



HVAC

SPACE HEATING BOILER

SWHC004-01

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MEASURE NAME

Space Heating Boiler

STATEWIDE MEASURE ID

SWHC004-01

TECHNOLOGY SUMMARY

A space heating boiler is a pressure vessel that transfer heat to water for use primarily in space heating applications. A boiler heats water using a heat exchanger that works like an instantaneous water heater or by the addition of a separate tank with an internal heat exchanger that is connected to the boiler. An energy efficient unit often features high-efficiency and/or low NOx burners, and typically has features such as forced air burners, relatively large heat exchange surfaces, and/or utilize heat recovery from stack gases.

A high-efficiency gas-fired boiler, typically rated above 90% thermal efficiency, is commonly known as a condensing boiler. A condensing boiler is equipped with larger heat exchanger that can recuperate additional thermal energy from the flue gas – compared to its non-condensing counterpart. Condensing boilers can condense moisture out of the flue gas, recovering the latent heat from the water vapor present. The removal of latent heat in the water vapor results in a lower flue gas temperature than a traditional boiler.

MEASURE CASE DESCRIPTION

The measure case is defined as a high-efficiency space heating boiler that meets the specifications below. As shown, measure offerings are designated by two tiers.

Measure Case Specification

Boiler Type	Rated Input (MBtuh)	Base Case Efficiency	Tier 1		Tier 2	
			Measure Efficiency	OA Reset Control	Measure Efficiency	OA Reset Control(s)
Hot Water	<300 (MFm)	82% AFUE	84% AFUE	-	-	-
	300 - 2,500	80%TE	85% TE	140-165 °F	94% TE	115-165 °F or 140-165 °F
	≥ 2,5000	80% TE	83% TE 85% CE	140-165 °F	94% TE	115-165 °F or 140-165 °F
Steam	300 - 2,500	79%TE	82% TE	140-165 °F	-	
	≥ 2,500 (Com)	79%TE	80% TE	140-165 °F	82% TE	140-165 °F

BASE CASE DESCRIPTION

The base case efficiency for multifamily space heating hot water boilers < 300 kBtu/h is 82% AFUE. The base case for all other space heating hot water boilers is a thermal efficiency of 80%. The base case for space heating steam boilers is a thermal efficiency of 79%.

CODE REQUIREMENTS

A space heating boiler installed in commercial or multifamily premise is subject to state regulation – as codified in the California State Appliance Efficiency Regulations (Title 20) and the California Building Energy Efficiency Standards (Title 24). Note that the more stringent code is applied in all relevant situations. In this case, 2019 California Title 24 code supersedes the 2019 Title 20 code as the regulatory baseline for all measure offerings.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2019)	Section 1605.1(e)	January 1, 2019
CA Building Energy Efficiency Standards – Title 24 (2019)	Section 110.2	January 1, 2020
Federal Standards	None.	n/a

Title 20, Section 1605.1(e):¹

Central Gas Furnaces, Central Gas Boilers, Central Oil Furnaces, Central Oil Boilers and Electric Residential Boilers. The AFUE, thermal efficiency, and combustion efficiency, as applicable, of central gas furnaces, central gas boilers, central oil furnaces, and central oil boilers manufactured on or after the effective dates shown shall be not less than the applicable values shown in Tables E-3 and E-4. Electric hot water residential boilers manufactured on or after September 1, 2012 shall meet the design standard shown in Table E-3.

Title 20 Section 1605.1(e), Table E-3 & E-4, Standards for Gas- and Oil-Fired Central Boilers and Electric Residential Boilers

Title 20 Std. Description	Min. Efficiency Rating	Units	Code Source or Reference
Boiler, hot water, Gas-Fired (< 300 kBtu/h)	82%	AFUE	Table E-3
Boiler, hot water, Gas Fired (>= 300 kBtu/h, <=2,500 kBtu/h)	80%	Thermal Efficiency	Table E-4
Boiler, steam, Gas-Fired all except natural draft (>= 300 kBtu/h, <=2,500 kBtu/h)	79%	Thermal Efficiency	Table E-4

¹ California Energy Commission (CEC). 2019. *California Code of Regulations Title 20*. CEC-140-2019-002. January.

The minimum efficiency rating of the measure, Boiler, hot water, Gas-Fired (< 300 kBTUh) is set to be updated to 84% effective from January 15, 2021.

Title 24, Section 110.2: ²:

Any space-conditioning equipment listed in this section may be installed only if the manufacturer has certified to the Commission that the equipment complies with all the applicable requirements of this section.

