Work Paper SCE13PR005

**Revision 3**

**Southern California Edison**

**Air Compressor VSD**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | PR-50059, PR-34445 |
| **Measure Description** | Variable Speed Drive Control on Air Compressor |
| **Base Case Description** | Load/Unload Control on Rotary Screw Compressor |
| **Units** | Per HP |
| **Energy Savings** | Refer to Excel Calculation Attachment |
| **Full Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Incremental Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Effective Useful Life** | CompAir-Screw-VSD: EUL 4.33yrs |
| **Measure Installation Type** | Retrofit Add-on (REA) |
| **Net-to-Gross Ratio** | Com-Default>2yrs: 0.6  Ind-Default>2yrs: 0.6 |
| **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** |
| 0 | 4/30/12 | Mike Casey/AESC | Original work paper for 2013-14 program cycle |
| 1 | 4/16/14 | 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. |
| 2 | 2/1/16 | Yun Han/SCE | * New template update for 2016 program year * Removed SCE building types * No value modifications |
| 3 | 4/22/16 | Ryan Cho/SCE | * Add Office - Small building type |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
|  |  |  |  |  |  |

Cal TF website: <http://www.caltf.org/>

# 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.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Variable Speed Drive Control on Air Compressor |
| Existing Condition | Load/Unload Control on Rotary Screw Compressor |
| Code/Standard | N/A |
| Industry Standard Practice | N/A |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
|  |  | 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:

* Health/Medical - Hospital
* Manufacturing - Bio/Tech
* Manufacturing - Light Industrial
* Office – small
* Retail - Single-Story Large

## 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.

## 1.3 Installation Types and Delivery Mechanisms

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

**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 |

The delivery methods are:

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

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.

**Delivery 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. |
| Partnership | The program implements projects through a partnership between the utility and an institutional, government, or community-based organization. |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Down-Stream Incentive | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. Such an incentive may be deemed or customized. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

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 | No |
| DEER Operating Hours | No |
| DEER eQUEST Prototypes | No |
| DEER Version | N/A |
| Reason for Deviation from DEER | DEER does not contain this type of measure. |
| 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.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| 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 |

**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.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **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.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| CompAir-Screw-VSD | Variable Speed Drive on Air Compressor Control | Any | CompAir | 13 | N/A |

### 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.

Code Summary

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

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

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.

## 1.6 Data Quality and Future Data Needs

N/A.

# Section 2. Calculation Methodology

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 below presents the energy savings:

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 1.

# 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.

Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Health/Medical - Hospital | Industrial | Industrial |
| Manufacturing - Bio/Tech | Industrial | Industrial |
| Manufacturing - Light Industrial | Industrial | Industrial |
| Office – Small | Industrial | Industrial |
| Retail - Single-Story Large | Industrial | Industrial |

# Section 4. 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

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.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Solution Code** | **Measure name** | **Measure Cost** | **Labor** | **Total Measure Cost** |
| PR-50059 | 5 up to 15 HP Variable Speed Drive on Air Compressor Control | $320.34 | $81.41 | $401.75 |
| PR-34445 | 15 up to 25 HP Variable Speed Drive on Air Compressor Control | $250.97 | $50.56 | $301.53 |

## 4.3 Full and Incremental Measure Cost

**Full and Incremental Measure Cost Equations**

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| REA | MEC + MLC | MEC + MLC | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

**Full and Incremental Costs**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| PR-50059 | REA | $401.75 | $401.75 | N/A |
| PR-34445 | REA | $301.53 | $301.53 | N/A |

# Attachments

1. 2. 3. 

# References



[352]