Work Paper SCE17RN023

**Revision 1**

**Southern California Edison**

**Refrigeration Floating Suction and Head Pressure Controls**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | RF-31355  RF-41488  RF-40395  RF-51222  RF-20965 |
| **Measure Description** | Floating head and suction pressure controls for commercial multiplex and industrial (process) refrigeration systems |
| **Base Case Description** | Commercial multiplex and process refrigeration systems with fixed head and suction pressure setpoints |
| **Units** | Per ton of cooling |
| **Energy Savings** | Refer to Excel Calculation Attachment 1 |
| **Full Measure Cost ($/unit)** | Refer to Excel Calculation Attachment 1 |
| **Incremental Measure Cost ($/unit)** | Refer to Excel Calculation Attachment 1 |
| **Effective Useful Life** | 5 years, capped at the RUL of the relevant host equipment RefgWrhs-Comp. ) |
| **Measure Installation Type** | REA – Retrofit Add-on |
| **Net-to-Gross Ratio** | Com-Default>2yrs & 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 | 12/07/2016 | Arvind Subramanya/TRC Solutions | - This work paper is an update of SCE13HC039.4  - New calculation template update for 2017 program year  - Updated the EUL value in accordance with Draft Resolution E-4807 [B]  - Work paper is updated with 2016 Title-24 code requirement language.  - Measure cost has been updated with costs from WO017 Cost Study Report |
| 1 | 10/16/17 | Yin Yin Wu/BASE Energy, Inc.  . | - DEER2017 values are checked. No change is made.  - Measure cost is updated based on the weighted average tons per discharge group, which is estimated based on market data  - The work paper calculation template is updated using Version 6.7.4 |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
|  |  |  | 9/21/2017 | * To update cost using the weighted average tons per discharge group, which is estimated based on market data | * Implemented |

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

# Section 1. General Measure & Baseline Data

## Measure Description & Background

The objective of this work paper is to evaluate the energy savings for commercial multiplex and industrial (process) refrigeration systems retrofitted with floating head and/or suction pressure controls.

The base and measure cases are summarized as follows (Section 1.2 describes these cases in greater technical detail):

**Base Case**: Existing fixed head pressure (or saturated condensing temperature, SCT) and fixed suction pressure (or saturated suction temperature, SST) setpoint controls for commercial multiplex and process refrigeration systems.

**Measure Case**: Floating head and suction pressure controls for commercial multiplex and process refrigeration systems. Floating head pressure is controlled based on ambient drybulb (Tdb) temperature for air-cooled systems, and on the ambient wetbulb (Twb) for evaporative-cooled systems. Floating suction pressure is controlled based on the worst-case zone demand.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Floating head and suction pressure controls for commercial multiplex and process refrigeration systems |
| Existing Condition | Fixed head and fixed suction setpoint controls for commercial multiplex and process refrigeration systems |
| Code/Standard | 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, 120.6(b)1; 120.6(B)2;120.6(a)4; 120.6(a)5 |
| Industry Standard Practice | N/A |

Table below describes the 5 core measures evaluated in this workpaper based on the condenser type (air-cooled or evap-cooled) and application (commercial or process).

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
|  |  | RF-31355 |  | Floating Head Pressure Controls on Commercial Air-Cooled Multiplex Refrigeration System |
|  |  | RF-41488 |  | Floating Head Pressure Controls on Commercial Evap-Cooled Multiplex Refrigeration System |
|  |  | RF-40395 |  | Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System |
|  |  | RF-51222 |  | Floating Suction Pressure Controls on Commercial Multiplex Refrigeration System |
|  |  | RF-20965 |  | Floating Suction Pressure Controls on Process Evap-cooled Refrigeration System |

**Eligibility, Implementation and Documentation Requirements**

The above-described measures are eligible for installations on existing commercial multiplex and process refrigeration systems which have fixed head and suction pressure controls according to the descriptions shown in **Base Cases** in Section 1.2.

