp, available in the default AIRMaster+ equipment inventory. Default AIRMaster+ settings were retained for compressor efficiencies, unloaded power and other controls and performance parameters. Compressor efficiencies contained in the AIRMaster+ database are currently used as industry standard in the California Statewide Customized Offering.The following assumptions were made in defining the compressor loading:

* Compressors run at 70% of full load capacity.
* Compressors are rated at 100 psig. 100 psig was chosen as a conservative assumption. System efficiency increases as operating pressure decreases; however discharge pressures below 100 psig may cause end users to function improperly.
* System air storage volume is equivalent to 2 gallons per acfm of compressed air demand. This is based on the minimum storage capacity specified in the proposed Title 24 (2013) compressed air standard.
* Compressors typically run 24 hours per day, 7 days per week for 50 weeks per year (8400 annual operating hours). However, the kWh usage in this work paper was scaled to match the DEER defined operating hours for Manufacturing - Light Industrial buildings (3220 hours).

Measure Case: AIRMaster+ does not include VSD controlled compressors in its equipment inventory, so it was necessary to construct a measure case VSD compressor in AirMaster+ to match each base case compressor. The performance profile of each measure case compressor was based on the AIRMaster+ performance of a single stage, lube injected rotary screw compressor using inlet modulation with unloading controls, of equivalent size to its respective base case compressor. The default AIRMaster+ performance profile for the compressor was then modified to simulate the performance of a VSD controlled compressor, using the following steps:

* The measure case (VSD) compressor was assumed to have equivalent rated air flow at 100 psig to its respective base case (load/unload) compressor.
* To account for the overhead power required to operate the added controls, the full load power of the VSD compressor was assumed to be 105% of the full load power of its respective load/unload compressor.
* The no load power of the VSD compressor was assumed to be 5% of the full load power of the load/unload compressor.
* The VSD compressor was assumed to unload at the same point (40% of full load capacity) as its respective load/unload compressor.
* The power at the unload point (40% of rated capacity) of the VSD compressor was assumed to be 45% of the full load power of the load/unload compressor.

**Energy Savings and Demand Reduction**

AIRMaster+ yielded kWh/year energy savings and kW peak demand, which were divided by hp ratings to obtain specific energy savings (kWh/hp/year and kW/hp). These were then averaged based on hp ranges specified by the 2 measures. It is assumed that the air compressor system operates at constant load and performance during the 2pm–5pm DEER peak period, so specific demand reduction is calculated by dividing energy savings by annual operating hours. Table 8 presents the energy savings:

Table 8 Energy Savings and Demand Reduction

|  |  |  |  |
| --- | --- | --- | --- |
| **Solution Code** | **Measure name** | **Annual Electric Savings (kWh/HP/year)** | **Demand Reduction (kW/HP)** |
| PR-50059 | 5 up to 15 HP Variable Speed Drive on Air Compressor Control | 491.48 | 0.15264 |
| PR-34445 | 15 up to 25 HP Variable Speed Drive on Air Compressor Control | 421.65 | 0.13095 |

Savings calculations are in Attachment 2.

# 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 Industrial load shape. See Table 9 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 9 Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| Building Type | E3 Alt. Building Type | Load Shape |
| Agricultural | Industrial | Industrial |
| Health/Medical - Hospital | Industrial | Industrial |
| Health/Medical - Clinic | Industrial | Industrial |
| Manufacturing - Bio/Tech | Industrial | Industrial |
| Manufacturing - Light Industrial | industrial | industrial |
| Industrial | Industrial | Industrial |
| Misc - Commercial | Industrial | Industrial |
| Retail - Single-Story Large | Industrial | Industrial |
| Transportation - Communication - Utilities | Industrial | Industrial |

# Section 4. Base Case & Measure Costs

## 4.1 Base Case Cost

For this measure category, the base case cost is assumed to be zero because these are discretionary modifications (retrofit add-on) to the customers’ existing equipment. The alternative is to make no changes to their existing system.

## 4.2 Measure Case Cost

For retrofit add-on measures, the gross measure cost is the full measure cost to purchase and install, as shown in Table 10. The measure costs shown in the table were obtained using data from the 2012 edition of RS Means Electrical Cost Data. RS Means covers VSDs from 3 HP to 200 HP. See Attachment 2 for more details.

GMC is represented by the equation below:

GMC = Measure Equipment Cost + Measure Labor Cost

Table 10 Measure Cost

|  |  |
| --- | --- |
| **Measure** | **GMC ($/hp)** |
| 5 up to 15 HP Variable Speed Drive on Air Compressor Control | $401.75 |
| 15 up to 25 HP Variable Speed Drive on Air Compressor Control | $301.53 |

## 4.3 Gross and Incremental Measure Cost

### 4.3.1 Gross Measure Cost

For retrofit add-on measures, the gross measure cost is the full measure cost to purchase and install, as shown in Table 10.

### 4.3.2 Incremental Measure Cost

Incremental Measure Cost (IMC) is the premium cost to install an energy efficient measure over a standard efficiency measure or code baseline measure. For retrofit add-on measures, the IMC is equal to the gross measure cost, as there exists no base case from which to compare the measure.

# Attachments

1. 

1. 
2. 

# References

[31]

[351]

[352]

[353]

[354]



# 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 |