(a) **Efficiency.** Equipment shall meet the applicable efficiency requirements in TABLE 110.2-A through TABLE 110.2-K subject to the following:

1. If more than one efficiency standard is listed for any equipment in TABLE 110.2-A through TABLE 110.2-K, the equipment shall meet all the applicable standards that are listed; and
2. If more than one test method is listed in TABLE 110.2-A through TABLE 110.2-K, the equipment shall comply with the applicable efficiency standards when tested with each listed test method; and
3. Where equipment can serve more than one function, such as both heating and cooling, or both space heating and water heating, it shall comply with all the efficiency standards applicable to each function; and
4. Where a requirement is for equipment rated at its "maximum rated capacity" or "minimum rated capacity," the capacity shall be as provided for and allowed by the controls, during steady-state operation.

2019 California Title 24, Section 110.2, Table 110.2-K, Gas- and Oil-Fired Boilers, Minimum Efficiency Requirements.

Title 24 Std. Description	Min. Efficiency Rating	Units	Code Source or Reference
Boiler, hot water, Gas-Fired (< 300 kBTUh)	82%	AFUE	Table 110.2-K
Boiler, hot water, Gas Fired (>= 300 kBTUh, <=2,500 kBTUh)	80%	Thermal Efficiency	Table 110.2-K
Boiler, hot water, Gas Fired (> 2,500 kBTUh)	82%	Combustion Efficiency	Table 110.2-K
Boiler, steam, Gas-Fired all except natural draft (>= 300 kBTUh, <=2,500 kBTUh)	79%	Thermal Efficiency	Table 110.2-K
Boiler, steam, Gas-Fired all, except natural draft (> 2,500 kBTUh)	79%	Thermal Efficiency	Table 110.2-K

NORMALIZING UNIT

kBtu/hr of boiler rated input

² California Energy Commission (CEC). 2018. 2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24). CEC-400-2018-020-CMF.

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
Normal Replacement (NR)	DnDeemDI	Com
Normal Replacement (NR)	UpDeemed	Com
Normal Replacement (NR)	DnDeemed	Com
Normal Replacement (NR)	DnDeemDI	Res (multifamily)
Normal Replacement (NR)	UpDeemed	Res (multifamily)
Normal Replacement (NR)	DnDeemed	Res (multifamily)
New Construction (NC)	DnDeemDI	Com
New Construction (NC)	UpDeemed	Com
New Construction (NC)	DnDeemed	Com
New Construction (NC)	DnDeemDI	Res (multifamily)
New Construction (NC)	UpDeemed	Res (multifamily)
New Construction (NC)	DnDeemed	Res (multifamily)

Documentation may be required, such as the manufacturer specification sheet that lists the boiler type, input rating, and efficiency rating.

Eligible Products

The boiler must be used for space heating to induce human comfort, as defined by the California Appliance Efficiency Regulations (Title 20) and Building Energy Efficiency Standards (Title 24).

The boiler must meet efficiency requirements based on input ratings and types shown in the Measure Case Description.

Eligible Building Types and Vintages

This measure is applicable for existing commercial and multifamily installations.

The installation address must have a commercial natural gas account.

Eligible Climate Zones

This measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

None.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

HVAC

ELECTRIC SAVINGS (kWh)

Not applicable

PEAK ELECTRIC DEMAND REDUCTION (kW)

There is peak demand reduction approved for this measure in the 2020 version of the Database for Energy Efficient Resources (DEER).

GAS SAVINGS (Therms)

Commercial

The gas energy savings of a space heating boiler were drawn directly from the Database of Energy Efficient Resources (DEER). The version used to calculate savings for these measures is DEER 2020. The results were reported in the Remote Ex-Ante Database Interface (READI) tool (version v.2.5.1).; the results have not been modified.