Proposed head pressure controls must operate the refrigeration systems according to:

* 12°F temperature difference (TD) between Tdb and SCT for air-cooled commercial systems on all building types except refrigerated warehouse
* 17°F TD between Twb and SCT for evap-cooled commercial systems on all building types except refrigerated warehouse
* 9°F TD between Twb and SCT for evap-cooled process systems on refrigerated warehouses
* Minimum SCT of 70oF

The proposed suction pressure controls must operate the refrigeration systems according to:

* Worst zone demand. The maximum suction setpoint is 5oF above the design temperature. The minimum is the same as the base case.

The following are ineligible:

* New construction installations.
* Floating head pressure controls on air-cooled process refrigeration systems.
* Floating suction pressure controls on refrigeration systems with variable speed evaporator fans.
* Any improvements which results in increased system energy use

Additionally, calculation of the design cooling load (tons) is to be based on connected display cases, walk-in coolers and freezers, cooled storage and prep areas only. Subcooler loads and air conditioning loads are ineligible for consideration.

## 1.2 Technical Description

This work paper focuses on floating head and suction pressure controls retrofits on existing commercial multiplex and process refrigeration systems with fixed head and suction pressure controls. The two largest energy consuming components of a refrigeration system are the compressor(s) and the heat rejection fan(s). Critical processes in a refrigeration cycle are described as follows:

1. Refrigerant close to its saturated vapor state is compressed to a super-heated vapor state at a higher pressure and temperature.
2. The superheated vapor is fed to the fan-powered condenser where heat is rejected to the ambient via air for air-cooled condenser or the combination of air and evaporating water for evaporative condenser. The condenser is designed to cool the refrigerant to the saturated-liquid state by rejecting the refrigerant heat to the ambient at lower temperature.
3. Refrigerant at the exit of the condenser is then flashed to a lower pressure and temperature via an expansion valve which enables it to absorb heat from the refrigerated zones which are maintained at a higher temperature relative to the refrigerant. This heat absorption brings it back to the saturated vapor state at the start of the compression process.

The common method for head pressure control is through condenser fan control. The amount of air (moist air) passing through the air cooled (evap-cooled) condenser is regulated to control condenser capacity and head pressure. Air flow control is achieved through the following schemes:

* Fan cycling
* Fan staging
* Fan speed modulation

Alternate method mentioned in DEER for head pressure control is condenser backflood. Liquid refrigerant is back-flooded to (or retained in) the condenser to reduce the effective condensing surface and condenser capacity. As liquid refrigerant accumulates in the condenser, the condenser pressure increases which directly affect the compressor discharge pressure. The back flood control setpoint (BSC) controls the temperature at or above which liquid refrigerant is retained in condenser.

The installation of floating head pressure controls reduces the compressor power draw by reducing the compressor discharge pressure when the ambient Tdb (Twb) temperatures are lower than what the air-cooled (evap-cooled) refrigeration system was designed for. The refrigeration system is set to have a minimum SCT in order to maintain refrigerant pressure at the inlet of the expansion valve.

Under a constant head pressure operation in cooler ambient conditions, the condenser heat rejection can be accomplished by taking advantage of larger temperature difference (TD) between SCT and ambient temperatures and the condenser fan can be cycled off (or throttled down) more frequently. However, under floating head pressure controls, SCT follows the ambient temperature to maintain a specified TD and the condenser fan will consume more energy as it will operate more often to accomplish heat rejection. However, this increase in fan energy usage is offset by the decrease in compressor energy usage.

The installation of floating suction pressure control similarly reduces the compressor power draw by increasing the compressor suction pressure based on the worst-case zone demand.

