eTRM
best in class

PROCESS

STEAM TRAP, COMMERCIAL

SWPR003-01

CONTENTS

MEASURE NAME

Steam Trap, Commercial

STATEWIDE MEASURE ID

SWPR003-01

TECHNOLOGY SUMMARY

A faulty steam trap (blocked, leaking, or blow-through) can be diagnosed with ultrasonic, temperature, or conductivity monitoring techniques. Use of such techniques is encouraged to identify a steam trap that fulfills the measure requirements for participation in a California utility program.

A new steam trap can be any type (thermostatic, mechanical, thermodynamic, or fixed orifice), and may include an entire steam trap or just the replacement of a steam trap "capsule" (the inner parts of a steam trap that is specifically designed to be replaced upon failure). The latter does not include existing standard steam traps that are modified, repaired, or are refurbished.

"Tunstall" Replacement Capsule

Assembled Disc Steam Trap w/ Replaceable Capsule

MEASURE CASE DESCRIPTION

The measure case is defined as a steam trap replacement in a commercial "12-24 hours per day" facility – with a steam plant operating a steam boiler for 12 to 24 hours per day.

BASE CASE DESCRIPTION

The base case is defined as a failed steam trap (in either the leaking failure or the blow-through failure mode).

CODE REQUIREMENTS

This measure is not governed by federal or state code or other jurisdictional requirements that pertain to commercial steam traps.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20	None.	n/a
CA Building Energy Efficiency Standards – Title 24	None.	n/a
Federal Standards	None.	n/a

NORMALIZING UNIT

Each

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 - retro-commissioning	DnDeemed	Commercial

The customer may be required to provide the location of the new steam trap in the steam loop, make and model number, a specification sheet, approximate (±5 psig) steam line (not boiler) pressure, and receipts showing the cost and purchase date.

Eligible Products

This measure is limited to the replacement of steam traps that have failed (in either the leaking failure or the blow-through failure mode) and are replaced with a new properly functioning steam trap or steam trap capsule.

Steam traps designed for any pipe size are eligible.

Eligible Building Types and Vintages

This measure is applicable for commercial "12-24 hours per day" facilities – primarily large commercial facilities with a steam plant operating a steam boiler for 12 to 24 hours per day. Such facilities may include large educational facilities, correctional facilities, general medical hospitals, surgical hospitals,

agricultural facilities, industrial launderers, teleproduction and other post-production services, and transportation equipment suppliers.

Eligible Climate Zones

This measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

Small commercial facilities which operate their steam systems less than 12 hours per day are excluded.

New construction installations are not eligible.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

Process heat

ELECTRIC SAVINGS (kWh)

Not applicable.

PEAK ELECTRIC DEMAND REDUCTION (kW)

Not applicable.

GAS SAVINGS (Therms)

Unit Energy Savings per Failed Steam Trap

The unit energy savings (UES) per failed steam trap was derived from the unit energy savings (UES) presented in *Steam Traps Workpaper for PY2006-2008* (Revision G) published in 2007.[1] The UES values however, were adjusted to account for several factors and engineering assumptions, as stipulated in the

[1] Energy and Environmental Analysis, Inc. 2007. *Steam Traps Workpaper for PY2006-2008.* Prepared for Southern California Gas Company. March 2006. B-REP-05-599-21E, Revision G.

Non-DEER Measure Review by the Data Management and Quality Control reviewers (ED/DMQC) of the California Public Utilities Commission (CPUC) Energy Division.[2]

The inputs for the UES calculation are provided in the table below, followed by explanations and sources of key inputs.

Gas Energy Savings Inputs

Parameter	Value	Source
Average steam trap inlet pressure (psig) – Commercial 12-24 facilities	35.51	Southern California Gas Company (SCG). 2005. "Enbridge Steam Trap Survey 2005.xls"
Average heat of evaporation of steam produced (Btu/lb)	924	Southern California Gas Company. 2005. "Key Parameters for Steam Traps.xls" See "Steam Tables" tab.
Average installed boiler efficiency	80%	Southern California Gas Company. 2005. "Key Parameters for Steam Traps.xls" See "DryCleaners Data" tab.
Boiler energy required to replace lost steam (Btu/lb)	1,155	*(Calculated)*
Annual operating hours	4,380	Professional judgement.
Average percentage of leaking & blow-thru steam traps	16.3%	*(Calculated)* Griffin, P. and D. Johnson (Enbridge Gas Distribution, Inc.). 2006. "The Enbridge Steam Saver Program Steam Boiler Plant Efficiency Update to Year End 2005." March 1. Table 7.
Average steam loss (lb/hr per trap)	19.65	*(Calculated)*
Average annual steam loss (lb/yr per trap)	86,046	*(Calculated = Average Steam Loss x Annual Operating Hours)*
Annual gas savings (therms/year per trap rebated)	687.0	Energy and Environmental Analysis, Inc. 2007. *Steam Traps Workpaper for PY2006-2008.* Prepared for Southern California Gas Company. March 2006. B-REP-05-599-21E, Revision G.
Averaging factor	50%	Energy and Environmental Analysis, Inc. 2007. *Steam Traps Workpaper for PY2006-2008.* Prepared for Southern California Gas Company. March 2006. B-REP-05-599-21E, Revision G. Griffin, P. and D. Johnson (Enbridge Gas Distribution, Inc.). 2006. "The Enbridge Steam Saver Program Steam Boiler Plant Efficiency Update to Year End 2005." March 1.

