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REFRIGERATION
SWCR022-01 EFFICIENT ADIABATIC CONDENSER

CONTENTS

MEASURE NAME

Variable Condensing Setpoint Control on Standard Adiabatic Condenser
Efficient Adiabatic Condenser replacing Standard Adiabatic Condenser

STATEWIDE MEASURE ID

SWCR022-01

TECHNOLOGY SUMMARY

An adiabatic condenser functions similarly to a traditional air-cooled condenser but integrates evaporative pre-cooling with the unit. Evaporation of water near the wet bulb temperature will lower the dry bulb temperature of the air stream and allow for greater system heat rejection. As a result, adiabatic condensers are highly effective in hot, dry environments; use less water than a traditional evaporative condenser; and can deliver the same cooling capacity with less fan motor horsepower than a traditional dry condenser.

Adiabatic condensers are available with variable speed fan capacity control and a fixed or two-speed saturated condensing temperature (SCT) control. The SCT is the refrigeration saturation temperature corresponding to the refrigerant pressure at the entrance of the condenser. Varying the SCT setpoint based on ambient temperature and required loads will minimize the total energy consumed, taking into account the trade-offs between compressor power and condenser fan power. For example, lower head pressure reduces the compressor power but increases fan power. [1]

The adiabatic condenser can alternate between dry and wet modes as the ambient temperature and environment changes throughout the day. The adiabatic condenser can switch to dry mode to take advantage of lower ambient temperatures during the night and cooler seasons and save water. It can switch to wet mode during hotter periods to allow greater heat rejection capability. In a 2017 Codes and Standards Enhancement (CASE) initiative study, *Adiabatic Condensers for Refrigerated Warehouses and Commercial Refrigeration – Final Report*[2], the statewide CASE team decided that the mean coincident wet bulb (MCWB) temperature should be used as the switching setpoint for each climate zone so that variations in climate would be factored into the analysis. The MCWB is the average of all the moisture levels that occur when the dry bulb temperature is highest, typically for 1% of the year. It was found that assuming a lower value for the switching setpoint would increase in energy savings but would also increase water consumption. The MCWB value provides a basis for the setpoint that considers both water and energy usage.

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[1] Scott, D. and T Bellon (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

[2] Scott, D. and T Bellon (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

MEASURE CASE DESCRIPTION

This workpaper addresses two measures:

Measure SWCR022A is implementing SCT controls, in wet mode and dry mode, to reset based on outdoor dry-bulb temperature (variable condensing setpoint control) on an existing code-compliant standard efficiency (45 Btu/W) adiabatic condenser serving a commercial refrigeration system using halocarbon refrigerants.

Measure SWCR022B is defined as installing an efficient adiabatic condenser rated at greater than or equal to 65 Btu/W replacing a code-compliant standard efficiency (45 Btu/W) adiabatic condenser serving a commercial refrigeration system using halocarbon refrigerants.

Measure Offering IDs

Statewide Measure Offering ID	Measure Offering Description	Measure Application Type
A	Variable Condensing Setpoint Control on Standard Adiabatic Condenser	BRO-RCx
B	Efficient Adiabatic Condenser replacing Standard Adiabatic Condenser	NR, NC

BASE CASE DESCRIPTION

For measure SWCR022A, the base case is defined as an existing code-compliant standard efficiency adiabatic condenser rated at 45 BTU/W with variable speed fan control and a *fixed* saturated condensing temperature setpoint.

For measure SWCR022B, the base case is defined as a 2019 Title 24 compliant adiabatic condenser rated at 45 Btu/W with variable speed fan control and a *variable* condensing setpoint. The measure case for SWCR022A is the base case for measure SWCR022B.

CODE REQUIREMENTS

The Variable Condensing Setpoint Control measure does not trigger any code compliance. The Efficient Adiabatic Condenser (≥65 Btu/W) measure triggers Title 24; however, the Title 24 code requirement is used as a baseline. Applicable state and federal codes for this measure are specified in below.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Building Energy Efficiency Standards – Title 24 (2019)	Section 120.6(b)(1)(A)	January 1, 2020
CA Appliance Efficiency Regulations – Title 20 (2019)	None.	n/a
Federal Standards – Code of Federal Regulations (2018)	None.	n/a

The building energy efficiency standards (Title 24)[3] regulates the efficiency standards for commercial refrigeration condensing units. The applicable excerpt is included below:

Section 120.6(b)(1)(A)

(b) Mandatory Requirements for Commercial Refrigeration

Retail food stores with 8,000 square feet or more of conditioned floor area, and that utilize either refrigerated display cases, or walk-in coolers or freezers, shall meet all applicable State and federal appliance and equipment standards consistent with Section 110.0 and 110.1 or, for equipment not subject to such standards, the requirements of Subsections 1 through 4.

1. Condensers serving refrigeration systems. Fan-powered condensers shall conform to the following requirements:

A. All condenser fans for air-cooled condensers, evaporative-cooled condensers, adiabatic condensers, gas coolers, air or water-cooled fluid coolers or cooling towers shall be continuously variable speed, with the speed of all fans serving a common condenser high side controlled in unison.

B. The refrigeration system condenser controls for systems with air-cooled condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient dry-bulb temperature.

C. The refrigeration system condenser controls for systems with evaporative-cooled condensers shall use variable-setpoint control logic to reset the condensing temperature setpoint in response to ambient wet-bulb temperature.

D. The refrigeration system condenser controls for systems with adiabatic condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient dry-bulb temperature while operating in dry mode.

EXCEPTION 1 to Section 120.6(b)1B, C and D: Condensing temperature control strategies approved by the executive director that have been demonstrated to provide equal energy savings.

EXCEPTION 2 to Section 120.6(b)1D: Systems served by adiabatic condensers in Climate Zone 16.

E. The saturated condensing temperature necessary for adiabatic condensers to reject the design total heat of rejection of a refrigeration system assuming dry mode performance shall be less than or equal to:

i. The design dry-bulb temperature plus 20°F for systems serving freezers;

ii. The design dry-bulb temperature plus 30°F for systems serving coolers.

F. The minimum condensing temperature setpoint shall be less than or equal to 70°F.

G. Fan-powered condensers shall meet the specific efficiency requirements listed in Table 120.6-C.

TABLE 120.6-C FAN-POWERED CONDENSERS –SPECIFIC EFFICIENCY REQUIREMENTS

CONDENSER TYPE	*MINIMUM SPECIFIC EFFICIENCY*	*RATING CONDITION*
Evaporative-Cooled	*160 Btuh/W*	*100°F SCT, 70°F Entering Wet-bulb Temperature*
Air-Cooled	*65 Btuh/W*	*105°F SCT, 95°F Entering Dry-bulb Temperature*
Adiabatic Dry Mode	*45 Btu/W (halocarbon)*	*105°F SCT, 95°F Entering Dry-bulb Temperature*

EXCEPTION 1 to Section 120.6(b)1G: Condensers with a Total Heat Rejection capacity of less than 150,000 Btuh at the specific efficiency rating condition.

[3] California Energy Commission (CEC). 2019. *2019 Nonresidential Compliance Manual for the Building Energy Efficiency Standards for Residential and Nonresidential Buildings*. CEC-400-2018-020-CMF.

EXCEPTION 2 to Section 120.6(b)1G: Stores located in Climate Zone 1.

EXCEPTION 3 to Section 120.6(b)1G: Existing condensers that are reused for an addition or alteration.

H. Air-cooled condensers shall have a fin density no greater than 10 fins per inch.

EXCEPTION 1 to Section 120.6(b)1H: Microchannel condensers.

EXCEPTION 2 to Section 120.6(b)1H: Existing condensers that are reused for an addition or alteration.

EXCEPTION to Section 120.6(b)1B, 1C, 1D, 1E, 1F, 1G: Transcritical CO2 refrigeration systems.

EXCEPTION to Section 120.6(b)1: New condensers replacing existing condensers when the attached compressor system Total Heat of Rejection does not increase and less than 25 percent of both the attached compressors and the attached display cases are new.

NORMALIZING UNIT

Condenser capacity (Tons)

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
BRO-RCx	DnDeemDI	Commercial
BRO-RCx	DnDeemed	Commercial
NR	DnDeemDI	Commercial
NR	DnDeemed	Commercial
NR	UpDeemed	Commercial
NC	DnDeemDI	Commercial
NC	DnDeemed	Commercial
NC	UpDeemed	Commercial

Eligible Products

Measure SWCR022A Variable Condensing Setpoint Controls must meet the following requirements:

- When operating in wet and dry mode, SCT reset is based on the outdoor dry-bulb temperature.

- A rated temperature difference of 10°F when operating in dry mode and 30°F when operating in wet mode.