Statewide Measure Offering IDs and DEER Energy Impact IDs

Statewide Measure Offering ID	Measure Offering Description	DEER Energy Impact ID
SWHC004A	Space Heating Boiler, Hot Water, <300 kBtu/hr, 84% AFUE	ExAnte2020 (eQuest data)
SWHC004B	Hot water boiler (300 - 2500 kBtuh, 85.0 Et, OA Reset from 140 to 165 F)	NG-HVAC-Blr-HW-300to2500kBtuh-85p0Et-Drft
SWHC004C	Hot water boiler (300 - 2500 kBtuh, 94.0 Et, condensing, OA reset from 140 to 165 F)	NG-HVAC-Blr-HW-300to2500kBtuh-94p0Et-CndStd
SWHC004D	Hot water boiler (300 - 2500 kBtuh, 94.0 Et, condensing, OA reset from 115 to 140 F)	NG-HVAC-Blr-HW-300to2500kBtuh-94p0Et-CndLow

Statewide Measure Offering ID	Measure Offering Description	DEER Energy Impact ID
SWHC004E	Hot water boiler (> 2500 kBtuh, 83.0 Et, 85.0Ec, OA Reset from 140 to 165 F)	NG-HVAC-Blr-HW-gt2500kBtuh-83p0Et-Drft
SWHC004F	Hot water boiler (> 2500 kBtuh, 94.0 Et, condensing, OA reset from 140 to 165 F)	NG-HVAC-Blr-HW-gt2500kBtuh-94p0Et-CndStd
SWHC004G	Hot water boiler (> 2500 kBtuh, 94.0 Et, condensing, OA reset from 115 to 140 F)	NG-HVAC-Blr-HW-gt2500kBtuh-94p0Et-CndLow
SWHC004H	Steam boiler (300 - 2500 kBtuh, 82.0 Et, OA Reset from 140 to 165 F)	NG-HVAC-Blr-Stm-300to2500kBtuh-82p0Et-Drft
SWHC004I	Steam boiler (> 2500 kBtuh, 80.0 Et, OA Reset from 140 to 165 F)	NG-HVAC-Blr-Stm-gt2500kBtuh-80p0Et-Drft
SWHC004J	Steam boiler (> 2500 kBtuh, 82.0 Et, OA Reset from 140 to 165 F)	NG-HVAC-Blr-Stm-gt2500kBtuh-82p0Et-Drft

The table below maps each California climate zone to an IOU service area to identify the appropriate saving value for each California climate zone.

Climate Zone-IOU Service Area Mapping

Program Administrator	Climate Zone
SCE	CZ06, CZ08, CZ09, CZ10, CZ14, CZ15, CZ16
PG&E	CZ01, CZ02, CZ03, CZ04, CZ05, CZ11, CZ12, CZ13
SDG&E	CZ07

Multifamily

The unit energy savings (UES) of a space heating boiler in a multifamily property was calculated as the difference between the base case and measure case unit energy consumption (UEC) derived from building energy use simulations in eQUEST 3-65.³ The base case energy models were based on DEER prototype buildings for each climate zone (CZ01-CZ16) and for the following existing and new building vintages: 2003, 2007, 2011, 2015 and 2020. Each model was modified to include a heating hot water circulation loop, heating hot water boiler, and a hot water coil at each air handling unit. Inputs were left to DEER prototype defaults unless otherwise noted below.

eQUEST was allowed to auto-size equipment specifications based on DEER prototype zone load requirements. All auto-sized components were left unchanged between the base case and measure cases.

³ Pacific Gas and Electric Company (PG&E). 2019. "SWHC004-01 eQUEST Calculations.zip."

Summary of the Changes to the Prototype eQUEST Models by DOE-2 Keyword

System	DOE-2 Keyword Change	Notes
HVAC Systems / Zones	HEAT-SOURCE = HOT-WATER	Changed AHU heat source from a natural gas furnace heating section to heating hot water coils. This was performed to each AHU
Circulation Loops	"DEFAULT-HW" = CIRCULATION-LOOP LIBRARY-ENTRY "DEFAULT-HW"	Created DHW circulation loop using eQUEST defaults
Boilers	TYPE = HW-BOILER-W/DRAFT	Defined baseline boiler type based on DEER database
Boilers	HEAT-INPUT-RATIO = {Parameter ("Boiler HIR")}	Defined boiler efficiency by a global parameter to allow for boiler efficiency adjustments based on measure
Boilers	CAPACITY-RATIO = {Parameter ("Boiler Cap")}	Defined boiler capacity by a global parameter to allow for boiler input capacity adjustments based on measure
Boilers	HW-LOOP = "DEFAULT-HW"	Assigned the boiler to serve the "DEFAULT-HW" circulation loop

The base case and measure case energy use models were changed to reflect the appropriate boiler efficiency, boiler type and capacity ratio for each measure offering. The following table provides the boiler type, boiler efficiency, and boiler heat input ratio (HIR) for each measure offering. These inputs were modified in each eQUEST model based on the measure.