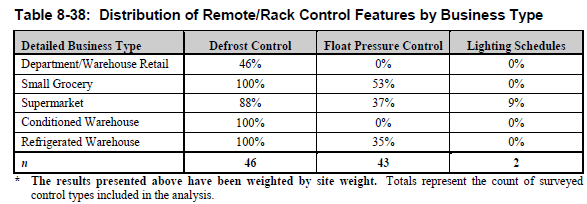
The following list describes the base and measure cases of the five measures evaluated in this work paper, based on information provided in DEER 2014:

* **Base Cases:**

1. RF-31355: Multiplex system, air-cooled condenser, fixed SCT = 80oF
2. RF-41488: Multiplex system, evap-cooled condenser, fixed SCT = 80oF
3. RF-40395: Evap-cooled condenser, fixed SCT = 85oF
4. RF-51222: Multiplex system, air-cooled condenser, fixed SST
5. RF-20965: Fixed SST

* **Measure Cases:**
  1. RF-31355: Floating head pressure control for commercial air-cooled multiplex refrigeration systems. This measure comprises three DEER measures, described as follows:
     1. DEER ID: D03-221: Multiplex system, air-cooled condenser, fixed SCT = 70oF
     2. DEER ID: D03-223: Multiplex system, air-cooled condenser, control SCT to ambient + 12oF TD, 70oF min, backflood setpoint of 68oF
     3. DEER ID: D03-225: Multiplex system, air-cooled condenser, control SCT to ambient + 12oF TD, 70oF min, backflood setpoint of 68oF, variable-speed fan control
  2. RF-41488: Floating head pressure control for commercial evap-cooled multiplex refrigeration systems. This measure comprises three DEER measures, described as follows:
     1. DEER ID: D03-222: Multiplex system, evap-cooled condenser, fixed SCT = 70oF
     2. DEER ID: D03-224: Multiplex system, evap-cooled condenser, control SCT to wetbulb + 17oF TD, 70oF min, backflood setpoint of 68oF
     3. DEER ID: D03-226: Multiplex system, evap-cooled condenser, control SCT to wetbulb + 17oF TD, 70oF min, backflood setpoint of 68oF, variable-speed fan control
  3. RF-40395: Floating head pressure control for process evap-cooled refrigeration systems. This measure comprises three DEER measures, described as follows:
     1. DEER ID: D03-307: Evap-cooled condenser, fixed SCT = 70oF, backflood setpoint of 68oF
     2. DEER ID: D03-308: Evap-cooled condenser, control SCT to wetbulb + 9oF TD, 70oF min, backflood setpoint of 68oF
     3. DEER ID: D03-309: Evap-cooled condenser, control SCT to wetbulb + 9oF TD, 70oF min, backflood setpoint of 68oF, var-speed fan control
  4. RF-51222: DEER ID: D03-220: Multiplex system, air-cooled condenser, reset SST based on worst-case demand
  5. RF-20965: DEER ID: D03-306: Reset SST based on worst-case zone demand

According to the California Commercial Saturation Survey [C], page 8-34, distribution of floating pressure control by business type is show below:



## Installation Types and Delivery Mechanisms

The delivery mechanisms for this measure are Financial Support Direct Install and Financial Support Down-Stream Deemed.

The install type for both of these delivery mechanisms 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 |

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** |
| Direct Install | The program implements energy efficiency measures for qualifying customers, at no cost to the customer. |
| 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. |
| On-bill Finance – Loan (OBF) | The program offers financing for the cost of an efficient measure as part of the utility bill. This can be an add-on option to an existing program or can serve as an organizing principle for its own program. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

The savings presented in this workpaper were based on the DEER 2014 database (DEER14) [386] and extracted from READi V.2.4.7, an interface for DEER17. DEER17 was a major update to the DEER 2014 version and incorporates changes based on the new 2016 Title 24. The database lists energy savings for 11 floating head and suction pressure measures listed in Section 2 and described in Section 1.2 under Measure Cases. Results were available for two building types in the 16 California climate zones: Grocery, employing commercial multiplex refrigeration systems, and Refrigerated Warehouse, employing process refrigeration systems.

Savings in this workpaper are based on DEER 2014 and are the same in READI v2.4.7 tool for DEER2017. Therefore, DEER 2017 is the reference for the savings impact in this revision.

