FISHER NICKEL inc.

Evaluating the Water Savings Potential of Commercial "Connectionless" Food Steamers

FINAL REPORT
June 2005

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Acknowledgments

Special thanks goes out to the end users that participated in this study and allowed the FSTC to monitor their equipment. FNi/FSTC appreciates their cooperation and support of programs dedicated to promoting water and energy efficiency in the food service industry. Recognition is extended to the Pacific Gas and Electric Company (PG&E) and Southern California Edison (SCE) for technical and financial support of this study.

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ABBREVIATIONS & ACRONYMS

ASTM	American Society for Testing and Materials
Avg.	Average
Btu	British Thermal Unit
Btu/h	British Thermal Units per hour
cu. ft.	cubic foot
EBMUD	East Bay Municipal Utility District
FSTC	Food Service Technology Center
gal/d	gallons per day
gal/h	gallons per hour
gal/min	gallons per minute
gpm	gallons per minute
kW	kilowatt
kWh	kilowatt-hour
kWh/d	kilowatt-hours per day
MWD	Metropolitan Water District
NC1a	Northern California Site #1a
NC1b	Northern California Site #1b
NC2	Northern California Site #2
NC3a	Northern California Site #3a
NC3b	Northern California Site #3b
NC4	Northern California Site #4
NC5	Northern California Site #5
NC6	Northern California Site #6
SC1	Southern California Site #1
SC2	Southern California Site #2
SC3	Southern California Site #3
SC4	Southern California Site #4
SC5	Southern California Site #5
SC6	Southern California Site #6
SCE	Southern California Edison
°F	degrees Fahrenheit

Executive Summary

In response to an increased emphasis by the food service industry on operating cost reductions, numerous manufacturers have introduced a "connectionless" technology within their steam cooker product line. Connectionless steamers (alternatively referred to as boilerless steamers) have a heated water reservoir in the bottom of the cooking compartment in lieu of a dedicated boiler or steam generator. There is no periodic de-scaling (de-liming) of a boiler required, the open reservoir is readily cleaned and, in electric steamers, the heating elements are isolated from the water and therefore not subjected to damaging scale build-up or corrosion. In addition to mitigating a maintenance burden associated with conventional boiler-based steamers, both water and energy consumption are dramatically reduced. What differentiates the connectionless technology from its boiler-based counterpart is that in connectionless steamers, the steam that condenses on the food product and compartment walls remains within the cavity and returns to the reservoir as opposed to being rejected to an open condensate drain. Since the hot condensate returned to the reservoir is recycled, the overall consumption of steam (i.e., water and energy) is reduced. Furthermore, since there is no steam rejected to a drain, there is no requirement for condensate-cooling water, which represents a large portion of the water used by boiler-based steamers. The absence of water and drain connections also simplifies the installation and reduces the associated cost of the connectionless steamers.

The FSTC estimates 25,000 compartment steamers are installed in California food service operations, the majority of which are conventionally plumbed, boiler-based units. Of these, the FSTC estimates (based on field experience) that up to 60% (or 15,000 units) are candidates for replacement by a connectionless model. Since the life of a properly maintained compartment steamer can be 10 to 15 years, a targeted utility incentive program could accelerate market transformation.

Within the scope of the Metropolitan Water District of Southern California's *Innovative Conservation Program*, this end-use monitoring project was initiated to explore the water savings potential of connectionless compartment steamers in commercial kitchens. The objective of this study was to quantify the annual water savings that could be achieved in commercial kitchens by replacing conventional boiler-based, atmospheric compartment steamers with equivalently sized models of the new generation connectionless steamers. Two additional components were added to the scope of this Innovative Conservation Program (ICP) project. The East Bay Municipal Utility District (EBMUD), Oakland, initiated a mirror of the southern California project in northern California. As well, the Southern California Edison Company and Pacific Gas and Electric Company provided support to add an energy-measurement component to the project. Because the water and energy consumption of food steamers is closely linked, the results from this study can support both water and energy utilities in the development of incentive programs to stimulate the purchase of connectionless steamers in California.

Executive Summary

A total of twelve sites were selected in which eleven boiler-based and three boilerless steamers were monitored to determine water and energy consumption in real-world kitchen settings, where the energy and water consumption was dependent on many factors including daily operating time, food products and cooking procedures, as well as the design and control strategy of the steamer itself.

The data show that the boiler-based steamers averaged approximately 30 times more water consumption than the boilerless, high-efficiency counterparts (407 gal/day vs. 13.9 gal/day), and on a per-compartment basis, the boiler-based units had an average water consumption rate of 40.5 gal/h, while the connectionless steamers used less than 2 gal/h. For the electric boiler-based steamers, the daily energy consumption was five times more (89.3 kWh/day vs. 16.9 kWh/day), and the average energy consumption rate was almost twice as much (8.1 kW vs. 4.5 kW). The results are summarized in Table ES-1.

Table ES-1. Field-Monitoring Results Summary

Location	Number of Compart-ments	Daily Operating Time (h)	Daily Water (gal/d) [1]	Water Rate (gal/h)[1, 2]	Daily Energy (kWh/d)	Avg. Energy Rate (kW)[2]
Boiler-based Steamers						
SC1 Casual Dining Restaurant	1	13.0	808	66.3	100.8	7.8
SC3 Corporate Cafeteria[3]	2	2.5	190[3]	37.0[3]	(gas)	(gas)
SC4 Hotel Banquet Kitchen	2	1.7	107	32.1	(gas)	(gas)
NC1a Corporate Cafeteria	2	8.4	479	27.9	104.1	6.2
NC2 Casual Dining Restaurant	1	3.1	128	41.6	25.1	8.1
NC3a University Cafeteria[3]	2	6.5	549[3]	42.2[3]	141.5	10.9
NC3b University Cafeteria[3]	2	4.9	421[3]	42.7[3]	103.7	10.6
NC5 Fine Dining Restaurant	1	14.6	644	44.1	64.4	4.4
NC6 Fine Dining Restaurant	1	11.0	340	30.9	85.2	7.7
Average		7.3	407	40.5	89.3	8.0
Boilerless Steamers						
SC2 Casual Dining Restaurant	1	1.6	3.2	2	12.2	7.6
NC1b Corporate Cafeteria	2	9.5	32.6	2	29.9	3.1
NC4 Country Club Kitchen	1	3.0	6.0	2	8.57	2.9
Average		4.7	13.9	2	16.9	4.5

[1] *Daily water consumption for boilerless* steamers *is extrapolated based on actual operating time and the laboratory-determined nominal water consumption rate of 2 gal/h*

[2] *Average energy rates and boiler-based water consumption rates are derived from daily consumption and average operating time values. Values are presented on a per-compartment average basis.*

[3] *Locations where only the condensate-cooling water was monitored; measurement of the boiler/generator fill consumption was not performed.*

Data from two case-study operations, one in southern California and one in northern California, where boilerless units had replaced boiler-based units, demonstrated dramatic reduction in utility costs due to the decrease in water and energy consumption. In southern California [Case Study 1], a restaurant with an older 3-pan boiler-based steamer was compared to an identical restaurant from the same chain that had replaced its old steamer with a 6-pan boilerless unit. The new boilerless unit's nominal water consumption rate of 2 gallons per hour, as compared to the boiler-based steamer's consumption rate of 66.3 gallons per hour, returned a $1,937 reduction in combined water and sewer charges. In terms of energy usage, the boiler-based steamer was consuming 100.8 kWh per day, while the boilerless unit used only 12.2 kWh per day. The combined savings from water and electrical utility costs realized by replacing the boiler-based steamer was $6,083.

Similar results also were obtained at a corporate cafeteria site in northern California [Case Study 2], where a 2-compartment, 6-pan, boiler-based unit was replaced with 2 boilerless, 6-pan steamers in a stacked configuration. Average water consumption dropped from 479 gallons to 33 gallons per day. The more energy-efficient boilerless unit consumed only 29.9 kWh per day versus 104 kWh per day, yielding a kWh reduction of over 70%. The annual operation cost for this steamer operation was reduced from $4,352 to $1,068, for a savings of $3,284. The cost savings for these two examples are summarized in Tables ES-2 and ES-3.

Table ES-2. Case Study 1: Annual Operating Costs for Southern California Restaurant

	Boiler-based	Boilerless
Water	$1,944	$7
Energy	$4,717	$571
Total	$6,661	$578
	Yearly Savings	*$6,083*

Values based on $0.13/kWh and combined water/sewer rate of $5.00/100 cu.ft. for steamer operating 360 days per year.

Table ES-3. Case Study 2: Annual Operating Costs for Northern California Cafeteria

	Boiler-based	Boilerless
Water	$833	$57
Energy	$3,519	$1,011
Total	$4,352	$1,068
	Yearly Savings	*$3,284*

Values based on $0.13/kWh and combined water/sewer rate of $5.00/100 cu.ft. for steamer operating 260 days per year.

The study confirmed that boiler-based steamers consume significantly more water than compartment steamers incorporating the "connectionless" technology. Applying the nominal savings of 40 gal/h per compartment, the water-saving potential of a two-compartment steamer operating 12 hours per day would be equivalent to an acre-foot of water use per year. For a single compartment steamer operated 6-hours per day (approximating the average 7.3 hours for the nine boiler-based steamer sites), the water savings would be in the order of 0.25 acre-feet per year. Applying this more conservative value of 0.25 acre-foot savings to each boiler-based steamer replaced by a connectionless unit, the statewide conservation impact could be in the order of 3750 acre-feet per year with the installation of 15,000 units. This would prorate on a population basis to an annual savings of 1500 acre-feet in the Metropolitan Water District service area. These water savings projections indicate that there is sufficient support for the development of utility incentive and/or educational programs to promote the purchase of water-efficient connectionless steamers.

This field-monitoring project clearly demonstrated that the installation of high-efficiency steamers would yield lower utility costs due to significantly lower water and energy consumption. For some large-scale food service operations and institutions, the use of boilerless steamers may not be an option, as their production requirements necessitate the higher constant steaming power and speed of the larger, high production capacity, boiler-based steamers. However, there are certainly many kitchens that can take advantage of the benefits of boilerless steamers—they are absolutely more water and energy efficient and are easier to maintain. Furthermore, the EPA has already recognized the majority of boilerless steamers as Energy Star® qualified commercial products.

Introduction

This report documents a compartment steamer field-monitoring project conducted in selected commercial food service operations in southern and northern California. The project was implemented under contract with the Metropolitan Water District (MWD) and carried out by Fisher-Nickel, inc. through the Food Service Technology Center with support from various steamer manufacturers and regional utility companies including East Bay Municipal Water District (EBMUD), the Pacific Gas & Electric Company (PG&E), and Southern California Edison (SCE). It should be noted that, although work for southern and northern California was conducted under separate funding arrangements, the results of both efforts were combined within this final report.