eQUEST Boiler Input Summary Table

Measure	Case	TYPE (DOE2 Keyword Listed)	Boiler Thermal Efficiency	HEAT-INPUT- RATIO
SWHC004A	Base	HW-BOILER-W/DRAFT	82%	1.2158
	Measure	HW-BOILER-W/DRAFT	84%	1.1904
SWHC004B	Base	HW-BOILER-W/DRAFT	80%	1.2500
	Measure	HW-BOILER-W/DRAFT	85%	1.1764
SWHC004C	Base	HW-BOILER-W/DRAFT	80%	1.2500
	Measure	HW-CONDENSING	94%	1.0638
SWHC004E ⁴	Base	HW-BOILER-W/DRAFT	80%	1.2500
	Measure	HW-BOILER-W/DRAFT	83%	1.2048
SWHC004F	Base	HW-BOILER-W/DRAFT	80%	1.2500
	Measure	HW-CONDENSING	94%	1.0638
SWHC004H	Base	STM-BOILER	79%	1.2658
	Measure	STM-BOILER	82%	1.2195

⁴ This measure uses combustion efficiency as the efficiency metric in both the baseline and measure case. DEER uses a 2% loss in converting from combustion to thermal efficiency. Therefore 2% was subtracted from both the baseline and measure combustion efficiencies to obtain the thermal efficiency.

All eQUEST simulations were performed using CZ2010 weather data specific to each climate zone. The previous version of the workpaper used various capacity ratios to get the average boiler capacity to fall within the size requirements for each measure offering. However, it was found that this methodology either greatly oversized or undersized the boiler capacity in relation to the heating loop load. Boilers below 300 kBtuh were found to be accurately sized for the net heating loop load generated by DEER models. Therefore, the DEER prototype models for existing and new vintages and all the 16 climate zones were simulated using a Capacity-Ratio of 1, while using appropriate baseline and measure case efficiencies for boiler capacity ranges listed in table above.

The boiler performance curve for condensing boiler was modified based on test data from boiler research project for ASHRAE Standard 155P.⁵ Boiler curve based on unit 2 (condensing boiler) was used to simulate the appropriate measure case.

The thermostat setting was updated in both baseline and measure case models to Tstat #4. A thermostat setting of 4 has both the highest average and median setpoint values (a conservative setting).

The final UES for each measure offering was calculated as the weighted average savings of all building vintages using the DEER impact weights.⁶ The impact weights are expressed as percentages for each of the “eras” used for DEER weighted measures. The impact weights were used to weight savings values provided for specific building vintages of each era. The eras and their vintages that were used within the calculations for this measure are as follows: “Ex” - Existing/Median Vintage: 2003, 2007, 2011, and 2015; “New” – New Vintage: New. The impact weights were found by normalizing the DEER weight (“wt_vint”) for each permutation of Building Type, Climate Zone, and Vintage by the total for its Building Type, Climate Zone, and Era.

The weighted UES values were then normalized to Therms/kBtuh of input capacity.

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 EUL and RUL specified for the space heating boiler measure are presented below. Note that RUL is only applicable for add-on equipment and early replacement installations, thus not applicable for this measure.

⁵ Pacific Gas and Electric Company (PG&E), Applied Technology Services. 2012. *Boiler Research Project – ASHRAE Standard 155P*. ET Project Number: ET11PGE5271. February 29.

⁶ Pacific Gas and Electric Company (PG&E). 2019. “SWHC004-01 DEER 2020 Building Weights Tables.xlsx.”

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs)	20.0	California Public Utilities Commission (CPUC), Energy Division. 2003. <i>Energy Efficiency Policy Manual v 2.0. Page 17.</i>
RUL (yrs)	n/a	-

BASE CASE MATERIAL COST (\$/UNIT)

The base case equipment costs were obtained from the *2010-2012 WO017 Ex Ante Measure Cost Study* conducted by Itron, Inc.⁷ These costs were scaled to reflect current pricing using RS Means Historical Cost Index using the average price index across 12 California cities.⁸ Costs are reported on a per input kBtuh basis.

MEASURE CASE MATERIAL COST (\$/UNIT)

The measure case equipment costs were obtained from the *2010-2012 WO017 Ex Ante Measure Cost Study* (“WO017 Study”) conducted by Itron, Inc.⁹ These costs were converted to 2018 values using the RS Means Historical Cost Index using the average price index across 12 California cities.¹⁰

The WO017 Study did not report measure costs for the steam boiler 82% TE, > 2,500 kBtuh. Thus, the cost for this measure offering was determined using the modeling approach outlined in the 2010-2012 WO017 Study. Costs are reported on a per input kBtuh basis.