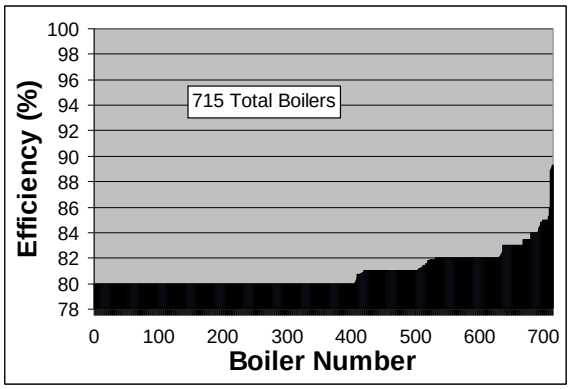
Operating Hours. For the commercial "12 to 24" market segment, a conservative estimate of the annual operating time was used: 4,380 hours per year (12 hours/day for 365 days/yr). Some institutional steam systems (correctional facilities, hospitals) may operate over 8,000 hours per year.

Boiler Efficiency. To calculate the cost of steam loss from a leaking trap, it is necessary to estimate of the efficiency of the steam generation boiler. To determine representative steam boiler efficiencies, data

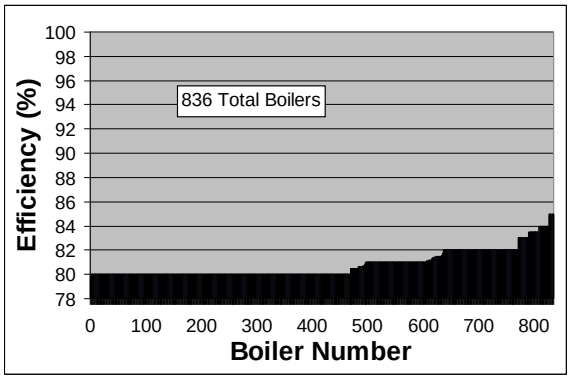
[2] California Public Utilities Commission (CPUC), Energy Division. 2010. "Data Management and Quality Control reviewers' recommendation in Steam Trap Workpaper Review Comments." March 10. Revision 8.

from the California Energy Commission (CEC)[3] were examined. CEC lists several hundred steam boilers, and these boilers were divided into two groups: ≤ 2 MMBtuh (steam only) and 2-10 MMBtuh (steam only). As shown in the figures below, the boiler efficiencies begin at 80%; a relatively large number of boilers in the database are rated at 80%, thus baseline efficiency value of 80% was used to compute the cost of steam generation.

CEC Efficiency Data (Steam Boilers ≤ 2 MMBtuh)



CEC Efficiency Data (Steam Boilers 2-10 MMBtuh)



Averaging Factor. The averaging factor is applied to account for the fact that the actual leak rate in most cases is less than the maximum "theoretical" leak rate.

[3] (No author). 2005. "Steam Boiler Efficiency CEC 2005.xlsx".

Adjustment Factors

Adjustment factors are defined to account for the following:

1. Pressure factor -- The recognition that the inlet pressure of a steam trap is greatly reduced due to the effect of a control valve which is between the steam line pressure and the steam trap.
2. Load factor -- The recognition that the hours that the trap is leaking steam are often less than the steam system operating hours.
3. Population factor- Represents the allocation by service type.
4. Failed Adjustment Factor -- Steam traps that were replaced within this program but were mistakenly identified as meeting the failure eligibility requirements, i.e., instead of being failing open (leaking or blowing through), the trap was failed closed (blocked).

Combined Adjustment Factor

A "combined adjustment factor" was calculated as the product of the population allocation by service type, the load factor adjustment, and the pressure factor adjustment. The combined adjustment factor adjusts the steam trap UES by steam trap population allocation by service type, the load factor, and the pressure factor.