Measure SWCR022B Efficient Adiabatic Condenser must meet the following requirements:

- The condenser must have an efficiency rating greater or equal to 65 Btu/W.
- The condenser must also have variable condensing setpoint controls installed.

Eligible Building Types and Vintages

This measure is applicable for any grocery buildings of any vintage.

Eligible Climate Zones

This measure is applicable in all climate zones in California.

PROGRAM EXCLUSIONS

Non-grocery building types are excluded from this workpaper. Grocery building HVAC systems are excluded from this measure. Carbon dioxide (CO_2) and ammonia (NH_3) based refrigeration systems are excluded.

DATA COLLECTION REQUIREMENTS

Project costs data shall be collected during program implementation for use in future workpaper updates.

USE CATEGORY

Commercial refrigeration (ComRefrig).

ELECTRIC SAVINGS (KWH)

The unit energy savings (UES) of the efficient adiabatic condenser and adiabatic condenser with variable condensing setpoint are based on assumptions from the 2017 Codes and Standards Enhancement (CASE) initiative study, *Adiabatic Condensers for Refrigerated Warehouses and Commercial Refrigeration – Final Report* .[4]

Base Case Prototypes

The building energy simulation tool DOE-2.2R (via eQuest Refrigeration 3.65) was used to derive base case and measure case unit energy consumption. The model is summarized as follows:[5]

1. The DEER 2020 prototypes were generated from MASControl version three and updated by Southern California Edison to account for current code and standard practice for commercial refrigeration systems.[6]
2. The weather files were updated using DEER 2020 CZ2010 weather data files.
3. Simulations were generated for Grocery building type, building vintage 2020, and for each of the 16 California climate zones.

Base Case Prototype Alterations

The standard practice model modified by SCE "Gro-CZ01-2020" was altered as described in the tables below to estimate energy impacts.

1. The adiabatic condensers for the medium-temperature and low-temperature systems were modeled as two-part condensers consisting of an air-cooled unit and an evaporatively-cooled unit separately. The system parameters for these condensers were pulled from the air-cooled and evap-cooled grocery prototype models and were left unchanged, with the exception of the fan power and saturated condensing temperature control.
2. The saturated condensing temperature setpoint control was changed from dry-bulb reset to fixed, with the prototype's default SCT setpoint left as 70°F.
3. Equipment controls and load management profiles were setup in eQuest to enable the refrigeration condensers to switch between dry (air-cooled) and wet (evaporatively-cooled) modes.
4. The eQuest equipment controls were set to switch between dry the air-cooled and evaporatively-cooled condensers at a specified temperature. The CASE study used the MCWB temperature as the switching temperature setpoint for each climate zone so that variations in climate would be factored into the analysis.[7] However, eQuest does not allow the use of wet bulb temperatures when creating load management profiles. As an alternative, the CZ2010 weather files were

[4] Scott, D. and T Bellon (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

[5] Southern California Edison (SCE). 2019. "SWCR022-01 eQuest Models.zip."

[6] Southern California Edison (SCE) and Solaris. 2019 "PG&E GrocerSmart Data for DEER 2020_V3-Solaris.xlsx"

[7] Scott, D. and T Bellon (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

analyzed on an hourly basis. For each climate zone, the lowest dry bulb temperature that coincided with the MCWB was found and used as the switching setpoint temperature in the eQuest load management controls. The MCWB 1% cooling design values were identified from *The Pacific Energy Center's Guide to: California Climate Zones and Bioclimatic Design*.[8] The MCWB values used, as well as the dry bulb switching setpoints used, can be found in **Error! Reference source not found.** below.

Table 1 - Mean Coincident Wet-bulb Values by Climate Zone

Climate Zone	Mean Coincident Wet Bulb (°F)	Dry Bulb Switching Setpoint (°F)
CZ01	63	75
CZ02	68	77
CZ03	64	70
CZ04	66	68
CZ05	68	79
CZ06	68	73
CZ07	69	70
CZ08	68	74
CZ09	70	71
CZ10	68	75
CZ11	68	70
CZ12	69	79
CZ13	70	78
CZ14	68	75
CZ15	74	83
CZ16	61	69

5. The analysis assumes that the condenser energy consumption is driven by the condenser fans. In order to estimate the fan power, the following calculation steps were taken:
    - The eQuest system condenser capacity for each system was divided by the default operating rating temperature difference (TD) used in eQuest to find the normalized heat rejection in BTU/°F.
    - The temperature difference is the difference between the SCT and the ambient air temperature. The condenser capacity rated at a 10°F TD was calculated in accordance with the CASE study. [9] Thus, the normalized BTU/°F for each condenser was multiplied by 10°F to find the condenser capacity at 10°F TD.
    - Total fan power (kW) was calculated by dividing the condenser capacity by the condenser efficiency for the base (45 BTU/W) and measure (65 BTU/W) case.