BASE CASE LABOR COST (\$/UNIT)

The base case installation labor costs were obtained from the *2010-2012 WO017 Ex Ante Measure Cost Study* conducted by Itron, Inc.¹¹ These costs were converted to 2018 values using the RS Means Historical Cost Index, using the average price index across 12 California cities.¹²

⁷ Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission. Table 3-20.

⁸ Gordian. (n.d.) “RSMeans Cost Index.pdf.”

⁹ Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission. Table 3-20.

¹⁰ Gordian. (n.d.) “RSMeans Cost Index.pdf.”

¹¹ Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission. Table 3-20.

¹² Gordian. (n.d.) “RSMeans Cost Index.pdf.”

MEASURE CASE LABOR COST (\$/UNIT)

The measure case installation labor costs were obtained from the *2010-2012 WO017 Ex Ante Measure Cost Study* conducted by Itron, Inc.¹³ These costs were converted to 2018 values using RSMeans Historical Cost Index, using the average price index across 12 California cities.¹⁴

NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. This NTG value is based upon the average of all NTG ratios for all evaluated 2006 – 2008 commercial programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. This sector average NTG (“default NTG”) is applicable to all energy efficiency measures that have been offered through commercial sector programs for more than two years and for which impact evaluation results are not available.

Net-to-Gross Ratios

Parameter	Value	Source
NTG - commercial	0.60	Itron, Inc. 2011. <i>DEER Database 2011 Update Documentation</i> . Prepared for the California Public Utilities Commission. Pages 15-4 Table 15-3.
NTG - residential	0.55	

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) 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. The assigned GSIA value for this measure is specified below. This GSIA rate is the current “default” rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment Rates

Parameter	Value	Source
GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. <i>Energy Efficiency Policy Manual Version 5</i> . Page 31.

NON-ENERGY IMPACTS

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

¹³ Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission. Table 3-20.

¹⁴ Gordian. (n.d.) “RSMeans Cost Index.pdf.”

DEER DIFFERENCES ANALYSIS

This section provides a summary of inputs and methods from the Database of Energy Efficient Resources (DEER), and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	Yes
Scaled DEER measure	No
DEER Base Case	Yes
DEER Measure Case	Yes
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	Yes
DEER Version	DEER 2020, READI v2.5.1
Reason for Deviation from DEER	DEER does not include boiler measures for the Multifamily (MFm) building type.
DEER Measure IDs Used	NG-HVAC-Blr-Stm-300to2500kBtuh-82p0Et-Drft NG-HVAC-Blr-Stm-gt2500kBtuh-80p0Et-Drft NG-HVAC-Blr-Stm-gt2500kBtuh-82p0Et-Drft NG-HVAC-Blr-HW-300to2500kBtuh-85p0Et-Drft NG-HVAC-Blr-HW-300to2500kBtuh-94p0Et-CndStd NG-HVAC-Blr-HW-gt2500kBtuh-83p0Et-Drft NG-HVAC-Blr-HW-gt2500kBtuh-94p0Et-CndStd NG-HVAC-Blr-Stm-gt2500kBtuh-80p0Et-Drft (OA Reset from 140 to 165 F) NG-HVAC-Blr-Stm-gt2500kBtuh-82p0Et-Drft (OA Reset from 140 to 165 F)
NTG	Source: DEER. The NTG of 0.60 is associated with NTG ID: <i>Com-Default>2yrs</i> . The NTG of 0.55 is associated with NTG ID: <i>Res-Default>2yrs</i> .
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER 2005. The value of 5 years is associated with EUL ID: <i>HVAC-Blr</i>

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	06/30/2018	Jennifer Holmes Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: PGECOHVC101, Revision 6 (January 1, 2017) WPSDGENRHC1061, Revision 1 (September 23, 2016) – short form WPSCGNRHC12026A, Revision 4 (March 17, 2014) Consensus reached among Cal TF members.
02	6/12/2019	Lake Casco TRC	Updates to: Condensing boiler measures with OA temp reset from 115 to 140°F and Steam boiler 82% TE, >2500 kBtuh added Code requirement updated to reflect 2019 Title 20 and 2019 Title 24 versions. Measure Offering updated to reflect newest DEER Material and Labor Cost for the Base case and Measure case updated to reflect current pricing. Net-to-Gross ratio for Residential sector included.
	06/13/2019	Jennifer Holmes Cal TF Staff	Revisions for submittal of version 01.