Pressure Factor. There are two service categories for steam traps:

- Traps on steam lines (implying the steam trap has the steam line pressure at its inlet, e.g., drip traps)
- Traps on steam loads (implying the steam line pressure has been reduced by a control valve, e.g., tracer, heat exchanger, coil, and process heater traps)

The following engineering assumptions were made to determine the steam trap inlet pressure:

- The inlet pressure of a line trap is the same as the steam line pressure. This analysis assumes that 25% of steam traps are line traps, as recommended by the Energy Division.[4]
- The inlet pressure of a load trap is greatly reduced due to the effect of the control valve which is between the steam line and the coil heat exchanger unit. This analysis assumes that 75% of steam traps are load traps, as recommended by the Energy Division.[5] The absolute pressure downstream of the control valve is assumed to be 56% of the trap inlet absolute pressure, as recommended by the Energy Division.[6] The table below provides the pressure factors for the two steam trap service categories. Note that this assumption of 56% pressure factor across control valves is conservative. In contrast, Spirax-Sarco recommends assuming a value of 75%[7] (p. 25):

> *"Where it is not known, it is reasonable to take a pressure drop across the [control] valve of some 25% of the absolute inlet pressure. Lower pressure drops down to 10%*

[4] California Public Utilities Commission (CPUC), Energy Division. 2010. "Data Management and Quality Control reviewers' recommendation in Steam Trap Workpaper Review Comments." March 10.

[5] California Public Utilities Commission (CPUC), Energy Division. 2010. "Data Management and Quality Control reviewers' recommendation in Steam Trap Workpaper Review Comments." March 10.

[6] California Public Utilities Commission (CPUC), Energy Division. 2010. "Data Management and Quality Control reviewers' recommendation in Steam Trap Workpaper Review Comments." March 10.

[7] Spirax-Sarco. 2004. *Design of Fluid Systems--Hook-ups.* 12th Edition.

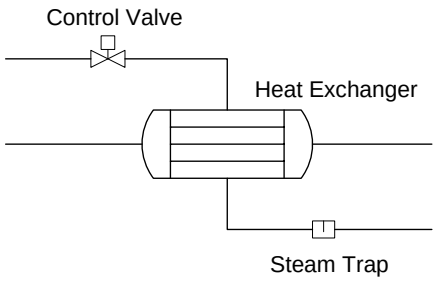
can give acceptable results where thermo-hydraulic control systems are used. Greater pressure drops can be used when it is known that the resulting downstream pressure is still sufficiently high. However, steam control valves cannot be selected with output pressures less than 58% of the absolute inlet pressure."

Load Factor. Key factors that impact the savings potential of this steam trap measure include the hours the steam leaks (which may not be the same as the boiler hours of operation) or the leak rate of the steam.

A steam trap is located downstream of the heat exchanger which is also downstream of its control valve. In practice, the control valve will modulate the flow of steam to the heat exchanger based on the demand requirements. If the control valve and heat exchanger system are working properly, the steam will be fully condensed when it reaches a steam trap operating normally. If the steam trap has failed open, the control valve will supply additional steam to the heat exchanger to maintain the desired pressure or temperature in the heat exchanger. As demand changes, the steam flow will vary through the heat exchanger. The failed trap can only leak steam that is delivered to it. Therefore, a factor can be applied to reduce the steam loss based on the load factor of the heat exchanger.

A load factor is equal to the effective full load hours (EFLH) divided by the heat exchanger operating hours. Process heaters, tank coils, and other steam heat exchangers are analogous to gas-fired process steam boilers, which have a load factor of 32%, as determined for the process boiler measure.[8] The process steam boiler load factor intrinsically represents the average load experienced by the boiler. However, if a steam heat exchanger has a 32% load factor, it might operate at 32% load for 100% of its operating hours, or it might operate at 100% load for 32% of its operating hours. If it operates at 32% load for 100% of its operating hours, the average steam loss will be 100% of the maximum steam loss through the trap. If it operates at 100% load for 32% of its operating hours, the average steam loss will be only 32% of the maximum steam loss through the trap. The typical average steam loss will be between these two extremes. Because of the lack of data, it is assumed that the load factor for a leaking steam trap downstream of a control valve is 32%.

Simple Process Flow Diagram of a Steam to Fluid Heat Exchanger



[8] Energy and Environmental Analysis, Inc. 2006. *Process Boilers (Including Direct Contact Water Heaters) Workpaper for PY2006-2008.* Prepared for Southern California Gas Company. B-REP-05-599-19B, Revision B. March20.

