Work Paper SCE17PR005

**Revision 0**

**Southern California Edison**

**Air Compressor VSD**

# 

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | PR-50059, PR-34445, PR-18655, PR-18656 |
| **Measure Description** | See Section 1.1 |
| **Base Case Description** | See Section 1.1 |
| **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** | 6.67 years (DEER EUL ID: CompAir-Screw-VSD) in accordance with Draft Resolution [510] |
| **Measure Installation Type** | Retrofit Add-on (REA)  New (NEW) or New Construction (NC)  Replace on Burnout (ROB) |
| **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 | 11/10/16 | M.Blum/SCE | * Updated SCE13PR005.3 to SCE17PR005.0 * New template update for 2017 program year * Clarified size (HP) ranges in measure description * Updated code * Add NEW or NC, and ROB Installation Types * Removed existing baseline requirement of Load/Unload controls * Updated costs and savings (savings update due to the clarification in HP ranges and DEER operating hours) * Updated attachments and references * Updated the EUL value in accordance with Draft Resolution E-4807 [510] |

# 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 cases are a variable speed drive control added to an existing rotary screw air compressor and a new variable speed drive control type air compressor for REA and ROB/NEW installation types respectively.

The base case is an existing rotary screw compressor using load/unload controls, with rated capacity ≥ 5 hp (4 kW) and < 25 hp (18 kW) for both REA and ROB/NEW installation types. If the compressed air system includes multiple compressors, the base case compressor operates as a trim compressor and the online capacity of the compressed air system must be less than 25 hp (18 kW) total.

**Base, Standard, and Measure Cases**

The table below describes the case for REA measures

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

The table below describes the case for ROB/NEW measures

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | New Variable Speed Drive Control Type Air Compressor |
| Existing Condition | Load/Unload Control Type 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 to < 15 HP Add Variable Speed Air Compressor Control |
|  |  | PR-34445 |  | 15 to < 25 HP Add Variable Speed Air Compressor Control |
|  |  | PR-18655 |  | 5 to < 15 HP Variable Speed Air Compressor (ROB/NEW) |
|  |  | PR-18656 |  | 15 to < 25 HP Variable Speed Air Compressor (ROB/NEW) |

The existing (REA) or new air compressor shall meet the following requirements:

* Must be a rotary screw compressor.
* Must have a horsepower rating ≥ 5 hp and < 25 hp (18 kW). Air compressor systems (online capacity) rated at 25 hp and greater are ineligible due to Title 24 (2016) code requirements.
* 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 to the following building types:

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

## 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), Replace on Burnout (ROB), New Construction (NC) or NEW.

**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 |
| Replace on Burnout (ROB) | Above Code or Standard | N/A | EUL | N/A |
| New Construction (NC) or NEW | Above Code or Standard | N/A | EUL | N/A |

The delivery methods are:

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

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. |
| New Construction | The program offers financial incentives and/or design assistance to customers involved with new building construction. This is intended is to motivate customer to exceed Title 24 building energy efficiency requirements (residential or nonresidential). |

The **SCE Savings by Design Program** offers incentives on a wide variety of energy-saving design and technologies that encourages design teams and building owners/managers to integrate a higher level of energy efficiency for their new construction and major building renovation projects. As a way to streamline incentivizing energy efficient lighting technologies, SBD offers an “express” way to participate in this opportunity using deemed equipment measures.

The process will direct the customer or their designated representative (customer) to work with an SCE New Construction Representative (NCR). The NCR will determine if the Whole Building Approach (WBA) or Deemed System Approach (DSA) will provide the most benefit to the project.

If the project qualifies for process measures, the NCR will provide the customer with a coded coupon, which the customer will use when ordering construction or renovation materials for their facility. The customer will receive the rebate incentive by presenting the coupon when applying for the rebate.

The pre-inspection and post-inspection process will follow the process used by SCE’s EE program via which this product is offered. It should be noted, DSA measures apply to new construction and major renovations.

**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 | Yes |
| 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 table below describes the case for ROB/NEW measures

The EUL and RUL values were obtained using the DEER READI tool.