[8] Pacific Energy Center. 2006. *The Pacific Energy Center's Guide to: California Climate Zones and Bioclimatic Design*. Prepared for the California Energy Commission.

[9] Scott, D. and T Bellon (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

- Individual fan power was normalized by the quantity of fans operating in each condenser, as shown in Table 2.
- The average input kW per fan is included for the base and measure case to estimate the condenser efficiency in Btu/W for each measure.[10]

Table 2. Calculation of Required Fan Power for Baseline Condenser Efficiency

Refrigeration System	Condenser Capacity (Btu/hr)[a]	Condenser TD (°F) [a]	Btu/°F [c]	Condenser Capacity at 10°F Rated TD (Btu/hr) [c]	Efficiency (Btu/W) [b]	Total Fan Power (kW) [c]	Fan Qty [a]	kW/Fan [c]
Medium Temperature	782,000	15	52,133	521,333	45	11.6	4	2.9
Low Temperature	464,000	10	46,400	464,000	45	10.3	4	2.6

a) Values from eQuest prototypes. b) CASE stated values. c) Calculated values. Review the fan power calculation sheet for more details. [10]

Modification to the base case models are detailed in the table below:

Table 3. Summary of Baseline Modifications to DEER Prototypes

eQUEST Keyword	Standard Practice Model Value	Modified Baseline Value	Explanation Section
Medium Temperature System BDL Inputs	SCT-CTRL = DRY-BULB-RESET	SCT-CTRL = FIXED *(eQuest prototype SCE setpoint = 70°F)*	Base Case Prototype Alterations: 2
Medium Temperature Refrigeration Condenser BDL Inputs	"MT_Condenser" = CONDENSER TYPE = AIR-COOLED RATED-CAPACITY = 782000 RATED-REFG-CLASS = HALOCARBON FAN-EIR-TD = 0.524945 NUMBER-OF-FANS = 4 CAPACITY-CTRL = VAR-SPEED-FAN RATED-TD = 15 REFG-SYSTEM = "MT_Multiplex" EQUIPMENT-REPORT = YES ..	"MT_Condenser_Air" = CONDENSER TYPE = AIR-COOLED RATED-CAPACITY = 782000 RATED-REFG-CLASS = HALOCARBON FAN-EIR-TD = 0 KW/FAN = 2.9 NUMBER-OF-FANS = 4 CAPACITY-CTRL = VAR-SPEED-FAN RATED-TD = 15 REFG-SYSTEM = "MT_Multiplex" EQUIPMENT-REPORT = YES ..	Base Case Prototype Alterations: 1, 5

[10] TRC Advanced Energy. 2019. "SWCR022-01 Condenser Switching Temps and Fan Power Calcs.xlsx."

eQUEST Keyword	Standard Practice Model Value	Modified Baseline Value	Explanation Section
		"MT_Condenser_Evap" = CONDENSER TYPE = EVAPORATIVE RATED-CAPACITY = 782000 RATED-REFG-CLASS = HALOCARBON FAN-EIR = 0 KW/FAN = 2.9 NUMBER-OF-FANS = 4 CAPACITY-CTRL = VAR-SPEED-FAN REFG-SYSTEM = "MT_Multiplex" EQUIPMENT-REPORT = YES ..	
Low Temperature System BDL Inputs	SCT-CTRL = DRY-BULB-RESET	SCT-CTRL = FIXED	Base Case Prototype Alterations: 2
Low Temperature Refrigeration Condenser BDL Inputs	"LT_Condenser" = CONDENSER TYPE = AIR-COOLED RATED-CAPACITY = 464000 RATED-REFG-CLASS = HALOCARBON FAN-EIR-TD = 0.524945 NUMBER-OF-FANS = 4 CAPACITY-CTRL = VAR-SPEED-FAN RATED-TD = 10 REFG-SYSTEM = "LT_Multiplex" EQUIPMENT-REPORT = YES ..	"LT_Condenser_Air" = CONDENSER TYPE = AIR-COOLED RATED-CAPACITY = 464000 RATED-REFG-CLASS = HALOCARBON FAN-EIR-TD = 0 KW/FAN = 2.6 NUMBER-OF-FANS = 4 CAPACITY-CTRL = VAR-SPEED-FAN RATED-TD = 10 REFG-SYSTEM = "LT_Multiplex" EQUIPMENT-REPORT = YES .. "LT_Condenser_Evap" = CONDENSER TYPE = EVAPORATIVE RATED-CAPACITY = 464000 RATED-REFG-CLASS = HALOCARBON FAN-EIR = 0 KW/FAN = 2.6 NUMBER-OF-FANS = 4 CAPACITY-CTRL = VAR-SPEED-FAN REFG-SYSTEM = "LT_Multiplex" EQUIPMENT-REPORT = YES ..	Base Case Prototype Alterations: 1, 5
Equipment Controls	None	"MT_Cond_Air" = EQUIP-CTRL TYPE = REFG-SYSTEM	Base Case Prototype Alterations: 3, 4