Background

A 2001 NAFEM study titled "Size and Shape of Industry Study" estimates the sale of compartment convection and pressureless steamers at 14,000 units per year in the USA.[1] Additionally, the Study estimates that 14,000 countertop steamers were sold in the USA that same year. This places the total annual sale of compartment steamers in the order of 28,000 units per year. If we assume an average life span of 12 years for compartment steamers (which impacts the number of replacement units) and a 3% real growth (which impacts new steamer sales), an installed base of 250,000 compartment steamers for the U.S. can be estimated. Prorating on a population basis, there could be 25,000 compartment steamers operating in California. The FSTC believes (based on field experience) that the connectionless technology has penetrated less than 5% of this installed base. However, not all boiler-based steamers are candidates for replacement by connectionless steamers given that the available connectionless steamers cannot match the high food production capacity of some of the larger boiler-based models (at least at this stage in the current market). Within the context of this limitation, the FSTC believes that 60% of the installed base (approximately 15,000 steamers) could be converted to the water/energy efficient connectionless technology.

The boiler-based steamers utilize a boiler or steam generator that injects steam into the cooking cavity at a constant rate. In order to maintain the compartment at atmospheric pressure (i.e., a pressureless condition), steam that does not immediately condense on the food product escapes as a mixture of steam and hot condensate through a drain at the bottom of the cavity. Not only is water wasted in the rejected steam, but also a substantial amount of additional water is required to condense this steam and cool the condensate water to an acceptable temperature before it enters an open floor drain (a maximum of 140°F, or as otherwise specified by local codes). This condensate-cooling water is injected directly into the steamer's drain line, just upstream of the external plumbing connection, and flows continuously while steam is being generated—even if there is no food being cooked. Additional energy is consumed from the generation of the excess steam, making boiler-based steamers energy inefficient as well, independent of being gas or electric.

Introduction

In recent years, the food service industry has seen the advent of more energy and water efficient boilerless compartment steamers. They were first termed "connectionless" steamers, because they were manually filled and drained with separate containers and had no external water supply or drain connections. Since then, some manufacturers have introduced models with auto-fill water and drain connections. Subsequently, these steamers have been broadly categorized as "boilerless," since the absence of a separate boiler or steam generator became the distinguishing characteristic. These new-generation steamers consist of a simple compartment with enough room below the bottom rack for a water reservoir. Steam, generated from the boiling water, rises by natural convection to condense on the food items above. A small amount of steam is vented through a port at the top of the compartment while the steam that condenses on the food product or cavity walls simply returns to the reservoir below to be steamed again. This design is self-contained, with no condensate drain or accompanying condensate-cooling water. There is no periodic de-scaling (de-liming) of a boiler required, the open reservoir is easily cleaned, and the heating elements (in electric steamers) are isolated from the water and therefore not subjected to damaging scale build-up or corrosion.

Since the development of the ASTM *Standard Test Method for the Performance of Steam Cookers* [F1484-04] by the FSTC in 1995, the Food Service Technology Center has tested various connectionless and boiler-based compartment steamers under controlled laboratory test conditions. In addition to determining cooking-energy efficiency and production capacities, researchers recorded water consumption rates of between 20 and 40 gallons per hour per compartment for boiler-based steamers, while the consumption rate for connectionless steamers was less than 2 gallons per hour.[2-9] While it was reasonable to extrapolate a foodservice operation's total water consumption of a connectionless steamer based on the consumption rate test data from the lab (because of the low order of magnitude), there was no authoritative "real-world" field test data documenting the total water consumption for boiler-based units. For example, did the boiler-based units get turned off throughout the day and/or did they continue to flow condensate-cooling water during idle periods?

Since it is the quantity of water used by the old technology (rather than the lack of water used by the new technology) that impacts the water-saving potential of this new steamer technology, this field study was initiated. Preliminary estimates placed the potential annual water savings resulting from the replacement of a single, 2-compartment conventional steamer with a typical connectionless type at up to one acre-foot per year per installation (value based on a 2-compartment steamer using 40 gal/h per compartment for 12 h/day). Based on the steamer cross-section of this study, the results suggest that this preliminary estimate was somewhat optimistic, but that savings of 0.25 acre-feet could be realized for a single compartment steamer.

Introduction

Project Objective

The objective was to monitor steamer performance in actual food service operations in order to quantify the water (and energy) savings that could be achieved in commercial kitchens by replacing conventional atmospheric compartment steamers with equivalent-sized models of the new generation “connectionless” steamers.

Scope of Project Activities

1. Monitor the water (and energy) consumption of 10 conventional compartment steamers (5 in southern California and 5 in northern California) in a range of food service establishments for a minimum 4-week period. At the conclusion of this period, replace the existing steamer with an equivalently sized new-generation “connectionless” steamer.
2. Monitor the water (and energy) consumption of the new steamers for a second 4-week period, projecting the annual water use reduction and resultant cost savings to the operator and benefit to water (and energy) utilities.
3. Based upon the savings profiles for the replacement steamers, project the potential water and (energy) savings for the MWD service areas along with those for the state of California.

Method

Although the ASTM standard has been applied to numerous steamers under ideal laboratory conditions at the FSTC, the water and energy consumption of compartment steamers has not been well documented for real-world operating conditions, where these pieces of equipment are subject to varying types of usage and maintenance programs. Securing real-world data was the catalyst for this study. A focus was placed on identifying food service operations that were using a boiler-based steamer but would be open to replacing them with an equivalent connectionless model. Monitoring sites were identified and selected with help from Southern California Edison Company or at the direct request from end users, who were aware of the steamer’s potential contribution to reduced energy costs, but not necessarily to the reduced water costs.

Once a site was selected, the existing steamer was instrumented and subsequently monitored for 30 days. Totalizing type water meters with pulse outputs were installed in series between the water source and the steamer, and data loggers that counted the pulses were used to record water consumption data every five minutes. Where applicable, energy meters also were installed either in the facility's electrical panel or inside the steamer. The instrumentation is detailed in the Setup and Instrumentation section of this report. After a 30-day monitoring period, the data were downloaded and analyzed to determine energy and water consumption. Where possible, an equivalently sized boilerless steam cooker (with the same fuel source) was installed, instrumented and monitored for comparison. Sites selected included casual dining restaurants, a corporate cafeteria, a university cafeteria, and hotel kitchens. The site locations and steamer types installed at each site are explained in the Field Site Description section.

Project Challenges

As with many field-monitoring projects, the scope of work as defined in the proposal may deviate from the scope of work as delivered when the research team meets head-on with the reality of the real world. In this case, the ability to secure field test sites in a timely fashion became a greater challenge than anticipated. The concept of having manufacturers identify sites that would be in support of their sales efforts did not mature as expected. Furthermore, promise to provide a connectionless unit at no-charge to the customer became a bit more of a financial issue when the actual time came for replacing the boiler-based unit. A few of these sites had relatively new boiler-based steamers, and because the customers were happy with their performance, they were reluctant to commit to a replacement—regardless of the savings potential described to them. Also, there was also political sensitivity to replacing a boiler-based unit from one manufacturer with a connectionless unit from another manufacturer.

In hindsight, the important aspect of the study was documenting the water consumption for representative samples of boiler-based steamers, as it was known in advance that the water consumption of the connectionless models would be trivial in comparison. Regardless of the constraints discussed, an appreciable sample was monitored, and two excellent case study operations were secured (one in Southern California and one in Northern California), where the two steamer technologies were directly compared.

Setup and Instrumentation

Three key pieces of equipment were used for data collection: a Dent Elite Pro data logger, an AEC MicroDataLogger (MDL), and a DLJ water meter. The equipment at each site was installed unobtrusively and out of view from the kitchen staff to ensure that the steamer was operated in the same manner as before the installation.

Figure 1.
ELITEpro Logger

For sites with electric steamers, Dent Instruments, ELITEpro poly-phase data logging power meters used in conjunction with Magnelab CT-0750-50 50A or CT-0750-100 100A split-core current transducers were installed to monitor energy consumption. The logger was either placed within the steamer enclosure, near the electrical connections, or within the main circuit breaker panel that fed the steamer. It was configured to record voltage, current, power and energy consumption information at 5-minute intervals.

Figure 2.
MicroDataLogger

Boiler-based steamer water consumption data was recorded with the AEC MicroDataLogger (MDL). They were configured with AEC Count 80-3 pulse counter modules to record the dry-contact switch closure pulse signals generated by the DLJ water meters. Each data logger was configured to record totalized pulses at 5-minute intervals and was either installed behind the steamer or placed within the steamer enclosure if there was enough room.

Figure 3.
DLJ Water Meter

The water consumption was measured with DLJ (model DLJSJ50C) single jet water meters (in conjunction with the AEC MicroDataLoggers). The DLJ water meters used a single impeller in the flow path and included a direct-read register that displayed cumulative gallons flowed and a dry contact reed switch with a resolution of 1 switch closure per gallon. Where steamers required a filtered and/or hot water supply for boiler fill, the water meter was placed inline only with the cold/unfiltered condensate-cooling supply.

Southern California Sites

Southern California Site #1 (SC1): Casual Dining Restaurant – Rancho Cucamonga

This casual dining restaurant was equipped with a countertop, 1-compartment, 3-pan, boiler-based electric steamer rated at 8.3 kW. It was equipped with boiler fill/refill and condensate-cooling water connections. The boiler fill/refill used a separate filtered supply and was not measured. The steamer featured controls for two cooking modes—a continuous-on manual mode and the timed mode.

Figure 4. SC1 Casual Dining Restaurant and Boiler-based Steamer

Southern California Site #2 (SC2): Casual Dining Restaurant – Corona

This casual dining restaurant from the same chain was identical to SC1 with a countertop (placed under-counter), 6-pan, 1-compartment, connectionless, 8-kW electric steamer. The steamer included a 3-gallon reservoir that was manually filled and drained, and had no external water supply or drain connections. Control settings on the unit included continuous steaming, timed steaming, thermostat controlled steaming, and a hold mode (sets steamer to maintain compartment temperature at the thermostat setting).

Figure 5. SC2 Casual Dining Restaurant and Boilerless Steamer

Southern California Site #3 (SC3): Corporate Cafeteria Kitchen – Irvine

This site is a corporate cafeteria kitchen with a floor-mounted, 2-compartment, 6-pan, boiler-based gas steamer rated at 200,000 Btu/h. The steamer had connections for boiler fill/refill and condensate-cooling water. It used an unfiltered cold-water supply for condensate cooling and a filtered hot-water supply for the boiler fill/refill. Only the condensate-cooling water consumption was monitored.

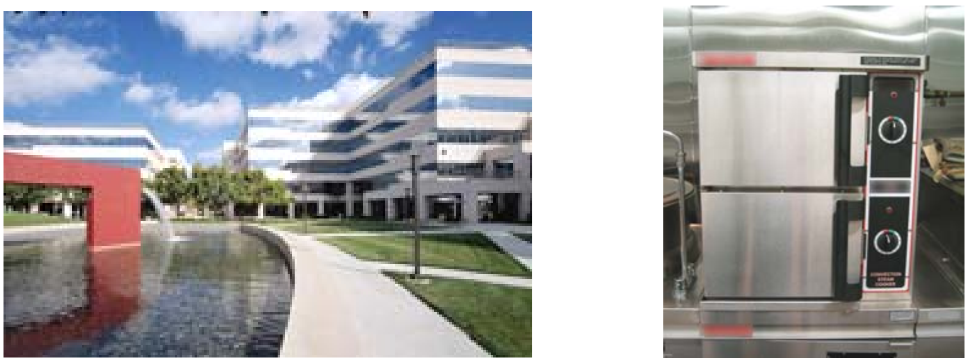

Figure 6. SC3 Corporate Cafeteria Kitchen and Boiler-based Steamer

Southern California Site #4 (SC4): Hotel Banquet Kitchen – Long Beach

This was a large hotel banquet kitchen with a floor-mounted, 2-compartment, 6-pan, boiler-based gas steamer. The unit was rated at 300,000 Btu/h and had connections for generator fill/refill and condensate-cooling water, which shared a single cold, unfiltered water supply. The steamer's controls allowed it to be operated in a continuous-on manual mode or a timed mode.

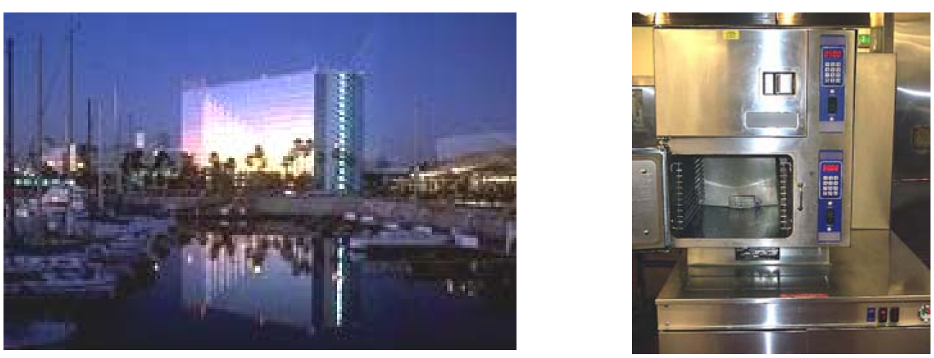

Figure 7. SC4 Hotel Banquet Kitchen and Boiler-based Steamer

Southern California Site #5 (SC5): Hotel Main Kitchen – Beverly Hills

This large hotel kitchen was equipped with a floor-mounted, 2-compartment, 6-pan, boiler-based gas steamer. The unit was rated at 90,000 Btu/h and used a single unfiltered cold-water supply for boiler fill/refill and condensate-cooling water. The steamer could be operated in continuous-steam or timed-steam modes.

Figure 8. SC5 Hotel Main Kitchen and Boiler-based Steamer

Southern California Site #6 (SC6): Fine Dining Restaurant – Redondo Beach

This fine dining restaurant had a countertop, 1-compartment, 4-pan, boiler-based, 9-kW electric steamer. The unit had connections for boiler fill/refill and condensate-cooling water, which shared a single, unfiltered cold-water supply line. A simple on-off switch controlled its operation.

Figure 9. SC6 Finel Dining Restaurant and Boiler-based Steamer

Northern California Sites

Northern California Site #1a (NC1a): Corporate Cafeteria Kitchen – San Ramon

This corporate cafeteria kitchen had a floor-mounted, 2-compartment, 6-pan, boiler-based electric steamer rated at 18 kW. A single cold-water supply connection was used for generator fill and condensate cooling. It incorporated controls with settings for constant or timed steaming and also included a hold setting.

Figure 10. NC1a Corporate Cafeteria Kitchen and Boiler-based Steamer

Northern California Site #1b (NC1b): Corporate Cafeteria Kitchen – San Ramon

This is the same corporate cafeteria kitchen as site NC1a but with 2 stacked, 6-pan (12 pans total), boilerless electric steamers rated at 8 kW each for a combined rating of 16 kW. These were connectionless steamers, which had no fill or drain lines. Control settings included continuous steaming, timed steaming, thermostat controlled steaming and a hold mode.

Figure 11. NC1b Corporate Cafeteria Kitchen and Stacked Boilerless Steamers

Northern California Site #2 (NC2): Casual Dining Restaurant – Livermore

This casual dining restaurant had a countertop, single-compartment, 5-pan, boiler-based electric steamer rated at 16.5 kW. A single, unfiltered cold-water supply was used for the generator fill and condensate-cooling water. The steamer control could be set to constant-steam or timed steaming modes.

Figure 12. NC2 Casual Dining Restaurant and Boiler-based Steamer

Northern California Site #3a (NC3a): University Cafeteria – Berkeley

This university cafeteria kitchen had a floor-mounted, 2-compartment, 10-pan, boiler-based electric steamer rated at 32 kW. Controls allow operation in either manual or timed modes. The boiler fill water was routed through an elaborate filtering system with limited capacity. Therefore, only the condensate-cooling water was monitored; it had no requirements for water quality, and city tap water was used.

Figure 13. NC3a University Cafeteria Kitchen and Boiler-based Steamer

Northern California Site #3b (NC3b): University Cafeteria – Berkeley

This steamer installation was the same as that in NC3a: a floor-mounted, 2-compartment, 10-pan, boiler-based, electric steamer rated at 32 kW with control settings for manual or timed modes. Only the unfiltered condensate-cooling water was monitored.

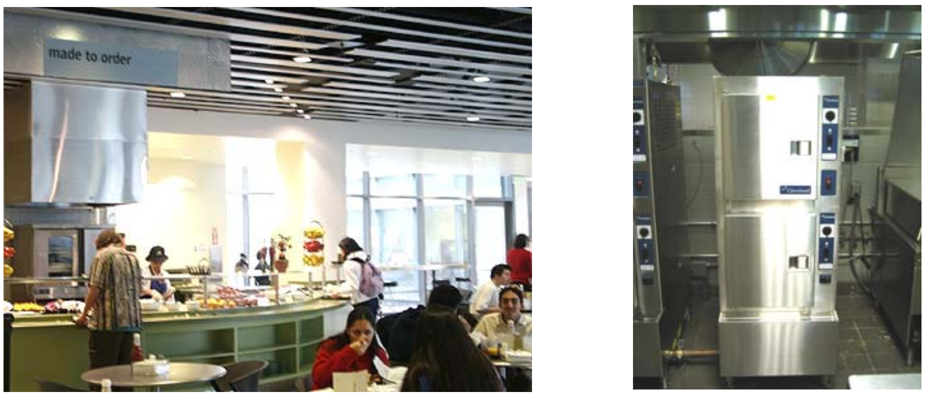

Figure 14. NC3b University Cafeteria Kitchen and Boiler-based Steamer

Northern California Site #4 (NC4): Country Club Kitchen – Alamo

This country club kitchen had a countertop, single-compartment, 6-pan, boilerless/connectionless, 6-kW electric steamer. The steamer was manually filled and drained and had no external water connections. Control settings allowed the unit to be operated in either continuous steaming, timed steaming, thermostat controlled steaming, or a hold mode.

Figure 15. NC4 Country Club Kitchen and Boilerless Steamer

Northern California Site #5 (NC5): Fine Dining Restaurant – Berkeley

This was a fine dining restaurant with a countertop, 1-compartment, 4-pan, boiler-based, 9-kW electric steamer with a simple on-off switch to control its operation. It used a single, unfiltered cold-water water supply for the generator fill/refill and condensate-cooling water.

Figure 16. NC5 Fine Dining Restaurant and Boiler-based Steamer

Northern California Site #6 (NC6): Fine Dining Restaurant – Oakland

This was a fine dining restaurant with a countertop, 1-compartment, 4-pan, boiler-based electric steamer. The unit was rated at 9 kW and used a single, unfiltered cold-water supply for the generator fill/refill and condensate-cooling water. It had a simple on-off switch for its control.

Figure 17. NC6 Fine Dining Restaurant and Boiler-based Steamer

Results and Discussion

A summary of the monitoring data from the different food service facilities is presented in Table 1. The results from each of the monitored sites follow, and the corresponding typical-day energy and water consumption profiles are presented in Figures 18 through 30. An analysis of the two sites where boilerless steamers replaced boiler-based units, along with the annual operating cost comparison for each steamer, are summarized and represented in Tables 2 and 3, and Figures 31 and 32.

Note: For boiler-based steamers that had a separate hot and/or filtered boiler or generator fill-water supply, only the condensate-cooling water was monitored, and monitoring of the boiler/generator fill consumption was not performed; while the majority of their water usage was attributable to the condensate-cooling water, the addition of the boiler fill-water quantity to the total would increase the actual average hourly consumption rate by an estimated 2-3 gal/h.

The boilerless steamer section in the summary table lists the measured energy consumption as well as the extrapolated daily water consumption, which is derived from the actual operating time multiplied by the nominal, 2-gal/h water consumption rate (laboratory test results have shown the actual water consumption to be less than 2 gal/h for the steamer models encountered in this study).

Depending on their controls, some of the steamers had the capability of being operated in idle or hold-mode settings that would deenergize the heating elements (or burners) and also stop water consumption during these periods. In these cases, only the periods of fully energized heating were used to calculate the operating times and average water and energy consumption rates. Furthermore, the monitored connectionless steamers had settings that allowed the internal heater controls to continually cycle the elements based on cavity temperature or pressure setpoints; the average energy rates were based on time-weighted averages, and are illustrated by the varying input rates in the graphed power profiles.

Table 1. Field Monitoring Results Summary

Location	Number of Compart-ments	Daily Operating Time (h)	Daily Water (gal/d)[1]	Water Rate (gal/h)[1, 2]	Daily Energy (kWh/d)	Avg. Energy Rate (kW)[2]
Boiler-based Steamers						
SC1 Casual Dining Restaurant	1	13.0	808	66.3	100.8	7.8
SC3 Corporate Cafeteria[3]	2	2.5	190[3]	37.0[3]	(gas)	(gas)
SC4 Hotel Banquet Kitchen	2	1.7	107	32.1	(gas)	(gas)
NC1a Corporate Cafeteria	2	8.4	479	27.9	104.1	6.2
NC2 Casual Dining Restaurant	1	3.1	128	41.6	25.1	8.1
NC3a University Cafeteria[3]	2	6.5	549[3]	42.2[3]	141.5	10.9
NC3b University Cafeteria[3]	2	4.9	421[3]	42.7[3]	103.7	10.6
NC5 Fine Dining Restaurant	1	14.6	644	44.1	64.4	4.4
NC6 Fine Dining Restaurant	1	11.0	340	30.9	85.2	7.7
Average		7.3	407	40.5	89.3	8.0
Boilerless Steamers						
SC2 Casual Dining Restaurant	1	1.6	3.2	2	12.2	7.6
NC1b Corporate Cafeteria	2	9.5	32.6	2	29.9	3.1
NC4 Country Club Kitchen	1	3.0	6.0	2	8.6	2.9
Average		4.7	13.9	2	16.9	4.5

[1] *Daily water consumption for boilerless* steamers *is extrapolated based on actual operating time and the laboratory-determined nominal water consumption rate of 2 gal/h.*

[2] *Average energy rates and boiler-based water consumption rates are derived from daily consumption and daily operating time values. Values are presented on a per-compartment average basis.*

[3] *Locations where only the condensate-cooling water was monitored; measurement of the boiler/generator fill consumption was not performed.*

Typical-Day Energy and Water Consumption

Southern California Site #1 (SC1): Casual Dining Restaurant – Rancho Cucamonga

The steamer located at this restaurant was a 1-compartment, 3-pan capacity, 8.3-kW electric boiler-based steamer. During the 30 days it was monitored, the steamer's average operating time (in a fully energized heating state) was 13 hours per day. On average, the steamer consumed 100.8 kWh of electricity per day, with a minimum of 54.7 kWh and a maximum of 134.0 kWh per day. Daily water consumption ranged between 439 and 1419 gallons per day and averaged 808.0 gallons per day. This equates to an average water consumption rate of 66.3 gallons per hour. A graph of the typical-day steamer energy and water profile is presented in Figure 18. The peak steamer operating hours of 6 AM to 12 AM are represented in the profile. The steamer had two modes, timed and manual. FSTC monitoring data showed that the morning crew often used the steamer in its full power, continuous-on manual mode and the evening crew used the steamer in its more efficient timed mode. This is illustrated in the graph by the continuous power segment from 6 AM to 3 PM, and the cycling segment from 3 PM to 12 AM.

