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Operating Guidelines for Advanced Water Heating within the Foodservice Industry

Improving Operational Performance of Commercial Foodservice Water Heating Systems

The purpose of this document is to help commercial kitchen operators get the most out of their existing hot water systems. This guide covers opportunities to optimize commercial kitchen hot water systems throughout various stages of the equipment life cycles, best practices in using hot water equipment efficiently, routine maintenance practices, and planning practices for equipment burnout with options to support decarbonization. Included in this guide are templates for start-up and shut-down procedures, maintenance checklists, and scheduling charts. For further information around designing new commercial kitchen layouts and choosing hot water equipment (such as water heaters and dish washing machines), please refer to the accompanying guide, Technical Design Guide for Advanced Water Heating within the Foodservice Industry.

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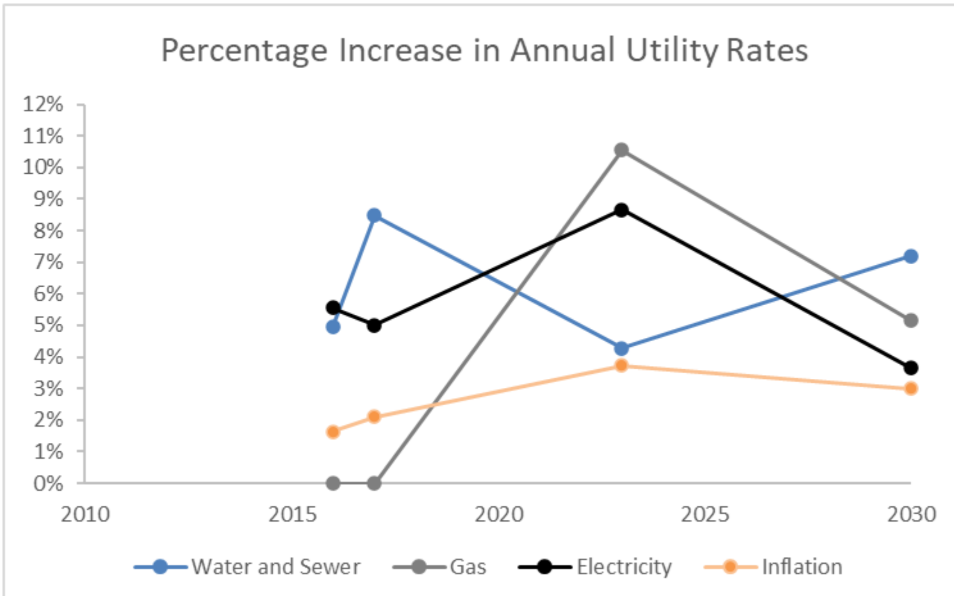
Introduction

This guide discusses strategies to maximize the water and energy efficiency of commercial foodservice hot water systems, while adequately meeting hot water and sanitation needs of the facility. Understanding how to maximize water and energy efficiencies is important because hot water systems can account for as much as half of a commercial foodservice facility's energy use as well as most of its water use. Proper hot water system commissioning, maintenance, and operation, can be paramount for maximizing performance and reducing operating costs of any facility.

Finding opportunities to reduce hot water costs has become even more prominent in recent years as utility costs are projected to rise through the 2020s and have been rising faster than inflation.



One of the best ways an operator can offset these cost increases is to maintain the energy and water efficiency of their hot water system through good maintenance practices. Operators can also increase efficiency through equipment replacement or optimizing operations. This includes regular equipment maintenance and performance spot checks, proper commissioning of new equipment, training staff to operate fixtures correctly, and alerting management when equipment malfunctions. It also includes planning for burnout and investing in energy and water efficient equipment for replace-on-burnout scenarios.

This guide defines these opportunities and provides examples of how implementing these activities results in cost savings. It builds on previous guides and caters information to operators of existing commercial foodservice facilities. It also includes lessons learned for operators from lab and field research including heat pump water heater demonstrations, condensing water heater demonstrations, and pre-rinse operations field monitoring studies. There is an accompanying guide for hot water system designers that goes into much greater technical detail, called the Technical Design Guide for Advanced Water Heating within the Foodservice Industry (referred to as the Technical Design Guide within this document). The technical design guide includes many options for designers and restaurant owners who are ready to decarbonize their hot water systems.

Background

Hot water is the lifeblood of restaurants. The hot water system provides hot water to clean hands, wash dishes and equipment, and cook food. For food safety reasons, foodservice facilities are not allowed to operate without an adequate supply of hot water for sanitation. Therefore, it is essential to maintain the water heating system to meet the needs of hot water using equipment under peak operation.

Conventional hot water systems in the foodservice industry are comprised of three fundamental component groups: water heater(s) with or without storage, distribution piping, and an array of point-of-use equipment such as water fixtures. Water heaters are usually installed in mechanical rooms and convert energy to hot water to be used by fixtures in the hot water system. Distribution piping simply connects the water heater to the points-of-use.

Point-of-use equipment includes fixtures such as pre-rinse operating equipment, dish machines, and faucets. The use of this equipment varies throughout the service day, but peaks typically during the lunch and dinner rush. End-of-day cleaning of the facility and associated use of a mop sink for filling buckets or attaching a floor hose for washing down can also be a major hot water draw. The level of operation and maintenance of fixtures drives hot water consumption and determines the amount of energy the water heater needs to supply to the system. Water consumption is also determined by facility use and staff operating procedures. A well-maintained, efficiently operated system will consume less water and energy on days when fewer customers visit the restaurant. A hot water system in a restaurant with inconsistent operation will not only consume water based on customer visits but also be based on the operating practices of the staff on any given day. It is possible to have staff members who effectively adopt different operating practices, which can drive water consumption.

Let's look at two mid-size, full-service restaurants which serve similar food and have similar operating hours monitored for their hot water consumption by the Food Service Technology Center. Both restaurants have conveyor dish machines, pre-rinse spray nozzles, a bar in the front of the house, and have similar-sized hot water systems with almost the same number of compartment, prep, and hand sinks fed with conventional efficiency gas-fired storage water heaters. Restaurant A is reasonably well-maintained, has ENERGY STAR® and WaterSense rated equipment, which was all installed within the last three years and has well-trained staff. Restaurant B has outdated equipment and a high turnover. Table 1 compares the water and energy use of restaurants A and B on a day where they served a similar number of customers. As shown in Table 1, restaurant A spends only $0.16 per meal on hot water and saves $.05 per meal compared to restaurant B simply due to maintaining energy efficient equipment and limiting staff turnover.

Table 1. Cost and Resource Impacts of Water and Energy Efficiency in Restaurants

Restaurant	Dish machine Age (yr)	# Meals Served	Hot Water Use (gal)	Gas Use (therm)	Electricity Use (kWh)	Utility Cost ($/day) [1,2,3]	Cost per meal
A	3	503	674	9.8	150	$78.37	$0.16
B	>5	495	1031	14.7	183	$104.49	$0.21

[1] Based on EBMUD water and wastewater combined rate for Foodservice establishments in FY2023/2024 at $14.13/HCF, 1 HCF = 748 gallons of water (EBMUD Water, 2023) (EBMUD Wastewater, 2023)
[2] Based on 2023 PG&E G-NR1 rate schedule with average annual natural gas rate of $1.80/therm.
[3] Based on 2023 PG&E B10-TOU average annual electricity rate of $0.32/kWh (PG&E, 2023).

Table 2 compares two meal periods, including preparation and cleanup (i.e., monitoring started at 4:00 p.m. and ended at 11:00 p.m. each day), at a cafeteria operated by two different groups of staff. In this example, the cost difference is only driven by the operating decisions made by the staff onsite. These included the choice to focus more on dry scrapping and using the pre-rinse sprayer on Thursday, the choice to jam the pre-rinse sprayer open on Wednesday, and a prolonged operation of a scrapper on Wednesday. The meal periods served roughly the same number and same type of meal in terms of food product, so the only differences in the water use could be attributed to staff. The more efficient operation of the same meal service with the same equipment saved 39 percent of the utility costs on Thursday compared to Wednesday. This demonstrates the significant cost savings opportunities associated with operating equipment efficiently.

Table 2. Cost and Resource Impacts of Varying Operating Decisions

Meal Service	# Meals Served	Hot Water Use (gal)	Gas Use (therm)	Electricity Use (kWh)	Utility Cost ($)*	% savings (Thursday/ Wednesday)	Cost per meal
Wednesday Dinner	405	1129	13.1	132	$87.15	-	$0.22
Thursday Dinner	412	488	5.6	107	$53.54	39%	$0.13

*Based on $14.13/HCF, $1.80/therm, $0.32/kWh.

Operator’s Path for Savings

The operator’s path for savings is presented as a list but it’s really a cycle. When new equipment or systems are installed, the operator needs to properly commission them, then maintain and operate them correctly through their lifecycles, then specify new equipment to replace them when necessary, and so on. Keeping a hot water system efficient is a continuous and constant process. The most important thing an operator can do is remember that the hot water system needs periodic attention, just like any other major mechanical building system.

1. **Commission new equipment and systems properly**
   When new equipment is installed, the operator is responsible for checking whether the new equipment operates as designed. This can mean checking the water heater setpoint and making sure newly installed dish machines are operating at the specified rinse pressure and flow rate.

2. **Operate systems efficiently and train staff well**
   Training staff to identify issues and how to use equipment correctly is challenging for many operators, but it can result in the lowest-cost utility savings possible in an existing facility. There should also be a daily startup and daily shutdown. Checklists should be used by staff to ensure equipment idling is minimized and equipment breakdowns are minimized, and the restaurant has been adequately cleaned and sanitized at the beginning and end of every service day. Examples of these are included in this guide. This step saves water and energy by reducing hot water demand, which is also a critical step in making heat pump water heaters viable for commercial foodservice. Of these steps, this is the easiest to implement immediately.

3. **Maintain systems and practice preventative maintenance**
   The operator is also responsible for identifying maintenance issues on the hot water system and address any known performance issues. The operator will become aware of maintenance issues when equipment fully breaks down or when the health department flags a malfunctioning piece of equipment, but it is generally cheaper and easier to identify and resolve smaller issues when they arise. It’s cheaper and easier to change a car’s oil every few thousand miles and pay attention to the lights on the dashboard than to replace a burnt out engine. Likewise, the operator essentially needs to check major operating parameters of hot water equipment periodically and note any unacceptable changes.

4. **Specify efficient equipment for replacing on burnout**
   When a piece of equipment needs to be replaced, the operator should look to the Technical Design Guide to select a more efficient piece of equipment. However, some recommendations for low-hanging-fruit upgrades are included in this guide. An operator should also identify when pieces of equipment need to be replaced and plan well in advance to replace at the end of a piece of equipment’s typical lifespan.

   The remainder of this guide explores each of these life cycle steps in detail.

1. Commissioning

As described in the Operator's Path for Savings, commissioning new equipment is an important step in the operation of a hot water system. Once the building designer or equipment purchaser has selected a new piece of equipment, commissioning is the first chance the operator has to interact with the new fixture. An operator should take an active role during commissioning because it will allow the operator to learn proper operating best practices from the commissioning agent who is typically the installer, the manufacturer's representative, or chemical supply company, depending on the equipment type or service provider. During commissioning, the operator can work with the commissioning agent to:

- Devise a maintenance schedule
- Learn about technicians in the area
- Learn about malfunctions and signs of wear to watch out for
- Learn how to train staff on how to start-up, shut down, and operate the equipment.

The most important reason for an operator to be involved in the commissioning process is to ensure that the new fixture works correctly and functions to the manufacturer's specifications. The first step in determining whether a piece of equipment is working properly is to read the manufacturer's specifications sheet, which should be supplied with the new piece of equipment. Generally, the Commissioning Agent should spot-check some basic operating parameters such as temperatures, flow rates, and pressures to ensure that they match the specifications sheet, and then make adjustments where necessary. Failures in the commissioning step can lead to poorly performing equipment and/or to increased utility costs throughout the lifetime of the equipment.

Dish machines are the most important fixture to commission correctly because they can use up to 75 percent of the hot water in a commercial kitchen, and they can account for as much as 85 percent of the utility cost of the hot water system. Most of the remaining discussion on commissioning in this guide will focus on dish machines for this reason, however, the guide also presents information on commissioning pre-rinse operation equipment and overall hot water systems for new construction or major retrofit projects.

COMMISSIONING DISH MACHINES

The most common fixture to have commissioning problems is the dish machine because it is one of the most mechanically complex components in the hot water system. Dish machines need to meet their specified wash and rinse temperatures in order to sanitize dishes and to pass health department checks. These are usually the first things commissioners will observe. While there are a variety of items to check when commissioning dish machines, the most important are the rinse pressure and ventilation systems.

The most common issue with dish machine commissioning is the rinse pressure, which sets the rinse flow rate. For dish machines without a pumped rinse system, the final rinse pressure is dependent on the inlet hot water pressure determined by a pressure regulator. If the regulator is set too low, there won't be enough pressure to adequately rinse larger glassware. If the regulator is set too high, the dish machine will consume more water and energy than it needs to, and the operator will face increased utility costs. Sometimes, the regulator is set according to manufacturer's specifications, and the rinse flow rate still doesn't match the specifications sheet. This can happen for any number of reasons ranging from a bad pressure gauge to defective or improperly sized rinse nozzles. It is a cause for further investigation regardless of the cause. Commissioning issues with the dish machine are important to identify quickly because dish machines have longer lifetimes in facilities than most other pieces of equipment, so they have the potential to cost more in the long run.

Another common commissioning issue with a dish machine, especially for dish machines which are replacing older models in an existing space, is a ventilation mismatch in the dish room. During installation, the airflow through the dish machine's exhaust system should be checked and compared to the specifications sheet. If the airflow is too low, the dish room will become hot and humid over the course of operation, and staff could experience hazardous working conditions that could lead to issues like potential heat stroke. An overly hot and humid dish room also has the potential to be a breeding ground for mold. Unfortunately, if the airflow is too low, it is possible that a new, larger exhaust fan would need to be installed. If the airflow is set too high, the exhaust fan will consume more energy than necessary to exhaust the dish room, which wastes money for the operator. This can sometimes be remedied by installing a variable frequency drive on the exhaust fan, which can be used to regulate the exhaust fan speed. If a ventilation mismatch is discovered upon commissioning, the operator should report this to the building manager or building engineer for next steps. One possible solution would be to install an Electronically Commutated Motor exhaust fan with a built-in variable frequency drive, but this may require significant work from the building engineer. For more information, please refer to the Dish Room Ventilation Design Guide. (https://caenergywise.com/design-guides/CKV-Dishroom-Sizing-Design-Guide.pdf)

While commissioning a dish machine, the operator should make sure that the following parameters are measured and compared to the specifications sheet before the commissioner or installer leaves the premises:

While commissioning a dish machine, the operator should make sure that the following parameters are measured and compared to the specifications sheet before the commissioner/installer leaves the premises:

- Tank temperature
- Rinse temperature
- Inlet hot water temperature
- Inlet cold water temperature
- Exhaust flow rate
- Rinse pressure
- Inlet hot water pressure
- Input voltage (on each leg for three phase models)
- Input amperage (on each leg for three phase models)
- Rinse water consumption (possibly through a catch-and-weigh test as described on page XX)
- Chemical consumption, which should be set by the chemical distributor

In addition to commissioning, many manufacturers offer initial training for their new fixtures. This is especially common for high-temperature rinse dish machines and this provides additional touchpoints for users to learn about their equipment.

Pre-Rinse operation equipment also needs to be properly commissioned. The maximum once-through flow rates of all pre-rinse operation equipment should be checked upon installation. Pre-rinse spray valves can be checked with a simple catch-and-weigh test, and occupancy sensors for other kinds of pre-rinse operating equipment should be checked for basic functionality. The commissioner should also set the recirculation flow rate and operating temperatures for scrappers and troughs. This can ensure that there is an appropriate mix of hot and cold water, that water won't scald staff, and that the flow rate is high enough to achieve good performance.

When **hot water systems are first commissioned in new construction or major retrofit,** the following tests should be performed to ensure basic functionality. These tests can also be performed to consider whether the hot water system should be recommissioned and will be especially useful to help diagnose poorly performing systems:

- Adequate hot water delivery at all fixtures (typically 140°F at dish machine and 120°F at all other fixtures)
- Record wait times at lavatory hand sinks
  - » If wait times are less than 10 seconds, move on
  - » If wait times are more than 10 seconds, there may be a problem with the recirculation pump or the lavatories may require point-of-use heaters
- Record water temperature at major points of use:
  - » Dish machine inlet (read the analog or digital gauge for the dish machine)
    - If this doesn't meet manufacturer specifications, a plumber must be contacted
  - » Dish machine rinse temperature
    - If this doesn't meet manufacturer specifications, a technician must be contacted
- Record wait times at any remote fixture, such as front-of-house bar equipment
  - » If the bar wait time is very long, a point-of-use heater may be required
  - » Check the operating temperature at the dish machine at the bar
- Check operating flow rates at all fixtures to ensure they match the intended design
  - » If dish machine's rinse flow rate is too low, it may not be adequately washing dishes
  - » If dish machine's rinse flow rate is too high, it is costing more money to operate
- Operate the two biggest flow rate fixtures simultaneously to ensure there are no pressure mismatch problems
  - » If this triggers a pressure problem, it is possible there is a problem with the water heater that needs to be addressed by a plumber. It may require upsizing or replacing the water heater to remedy this.

2. Operation

Once the equipment is in operation, the next key step in commercial kitchen hot water efficiency is examining operation procedures. This is important as operation of equipment can have large impacts on water and energy use. For example, data from a pre-rinse operations study performed on a large dish room showed a huge variation in pre-rinse water use from day to day. The average pre-rinse water use per meal at this facility on June 3 and June 4 were wildly different despite the facility having the same pre-rinse equipment and serving a similar menu on each day. Breaking out the water use into the facility's breakfast, lunch, and dinner periods on these days shows that between the lowest water use meal period (dinner on June 3) and the highest water use meal period (dinner on June 4) there was a 20x water use difference. The only thing that changed between these meal periods was the staff operating the dish room.

The staff operating on June 3 were mostly focused on dry-scrapping with use of a pre-rinse spray valve for anything that couldn't be manually removed. Dry-scrapping is a method where food scraps are removed from dishes manually or by use of a scraper into a garbage bin before being placed on racks and fed through a dish machine. The staff on June 4 was using a floor-washing hose with no nozzle in place of a pre-rinse spray valve to remove the scraps from the dishes.

To support staff using the equipment efficiently, facilities should have a standard training procedure for all dish room employees. Keeping staff trained and aware of their water and energy use impacts in commercial food service facilities is difficult for a number of reasons including high turnover compared to other industries and low staff incentive to save water and energy. Standard operating procedures should be clearly articulated, and employees who adhere to these procedures should be rewarded.

A proper training program for dish rooms should include the following components:

- Standard start-up and shut-down procedures for all equipment
- Standard operating procedures for all equipment
- Designation of a clean and a dirty zone in the dish room
- Daily cleaning schedules and procedures for all equipment
- Close of shift/facility shut-down procedure
- An incentive to report malfunctioning equipment to management

The remainder of this section presents best practices for operating hot water systems and common practices to avoid. It then identifies maintenance issues that operators should report to their managers. Lastly, it includes example start-up and shut-down checklists for operators.

BEST OPERATING PRACTICES AND COMMON PRACTICES TO AVOID

Below are best operating practices that managers can incorporate into their training program and documentation:

- Dish machine
  - » Only start up the dish machine just before you expect to wash dishes
  - » Check if the dish machine requires a dump and refill between meal periods. If so:
    - Upon dumping, clean out the dish machine and make sure the areas around any sensors are free of grime. This will keep the tank heaters from overcycling
    - Do not refill until the next rush period when you expect to wash more wares
    - Dump the machine and clean it before closing for the day
    - Turn off the machine overnight
  - » Dump the machine and clean it before closing down for the day.
  - » Turn off the machine overnight
- Scrapping
  - » Depend as much as possible on dry-scrapping and using the pre-rinse spray valve. A dry-scrapping sample methodology is included later in this guide
- Wash-down
  - » Only fill mop buckets at the end of the day or between meal periods if possible
  - » During wash-down, check for leaks

In addition to best practices, it is important to be aware of common misuse of equipment. This can help managers train new staff on common pitfalls and behaviors to avoid when using hot water system equipment.

- Dish machine
  - » Opening the door of a dish machine when it's in the middle of its cycle, especially if it's a heat recovery machine
  - » Washing less-than-full racks of dishes
  - » Washing over-full racks of dishes
  - » Having the same dish room worker load and unload a dish washer
  - » Not fully closing the drain after a dump-and-fill
- Scrapping
  - » Using anything other than the pre-rinse spray valve as a pre-rinse sprayer
  - » Activate pre-rinse spray valve as needed and leaving in ON position throughout the dishwashing period
  - » Disabling automatic occupancy sensors on any pre-rinse operating equipment

MAINTENANCE ISSUES TO REPORT WHEN OPERATING EQUIPMENT

In addition to training staff on how to use equipment efficiently, managers also need to train staff on maintenance issues to look for and report. The following list are example problems that staff can experience when operating equipment and should report to managers when they are experienced:

- The pre-rinse spray valve doesn't clean as well as it used to
  - » If in hard water area, consider descaling pre-rinse spray valve
  - » If worn out, replace the pre-rinse sprayer
- The dishwasher oversprays and sprays water out of the machine
  - » If conveyor: check the dishwasher's exterior spray curtains
  - » If conveyor: also check interior spray curtains between tanks and spray zones to ensure wash or rinse water are not contaminating each others' tanks and causing one tank to over flow to drain and the other tank to use fresh water to auto refill tank
  - » If door: check that the door closes all the way
  - » For any dishwasher without pumped rinse: check the pressure regulator
- Staff need to wash the same rack of dishes multiple times to get them clean
  - » Check the rinse pressure regulator for low pressure
  - » Check the wash arm nozzles for scale or debris that is impairing its operation
- Staff need to wait a longer time than normal to get hot water at the dish room
  - » Check to see that the water heater is functioning correctly
  - » Check to see if the recirculation pump is running
  - » If it is a tankless water heater, it may be related to excessive water pressure loss due to simultaneous fixture operation that exceeds the capacity of the tankless unit(s) flow rate or a dirty inlet water filter on the tankless unit.
- The lavatory or hand sink water pressure fluctuates and flow rate can slow to a trickle
  - » Check tankless heater for clogged inlet water filter
- The dishwasher is showing an error code/the dishwasher's rinse temperature is too low
  - » Call the dishwasher technician

SAMPLE START-UP CHECKLIST

Dish room Start-up

- ☐ Is the dish room clean?
  - » Check for any spills, messes, unclean surfaces
  - » Lift non-slip mats to see hidden spills
  - » Check all stainless steel surfaces and clean any debris
  - » Check for any puddles of water on floors and surfaces, and check whether they came from any leaks
  - » Check whether sinks are clean
  - » Check sink faucets for leaks
- ☐ Before turning on dish machine
  - » Check whether the dish machine is clean
  - » Check whether any small wares have been left inside the machine and remove if so
  - » Check if there is anything stuck in the drain (if readily visible) and remove
  - » Ensure all food and drain traps are placed correctly
  - » Check rinse nozzles for any visible wear or damage
- ☐ Turn on dish machine and run fill cycle
  - » Ensure correct tank temperature
  - » Ensure correct rinse temperature
  - » Run the rinse cycle a few times
  - » Check pressure gauge and ensure operating pressure meets manufacturer's specifications (typically 20 psi)
  - » Check wash setting is set for the correct wares to be washed
- ☐ Turn on pre-rinse sprayer
  - » Turn hot and cold faucets to desired temperature
  - » Check sprayer for leaks
  - » Check face of pre-rinse sprayer for any obvious signs of wear
  - » Test spray a few times to ensure adequate pressure and flow
  - » If flow seems low or spray pattern is strange/inconsistent, tell your shift lead
- ☐ Turn on any other Pre-Rinse Operations equipment only when dishroom needs to be used
  - » Check for leaks as appropriate

Other Areas Startup

- ☐ Go to mechanical room
  - » Check water heater's setpoint temperature
  - » Make sure circulation pump is running
  - » Check for leaks
- ☐ Go to sinks in food preparation areas
  - » Remove food debris and clean as appropriate
  - » Check for any leaks
- ☐ Bar
  - » Check floors for cleanliness and any puddles, follow puddles back to source of leak

SAMPLE SHUT-DOWN CHECKLIST

Dish room shutdown

- ☐ Is the dish room clean?
  - » Wash any remaining dishes, dry and put away as appropriate
  - » Clean all surfaces
  - » