**Work Paper SCE13HC043**

**Revision 1**

**Southern California Edison Company**

**Water-Cooled Chillers**

# At-a-Glance Summary

|  |  |
| --- | --- |
| ****Applicable Measure Codes:**** | *Refer to Table 1* |
| **Measure Description:** | High efficiency water-cooled variable or constant speed chiller exceeding Title 24 IPLV minimum efficiency requirements by 5-22.8% and Title 24 full-load efficiency requirements of 0-11.6%%, depending on the chiller compressor type, category, and incentive tier level. |
| **Base Case Description:** | Constant speed or variable speed water-cooled chiller operating at the Title 24 minimum efficiency requirements. |
| **Energy Impact Common Units:** | Ton |
| **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):** | 20 years |
| **Measure Application Type:** | Replace on Burnout (ROB) |
| **Net-to-Gross Ratios:** | Refer to Table 3 |
| **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 |
| SCE13HC043.0 | No | 05/31/2012 | Alex MacCurdy/Energy Solutions | Workpaper adapted from WPSCNRHC0043.0 |
| SCE13HC043.1 | Yes | 5/14/2014 | Andrew Nishida/ Lincus, Inc. | -Updated to calculation methodology for screw/scroll chiller energy savings and demand reduction & updated to 2013 Title 24 Standards.  -Work paper updated for the reporting period, effective 7/1/14 – 12/31/14. |

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This work paper involves the installation of high efficiency water-cooled variable or constant speed chillers exceeding Title 24 minimum Integrated Part Load Value (IPLV) Efficiency requirements by 5-22.8% and Full-Load Efficiency (FLE) requirements by 0-11.6%, depending on the chiller compressor type and category. See Table 1 below for details on the tiers of incentives and capacity ranges for each type of chiller.

The base case is a constant speed (Path A) or variable speed (Path B) water-cooled chiller operating at the Title 24 minimum efficiency requirements. The measure minimum efficiency requirement for each solution code is listed in Table **2** and Table 3.

Table 1. Measure Names

|  |  |
| --- | --- |
| **Screw and Scroll Chillers** | |
| **Solution Code** | **Measure name** |
| AC-21019 | 75 – 149 tons - Better than T24 Path B by at least 12.6% IPLV and 5.1% FL (Tier 1) High Efficiency Water-Cooled Screw or Scroll Chiller |
| AC-78177 | 75 – 149 tons - Better than T24 Path B by at least 18.4% IPLV and 11.4% FL (Tier 2) High Efficiency Water-Cooled Screw or Scroll Chiller |
| AC-38845 | 150 – 299 tons - Better than T24 Path B by at least 16.5% IPLV and 8.1% FL (Tier 1) High Efficiency Water-Cooled Screw or Scroll Chiller |
| AC-68664 | 150 – 299 tons - Better than T24 Path B by at least 22.8% IPLV and 15.0% FL (Tier 2) High Efficiency Water-Cooled Screw or Scroll Chiller |
| AC-28103 | >= 300 tons - Better than T24 Path B by at least 10.0% IPLV and 0.0% FL (Tier 1) High Efficiency Water-Cooled Screw or Scroll Chiller |
| AC-89224 | >= 300 tons - Better than T24 Path B by at least 22.7% IPLV and 10.0% FL (Tier 2) High Efficiency Water-Cooled Screw or Scroll Chiller |
| **Centrifugal Chillers** | |
| **Solution Code** | **Measure name** |
| AC-90421 | 150 - 299 tons - Better than T24 Path A by at least 20% IPLV and 0.0% FL (Tier 1) High Efficiency Water-Cooled Centrifugal Chiller |
| AC-39620 | 150 - 299 tons - Better than T24 Path B by at least 12.7% IPLV and 6.1% FL (Tier 1) High Efficiency Water-Cooled Centrifugal Chiller |
| AC-40798 | 150 - 299 tons - Better than T24 Path B by at least 17% IPLV and 11.0% FL (Tier 2) High Efficiency Water-Cooled Centrifugal Chiller |
| AC-10944 | 300 - 599 tons Better than T24 Path A by at least 20% IPLV and 0.0% FL (Tier 1) High Efficiency Water-Cooled Centrifugal Chiller |
| AC-50980 | 300 - 599 tons - Better than T24 Path B by at least 5% IPLV and 6.6% FL (Tier 1) High Efficiency Water-Cooled Centrifugal Chiller |
| AC-51423 | 300 - 599 tons - Better than T24 Path B by at least 10% IPLV and 11.6% FL (Tier 2) High Efficiency Water-Cooled Centrifugal Chiller |
| AC-74365 | >= 600 tons - Better than T24 Path A by at least 20% IPLV and 0.0% FL (Tier 1) High Efficiency Water-Cooled Centrifugal Chiller |
| AC-88382 | >=600 tons - Better than T24 Path B by at least 5% IPLV and 6.6% FL (Tier 1) High Efficiency Water-Cooled Centrifugal Chiller |
| AC-78252 | >=600 tons - Better than T24 Path B by at least 10% IPLV and 11.6% FL (Tier 2) High Efficiency Water-Cooled Centrifugal Chiller |

**Table 2: Screw/Scroll Water-Cooled Chiller Measure Minimum Efficiency Requirements based on Path B Requirements for Water Chilling Packages Minimum Efficiency**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Solution Code** | **Compressor Type** | **Size Category** | **Tier** | **Baseline Full Load Efficiency (FLE)** | **Baseline Integrated Part-Load Value (IPLV)** | **Measure % Improvement over Title 24 FLE** **Range\*** | **Measure % Improvement over Title 24 IPLV** **Range\*** |
| **AC-21019** | Screw/Scroll | ≥75 Tons  <150 Tons | 1 | 0.790 | 0.586 | ≥5.1%  <11.4% | ≥12.6%  <18.4% |
| **AC-78177** | Screw/Scroll | ≥75 Tons  <150 Tons | 2 | 0.790 | 0.586 | ≥11.4% | ≥18.4% |
| **AC-38845** | Screw/Scroll | ≥150 Tons <300 Tons | 1 | 0.718 | 0.540 | ≥8.1%  <15.0% | ≥16.5%  <22.8% |
| **AC-68664** | Screw/Scroll | ≥150 Tons <300 Tons | 2 | 0.718 | 0.540 | ≥15.0% | ≥22.8% |
| **AC-28103** | Screw/Scroll | ≥300 Tons | 1 | 0.639 | 0.490 | ≥0%  <10.0% | ≥10.0%  <22.7% |
| **AC-89224** | Screw/Scroll | ≥300 Tons | 2 | 0.639 | 0.490 | ≥10.0% | ≥22.7% |

\*Title 24 minimum IPLV efficiency requirements for centrifugal water-cooled chillers change depending on the rated conditions of the chiller. The IPLV efficiencies listed above are calculated at AHRI 550/590 conditions, which are to be used when determining the tier efficiencies (percent improvement over Title 24)

**Table 3: Centrifugal Water-Cooled Chiller Measure Minimum Efficiency Requirements based on Path A Requirements for Constant Speed and Path B for Variable Speed Water Chilling Packages**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Solution Code** | **Compressor Type** | **Size Category** | **Tier** | **Baseline Full Load Efficiency (FLE)** | **Baseline Integrated Part-Load Value (IPLV)** | **Measure % Improvement over Title 24 FLE** **Range** | **Measure % Improvement over Title 24 IPLV** **Range** |
| **AC-90421\*\*** | Constant Speed Centrifugal | ≥150 Tons <300 Tons | 1 | 0.634 | 0.596 | ≥0% | ≥20% |
| **AC-39620** | Variable Speed Centrifugal | ≥150 Tons <300 Tons | 1 | 0.639 | 0.450 | ≥6.1%  <11.0% | ≥12.7%  <17.0% |
| **AC-40798** | Variable Speed Centrifugal | ≥150 Tons <300 Tons | 2 | 0.639 | 0.450 | ≥11.0% | ≥17.0% |
| **AC-10944\*\*** | Constant Speed Centrifugal | ≥300 Tons  <600 Tons | 1 | 0.576 | 0.549 | ≥0% | ≥20.0% |
| **AC-50980** | Variable Speed Centrifugal | ≥300 Tons  <600 Tons | 1 | 0.600 | 0.400 | ≥6.6%  <11.6% | ≥5.0%  <10.0% |
| **AC-51423** | Variable Speed Centrifugal | ≥300 Tons  <600 Tons | 2 | 0.600 | 0.400 | ≥11.6% | ≥10.0% |
| **AC-74365\*\*** | Constant Speed Centrifugal | ≥600 Tons | 1 | 0.570 | 0.539 | ≥0% | ≥20.0% |
| **AC-88382** | Variable Speed Centrifugal | ≥600 Tons | 1 | 0.590 | 0.400 | ≥6.6%  <11.6% | ≥5.0%  <10.0% |
| **AC-78252** | Variable Speed Centrifugal | ≥600 Tons | 2 | 0.590 | 0.400 | ≥11.6% | ≥10.0% |