eQUEST Keyword	Standard Practice Model Value	Modified Baseline Value	Explanation Section
		REFG-SYSTEM = "MT_Multiplex" CONDENSERS-1 = ("MT_Condenser_Air") CONDENSER-SEQ-1 = (1) .. "LT_Cond_Air" = EQUIP-CTRL TYPE = REFG-SYSTEM REFG-SYSTEM = "LT_Multiplex" CONDENSERS-1 = ("LT_Condenser_Air") CONDENSER-SEQ-1 = (1) .. "MT_Cond_Evap" = EQUIP-CTRL TYPE = REFG-SYSTEM REFG-SYSTEM = "MT_Multiplex" CONDENSERS-1 = ("MT_Condenser_Evap") CONDENSER-SEQ-1 = (1) .. "LT_Cond_Evap" = EQUIP-CTRL TYPE = REFG-SYSTEM REFG-SYSTEM = "LT_Multiplex" CONDENSERS-1 = ("LT_Condenser_Evap") CONDENSER-SEQ-1 = (1) ..	
Load Management	None	"Condenser_Switch_MT" = LOAD-MANAGEMENT TYPE = OA-TEMP TEMPS-THRU-1 = [*Lowest DB Temp*] TEMPS-THRU-2 = 125 EQUIP-CTRLS-1 = ("MT_Cond_Air") EQUIP-CTRLS-2 = ("MT_Cond_Evap") .. "Condenser_Switch_LT" = LOAD-MANAGEMENT TYPE = OA-TEMP TEMPS-THRU-1 = [*Varies by Climate Zone*] TEMPS-THRU-2 = 125 EQUIP-CTRLS-1 = ("LT_Cond_Air") EQUIP-CTRLS-2 = ("LT_Cond_Evap") ..	Base Case Prototype Alterations: 3, 4

Measure Case Simulations

The baseline standard practice models were modified to simulate measure SWCR022A (Variable Condensing Setpoint Control) by changing the SCT control from fixed to dry-bulb reset, as shown in Table 4.

Table 4. Summary of Modifications for Variable SCT Measure

eQUEST Keyword	Modified Baseline Value	Measure – Variable SCT
Medium Temperature Refrigeration System BDL Inputs	SCT-CTRL = FIXED	SCT-CTRL = DRY-BULB-RESET
Low Temperature Refrigeration System BDL Inputs	SCT-CTRL = FIXED	SCT-CTRL = DRY-BULB-RESET

The model for measure SWCR022A was then modified to simulate measure SWCR022B, Efficient Adiabatic Condenser (≥ 65 Btu/W), as shown below. As with the base case condenser efficiency, the measure case condenser efficiency is modelled by modifying the fan power for the condenser. See the Base Case Prototype Alterations, bullet 5 for a description of the fan power calculation.