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

The table below describes the case for REA measures

The EUL and RUL values were obtained in accordance with Draft Resolution E-4807 [510].

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| CompAir-Screw-VSD | Variable Speed Drive on Air Compressor Control | Any | CompAir | 6.67 | NA |

### 1.4.2 Codes and Standards Analysis

Title 24 (2016), Section 120.6(e) provides the following requirements for new systems, additions, and alterations of compressed air systems with a combined online horsepower of 25 hp or greater [496].

(e) **Mandatory Requirements for Compressed Air Systems.** All new compressed air systems, and all additions or

alterations of compressed air systems where the total combined online horsepower (hp) of the compressor(s) is

25 horsepower or more shall meet the requirements of Subsections 1 through 3. These requirements apply to the compressors and related controls that provide compressed air and do not apply to any equipment or controls that

use or process the compressed air.

**EXCEPTION to Section 120.6(e):** Alterations of existing compressed air systems that include one or more centrifugal compressors.

1. **Trim Compressor and Storage*. .*** The compressed air system shall be equipped with an appropriately sized trim compressor and primary storage to provide acceptable performance across the range of the system and to avoid control gaps. The compressed air system shall comply with Subsection A or B below:

1. The compressed air system shall include one or more variable speed drive (VSD) compressors. For systems with more than one compressor, the total combined capacity of the VSD compressor(s) acting as trim compressors must be at least 1.25 times the largest net capacity increment between combinations of compressors. The compressed air system shall include primary storage of at least one gallon per actual cubic feet per minute (acfm) of the largest trim compressor; or,
2. The compressed air system shall include a compressor or set of compressors with total effective trim capacity at least the size of the largest net capacity increment between combinations of compressors, or the size of the smallest compressor, whichever is larger. The total effective trim capacity of single compressor systems shall cover at least the range from 70 percent to 100 percent of rated capacity. The effective trim capacity of a compressor is the size of the continuous operational range where the specific power of the compressor (kW/100 acfm) is within 15 percent of the specific power at its most efficient operating point. The total effective trim capacity of the system is the sum of the effective trim capacity of the trim compressors. The system shall include primary storage of at least 2 gallons per acfm of the largest trim compressor.

**EXCEPTION 1 to Section 120.6(e)1:** Compressed air systems in existing facilities that are adding or replacing less than 50 percent of the online capacity of the system.

**EXCEPTION 2 to Section 120.6(e)1:** Compressed air systems that have been approved by the Energy Commission Executive Director as having demonstrated that the system serves loads for which typical air demand fluctuates less than 10 percent.

2. **Controls.** Compressed air systems with more than one compressor online, having a combined horsepower rating of more than 100 hp, must operate with a controller that is able to choose the most energy efficient combination of compressors within the system based on the current air demand as measured by a sensor.

3. **Compressed Air System Acceptance.** Before an occupancy permit is granted for a compressed air system subject to Section 120.6(e), the following equipment and systems shall be certified as meeting the Acceptance Requirements for Code Compliance, as specified by the Reference Nonresidential Appendix NA7. A Certificate of Acceptance shall be submitted to the enforcement agency that certifies that the equipment and systems meet the acceptance requirements specified in NA 7.13.

This measure will not be offered for air compressor systems with an online capacity of 25 hp (18 kW) or greater. Retrofit Add-On (REA) projects for air compressor systems with an online capacity of 25 HP or greater may be eligible for customized solutions.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | Section 120.6(e) Mandatory Requirements for Compressed Air Systems | January 1, 2017 |

## 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 Title 24 (2016) 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 existing buildings in SCE Climate zones (Com-Indoor-LF lighting type, 2920 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 airflow 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 (Attachment 2, “AM+ Results” worksheet):

Energy Savings and Demand Reduction

|  |  |  |  |
| --- | --- | --- | --- |
| **Solution Code** | **Measure name** | **Annual Electric Savings (kWh/HP/year)** | **Demand Reduction (kW/HP)** |
| PR-50059 | 5 to < 15 HP Add Variable Speed Air Compressor Control | 465.16 | 0.15930 |
| PR-34445 | 15 to < 25 HP Add Variable Speed Air Compressor Control | 384.99 | 0.13185 |
| PR-18655 | 5 to < 15 HP Variable Speed Air Compressor (ROB/NEW) | 465.16 | 0.15930 |
| PR-18656 | 15 to < 25 HP Variable Speed Air Compressor (ROB/NEW) | 384.99 | 0.13185 |

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 |
| Retail - Single-Story Large | Industrial | Industrial |
| Office – Small | Industrial | Industrial |

# Section 4. Costs

## 4.1 Base Case Cost

For the REA 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.