DEER17 contains savings results for the three measure variations in each of the solution codes RF-31355, RF-41488, RF-40395 presented in Section 1.2. Since the three measure variations address the same baseline condition (Base Case #3: Fixed SCT control for process evap-cooled refrigeration systems, for example), their savings results were averaged to obtain a single savings value for the measure. Table below shows the Run IDs for DEER17 measures. Refer to Section 2 for a detailed methodology description.

DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Workpaper?** |
| Modified DEER methodology | Yes |
| Scaled DEER measure | Yes |
| DEER Base Case | Yes |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | Yes |
| DEER Version | DEER17 |
| Reason for Deviation from DEER | See Above Paragraph |
| DEER Measure IDs Used | D03-221, D03-223, D03-225, D03-222, D03-224, D03-226, D03-307, D03-308, D03-309, D03-220, D03-306 |

**Net-to-Gross Ratio**

The NTG values were obtained using the DEER READI v2.4.7 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 | All | 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 | All | 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. 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 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 in accordance with Draft Resolution E-4807 [B] and Draft Resolution E-4818 [A]. According to Resolution E-4818, the EUL of REA measures is capped at the RUL of the host equipment. 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 host equipment available from the EUL table of DEER2017 is *Refrigeration Upgrades - Variable Speed Compressors* (EUL ID: RefgWrhs-Comp), which has an EUL of 15 and a RUL of 5. The EUL from DEER2017 of the measures in this work paper is 15 years. Therefore, the EUL of the measures is capped at 5 years.

DEER14 EUL Value/Methodology

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| Grocsys-FltHdPres  Grocsys-FltSucPres | Refrigeration Upgrades (Head Pressure & Suction Pressure) - Grocery | Com | ComRefrig | 5\* | N/A |
| RefgWrhs-FltHdPres  RefgWrhs-FltSucPres | Refrigeration Upgrades (Suction Pressure & Head Pressure) - Refg Warehouse | Com | ProcRefrig | 5\* | N/A |

\* Capped at the RUL of the host equipment. See paragraph above for explanation.

### 1.4.2 Codes and Standards Analysis

This work paper deals with REA-type measures whose savings are not impacted by code standards. Discussion on the standards as they relate to the measures is presented here for information purposes only.

Chapter 10.5 of the California’s Title 24 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings [496] addresses commercial refrigeration systems in retail food stores. Chapter 10.5.2, Section A requires that all new commercial air-cooled and evaporative condenser fans be continuously variable speed. Additionally, head pressure must float in response to Tdb or Twb, and the minimum SCT must be 70oF or less. Table 10-2 in Title 24 specifies the minimum specific efficiency requirements (Btu-h/Watt) for new fan-powered condensers. Chapter 10.5.3, Section A requires floating suction pressure controls based on worst-case demand for all new remote refrigeration systems.

Chapter 10.6.3 addresses the mechanical systems serving refrigerated warehouses. Section B requires that all new commercial air-cooled and evaporative condenser fans be continuously variable speed. Additionally, head pressure must float in response to Tdb or Twb, and the minimum SCT must be 70oF or less. Table 10-6 in Title 24 specifies the minimum specific efficiency requirements (Btu-h/Watt) for new fan-powered condensers. Floating suction pressure controls are not mandatory. Additionally, areas within refrigerated warehouses designed for quick chilling or freezing of products are exempt.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, Section 120.6(b)1; 120.6(B)2 | January 1, 2017 |
| Title 24 (2016) | 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings, Section 120.6(a)4; 120.6(a)5 | January 1, 2017 |

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

### 1.5.1 Non-DEER Study Review

All data was taken from either DEER17 or 2016 Title 24 code standards.

## 1.6 Data Quality and Future Data Needs

N/A

# Section 2. Calculation Methodology

As described in technical detail in Section 1.2, floating head and suction controls ultimately reduce the required lift (pressure increase) at the compressor and improve the overall refrigeration system efficiency.

