Work Paper SCE13HC043

**Revision 2**

**Southern California Edison**

**Water-Cooled Chillers**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | AC-21019, AC-78177, AC-38845, AC-68664, AC-28103, AC-89244, AC-90421, AC-39620, AC-40798, AC-10944, AC-50980, AC-51423, AC-74365, AC-88382, AC-78252 |
| **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. |
| **Units** | Per ton |
| **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** | 20 years (DEER EUL ID: HVAC-Chlr, DEER2014 version) |
| **Measure Installation Type** | Replace on Burnout (ROB) |
| **Net-to-Gross Ratio** | 0.6 (DEER NTG ID: Com-Default>2yrs, DEER2014 version) |
| **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 | 5/31/12 | Alex MacCurdy/Energy Solutions | Workpaper adapted from WPSCNRHC0043.0 |
| 1 | 5/14/14 | 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. |
| 2 | 1/25/16 | Ryan Cho/SCE | - New template update for 2016 program year  - WP effective from 1/1/2016 thru 12/31/2016 |

# 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

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | 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. |
| Existing Condition | N/A |
| Code/Standard | Constant speed or variable speed water-cooled chiller operating at the Title 24 minimum efficiency requirements. |
| Industry Standard Practice | N/A |

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.

Measures and Codes

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

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 the tables shown below.

**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)

**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 [355]. 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) [355]. 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 Installation Types and Delivery Mechanisms

The delivery method is:

**Up-Stream Incentive / Up-Stream Buy Down**

The install type is:

**Replace on Burnout (ROB)**

**Installation Type Descriptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Replace on Burnout (ROB) | Above Code or Standard | 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** |
| Up-Stream Programs | *See Up-Stream Incentive in the Incentive Method Descriptions table.* |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Up-Stream Incentive  Up-Stream Buy Down | The program gives a financial incentive to an upstream market actor (manufacturer or distributor) to encourage the manufacture, provision, or distribution of efficient measures. Buy Down means that the incentive is required to be passed down to the end-use customer. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

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.

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 | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | Yes |
| DEER Version | DEER 2014 2.0.1v |
| Reason for 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 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 |

**Spillage Rate**

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

**Installation Rate**

The IR values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

**Effective and Remaining Useful Life**

The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for an RET measure with an applicable code baseline. The relevant EUL and RUL values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| HVAC-Chlr | High Efficiency Chillers | Com | HVAC | 20 | 6.7 |

### 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 [355]. 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.

Code Summary

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

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 |

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

N/A

## 1.6 Data Quality and Future Data Needs

N/A

# Section 2. Calculation Methodology

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 the table 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.

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:

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 300 tons 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 the tables shown 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.

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 |

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 [355]. For each of the tier levels defined in the tables shown above in Section 1.1, 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:

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 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 - Secondary School | DEER:HVAC\_Chillers | NON\_RES |
| Education - Community College | DEER:HVAC\_Chillers | NON\_RES |
| Education - University | DEER:HVAC\_Chillers | NON\_RES |
| Health/Medical - Hospital | DEER:HVAC\_Chillers | NON\_RES |
| Health/Medical - Nursing Home | DEER:HVAC\_Chillers | NON\_RES |
| Lodging - Hotel | DEER:HVAC\_Chillers | NON\_RES |
| Manufacturing - Bio/Tech | DEER:HVAC\_Chillers | NON\_RES |
| Office - Large | DEER:HVAC\_Chillers | NON\_RES |
| Office - Small | DEER:HVAC\_Chillers | NON\_RES |
| Retail - Multistory Large | DEER:HVAC\_Chillers | NON\_RES |

# Section 4. 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 [C]. 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

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 |

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

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 |

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 Full and Incremental Measure Cost

**Full and Incremental Measure Cost Equations**

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| ROB | (MEC + MLC) – (BEC + BLC) | (MEC + MLC) – (BEC + BLC) | N/A |
| NEW/NC |
| RET/ER | (MEC + MLC) – (BEC + BLC) | MEC + MLC | (MEC + MLC) – (BEC + BLC) |
| REF | (MEC + MLC) – (BEC + BLC) | MEC + MLC | N/A |
| 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** |
| AC-21019 | ROB | $139.71 | $139.71 | N/A |
| AC-78177 | ROB | $238.65 | $238.65 | N/A |
| AC-38475 | ROB | $59.29 | $59.29 | N/A |
| AC-68664 | ROB | $89.66 | $89.66 | N/A |
| AC-28103 | ROB | $34.70 | $34.70 | N/A |
| AC-89224 | ROB | $116.89 | $116.89 | N/A |
| AC-90421 | ROB | $112.95 | $112.95 | N/A |
| AC-39620 | ROB | $126.20 | $126.20 | N/A |
| AC-40798 | ROB | $193.99 | $193.99 | N/A |
| AC-10944 | ROB | $45.01 | $45.01 | N/A |
| AC-50980 | ROB | $137.11 | $137.11 | N/A |
| AC-51423 | ROB | $114.23 | $114.23 | N/A |
| AC-74365 | ROB | $56.13 | $56.13 | N/A |
| AC-88382 | ROB | $71.60 | $71.60 | N/A |
| AC-78252 | ROB | $112.95 | $112.95 | N/A |

# Attachments

1. 
2. 
3. eQuest models (available upon request)
4. 

# References



[355]

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

[D] Attachment 4: IPLV Verification

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)