Measure Type REA ONLY

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Solution Code** | **Measure name** | **Base Cost** | **Labor** | **Total Base Cost** |
| PR-50059 | 5 HP to < 15 HP ADD Variable Speed Drive on Air Compressor Control | $0 | $0 | $0 |
| PR-34445 | 15 to < 25 HP ADD Variable Speed Drive on Air Compressor Control | $0 | $0 | $0 |

For NEW or ROB, the base case cost is a load/unload air compressor control. Base case screw type air compressor costs were found with a web search and included in Attachment 2. Labor costs were averaged from the 2016 edition of RS means. Labor cost for both the baseline and measure are equivalent.

The cost data was used to perform regression analysis. The cost data includes air compressors within the rated 5 HP to 20 HP range that are standard sizes and are included in the air compressor ranges allowed by these solution codes. The regression curve data was used to calculate the average base cost and labor for air compressors in the ranges stated for each solution code in the table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Solution Code** | **Measure name** | **Base Cost** | **Labor** | **Total Base Cost** |
| PR-18655 | 5 to < 15 HP Variable Speed Air Compressor (ROB/NEW) | $620.28 | $148.89 | $769.17 |
| PR-18656 | 15 to < 25 HP Variable Speed Air Compressor (ROB/NEW) | $505.75 | $105.42 | $611.17 |

## 4.2 Measure Case Cost

The measure costs for REA were obtained using data from the 2016 edition of RS Means Electrical Cost Data. RS Means covers VSDs from 3 HP to 200 HP. See Attachment 2 for data and detailed calculations. The average cost of the measure and labor costs for the REA installation type are listed in the table below.

Measure Type REA ONLY

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Solution Code** | **Measure name** | **Measure Cost** | **Labor** | **Total Measure Cost** |
| PR-50059 | 5 HP to < 15 HP ADD Variable Speed Drive on Air Compressor Control | $340.25 | $98.80 | $439.05 |
| PR-34445 | 15 to < 25 HP ADD Variable Speed Drive on Air Compressor Control | $258.35 | $57.64 | $315.99 |

The measure costs for NEW or ROB are based on a variable speed air compressors. Measure case variable speed screw-type air compressor costs were found with a web search and included in Attachment 2. The cost data includes air compressors within the rated 5 HP to 20 HP range that are standard sizes. The regression curve data was used to calculate the average measure cost and labor for air compressors in the ranges stated for each solution code in the table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Solution Code** | **Measure name** | **Measure Cost** | **Labor** | **Total Measure Cost** |
| PR-18655 | 5 to < 15 HP Variable Speed Air Compressor (ROB/NEW) | $985.02 | $148.89 | $1133.91 |
| PR-18656 | 15 to < 25 HP Variable Speed Air Compressor (ROB/NEW) | $728.01 | $105.42 | $833.43 |

## 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 |
| ROB | (MEC + MLC) – (BEC + BLC) | (MEC + MLC) – (BEC + BLC) | N/A |
| NEW/NC |

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 | $439.05 | $439.05 | N/A |
| PR-34445 | REA | $315.99 | $315.99 | N/A |
| PR-18655 | NEW/ROB | $364.74 | $364.74 | N/A |
| PR-18656 | NEW/ROB | $222.26 | $222.26 | N/A |

# Attachments

1. SCE17PR005.0 A1 – Calculation Template\_Final.zip
2. SCE17PR005.0 A2 - Savings and Cost Calculations.xlsx
3. SCE17PR005.0 A3 - AirMaster db.mdb

# References

1. References\_12122016\_100741.xlsx

[352]

[496]

[510]