Electrical energy and demand as well as natural gas savings for the 5 core measures were based on the following eleven DEER17 measures for the 16 California climate zones (CZs):

1. D03-220: Commercial Refrigeration Floating Suction Pressure
2. D03-221: Commercial Refrigeration Floating Head Pressure, Fixed Setpoint (air-cooled)
3. D03-222: Commercial Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled)
4. D03-223: Commercial Refrigeration Floating Head Pressure, Variable Setpoint (air-cooled)
5. D03-224: Commercial Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled)
6. D03-225: Commercial Refrigeration Floating Head Pressure, Variable Setpt & Speed (air-cooled)
7. D03-226: Commercial Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled)
8. D03-306: Process Refrigeration Floating Suction Pressure
9. D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled)
10. D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled)
11. D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled)

The following table indicates which measures are taken directly from or created with the DEER READI v2.4.7 tool.

READI Data Used

|  |  |  |
| --- | --- | --- |
| **Measure Code** | **Measure Name** | **READI Data** |
| RF-31355 | Floating Head Pressure Controls on Commercial Air-Cooled Multiplex Refrigeration System |  |
| RF-41488 | Floating Head Pressure Controls on Commercial Evap-Cooled Multiplex Refrigeration System |  |
| RF-40395 | Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System |  |
| RF-51222 | Floating Suction Pressure Controls on Commercial Multiplex Refrigeration System |  |
| RF-20965 | Floating Suction Pressure Controls on Process Refrigeration System |  |

The savings for each of the floating head pressure measures were direct averages of three DEER17 measures which address the same baseline. The remaining floating suction pressure measures were based on one DEER17 measure each. The table above shows the assignment of DEER17 measures to each of the core measure. Please refer to Measure Case in Section 1.2 for technical descriptions of each DEER17 measure.

Within the same core measure group, the refrigeration system capacity (tons) was the same. Therefore the savings values from the three DEER17 measures were averaged to obtain the core measure savings. The following equation was used to calculate the kWh, kW, and Therm savings values for the floating head pressure measures in each CZ:

Where:

AMSavCLZ = Average measure savings for the core measure

IMSavCLZFS,FS = Individual measure savings for a fixed SCT set point, fixed fan speed system

IMSavCLZVS,FS = Individual measure savings for a variable SCT set point, fixed fan speed system

IMSavCLZVS,VS = Individual measure savings for a variable SCT set point, variable fan speed system

The tables below gives a sample summary of READi v2.4.7 outputs for the three DEER17 measures D03-307, D03-307, and D03-308 comprising RF-40395 (Floating Head Pressure on Process Evap-cooled Refrigeration System) in 16 CZs. These results have been modified using READi v2.4.7 tool for each measureID and are being included in the workpaper for reference. The summary of results for RF-40395 is also presented in the table below.