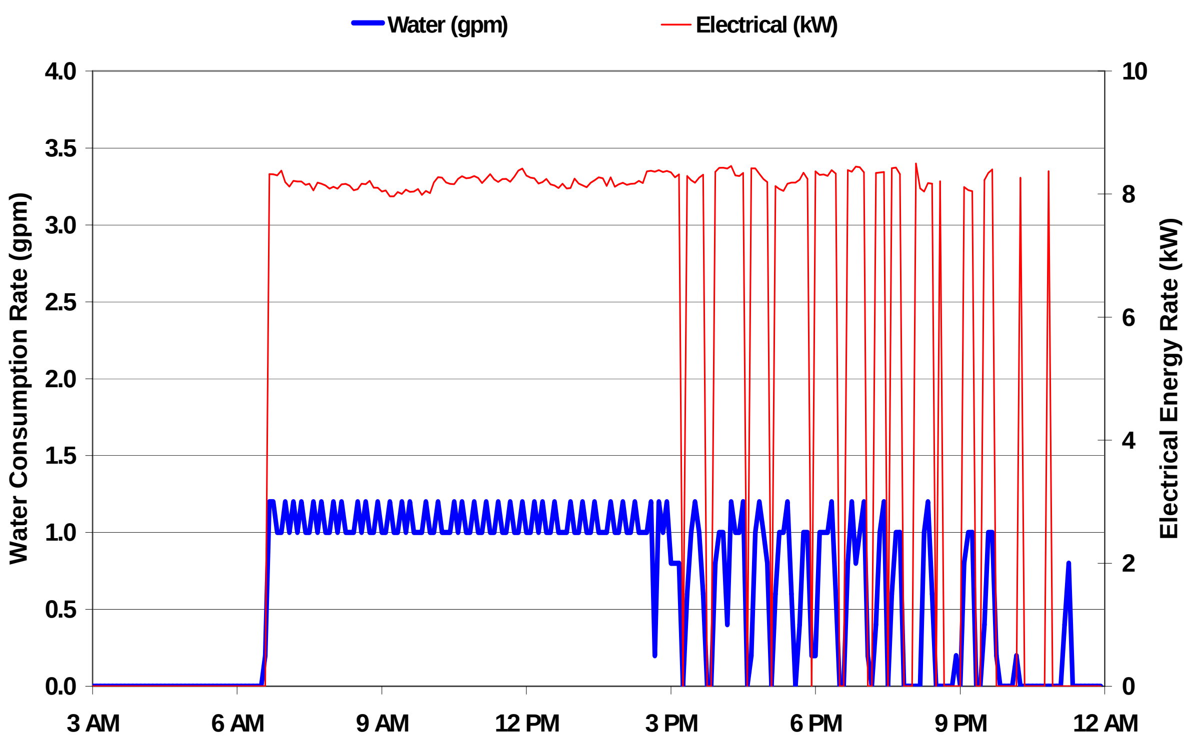

Figure 18. SC1 Boiler-based Steamer Typical-Day Energy and Water Profile

Southern California Site #2 (SC2): Casual Dining Restaurant – Corona

The steamer at this restaurant was a 1-compartment, 6-pan capacity, 8-kW electric connectionless steamer. During the 30 days that it was monitored, the steamer was in a fully energized heating state an average of 1 hour and 34 minutes per day. Although the actual time of use was longer (i.e., cooking periods), the steamer's controls cycled the heating elements depending on the internal compartment temperature and pressure conditions while cooking. On average, the steamer consumed 12.2 kWh of electricity, with a minimum of 7.6 kWh and a maximum of 14.6 kWh per day. Using the nominal 2-gal/h water consumption rate in conjunction with the average fully energized hours per day yields an average daily water consumption of 3.2 gallons per day. A graph of the typical-day steamer energy profile is provided in Figure 19.

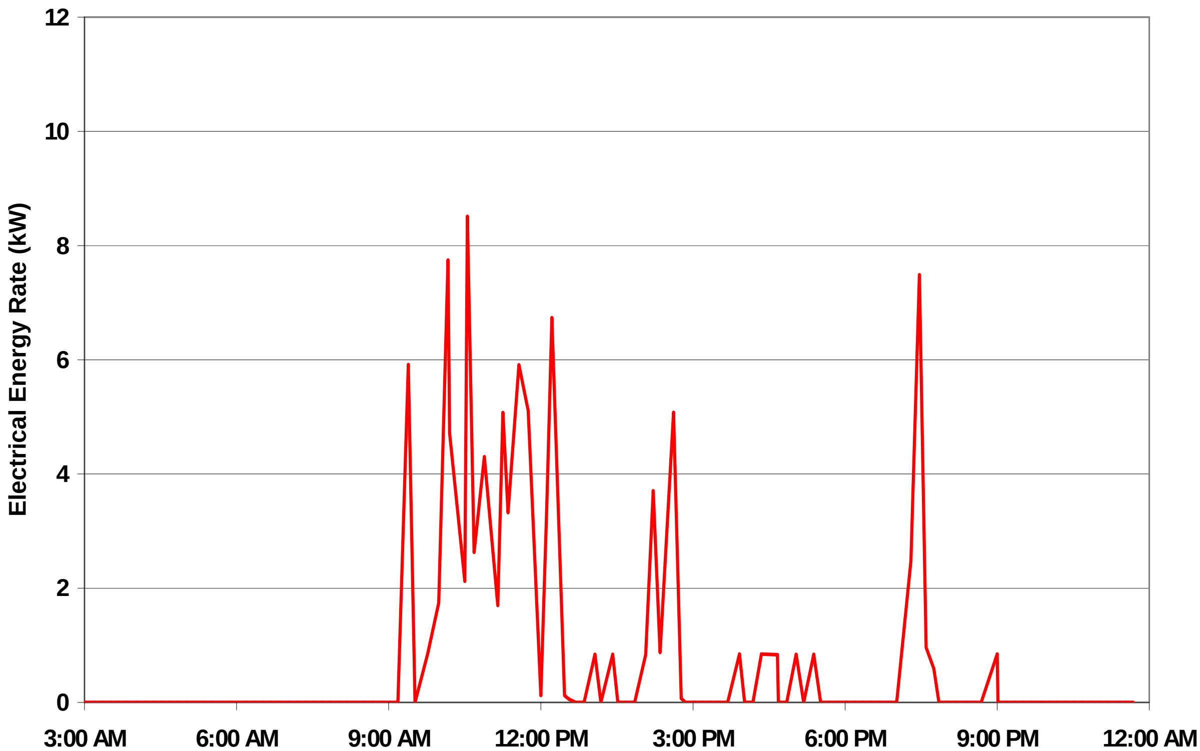

Figure 19. SC2 Boilerless Steamer Typical-Day Energy Profile

Southern California Site #3 (SC3): Corporate Cafeteria Kitchen – Irvine

The steamer in this facility was a 2-compartment, 6-pan capacity, 200,000 Btu/h gas boiler-based steamer. During the 30 days it was monitored, the steamer was in a full-steaming state an average of 2 hours and 32 minutes per day. On average, the steamer consumed 190 gallons of water (condensate-cooling) per day and ranged between a minimum of 33 gallons and a maximum of 718 gallons per day. The average hourly water consumption rate was 73.9 gallons per hour in condensate-cooling water alone. A graph of the typical-day condensate-cooling water profile is provided in Figure 20.

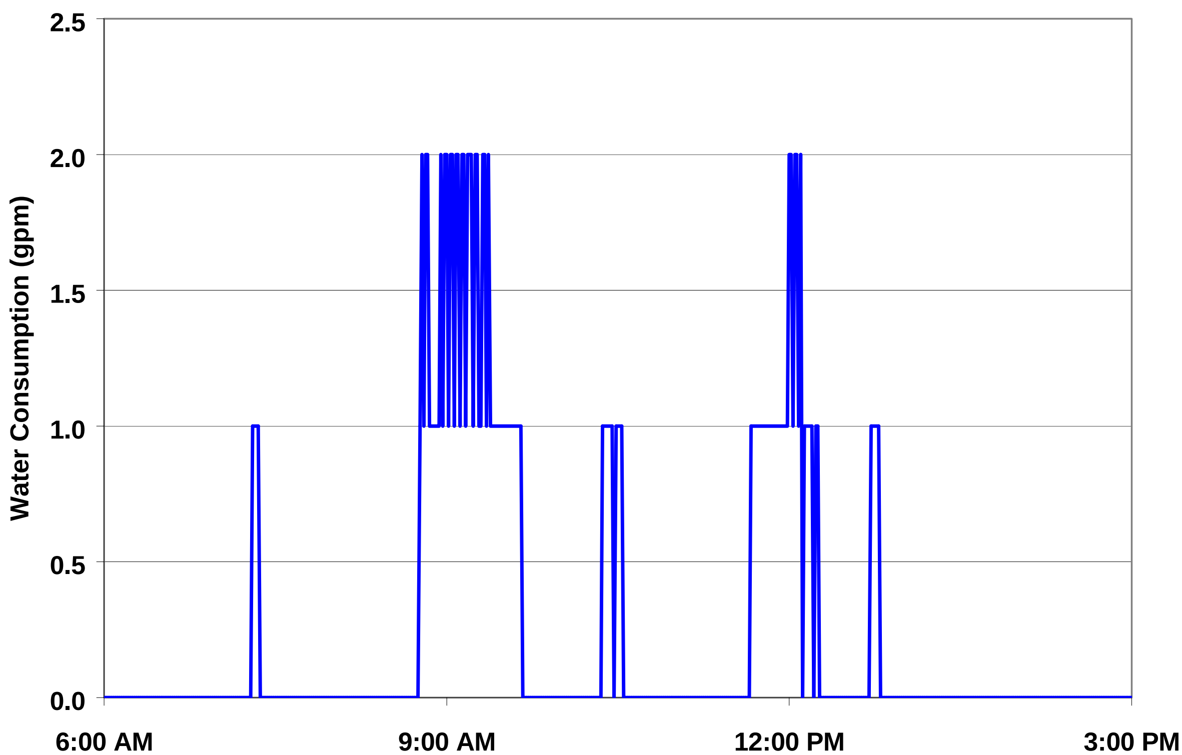

Figure 20. SC3 Boiler-based Steamer Typical-Day Water Consumption Profile

Southern California Site #4 (SC4): Hotel Banquet Kitchen – Long Beach

The steamer in this facility was a 2-compartment, 6-pan capacity, 300,000 Btu/h gas boiler-based steamer. Through the 30-day monitoring period, the steamer was in a full-steaming state an average of 1 hour and 41 minutes per day. The steamer consumed an average of 106.6 gallons of water per day, with a minimum of 54 gallons and a maximum of 177 gallons per day. The average hourly water consumption rate was 64.1 gallons per hour. A graph of the typical-day steamer water consumption profile is provided in Figure 21, which shows steamer operating hours between 6 AM to 12 AM. The 2-gpm water consumption peaks are indicative of the higher flow rate during the preheat/generator fill cycle in the morning and the generator blow-down rinsing cycle at night.

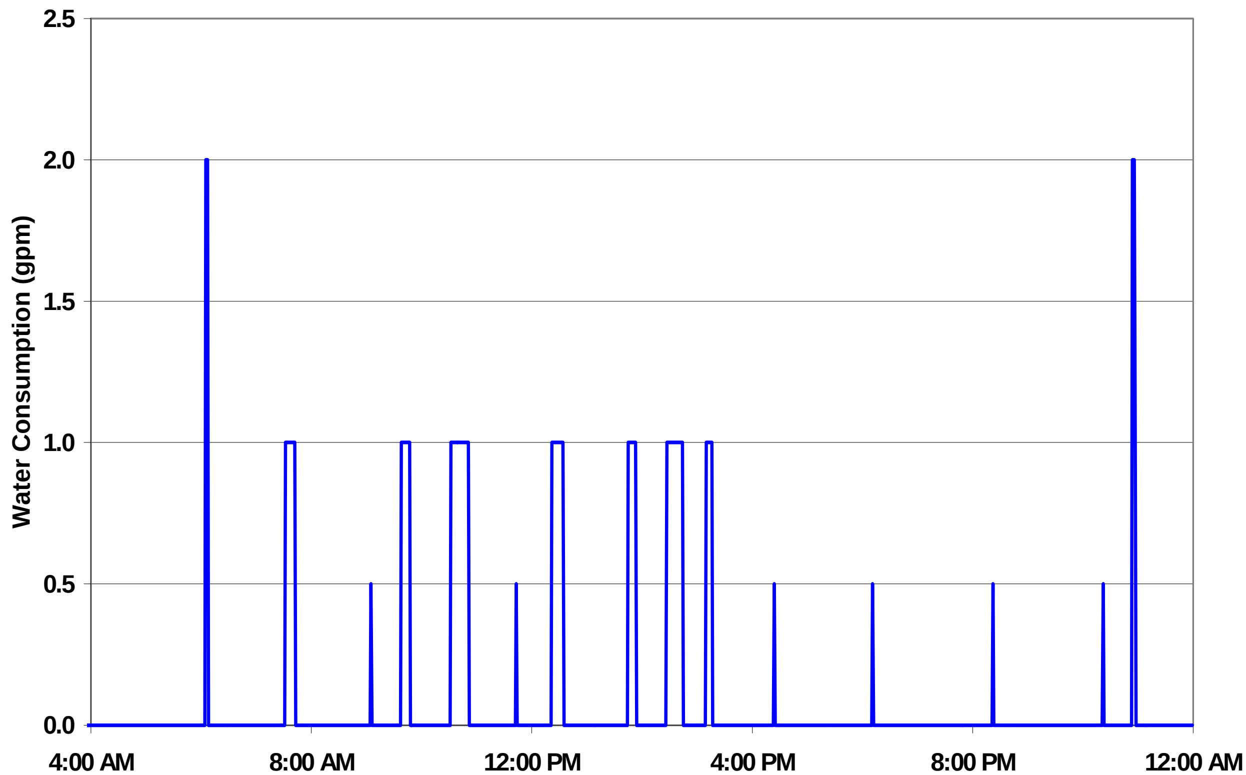

Figure 21. SC4 Boiler-based Steamer Typical-Day Water Consumption Profile

Southern California Site #5 (SC5): Hotel Main Kitchen – Beverly Hills

The steamer in this facility was a 2-compartment, 6-pan capacity, 90,000 Btu/h gas boiler-based steamer. Logging equipment was installed to monitor both the generator fill and condensate-cooling water. Upon retrieval of the data and instrumentation at this location, it was discovered that the water meter was irreparably damaged (the entire odometer register and contact output module were missing) and the MicroDataLogger was missing from inside the steamer's lower cabinet where it had been installed. The only data available is for the first few minutes when the data logger was being tested to confirm it was recording data correctly. This data showed an instantaneous water consumption rate of 48 gallons per hour with both compartments steaming. Data from site SC5 were not included in the final results calculations.

Southern California Site #6 (SC6): Fine Dining Restaurant – Redondo Beach

The steamer in this restaurant was a 1-compartment, 4-pan capacity, 9-kW electric boiler-based steamer. Data loggers were installed to monitor water and energy consumption. After analyzing the data, it was determined that although the steamer was cooking adequately, it was experiencing a partial malfunction: the water consumption rate was lower than it should be for this particular steamer, and at the same time, the water flow never stopped, even when the steamer was turned off at night. The low flow rate is likely the result of a clogged condensate-cooling water port, and the uninterrupted steady water flow can be attributed to a leaking internal shut-off solenoid valve. In this operating state, the steamer consumed an average of 360.0 gallons per day—or a constant 15 gallons per hour. Because of the partial malfunction, data from site SC6 were not included in the final results calculations.

Northern California Site #1a (NC1a): Corporate Cafeteria Kitchen – San Ramon

The steamer in this facility was a 2-compartment, 6-pan capacity, 18-kW electric boiler-based steamer. During the 30 days it was monitored, the steamer was in a full-steaming state an average of 8 hours and 26 minutes per day. On a typical day, the steamer consumed 104.1 kWh of electricity, with a minimum of 46.7 kWh and a maximum of 170.2 kWh per day. Daily water consumption for this steamer ranged between 210 and 887 gallons per day and averaged 478.6 gallons per day, which equates to an average consumption rate of 55.7 gallons per hour, normalized to 27.9 gal/h per compartment. A graph of the typical-day steamer energy and water profile is provided in Figure 22.

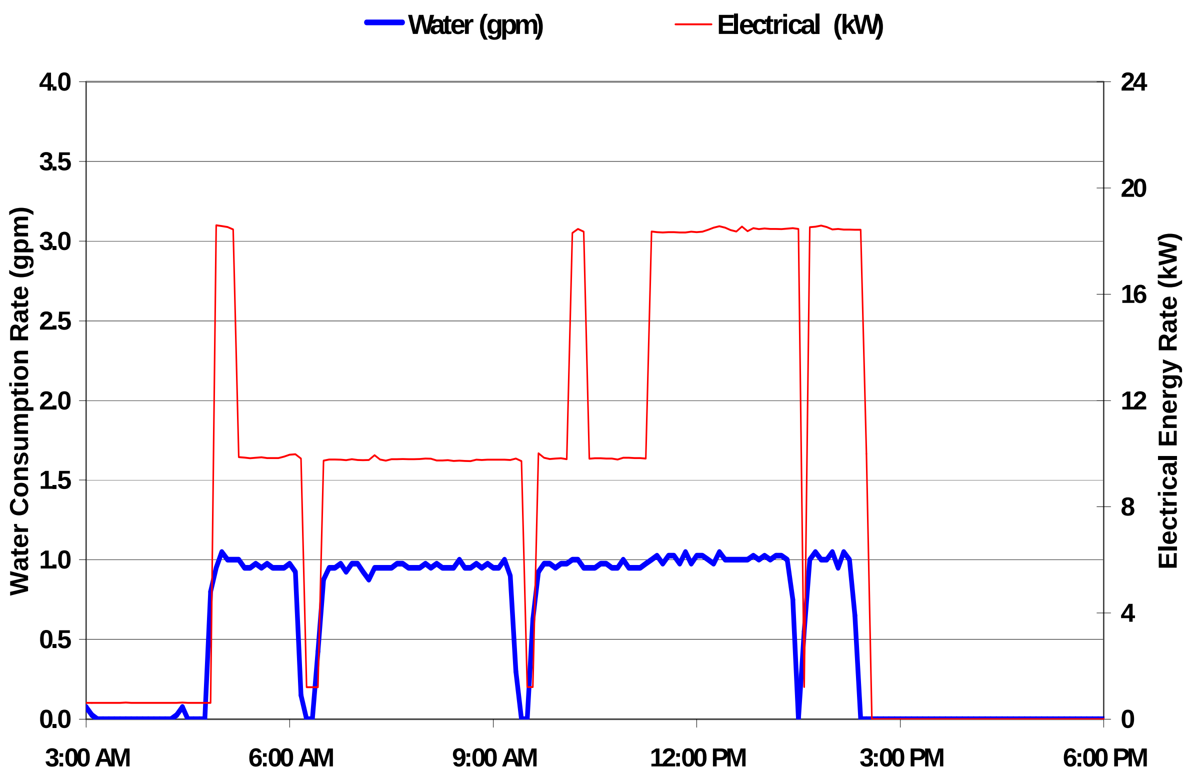

Figure 22. NC1a Boiler-based Steamer Typical-Day Energy and Water Profile

Northern California Site #1b (NC1b): Corporate Cafeteria Kitchen – San Ramon

This facility had two (double stacked), 6-pan capacity, 8-kW electric connectionless steamers. During the 30 days the steamers were monitored, the upper steamer was on (in a fully energized heating state) an average of 9 hours and 30 minutes per day while the lower steamer was on (fully energized heating) an average of 6 hours and 48 minutes per day. On average, the steamers consumed 29.9 kWh of electricity combined, with 17.8 kWh/day used by the upper steamer and 12.1 kWh/day used by the lower steamer. Multiplying the nominal 2 gallons per hour water consumption rate value by the daily operating time yields an average daily water consumption of 19.0 gallons per day for the upper unit and 13.6 gallons per day for the lower unit, for a total of 32.6 gallons per day. Graphs showing the typical-day steamer energy and water profiles are in Figure 23 and 24.

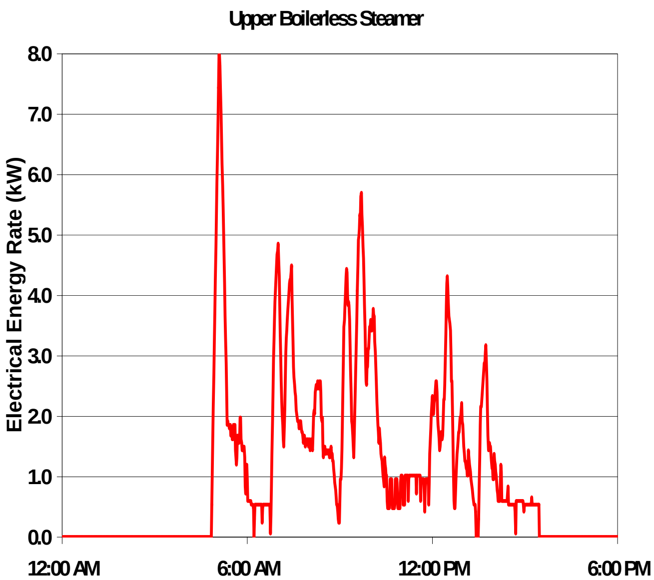

Figure 23. NC1b Upper Boilerless Steamer Typical-Day Electrical Energy Profile

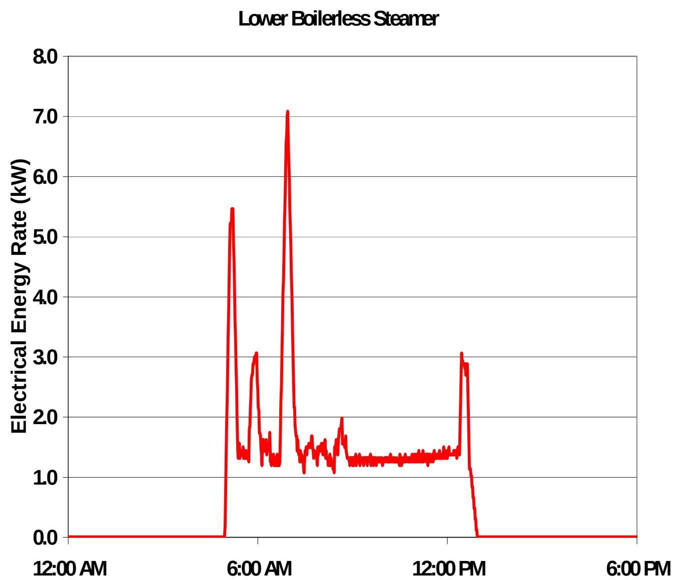

Figure 24. NC1b Lower Boilerless Steamer Typical-Day Electrical Energy Profile

Northern California Site #2 (NC2): Casual Dining Restaurant – Livermore

The steamer in this facility was a 1-compartment, 5-pan capacity, 16.5-kW electric boiler-based steamer. Of the 30 days it was monitored, the steamer was in a full-steaming state an average of 3 hours and 8 minutes per day. The average daily energy consumption was 25.1 kWh per day, with a minimum of 6.4 kWh and a maximum of 49.1 kWh per day. It was noted that one set of heating elements was not functioning, and the steamer was operating at about half the rated power (8.1 kW vs.16.5 kW) but still performed well. The effects on the overall water consumption were negligible since the condensate-cooling water flow rate was unaffected. The daily water consumption ranged between 37 and 236 gallons per day and averaged 127.7 gallons per day, which equates to an average water consumption rate of 41.6 gallons per hour. The steamer's energy and water profiles of a typical day are represented in Figure 25.

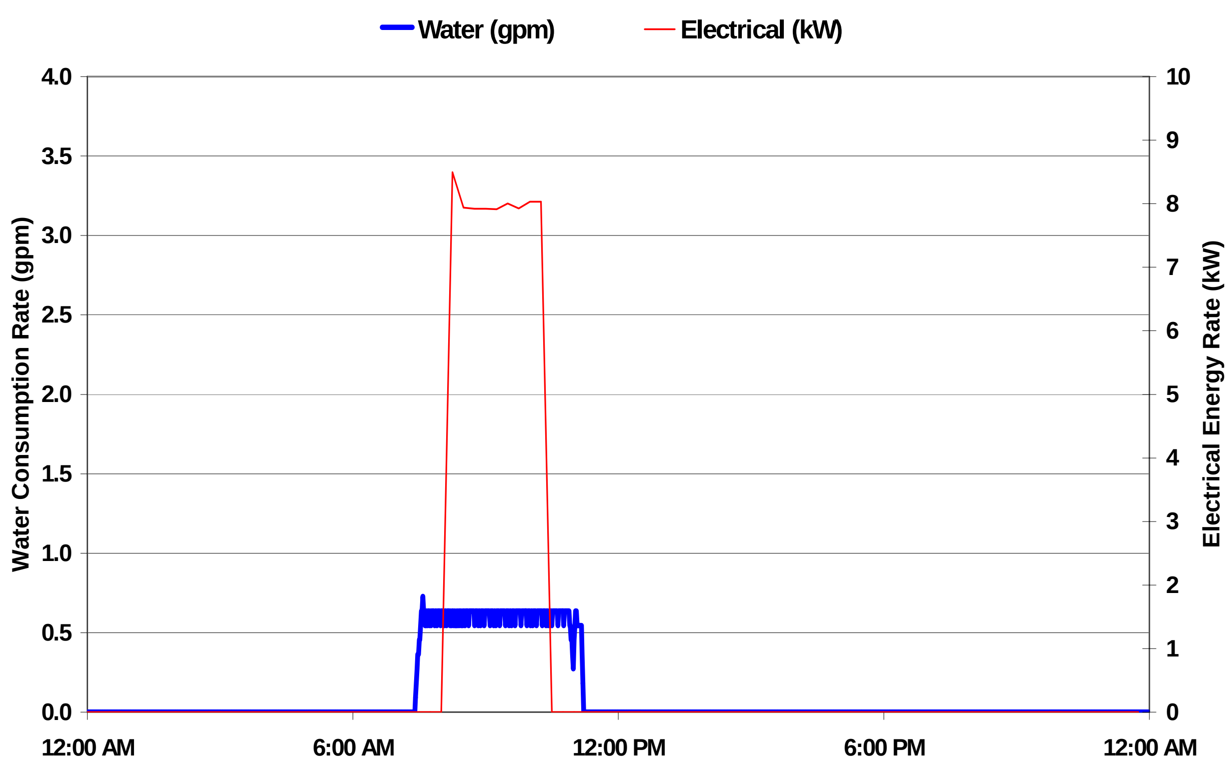

Figure 25. NC2 Boiler-based Steamer Typical-Day Energy and Water Profile

Northern California Site #3a (NC3a): University Cafeteria – Berkeley

This facility employed a 2-compartment, 10-pan capacity, 32.6-kW electric boiler-based steamer with separate connections for boiler refill and condensate-cooling water. Since the steamer had an elaborate water filtration system for the boiler fill water, it was decided that only the condensate-cooling portion of the water would be measured. During the 30 days it was monitored, the steamer was in fully energized steaming state an average of 6 hours and 30 minutes per day, using both compartments 34.5% and one compartment 51.5% of the time. The steamer consumed 141.5 kWh per day on average, with a minimum of 27.0 kWh and a maximum of 237.6 kWh per day. Daily water consumption (condensate-cooling only) ranged between 114 and 933 gallons per day, and the average was 548.9 gallons per day, yielding an hourly consumption rate of 84.4 gal/h for both compartments and 42.2 gal/h when normalized for each compartment. The profiles in Figure 26 represent the steamer's consumption rates on a typical day.

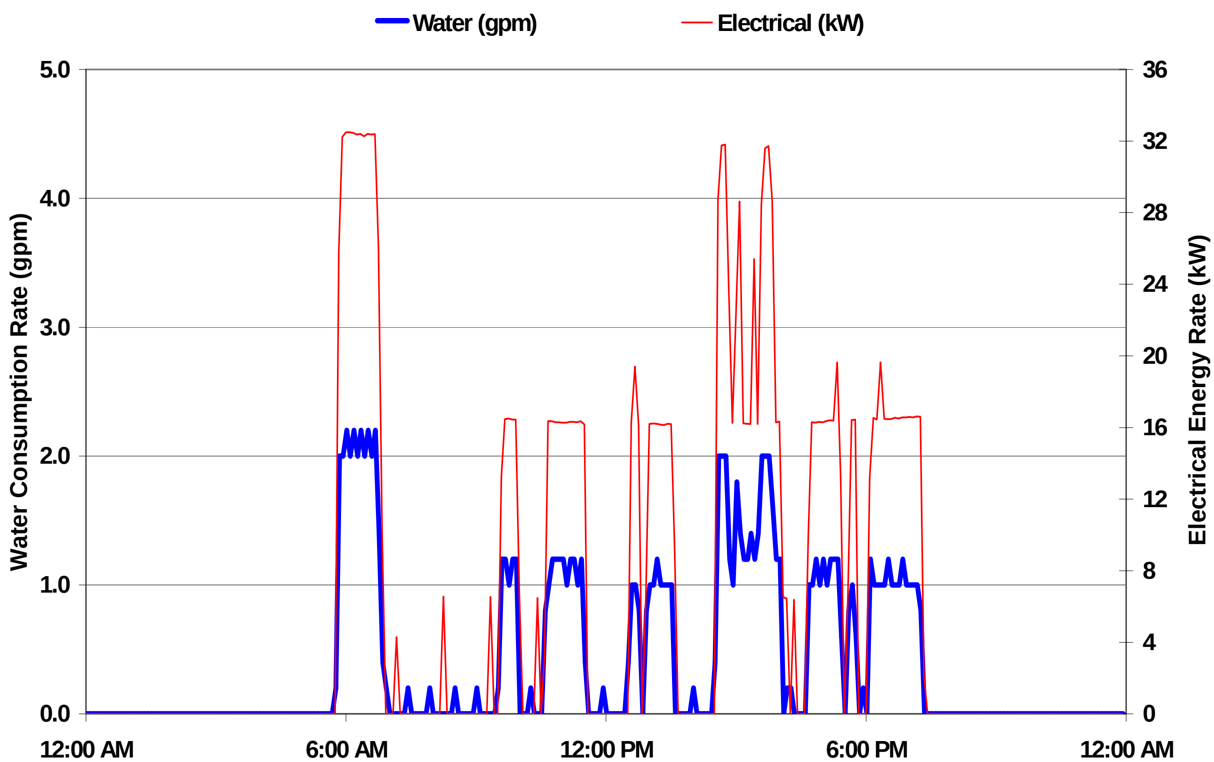

Figure 26. NC3a Boiler-based Steamer Typical-Day Energy and Water Profile

Northern California Site #3b (NC3b): University Cafeteria – Berkeley

The facility employed another 2-compartment, 10-pan capacity, 32.6-kW electric boiler-based steamer with separate connections for boiler refill and condensate cooling. Only the condensate-cooling water consumption was recorded. Of the 30 days it was monitored, the steamer was in a full-steaming state an average of 4 hours and 56 minutes per day. The steamer consumed an average of 103.7 kWh per day of electricity, with a minimum of 48.0 kWh and a maximum of 163.7 kWh per day. Daily water consumption (condensate-cooling only) ranged between 205 and 657 gallons per day; the average was 421.3 gallons per day, translating to an hourly consumption rate of 85.4 gal/h for both compartments or the equivalent of 42.7 gal/h when normalized for each compartment. The profiles in Figure 27 show the steamer's water and energy usage patterns of a typical day.

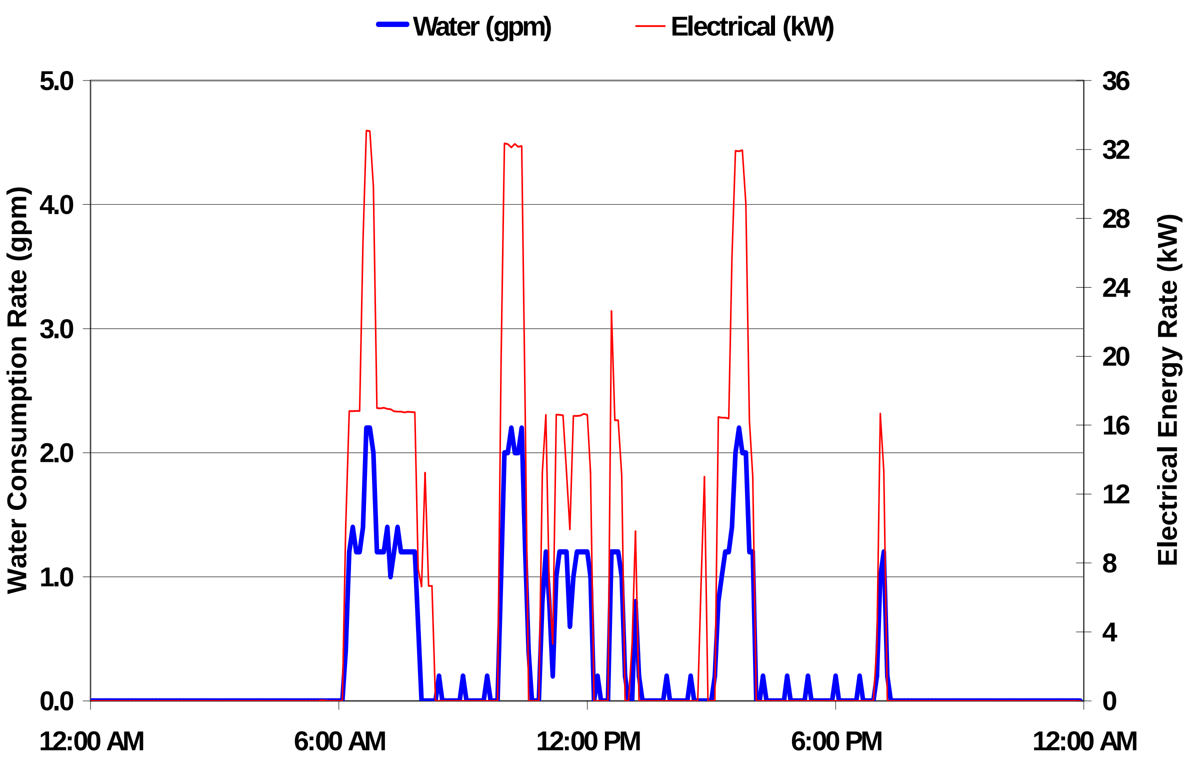

Figure 27. NC3b Boiler-Based Steamer Typical-Day Energy and Water Profile

Northern California Site #4 (NC4): Country Club Kitchen – Alamo

The steamer in this facility is a 1-compartment, 6-pan capacity, 8.0-kW electric connectionless steamer. Logging equipment was installed to monitor the electrical energy consumption, and the water consumption was extrapolated from the operating time and the predetermined water consumption rate of a nominal 2 gal/h. The steamer was in a fully energized steaming state for an average of 3 hours and 2 minutes per day during the 31 days it was monitored. At a water consumption rate of 2 gal/h, the steamer used an average of 6 gallons per day. The steamer's average daily electrical energy consumption was 8.6 kWh per day, with a minimum of 2.3 kWh and a maximum of 19.1 kWh per day. A graph of the typical-day energy profile is provided in Figure 28.

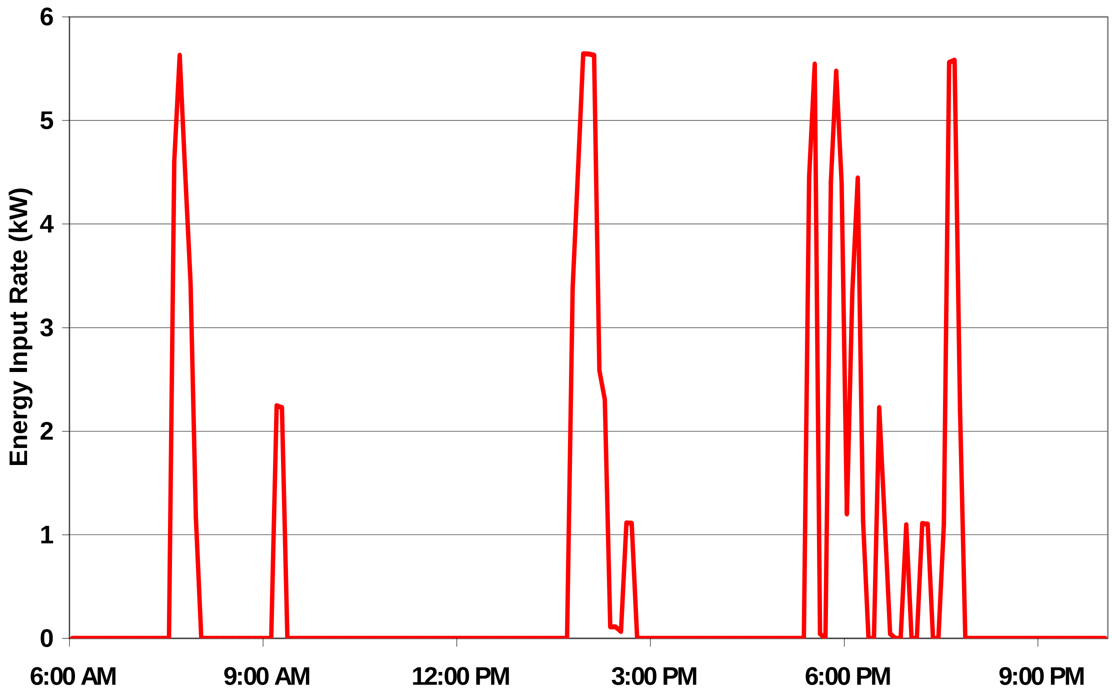

Figure 28. NC4 Boilerless Steamer Typical-Day Electrical Energy Profile

Northern California Site #5 (NC5): Fine Dining Restaurant – Berkeley

The steamer in this facility was a 1-compartment, 4-pan capacity, 9-kW electric boiler-based steamer. Data loggers were installed to monitor and record water and energy consumption. The steamer was monitored for 33 days, during which its average daily operating time was 14 hours and 36 minutes per day. Daily energy consumption averaged 64.4 kWh/day and ranged between 57.9 and 70.8 kWh/day. The daily water consumption was 644.0 gallons per day and ranged between 569 to 694 gallons per day. The average hourly water consumption rate was 44.1 gal/h. Although this steamer's heater elements were controlled only by the main on-off switch, it was noted the steamer would operate at its rated energy input rate briefly and only when first turned on in the mornings, and would operate at only about half-power thereafter. A kitchen employee reported that the steamer performed adequately but with the penalty of requiring a longer cook time. A failing pole on the three-phase heating element contactor was suspected to be the cause. Water consumption was unaffected, as it was controlled by a solenoid that was open whenever the unit was switched on. A graph of the steamer's typical-day energy and water consumption profiles is provided in Figure 29.

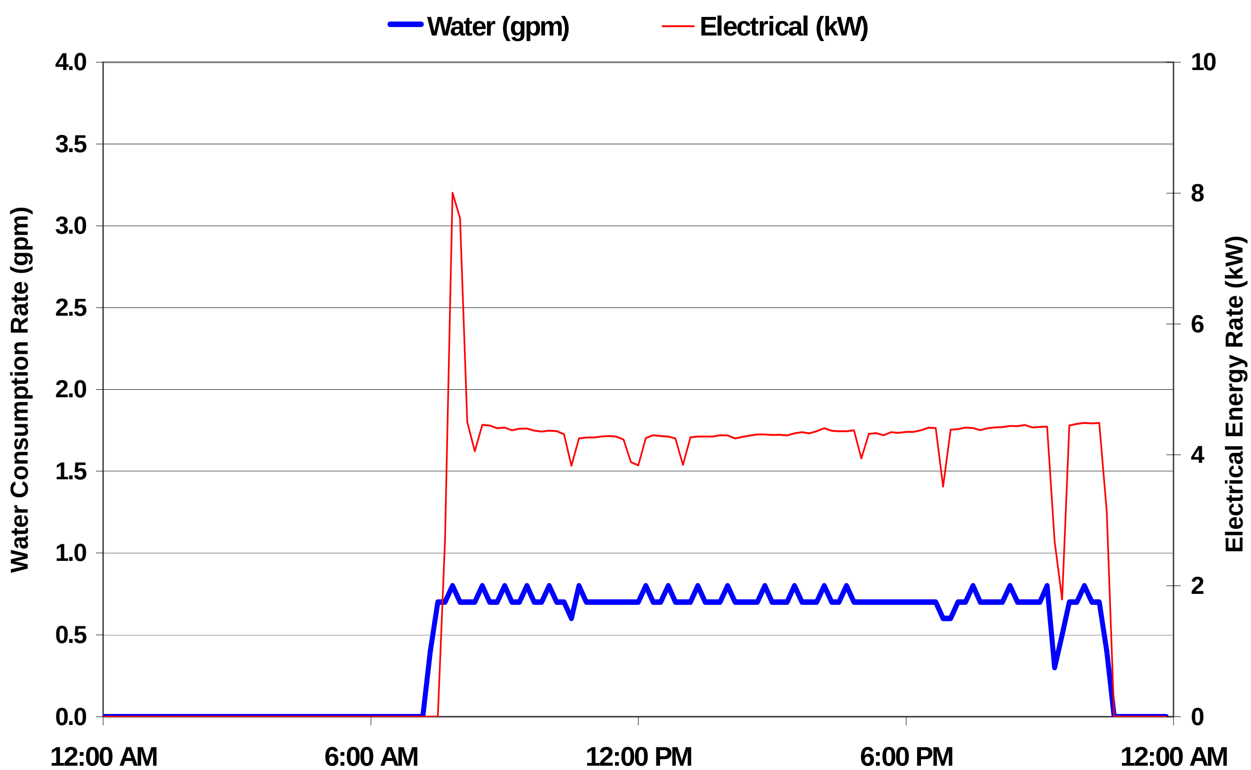

Figure 29. NC5 Boiler-based Steamer Typical-Day Profile

Northern California Site #6 (NC6): Fine Dining Restaurant – Oakland

The steamer in this facility was a 1-compartment, 4-pan capacity, 9-kW electric boiler-based steamer. Data loggers were installed to monitor water and energy consumption for a 31-day period. The steamer's average operating time was 11.0 hours per day. The average daily energy consumption was 85.2 kWh/day and ranged between 41.8 and 125.5 kWh/day. Daily water consumption ranged from 166 to 473 gallons per day. The average was 340 gallons per day, which equates to an average water consumption rate of 30.9 gal/h. A graph of the typical-day energy and water consumption profiles is provided in Figure 30.

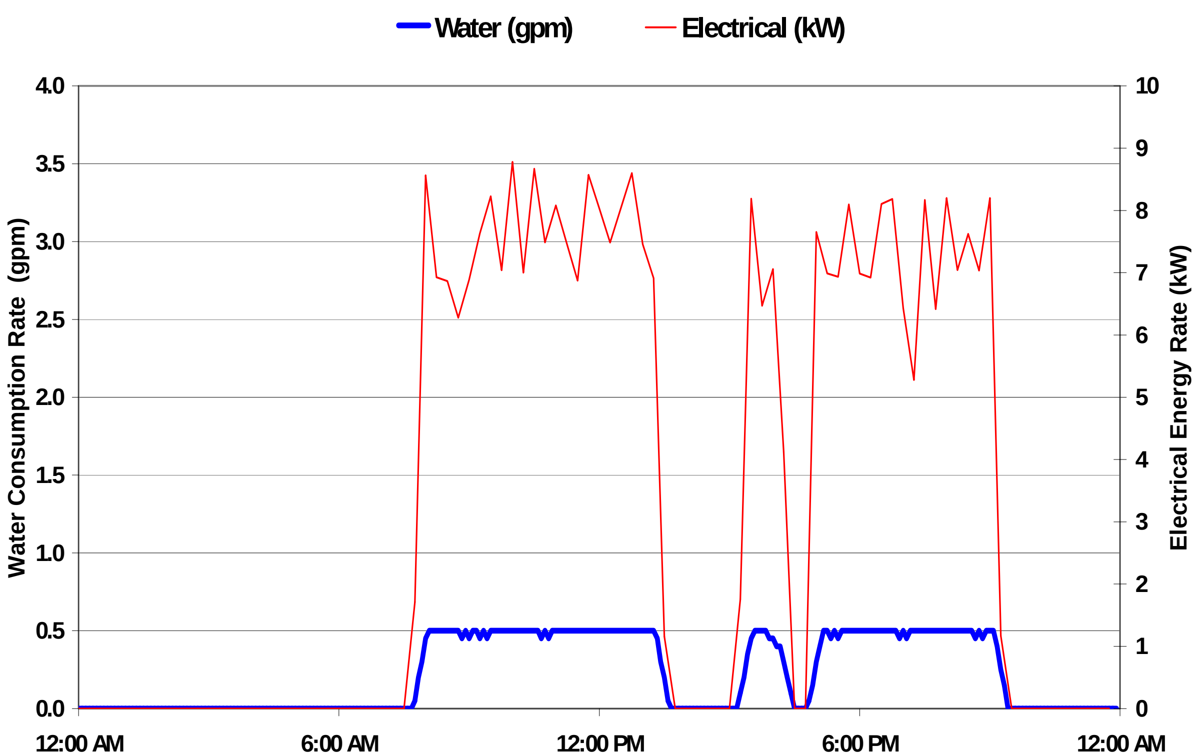

Figure 30. NC6 Boiler-based Steamer Typical-Day Profile

Steamer Operation Cost Comparison

The FSTC team monitored and compared a boiler-based steamer and its connectionless replacement at two locations: one in southern California (SC1 and SC2) and one in northern California (NC1a and NC1b).

Operating Cost Comparison Example #1

SC1 and SC2 are identical restaurants from the same chain, located less than 20 miles apart in neighboring towns in southern California. Since the menu items and food cooked were the same and it was determined from store records that the customer volume was equivalent, the two restaurants effectively could be compared to show a "before and after" savings effect from replacing a boiler-based steamer with a connectionless unit. Table 2 and Figure 31 below show the comparative steamer water and energy costs in these facilities. The connectionless steamer cost $7 per year for combined water and sewer and $571 per year for electricity, totaling $578 per year. On the other hand, the boiler-based steamer cost $1,944 per year for water and $4,717 per year for electricity, for a total annual cost of $6,661. Although variances in steamer production and kitchen operation may slightly affect the usage at each location, there was clearly an operational cost benefit to the boilerless technology. With a $6,083 per year difference in combined water and energy costs, the connectionless steamer would pay for itself within one year.

Table 2. Yearly Steamer Operating Cost (#1)

	Boiler-based	Boilerless
Water	$1,944	$7
Energy	$4,717	$571
Total	$6,661	$578
	Yearly Savings	*$6,083*

Values based on $0.13/kWh and combined water/sewer rate of $5.00/100 cu.ft. for steamer operating 360 days per year.

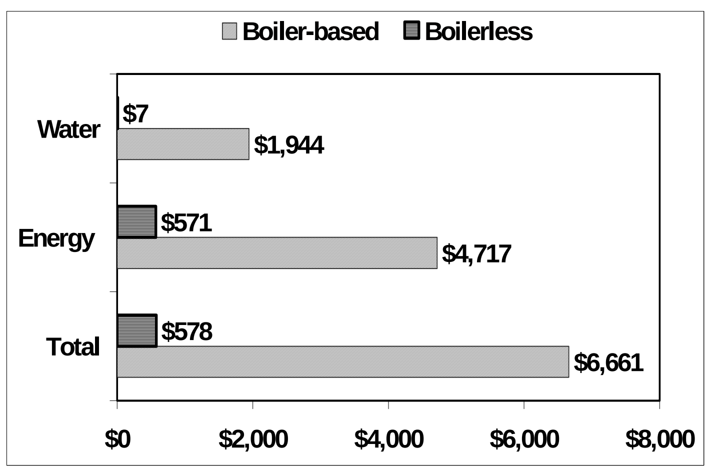

Figure 31. Yearly Operation Cost (#1): Boiler-based vs. Boilerless

Operating Cost Comparison Example #2

NC1a and NC1b were steamer installations operated within the same kitchen facility. NC1a was a 2-compartment, 6-pan capacity, electric boiler-based steamer rated at 18 kW and was replaced with NC1b, a double-stacked connectionless steamer configuration with a 12-pan total capacity with an input rate of 16 kW (8 kW each). Table 3 below shows the energy and water/sewer consumption costs for each setup. Figure 32 illustrates the respective operating costs and savings realized when this site replaced the boiler-based unit with a double-stacked connectionless configuration. Operating 260 days per year, yearly utility costs were calculated to be $4,352 for the boiler-based steamer and $1,068 for the stacked connectionless steamers. The annual savings achieved were approximately $3,284.

Table 3. Yearly Steamer Operating Cost (#2)

	Boiler-based	Boilerless
Water	$833	$57
Energy	$3,519	$1,011
Total	$4,352	$1,068
	Yearly Savings	*$3,284*

Values based on $0.13/kWh and combined water/sewer rate of $5.00/100 cu.ft. for steamer operating 260 days per year.

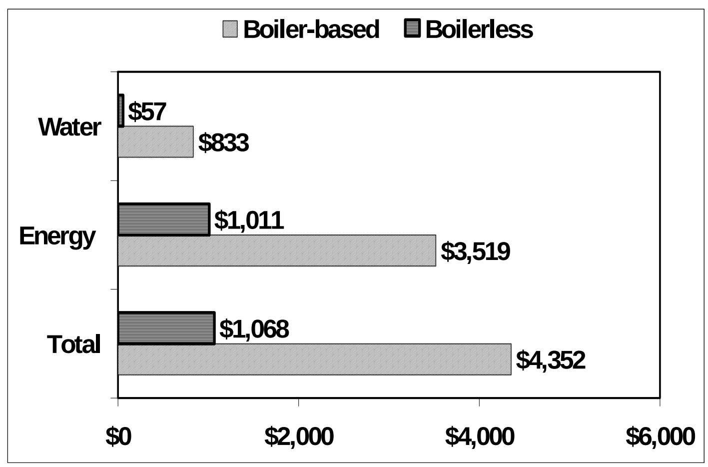

Figure 32. Yearly Operation Cost (#2): Boiler-based vs. Boilerless

Conclusions and Recommendations

The study confirmed that boiler-based steamers consume significantly more water than compartment steamers incorporating the “connectionless” or “boilerless” technology. Applying the nominal savings of 40 gal/h per compartment, the water-saving potential of a two-compartment steamer operating 12 hours per day would be equivalent to an acre-foot of water use per year. For a single compartment steamer that was operated 6-hours per day (approximating the average 7.3 hours for the ten boiler-based steamer sites), the water savings potential would be in the order of 0.25 acre-feet per year per steamer compartment. Applying this more conservative value of 0.25 acre-foot savings to each boiler-based steamer replaced by a connectionless unit, the statewide conservation impact could be in the order of 3750 acre-feet per year by retrofitting 15,000 units. This would prorate on a population basis to an annual savings of 1500 acre-feet in the Metropolitan Water District service area. These water savings projections indicate that there is sufficient support for the development of utility incentive and/or educational programs to promote the purchase of water-efficient connectionless steamers. Furthermore, the EPA has already recognized the majority of boilerless steamers as Energy Star® qualified commercial products.

This field-monitoring project clearly demonstrated that the installation of high-efficiency steamers would yield lower utility costs due to significantly lower water and energy consumption. For some large-scale food service operations and institutions, the use of boilerless steamers may not be an option as their production requirements necessitate the higher constant steaming power and speed of the larger, high capacity, boiler-based models. However, there are certainly many commercial kitchens that can take advantage of the benefits of boilerless steamers—they are easier to install and maintain, and are absolutely more water and energy efficient—a win-win combination for the food service operator.

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Glossary

Boiler
Self-contained electric, gas, or steam coil powered vessel wherein water is boiled to produce steam for the steam cooker. Also called a steam generator.

Condensate
A mixture of condensed steam and cooling water, exiting the steam cooker and directed to the floor drain.

Energy Efficiency (%)

The quantity of energy input to the food products; expressed as a percentage of the quantity of energy input to the appliance.

Energy Input Rate (kW or kBtu/h)
Energy Consumption Rate
Energy Rate

The peak rate at which an appliance will consume energy, typically reflected during preheat.

Measured Input Rate (kW or Btu/h)
Measured Energy Input Rate
Measured Peak Energy Input Rate

The maximum or peak rate at which an appliance consumes energy, typically reflected during appliance preheat (i.e., the period of operation when all burners or elements are "on").

Preheat Energy (kWh or Btu)
Preheat Energy Consumption

The total amount of energy consumed by an appliance during the preheat period.

Preheat Rate (°F/min)

The rate at which the cooking surface heats during a preheat.

Production Capacity (lb/h)
The maximum production rate of an appliance while cooking a specified food product in accordance with the heavy-load cooking test.

Rated Energy Input Rate
(kW, W or Btu/h, Btu/h)
Input Rating (ANSI definition)
Nameplate Energy Input Rate
Rated Input

The maximum or peak rate at which an appliance consumes energy as rated by the manufacturer and specified on the nameplate.

Steam Cooker
Cooking appliance wherein heat is imparted to food in a closed compartment by direct contact with steam. The compartment can be at or above atmospheric pressure. The steam can be static or circulated.

Test Method

A definitive procedure for the identification, measurement, and evaluation of one or more qualities, characteristics, or properties of a material, product, system, or service that produces a test result.

Typical Day

A sampled day of average appliance usage based on observations.

Water Consumption Rate (gal/h)

Water consumed by the steam cooker. Includes both water used in the production of steam and cooling water (if applicable) for condensing/ cooling unused steam.