Table 5. Calculation of Required Fan Power for Measure Case Condenser Efficiency

Refrigeration System	Condenser Capacity (Btu/hr)[a]	Condenser TD (°F) [a]	Btu/°F [c]	Condenser Capacity at 10°F Rated TD (Btu/hr) [c]	Efficiency (Btu/W) [b]	Total Fan Power (kW) [c]	Fan Qty [a]	kW/Fan[c]
Medium Temperature	782,000	15	52,133	521,333	65	8.0	4	2.0
Low Temperature	464,000	10	46,400	464,000	65	7.1	4	1.8

a) Values from eQuest prototypes. b) CASE stated values. c) Calculated values. Review the fan power calculation sheet for more details. [11]***Error! Bookmark not defined.***

Table 6. Summary of Modifications for Efficient Adiabatic Condenser

eQUEST Keyword	Modified Baseline Value	Measure – Efficient Adiabatic Condenser
Medium Temperature Refrigeration Condenser Fan Power BDL Inputs	KW/FAN = 2.9	KW/FAN = 2

[11] TRC Advanced Energy. 2019. "SWCR022-01 Condenser Switching Temps and Fan Power Calcs.xlsx."

eQUEST Keyword	Modified Baseline Value	Measure – Efficient Adiabatic Condenser
Low Temperature Refrigeration Condenser Fan Power BDL Inputs	KW/FAN = 2.6	KW/FAN = 1.8

Electric Unit Energy Savings

The total energy savings were calculated as the difference between the modeled total (whole building) energy consumption of the base case and measure case models, as shown below. The unit electric energy savings (kWh per year per ton) were calculated by dividing the total energy savings by the total refrigeration condenser capacity.

$$ES = EC_{Base} - EC_{Measure}$$

$$Cap.Tons_{Refrig} = Cap.Tons_{MT\ Refrig} + Cap.Tons_{LT\ Refrig}$$

$$UES_{Tons} = \frac{ES}{Cap.Tons_{Refrig}}$$

ES =	*Total energy savings (kWh)*
EC =	*Modeled energy consumption of the base case and measure case units (kWh)*
UES_{Tons} =	*Unit energy savings (kWh/Ton)*
Cap. $Tons_{Refrig}$ =	*Total cooling capacity of the medium-temperature and low -temperature systems (Tons)*

The total refrigeration tonnage used to normalize the energy savings was obtained from the building model and can be found in Table 7 below.

Table 7. Electric UES and Peak Demand Reduction Inputs

Parameter	Base Case Model	Measure Case Model	Source
Modeled energy consumption and demand	*Varies by climate zone*		Southern California Edison (SCE). 2019. "SWCR022-01 eQuest Models.zip."
Total capacity of Medium Temperature System condensing units (Tons)	65	65	Modeled as a two-part condenser - MT_Condenser_Air - MT_Condenser_Air
Total capacity of Low Temperature System condensing units (Tons)	39	39	Modeled as a two-part condenser - LT_Condenser_Air - LT_Condenser_Air

The following is an example of the energy savings calculations for CZ08.

$$EC_{Base} = 1{,}335{,}540.00\ kWh$$

$$EC_{Measure\ (SCT)} = 1{,}254{,}930.00\ kWh$$

$$EC_{Measure\ (SCT+Eff\ Cond.)} = 1{,}250{,}680.00\ kWh$$

$$Cap.Tons_{\ MT\ Refrig} = 65\ Tons$$

$$Cap.Tons_{\ LT\ Refrig} = 39\ Tons$$

$$ES_{SCT} = 1{,}335{,}540.00\ kWh - 1{,}254{,}930.00\ kWh = 80{,}610.00\ kWh$$

$$ES_{SCT+Eff\ Cond.} = 1{,}254{,}930.00\ kWh - 1{,}250{,}680.00\ kWh = 4{,}250.00\ kWh$$

$$Cap.Tons_{Refrig} = 65\ Tons + 39\ Tons = 104\ Tons$$

$$UES_{Ton(SCT)} = \frac{80{,}610.00\ kWh}{104\ Tons} = 775.10\ {kWh}/{Ton}$$

$$UES_{Ton(SCT+Eff\ Cond.)} = \frac{4{,}250.00\ kWh}{104\ Tons} = 40.87\ {kWh}/{Ton}$$

PEAK ELECTRIC DEMAND REDUCTION (KW)

Peak demand was calculated for each climate zone as the average of the electrical power draw between 4:00 p.m. – 9:00 p.m. in conformance with the Database for Energy Efficiency Resources (DEER) peak definition.[12] The peak power was calculated by averaging the 15 DEER peak hours from the 8760-hour load profile extracted from the eQuest models. Peak demand reduction is calculated as the difference between the modeled base case and measure case peak demand from the DOE-2.2R simulations summarized in the Electric Savings section.