Sample READi Summary of DEER17 Savings Outputs Used for RF-40395

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **DEER14 Measure** | **CZ** | **kWh/ton Savings** | **kW/ton**  **Savings** | **Therm/ton Savings** | |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ01 | 1460 | 0.201 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ02 | 1490 | 0.0926 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ03 | 1520 | 0.0981 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ04 | 1360 | 0.031 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ05 | 1520 | 0.184 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ06 | 1420 | 0.136 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ07 | 1350 | 0.105 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ08 | 1370 | 0.148 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ09 | 1360 | 0.0606 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ10 | 1400 | 0.0776 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ11 | 1450 | 0.104 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ12 | 1360 | 0.0771 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ13 | 1310 | 0.0728 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ14 | 1580 | 0.136 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ15 | 1350 | 0.0894 | 0 |
| D03-307: Process Refrigeration Floating Head Pressure, Fixed Setpoint (evap-cooled) | CZ16 | 1520 | 0.173 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ01 | 1460 | 0.201 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ02 | 1490 | 0.0926 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ03 | 1520 | 0.0981 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ04 | 1360 | 0.031 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ05 | 1520 | 0.184 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ06 | 1430 | 0.136 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ07 | 1360 | 0.105 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ08 | 1380 | 0.148 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ09 | 1370 | 0.0606 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ10 | 1410 | 0.0776 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ11 | 1450 | 0.103 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ12 | 1360 | 0.0769 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ13 | 1310 | 0.0726 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ14 | 1580 | 0.136 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ15 | 1350 | 0.0894 | 0 |
| D03-308: Process Refrigeration Floating Head Pressure, Variable Setpoint (evap-cooled) | CZ16 | 1520 | 0.173 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ01 | 1910 | 0.218 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ02 | 1900 | 0.0931 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ03 | 1940 | 0.0981 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ04 | 1720 | 0.031 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ05 | 1920 | 0.194 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ06 | 1860 | 0.147 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ07 | 1790 | 0.11 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ08 | 1720 | 0.153 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ09 | 1730 | 0.0608 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ10 | 1840 | 0.0781 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ11 | 1850 | 0.105 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ12 | 1770 | 0.0805 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ13 | 1700 | 0.075 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ14 | 1980 | 0.139 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ15 | 1750 | 0.0927 | 0 |
| D03-309: Process Refrigeration Floating Head Pressure, Variable Setpt & Speed (evap-cooled) | CZ16 | 1880 | 0.173 | 0 |

**Summary of Savings for RF-40395**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Core Measure** | **CZ** | **kWh/ton Savings** | **kW/ton**  **Savings** | **Therm/ton Savings** | |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ01 | 1610 | 0.20667 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ02 | 1626.67 | 0.09277 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ03 | 1660 | 0.0981 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ04 | 1480 | 0.031 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ05 | 1653.33 | 0.18733 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ06 | 1570 | 0.13967 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ07 | 1500 | 0.10667 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ08 | 1490 | 0.14967 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ09 | 1486.67 | 0.06067 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ10 | 1550 | 0.07777 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ11 | 1583.33 | 0.104 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ12 | 1496.67 | 0.07817 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ13 | 1440 | 0.07347 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ14 | 1713.33 | 0.137 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ15 | 1483.33 | 0.0905 | 0 |
| Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | CZ16 | 1640 | 0.173 | 0 |

Below is an example of electrical energy, electrical demand and natural gas savings calculations for RF-40395 in CZ6:

kWh Savings Calculations:

AMSavCLZ6 = (1420+1430+1860)/3 = 1570 kWh

kW Savings Calculations:

AMSavCLZ6 = (0.136+0.136+0.147)/3 = 0.13967 kW

Therm Savings Calculations:

AMSavCLZ6 = 0 Therms

Refer to Attachment 1 for the detailed calculations and savings values for all measures in 16 CZs.

# 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** |
| Education - Community College | Refrigeration | College\_University |
| Education - University | Refrigeration | College\_University |
| Grocery | Refrigeration | Grocery\_Store |
| Health/Medical - Hospital | Refrigeration | Hospital |
| Health/Medical - Nursing Home | Refrigeration | Medical\_Clinic |
| Lodging - Hotel | Refrigeration | Hotel\_Motel |
| Manufacturing - Bio/Tech | Refrigeration | Industrial |
| Manufacturing - Light Industrial | Refrigeration | Industrial |
| Restaurant - Fast-Food | Refrigeration | Fast\_Food\_Restaurant |
| Restaurant - Sit-Down | Refrigeration | Sit\_Down\_Restaurant |
| Retail - Multistory Large | Refrigeration | Large\_Retail\_Store |
| Retail - Single-Story Large | Refrigeration | Large\_Retail\_Store |
| Retail - Small | Refrigeration | Small\_Retail\_Store |
| Storage - Conditioned | Refrigeration | Storage\_Building |
| Warehouse - Refrigerated | Refrigeration | Refrigerated\_Warehouse |
| Office - Small | Refrigeration | Small\_Office |

# Section 4. Costs

## 4.1 Base Case Cost

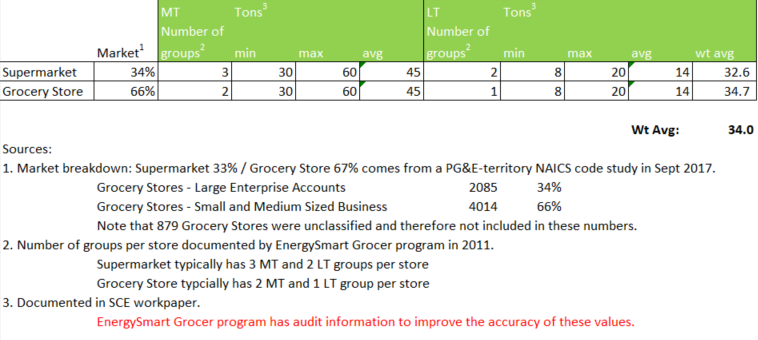
The base case cost is $0 since the existing refrigeration system can continue to operate without floating head and suction pressure controls.

## 4.2 Measure Case Cost

The measure case costs have been revised based on the “2010-2012 WO017 Ex Ante Measure Cost Study” [475].

Based on the review of refrigeration schedules for a sample of chain supermarkets, low temperature discharge group design load ranges from 8 tons to 20 tons. Medium discharge group design load ranges from 30 ton to 60 Tons.

Work order 17 provides cost of controller per discharge group, whereas the DEER savings are on per ton basis. To estimate cost per ton, the weighted average of 34 tons per discharge group, evaluated based on market data from a California Technical Forum meeting, is used for conversion. Refer to table below for the weighted average tonnage evaluation. Therefore, the cost per ton is calculated as cost per discharge group/34 Tons.



MT = medium temperature; LT = low temperature.

Source: California Technical Forum, Commercial Refrigeration Subcommittee Meeting #5, September 2017.

Measure Costs

The measure costs are based on cost data extracted from WO017, Summary tables on Page 4 of Appendix C. The table below summarizes the measure cost. The cost for the air-cooled floating head pressure controls measure is the average of three values from the WO017 cost data. The cost for the two evaporative-cooled floating heat pressure controls measures is the average of three values from the WO017 cost data. Refer to Attachment-2 for detailed cost calculation.

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure** | **Measure Equipment Cost ($/Ton)** | **Measure Labor Cost ($/Ton)** | **Gross Measure Cost ($/Ton)** |
| RF-31355: Floating Head Pressure Controls on Commercial Air-Cooled Multiplex Refrigeration System | $143.69 | $173.92 | $317.61 |
| RF-41488: Floating Head Pressure Controls on Commercial Evap-Cooled Multiplex Refrigeration System | $157.92 | $174.63 | $332.55 |
| RF-40395: Floating Head Pressure Controls on Process Evap-Cooled Refrigeration System | $104.11 | $172.68 | $276.78 |
| RF-51222: Floating Suction Pressure Controls on Commercial Multiplex Refrigeration System | $182.66 | $233.65 | $416.30 |
| RF-20965: Floating Suction Pressure Controls on Process Refrigeration System | $143.09 | $231.68 | $374.76 |

## 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** |
| RF-31355 | REA | $317.61/ton | $317.61/ton | N/A |
| RF-41488 | REA | $332.55/ton | $332.55/ton | N/A |
| RF-40395 | REA | $276.78/ton | $276.78/ton | N/A |
| RF-51222 | REA | $416.30/ton | $416.30/ton | N/A |
| RF-20965 | REA | $374.76/ton | $374.76/ton | N/A |

# Attachments

1. SCE17RN023.1 - Cal. Template V6.7.4
2. SCE17RN023.1 - Calculations

# References



[386]

[475]

[496]

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[A] Resolution E-4818. D. 16-08-019 / CT6. March 3, 2017. Retrieved from <http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M179/K264/179264220.PDF>

[B] Resolution E-4807 Final. December 15, 2016. Retrieved from <http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M171/K329/171329677.PDF>

[C] California Commercial Saturation Survey, Prepared for California Public Utilities Commission. Itron. July 15, 2014.