The load factors for the two steam trap service categories (line and load) are provided below, as well as the corresponding combined adjustment factor due to the load factor and the pressure factor. The combined adjustment factor was calculated as the product of the population allocation by service type, the load factor adjustment, and the pressure factor adjustment. This combined adjustment factor of 21.4% replaces the "0.67 multiplier" recommended by the Energy Division,[9] but will have same effect.

Combined Adjustment Factor Calculation Inputs

Adjustment Factor	Service		Source
	Line	Load	
Population (%)	25%	75%	California Public Utilities Commission (CPUC), Energy Division. 2010. "Data Management and Quality Control reviewers' recommendation in Steam Trap Workpaper Review Comments." March 10. Revision 8.
Load Factor (%)	32%	32%	Energy and Environmental Analysis, Inc. 2006. *Process Boilers (Including Direct Contact Water Heaters) Workpaper for PY2006-2008.* Prepared for Southern California Gas Company. B-REP-05-599-19B, Revision B. March20.
Pressure Factor (%)	100%	56%	California Public Utilities Commission (CPUC), Energy Division. 2010. "Data Management and Quality Control reviewers' recommendation in Steam Trap Workpaper Review Comments." March 10.
Combined Factor (%)	8.00%	13.44%	*Calculated = population x load x pressure*
Combined adjustment factor for Line and Load Traps	21.44%		*Calculated = Line factor + Load factor*

Failed Adjustment Factor

Steam traps that were replaced through the Enbridge program but were mistakenly identified as meeting the failure eligibility requirements, i.e., instead of being failing open (leaking or blowing through), the trap was failed closed (blocked). A survey of 2,650 steam traps at a large Southern California oil refinery found 27.7% were "leaking heavily" or blow-through, with an additional 6.3% blocked, as discussed in the Steam Trap Revision G workpaper.[10] Thus, the survey showed that only 81% [27.7% / (27.7% + 6.3%)] of the failed traps had failed open. A second adjustment factor called the *failed adjustment factor* of 81% was therefore applied to the steam loss per failed trap.

Adjusted Unit Energy Savings per Failed Steam Trap

To determine the UES of a failed steam trap, the UES was multiplied by the combined adjustment factor and the failed adjustment factor defined above. This calculation is represented as:

$$UES_{adj} = UES_{revG} \times CAF \times FAF$$

UES_{adj} = *Energy savings per failed steam trap, adjusted (therms/year per trap, gross)*

[9] California Public Utilities Commission (CPUC), Energy Division. 2010. "Data Management and Quality Control reviewers' recommendation in Steam Trap Workpaper Review Comments." March 10. Revision 8.

[10] Energy and Environmental Analysis, Inc. 2007. *Steam Traps Workpaper for PY2006-2008.* Prepared for Southern California Gas Company. March 2006. B-REP-05-599-21E, Revision G.

UES_{revG} = Energy savings for commercial 12-24 hr/day applications as expressed in the Steam Traps Workpaper for PY2006-2008 (2007), Revision G
CAF = Combined Adjustment Factor
FAF = Failed Adjustment Factor

Measure Description	Gross per Trap Savings (th/yr)
Combined Adjustment Factor (CAF)	21.44%
Failed Adjustment Factor (FAF)	81%

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 commercial steam traps are specified below. The EUL was stipulated in Resolution E-4952[11] to comply with the California Public Utilities Commission (CPUC) Decision 16-08-019, which created the behavioral, operational, and retrocommissioning (BRO) measure classification. D.16-08-019 also provided the policy direction to assign a three-year EUL for BRO measures. Note that RUL is only applicable for add-on equipment and accelerated replacement measures and is not applicable for this measure.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs)	3.0	California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. Page A-37.
RUL (yrs)	n/a	n/a

BASE CASE MATERIAL COST ($/UNIT)

The base case scenario for this measure is to do nothing; therefore, the base case cost for this measure is $0.

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

MEASURE CASE MATERIAL COST ($/UNIT)

The measure case costs for a steam trap replacement in a commercial "12-24 facility" was derived from a vendor cost survey conducted in 2006 [12] that covered three of the four main types of steam traps (orifice type traps were excluded).

- Float & thermostatic
- Mechanical (inverted bucket)
- Thermodynamic

The results of the vendor survey are shown below. The prices are grouped by steam trap type and by maximum operating pressure. This measure analysis focused on steam traps with pipe connections up to two inches, and representative prices were collected within this size range. Based on personal communication with vendors and with Enbridge in December 2005, about half of all steam traps sold are of the float and thermostatic design, and the remaining half are split between inverted bucket and thermodynamic. For averaging purposes, the cost results are therefore split into two categories: 1) float and thermostatic and 2) other (includes both inverted bucket and thermodynamic). The average price shown at the bottom of the table represents the average price between the two categories.

Steam Trap Costs Provided by Vendors

Type of Steam Trap	Pressure (psig)							
	15	30	75	125	150	180	200	250
Float & Thermostatic								
3/4 inch	$127	$150	$203	$207	$454	$454	$454	---
1 1/2 inch	$258	$314	$352	$352	---	---	---	---
Average	$192	$232	$278	$279	$454	$454	$454	---
Other								
Inverted bucket	$82	$82	$82	$82	$105	$105	$105	$105
1/2 inch thermodynamic	$185	$185	$185	$185	$185	$185	$185	$185
3/4 inch thermodynamic	$235	$235	$235	$235	$235	$235	$235	$235
Average	$168	$168	$168	$168	$175	$175	$175	$175
All								
Average (All)	$180	$200	$223	$223	$315	$315	$315	$175

An Enbridge survey[13] was used to determine a typical distribution leaking traps, by pressure. This population profile is shown in below. The vendor-based cost data, combined with the population profile information, was then used to compute a weighted cost for all steam traps and for steam traps that operate at and above 15 psig shown at the bottom of the table. The average cost of all traps with psig > 15 was adopted for this measure.

[12] Southern California Gas Company. 2005. "Key Parameters for Steam Traps.xls" See "Cost Data" tab.

[13] Southern California Gas Company (SCG). 2005. "Enbridge Steam Trap Survey.xls"

Estimated Steam Trap Costs for Two Categories (≤ 15 psig and > 15 psig)

Parameter	Pressure (psig)							
	15	30	75	125	150	180	200	250
# of Leaking Traps	1,539	171	235	264	54	0	2	26
Total Replacement Cost ($)	$276,892	$34,145	$52,207	$58,887	$16,983	$0	$629	$4,553
Average Cost per Trap ($)	**$180**	**$223**						

BASE CASE LABOR COST ($/UNIT)

The base case scenario for this measure is to do nothing; therefore, the base case labor cost for this measure is equal to $0.

MEASURE CASE LABOR COST ($/UNIT)

Measure case labor costs were derived from the 2018 on-line edition of RSMeans.[14] Specifically, the labor cost per steam trap unit was calculated as the average of the costs to install a steam trap, weighted by size (inches). Program data from 2015-YTD was used to determine the number of steam traps install of each size.

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.[15] The NTG value adopted for this measure was documented in the 2011 DEER Update Study conducted by Itron, Inc.

Net-to-Gross Ratios

Parameter	Value	Source
NTG	0.68	Itron, Inc. 2011. *DEER Database 2011 Update Documentation*. Prepared for the California Public Utilities Commission. Section 9 Table 9-1.

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

[14] Southern California Gas Company (SCG) and Pacific Gas and Electric (PG&E). 2019. "Steam_trap_cost_programs_RSMeans.xlsx."

[15] Itron, Inc. 2011. *DEER Database 2011 Update Documentation*. Prepared for the California Public Utilities Commission. Section 9 Table 9-1.

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.

Gross Savings Installation Adjustment

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

NON-ENERGY IMPACTS

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

DEER DIFFERENCES ANALYSIS

This section provides a summary of inputs and methods adopted from the Database of Energy Efficient Resources (DEER), and the rationale for inputs and methods that are not DEER-based. There is no steam trap measure available in DEER.

DEER Difference Summary

DEER Item	Comment
Modified DEER methodology	
Scaled DEER measure	
DEER Base Case	
DEER Measure Case	
DEER Building Types	
DEER Operating Hours	
DEER eQUEST Prototypes	
DEER Version	
Reason for Deviation from DEER	There are no steam trap measures available in DEER.
DEER Measure IDs Used	
NTG	Source: DEER. The NTG of 0..68 is associated with NTG ID: *NonRes-sAll-mStmTrp-dn*
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER. The value of 3 years is associated with EUL ID: *DEER 2017 NonRes-RCx-Operational*

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: SCGWP100310A, Revision 9 (August 12, 2011) Energy & Environmental Analysis, Inc. 2007. *Steam Traps Workpaper for PY 2006-2008.* Prepared for the Southern California Gas Company. B-REP-05-599-21G, Revision G. Consensus reached among Cal TF members.
			Updates for SCGWP100310A, Revision 10
			Updates to material labor cost
	03/29/2019	Jennifer Holmes Cal TF Staff	Updates for submission of version 01