\*\*Note that these tiers use Path A Title 24 Minimum Efficiency requirements.

Eligibility for incentive requires that the water-cooled chiller must fulfill the minimum requirements as set within the 2013 Title 24 Building Energy Efficiency Standards [C]. These minimum requirements are shown in Tables 1, 2, and 3 above. The following are exempt to these requirements:

* Centrifugal chillers with design leaving-evaporator temperature < 36°F; or
* Positive displacement chillers with design leaving fluid temperature ≤ 32°F.

The evaluated chiller must meet the minimum requirements of Path A or Path B, and both full load efficiency and IPLV must be met to fulfill the requirements of the applicable path. These requirements are to be performed under the AHRI 550/590 test procedure [A] conditions. Specification sheets outlining these conditions must be presented to claim rebates.

## 1.2 Technical Description

Chilled water systems use a central chiller plant to cool and distribute water that is in turn used to cool air to meet a building’s cooling demand. Water-cooled chillers use a condenser water loop and cooling towers to reject heat from the refrigeration cycle, achieving higher efficiencies relative to air-cooled systems. Water-cooled chillers are common in commercial and industrial applications and are available in a wide range of capacities, from under 50 tons to several thousand tons. Chillers used for applications requiring a capacity of 75 tons or lower typically utilize air-cooled chillers and are therefore not considered within this workpaper.

Electrically operated water-cooled chillers are categorized by compressor type and tonnage capacity in efficiency standards such as ASHRAE 90.1 2013 [A] and California 2013 Building Energy Efficiency Standards (Title 24) [C]. Compressor technologies include Positive Displacement (reciprocating), Positive Displacement (rotary screw or scroll), and Centrifugal. Since reciprocating chillers and centrifugal chillers under 150 tons are no longer common in today’s market, they were not included in this work paper.

The efficiency ratings for a water-cooled chiller are based on the unit operating under standard test conditions, normally determined by AHRI Standard 550/590 - 2011 [B]. Chillers are rated both on full-load efficiency performance, and Integrated Part-Load Value efficiency (IPLV), expressed in the Coefficient of Performance (COP) metric, or more commonly in the water-cooled chiller industry, in kW/ton.

High efficiency chillers range widely in rated kW/ton performance, therefore three to four tiers are used to present savings for each type of chiller. Centrifugal chillers are often designed to operate at conditions other than those specified by AHRI 550/590. Title 24 has established tables that show the different full and part load minimum efficiencies required at these non-standard operating conditions. Therefore, tiers have been established to claim savings based on the efficiency requirements for centrifugal chillers expressed as a percent improvement over Title 24.

## 1.3 Measure Application Type

The delivery methods for this work paper are Upstream Programs / Up-Stream Incentive, Financial Support / Down-Stream Incentive – Deemed, and Partnership / Down-Stream Incentive – Deemed. The measure installation type is Replace on Burnout (ROB).

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.

## 1.4 Measure and Base Case Cost Effectiveness Data

### 1.4.1 DEER Measure and Base Case Analysis

Savings per ton for centrifugal chillers were derived using a combination of two methods using eQUEST v3.65. eQUEST v3.65 uses a DOE 2.2 software engine licensed from the Department of Energy. Savings per efficiency improvement for screw and scroll chillers were derived by taking the difference in kW/ton at full load and part load requirements based on Title 24 minimum standards and improved efficiencies in the proposed measures. A detailed explanation of the estimated energy savings and demand reduction calculations is included in Section 2.

Table 4 DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Difference Summary Table** | |
| Modified DEER Methodology | No |
| Scaled DEER Measure | No |
| DEER Building Prototypes Used | Yes |
| Deviation from DEER | For centrifugal and screw chillers, energy savings and demand reduction were modeled in eQUEST using DEER-based prototype from MAScontrol Tool v3.00.19. |
| DEER Version | DEER 2014 2.0.1v |
| DEER Run ID and Measure Name (Sample) | NE-HVAC-Chlr-Cent-lt150tons-0p560kwpton-ConstSpd |

**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 5 below.

Table 5 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 | Com | 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 work paper 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 6 below.

Table 6 Installation Rate

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| GSIA\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID | GSIAValue\* |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1.0 |

**Spillage Rate**

Spillage rate will also be applied to measures however the values will not be tracked in the work papers. 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.

Table 7 READi Tech IDs

|  |  |
| --- | --- |
| READi Field Name | Values included in this workpaper |
| Measure Case UseCategory | HVAC |
| Measure Case UseSubCats | SpaceCool |
| Measure Case TechGroups | Chiller |
| Measure Case TechTypes | CentChlr, Screw |
| Base Case TechGroups | Chiller |
| Base Case TechTypes | CentChlr, Screw |

### 1.4.2 Codes and Standards Analysis

**Title 20:** This measure does not fall under Title 20 of the California Energy Regulations.

**Title 24:** This measure does fall under the 2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24) of the California Regulations [C]. Under this regulation, the following is required by Section 110.2 (a), “Equipment shall meet the applicable efficiency requirements in TABLE 110.2-A through TABLE 110.2-K”. Efficiency requirements for water-cooled packaged chillers are identified in Table 110.2-D. Note that efficiency requirements can follow two different paths. The analysis performed for this work paper utilizes both Path A and Path B requirements. Title 24 provides minimum full load and IPLV requirements in units of kW/ton.

Table 8 Code Summary

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Dates |
| Title 24 (2013) | 2013 Non-Residential Compliance manual, Table 4-4 Water Chilling Packages Minimum Efficiency | July 1, 2014 |

Table 9. Title 24 Minimum Efficiency Requirement for Water-Cooled Chillers in kW/ton

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Water-Cooled Chiller Equipment Categories** | | **Path A** | | **Path B** | |
| **Full Load** | **IPLV[[1]](#footnote-1)** | **Full Load** | **IPLV** |
| Electrically Operated Positive Displacement (Rotary Screw and Scroll) | < 75 Tons | ≤0.780 | ≤0.630 | ≤0.800 | ≤0.600 |
| ≥75 tons and <150 Tons | ≤0.775 | ≤0.615 | ≤0.790 | ≤0.586 |
| ≥150 & <300 Tons | ≤0.680 | ≤0.580 | ≤0.718 | ≤0.540 |
| ≥300 Tons | ≤0.620 | ≤0.540 | ≤0.639 | ≤0.490 |
| Electrically Operated, Centrifugal, Operating at Standard Conditions | ≥150 & <300 Tons | ≤0.634 | ≤0.596 | ≤0.639 | ≤0.450 |
| ≥300 Tons & <600 Tons | ≤0.576 | ≤0.549 | ≤0.600 | ≤0.400 |
| ≥600 Tons | ≤0.570 | ≤0.539 | ≤0.590 | ≤0.400 |

### 1.4.3 Non-DEER Study Review

All data used in the analysis performed in this work paper were based on Title 24 requirements and from DEER’s MAScontrol Tool v3.00.19.

### 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 “DEER2014-EUL-table-update\_2014-02-05.xlsx” 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.

To obtain the EUL value the DEER14 update documentation, “DEER2014-EUL-table-update\_2014-02-05.xlsx”, was consulted. Table 10 below identifies the value/methodology used for the measures in this work paper.

Table 10 DEER14 EUL Value/Methodology

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| READi EUL ID | Market | Enduse | Measure | EUL (Years) | RUL (Years) |
| HVAC-Chlr | Non-Residential | HVAC | High Efficiency Chillers | 20 | N/A |

#### 

# Section 2. Energy Savings & Demand Reduction Calculations

Based on the improved efficiencies suggested by the proposed measures, there were cases in which the improved IPLV efficiencies, based on calculations using the standard eQUEST performance curves, translated to a FLE that did not meet Title 24 minimum FLE requirements. This resulted in cases where a difference in FLE inputs between the base and measure cases would be either zero or negative. From this, it was determined that the proposed measures could not be calculated using a single methodology and an alternate analysis was necessary for specific measures.

One method is an IPLV-based eQUEST methodology which calculates savings based on the base kWh usage and the difference between Title 24 IPLV and a calculated IPLV based on Title 24 minimum FLE requirements. This method applies to the cases where the resultant FLE calculated from the improved IPLV does not exceed that of Title 24 minimum FLE requirements. These cases include, all of the constant-speed (Path A) chiller measures (AC-90421, AC-10944, AC-74365, and for one of the variable-speed (Path B) chiller measures (AC-28103). The second method is an eQUEST calculation using simulations of standard DEER models for each building type, climate zone, chiller type, and chiller size based on Title 24 FLE and IPLV requirements. The latter method is used to calculate the remaining measures.

IPLV-Based eQUEST Methodology

IPLV was determined from FLE using a separate calculation from the standard eQUEST performance curves [D]. This calculation utilizes the EIRfPLR&dT and EIRfCHWT&ECT performance curves, which calculate the Energy Input Ratio(EIR) as a function of the Part Load Ratio (PLR), Chilled Water Temperature (CHWT), and Entering Condenser Temperature(ECT). The EIRfPLR&dT is a bi-quadratic equation that calculates EIR from PLR and the temperature differential (dT) of ECT and CHWT. The EIRfCHWT&ECT curve is a bi-quadratic equation calculating EIR as a function of CHWT and ECT. For each full load efficiency and EIR curve representative of the pump type, an IPLV was calculated and verified.

For this methodology, measure annual savings per ton are based on the difference between Title 24 minimum IPLV and IPLV calculated assuming an FLE of 0% improvement over the Title 24 minimum. This difference is summarized in Table 11 below. Equation 1 and Equation 2 below are used to calculate energy savings per ton and demand reduction per ton respectively for each building type and climate zone relevant to the measure.

Table 11. IPLV calculated based on Title 24 FLE requirements.

|  |  |  |  |
| --- | --- | --- | --- |
| **Solution Code** | **T24 IPLV Minimum Requirement** | **T24 FLE Minimum Requirements** | **Resultant Post IPLV** |
| AC-28103 | 0.490 | 0.639 | 0.437 |
| AC-90421 | 0.596 | 0.634 | 0.440 |
| AC-10944 | 0.549 | 0.576 | 0.399 |
| AC-74365 | 0.539 | 0.570 | 0.395 |

*Equation 1:*

*Equation 2:*

Where: IPLV (kW/ton)Base = Title 24 Integrated Part Load minimum

IPLV (kW/ton)Post = Integrated Part Load based on Title 24 minimum FLE requirements

Ton-hour = ton-hour of base case from DEER simulation

Rated Capacity = resultant calculated capacity from DEER model simulation

Hour = hours of operation based on eQUEST simulation

Sample Calculation for Solution Code AC-28103 for Education-Community Building in CZ 6:

Table 12. Demand Reduction and Energy Savings Summary for Solution Code AC-28103

for Education-Community College Building in CZ 6 using the IPLV-based methodology

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **IPLV\_Base**  **kW/ton** | **IPLV\_Post**  **kW/ton** | **Chiller Rated Capacity Tons[[2]](#footnote-2)** | **Ton-hour** | **Demand Reduction (kW/ton)** | **Energy Savings (kWh/ton)** |
| AC-28103 | 0.490 | 0.437 | 594 | 2,743,119 | 0.053 | 244.93 |

The ton-hour was calculated by dividing the annual kWh by the resultant EIR in kW/ton. These values were determined using the MAScontrol eQUEST model for the base case chiller (Title 24 FLE minimum as base case efficiency). The rated capacity was determined using the simulation file resulting from the base case simulation run.

Standard DEER eQUEST Model Methodology

For the remaining solution codes, Measure Annual Savings per Ton and Demand Reduction per ton for Path B centrifugal and screw/scroll water-cooled chillers are based on results from eQUEST v3.65. The models were downloaded from the MAScontrol Tool v3.00.19 for each requested building type and climate zone to be analyzed. It was observed during the analysis that about 75% of the models had situations where chiller capacities estimated by the models did not match up with stated size ranges (<150 tons, between 150 and 299 tons and 300tons and over) that were being modeled. None of the models were revised to bring the energy model estimated chiller capacities within stated size ranges, though each model was altered to match the baseline (Title 24 Standard) and measure (Incentive Tier) full-load and hence by association, part load efficiencies.

For each model, the climate zone locations and peak period definitions were updated from 2008 Title-24 to 2013 Title-24 Building Efficiency Standards. The specifics of these updates are shown in Table 13 and

Table 14 below. As a result of these changes, each model is representative of a DEER standard building type and climate zone with a specific DEER peak period for the latest chillers on the market.

Table 13. Changes From 2008 to 2013 Title 24 climate zone locations.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Climate Zone** | **2008 Title-24 (DEER 2011)** | | **2013 Title-24 (DEER2013)** | |
| **location** | **elevation (ft)** | **location** | **elevation (ft)** |
| CTZ06 | Los Angeles | 97 | Torrance | 88 |
| CTZ08 | El Toro | 383 | Fullerton | 395 |
| CTZ09 | Pasadena | 655 | Burbank-Glendale | 741 |
| CTZ10 | Riverside | 1543 | Riverside | 840 |
| CTZ13 | Fresno | 328 | Fresno | 335 |
| CTZ14 | China Lake | 2293 | Palmdale | 2523 |
| CTZ15 | El Centro | -30 | Palm Springs-Intl | 475 |
| CTZ16 | Mount Shasta | 3544 | Blue Canyon | 5279 |

Table 14. Changes from 2008 to 2013 Title 24 DEER peak period definitions.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Climate Zone** | **CZ2 (2008 Title-24) Weather Files** | | | | | **CZ2010 (2013 Title-24) Weather Files** | | | | |
| **Start Date** | | **Weekday** | **Peak T** | **AVE T[[3]](#footnote-3)** | **Start Date** | | **Weekday** | **Peak T** | **AVE T** |
| CZ06 | Jul | 9 | Tue | 85 | 69.0 | Sep | 1 | Tue | 102 | 77.1 |
| CZ08 | Sep | 23 | Mon | 98 | 78.2 | Sep | 1 | Tue | 105 | 79.8 |
| CZ09 | Aug | 6 | Tue | 101 | 78.3 | Sep | 1 | Tue | 107 | 86.6 |
| CZ10 | Jul | 8 | Mon | 104 | 83.5 | Sep | 1 | Tue | 109 | 86.3 |
| CZ13 | Aug | 14 | Wed | 106 | 87.1 | Jul | 8 | Wed | 108 | 86.7 |
| CZ14 | Jul | 9 | Tue | 106 | 89.7 | Aug | 26 | Wed | 105 | 86.8 |
| CZ15 | Jul | 30 | Tue | 114 | 96.2 | Aug | 25 | Tue | 112 | 97.5 |
| CZ16 | Aug | 6 | Tue | 96 | 73.1 | Jul | 8 | Wed | 90 | 78.8 |

Once the climate zone location and the peak period definition were defined, the base case simulation was defined using the “Building Creation Wizard” function. The baseline full load efficiency value was set either at the 2013 Title 24 full-load efficiency minimum requirement, or a full-load efficiency representative of the Title 24 IPLV minimum requirement for the appropriate chiller type and size range, whichever efficiency was greater. This ensured that for each case, both requirements were fulfilled. These minimum requirements can be found in Table 110.2-D Water Chilling Packages - Minimum Efficiency Requirements in the 2013 Title-24 Building Energy Efficiency Standards [C]. For each of the tier levels defined in Tables 2 and 3 above, measures were defined by tier number in the “Energy Efficiency Measure Wizard” and valued at a chiller full-load efficiency that would satisfy the respective full-load efficiency and IPLV for the tier.

With the parameters set, the building performance was simulated. The DEER peak period kW was determined from the exported “Hourly Results (CSV)” files for the base case as well as the measure case. The energy usage for the base case and each measure were found in the “Annual Building Summary” parametric run output tables from the electric kWh usage in HVAC energy. The rated capacity in tons for each chiller was obtained from the simulation files for the respective efficiency tiers. These simulation files were created once the model was run through the defined measures.

Demand reduction and energy savings were calculated using the equations below:

*Equation 3:*

*Equation 4:*

Where: kWBase/Measure = DEER Peak Period kW for baseline and measure cases respectively

kWhBase/Measure = Annual HVAC energy usage for base and measure cases respectively

Measure Chiller Capacity = Rated Capacity from simulation of measure case chiller

Sample Calculation for Solution Code AC-21019 for Education-Community College Building in CZ 6:

Table 15. Demand Reduction and Energy Savings Summary for Solution Code AC-21019 and AC-78177 for Education-Community College Building in CZ 6 using the standard DEER eQUEST methodology

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Category** | **Full Load kW/ton** | **IPLV**  **kW/ton** | **Chiller Rated Capacity Tons[[4]](#footnote-4)** | **Total HVAC kWh Usage** | **DEER Peak Period kW** | **Demand Reduction (kW/ton)** | **Energy Savings (kWh/ton)** |
| **Baseline** | 0.790 | 0.586 | 591.83 | 1,877,149 | 1,272.50 | - | - |
| **AC-21019 (Tier 1)** | 0.750 | 0.512 | 592.25 | 1,844,172 | 1,254.25 | 0.0308 | 55.68 |
| **AC-78177 (Tier 2)** | 0.700 | 0.478 | 592.58 | 1,804,874 | 1,231.91 | 0.06849 | 121.97 |

# 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 DEER:HVAC\_Chillers load shape. See Table 16 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 16 Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **E3 Alt. Building Type** | **Load Shape** |
| Education - Secondary School | NON\_RES | DEER:HVAC\_Chillers |
| Education - Community College | NON\_RES | DEER:HVAC\_Chillers |
| Education - University | NON\_RES | DEER:HVAC\_Chillers |
| Health/Medical - Hospital | NON\_RES | DEER:HVAC\_Chillers |
| Health/Medical - Nursing Home | NON\_RES | DEER:HVAC\_Chillers |
| Lodging - Hotel | NON\_RES | DEER:HVAC\_Chillers |
| Manufacturing - Bio/Tech | NON\_RES | DEER:HVAC\_Chillers |
| Office - Large | NON\_RES | DEER:HVAC\_Chillers |
| Office - Small | NON\_RES | DEER:HVAC\_Chillers |
| Retail - Multistory Large | NON\_RES | DEER:HVAC\_Chillers |

# Section 4. Base Case & Measure Costs

Distributors in SCE territory for four major national chiller brands were asked to provide equipment cost and rated efficiency (full load and IPLV) information for ranges of basic and high efficiency water-cooled chiller models [E]. Basic chillers represented equipment with performance closest to base line T24 qualifying units. Datasets were compiled for positive displacement (screw and scroll) chillers in the range of under 150 tons, 150 to 300 tons, and 300 tons and over. Similar datasets were also compiled for centrifugal chillers in the range of 150 to 300 tons, and 300 tons and over.

## 4.1 Base Case Cost

Table 17. Base Case Equipment Cost per ton for Screw/Scroll Water Cooled Chillers

|  |  |  |
| --- | --- | --- |
| **Solution Code** | **Chiller Capacity Range** | **Base Case Equipment Cost per Ton** |
| **AC-21019**  **AC-78177** | <150 tons | $454.88 |
| **AC-38845**  **AC-68664** | 150-299 tons | $331.24 |
| **AC-28103**  **AC-89224** | ≥300 tons | $297.42 |

Table 18. Base Case Equipment Cost per ton for Centrifugal Water Cooled Chillers

|  |  |  |
| --- | --- | --- |
| **Solution Code** | **Chiller Capacity Range** | **Base Case Equipment Cost per Ton** |
| **AC-90421** | 150-299 tons | $291.16 |
| **AC-39620**  **AC-40798** | 150-299 tons | $454.58 |
| **AC-10944** | 300-599 tons | $257.18 |
| **AC-50980**  **AC-51423** | 300-599 tons | $422.61 |
| **AC-74365** | ≥600 tons | $226.96 |
| **AC-88382**  **AC-78252** | ≥600 tons | $332.34 |

## 4.2 Measure Case Cost

Table 19. Measure Case Equipment Cost per ton for Screw/Scroll Water Cooled Chillers

|  |  |  |
| --- | --- | --- |
| **Solution Code** | **Chiller Capacity Range** | **Measure Cost per Ton** |
| **AC-21019** | <150 tons | $594.59 |
| **AC-78177** | <150 tons | $693.53 |
| **AC-38845** | 150-299 tons | $390.53 |
| **AC-68664** | 150-299 tons | $420.91 |
| **AC-28103** | ≥300 tons | $332.12 |
| **AC-89224** | ≥300 tons | $414.31 |

Table 20. Measure Case Equipment Cost per ton for Centrifugal Water Cooled Chillers

|  |  |  |
| --- | --- | --- |
| **Solution Code** | **Chiller Capacity Range** | **Measure Cost per Ton** |
| **AC-90421** | 150-299 tons | $404.11 |
| **AC-39620** | 150-299 tons | $580.78 |
| **AC-40798** | 150-299 tons | $648.57 |
| **AC-10944** | 300-599 tons | $467.63 |
| **AC-50980** | 300-599 tons | $559.72 |
| **AC-51423** | 300-599 tons | $341.19 |
| **AC-74365** | ≥600 tons | $388.47 |
| **AC-88382** | ≥600 tons | $403.94 |
| **AC-78252** | ≥600 tons | $404.11 |

## 4.3 Gross and Incremental Measure Cost

### 4.3.1 Gross Measure Cost

For ROB measures, Gross Measure Cost (GMC) is represented by the equation below:

Equation 5: *GMC = (Measure Equipment Cost + Measure Labor Cost) – (Base Case Equipment Cost + Base Case Labor Cost)*

\*Note: The measure case labor and base case labor are assumed to be the same value reducing the equation to the following:

Equation 6: *GMC = Measure Equipment Cost – Base Case Equipment Cost*

Table 21. Gross Measure Cost per ton for Screw/Scroll Water Cooled Chillers

|  |  |
| --- | --- |
| **Solution Code** | **Gross Measure Cost per Ton** |
| **AC-21019** | $139.71 |
| **AC-78177** | $238.65 |
| **AC-38475** | $59.29 |
| **AC-68664** | $89.66 |
| **AC-28103** | $34.70 |
| **AC-89224** | $116.89 |

Table 22. Gross Measure Cost per ton for Centrifugal Water Cooled Chillers

|  |  |
| --- | --- |
| **Solution Code** | **Gross Measure Cost per Ton** |
| **AC-90421** | $112.95 |
| **AC-39620** | $126.20 |
| **AC-40798** | $193.99 |
| **AC-10944** | $45.01 |
| **AC-50980** | $137.11 |
| **AC-51423** | $114.23 |
| **AC-74365** | $56.13 |
| **AC-88382** | $71.60 |
| **AC-78252** | $112.95 |

### 4.3.2 Incremental Measure Cost

For ROB measures the Gross Measure Cost is equal to the Incremental Measure Cost.

# Attachments

1. 

# 

# eQUEST models (available upon request)

# 

# References

[31]

[351]

[436]



[A] “Energy Standard for Buildings Except Low-rise Residential Buildings,” ANSI/ASHRAE/IESNA Standard 90.1-2013, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.

[B] “2011 Standard for Performance Rating of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle,” AHRI Standard 550/590, Air-Conditioning, Heating and Refrigeration Institute.

[C] “2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings”

[D] Attachment 4: IPLV Verification

[E] Confidential chiller manufacturer cost data prepared by Energy Solutions.

# 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 |

1. Minimum Efficiency requirements are based on AHRI 550/590 test conditions. These conditions state that for water-cooled condensers at 100%, 75%, 50%, and 25% loading conditions, the entering water temperature (EWT) is 85F, 75F, 65F, and 65F respectively, while the leaving water temperature (LWT) is constant at 44F for all loads. [↑](#footnote-ref-1)
2. Chiller capacity used for demand reduction and energy savings calculations is the rated capacity from the baseline and tiered measures from eQUEST models [↑](#footnote-ref-2)
3. Indicates average temperature for the climate zone as defined by DEER14. [↑](#footnote-ref-3)
4. Chiller capacity used for demand reduction and energy savings calculations is the rated capacity from the baseline and tiered measures from eQUEST models. [↑](#footnote-ref-4)