$$PeakDemandSav_{Adiabatic\ Condenser} = PeakDemand_{Base} - PeakDemand_{Measure}$$

$$UnitPeakDemandSav_{Tons} = \frac{PeakDemandSav_{Adiabatic\ Condenser}}{Cap.Tons_{Refrig}}$$

$$Cap.Tons_{Refrig} = Cap.Tons_{\ MT\ Refrig} + Cap.Tons_{LT\ Refrig}$$

$PeakDemandSav_{Adiabatic\ Condenser} =$	*Total peak demand reduction (kW)*
$PeakDemand =$	*Modeled peak demand for base case and measure case units (kW)*
$UnitPeakDemandSav_{Ton} =$	*Unit energy savings (kW/Ton)*
$Cap.\ Tons_{Refrig} =$	*Total cooling capacity of the medium-temperature and low - temperature systems (Tons)*

The following is an example of the energy savings calculations for CZ08.

$$PeakDemand_{Base} = 185.73087\ kW$$

[12] California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11.

$$PeakDemand_{Measure\ (SCT)} = 169.60347\ kW$$

$$PeakDemand_{Measure\ (SCT+Eff\ Cond.)} = 168.3688\ kW$$

$$Cap.Tons_{\ MT\ Refrig} = 65\ Tons$$

$$Cap.Tons_{\ LT\ Refrig} = 39\ Tons$$

$$PeakDemandSav_{SCT} = 185.73087\ kW - 169.60347\ kW = 16.12740\ kW$$

$$PeakDemandSav_{SCT+Eff\ Cond.} = 169.60347\ kW - 168.3688\ kW = 1.23467\ kW$$

$$Cap.Tons_{Refrig} = 65\ Tons + 39\ Tons = 104\ Tons$$

$$UnitPeakDemandSav_{Ton(SCT)} = \frac{16.12740\ kW}{104\ Tons} = 0.15507\ {}^{kW}/_{Ton}$$

$$UnitPeakDemandSav_{Ton(SCT+Eff\ Cond.)} = \frac{1.23467\ kW}{104\ Tons} = 0.01187\ {}^{kW}/_{Ton}$$

GAS SAVINGS (THERMS)

Not applicable.

LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration. The RUL is only applicable to the first baseline period for a retrofit measure with an applicable code baseline.

The EUL for the variable SCT control measure specified below was stipulated in the "Workpaper Disposition for Residential HVAC Quality Maintenance" issued by the California Public Utilities Commission (CPUC) Energy Division in May 2013[13]. As per Resolution-4952[14] and Resolution-5009[15], the California Public Utilities Commission (CPUC) created the Behavioral Operational Retrocommissioning (BRO-RCx) measure classification which provides corrected EUL and RUL values shown below.

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[13] California Public Utilities Commission (CPUC), Energy Division, Ex Ante Review Team. 2013. "Workpaper Disposition for Residential HVAC Quality Maintenance." May 2.

[14] California Public Utilities Commission (CPUC), Energy Division. 2018. *DEER resolution E-4952.* 11 October 2018

[15] California Public Utilities Commission (CPUC), Energy Division. 2019. *Draft DEER resolution E-5009.* 15 August 2019

Table 8. Effective Useful Life and Remaining Useful Life

Measure Offering ID	Parameter	Value	Source
SWCR022B	EUL (yrs) – measure, Efficient Adiabatic Condenser	15.0	CPUC, Energy Division. 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx"
SWCR022A	EUL (yrs) -Measure, Variable SCT Control	3	California Public Utilities Commission (CPUC), Energy Division. 2018. *DEER resolution E-4952*. 11 October 2018
N/A	RUL (yrs)	0	California Public Utilities Commission (CPUC), Energy Division. 2019. *Draft DEER resolution E-5009*. 15 August 2019

BASE CASE MATERIAL COST ($/UNIT)

The base case for measure SWCR022A assumes an existing standard efficiency adiabatic condenser with a fixed SCT setpoint. Therefore, the base case material cost is $0.

The base case for measure SWCR022B assumes a Title 24 compliant adiabatic condenser with a standard efficiency of 45 Btu/W. The statewide CASE team estimated the cost of a Title 24 compliant standard efficiency adiabatic condenser to be $911.99 per ton[16]. This cost was based on 2017 market prices and escalated to 2020 costs by the statewide CASE team[17] and are adopted with no changes.

MEASURE CASE MATERIAL COST ($/UNIT)

The measure case for measure SWCR022A assumes a Title 24 compliant adiabatic condenser. Currently, adiabatic condensers do not come with the ability to vary the SCT setpoint based on ambient conditions using the local controller from the manufacturer. However, typical installations observed show that commercial installations have the condenser integrated into the supervisory control system, so implementation costs only involve start-up, programming, and fine tuning. As these activities do not involve equipment, the measure case material cost is $0.

To calculate incremental cost for measure SWCR022B, condenser models were grouped into narrow bins of 10,000 Btu/hr rated capacity, starting from 200,000 Btu/hr to 800,000 Btu/hr, using dry-mode heat rejection information only. The statewide CASE team analyzed each bin to determine the average incremental cost per increase in the condenser specific efficiency as $500/Btuh/W. This was used to

[16] Scott, D., T Bellon, (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

[17] Scott, D., T Bellon, (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

estimate the cost material cost for an adiabatic condenser with an efficiency of 65 BTU/W as $1,104.30 per ton.[18]

Measure case material costs were based on 2017 market prices and escalated to 2020 costs by the statewide CASE team[19] and are adopted with no changes.

BASE CASE LABOR COST ($/UNIT)

As SWCR022A is a BRO-RCx measure, the baseline labor costs for it are $0.

The estimated base labor costs for measure SWCR022B are the same as the measure labor cost for the installation of an efficient adiabatic condenser. The incremental labor cost associated with this measure is $0 per ton installed.

MEASURE CASE LABOR COST ($/UNIT)

The estimated labor costs for measure SWCR022A were derived from the 2017 CASE Initiative study "Adiabatic Condensers for Refrigerated Warehouses and Commercial Refrigeration – Final Report" (2019-NR-MECH6-F).[20] The labor costs associated with this offering are $16.67 per ton.

The estimated labor costs for measure SWCR022B are the same as the base labor cost for the installation of a standard efficiency adiabatic condenser. The incremental labor cost associated with this measure is $0 per ton installed.

Labor costs were based on 2017 market prices and escalated to 2020 costs by the Statewide CASE team[21] and are adopted with no changes.

NET-TO-GROSS (NTG)

The NTG ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. This NTG is applicable to all energy efficiency measures that have been offered for less than two years and for which impact evaluation results are not available, as documented in the *2011 DEER Update Study* conducted by Itron, Inc..

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[18] Scott, D., T Bellon, (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

[19] Scott, D., T Bellon, (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

[20] Scott, D., T Bellon, (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

[21] Scott, D., T Bellon, (VaCom) and C. Chappell (TRC). 2017. *Codes and Standards Enhancement Initiative (CASE), 2019 California Building Energy Efficiency Standards. Adiabatic Condensers for Refrigerated Warehouse and Commercial Refrigeration – Final Report*. Measure Number 2019-NR-MECH6-F.

Table 9: Net-to-Gross Ratios

Parameter	Value	Source
NTG – *All-Default<=2yrs*	0.70	Itron, Inc. 2011. DEER Database 2011 Update Documentation. Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3.

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. This GSIA rate is the current default rate, specified for measures for which an alternative GSIA has not been estimated and approved.

Table 10: Gross Savings Installation Adjustment

Parameter	Value	Source
GSIA – *Def-GSIA*	1.0	CPUC, Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31.

NON-ENERGY IMPACTS

Non-energy impacts for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

The table below summarizes the inputs and methods that are and are not based upon DEER.

Table 11: DEER Difference Summary

DEER Item	Comment / 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 (MASControl version 3 for vintage 2020, Modified for 2020 ISP/Code)
DEER Version	n/a
Reason for Deviation from DEER	n/a
DEER Measure IDs Used	n/a
NTG	Source: DEER2011 (DEER2011_NTGR_2012-05-16.xls). Value of 0.70 is associated with NTG ID: *All-Default<=2yrs*
GSIA	Source: DEER READI. The value of 1.0 is associated with GSIA ID: *def-GSIA*
EUL/RUL	Source: DEER2014 (2014-EUL-table-update-2014-02-05.xls). Value of 15 years is associated with EUL ID: *GrocSys-Cndsr*

DEER Item	Comment / Used for Workpaper
	2018 Resolution E-4952. EUL values of one to three years with retrocommissioning assigned a three-year EUL. EUL and RUL values are corrected based on Table 8 in E-4952. The value of 3 years is associated with EUL ID: *NonRes-RCx-Operational*. 2019 Resolution E-5009. RUL value for BRO measures corrected to 0 years.

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	07/19/2019	Sergio Corona, Lake Casco PE TRC	First draft of consolidated text for this statewide measure is based upon: 2019-NR-MECH6-F (September 2017)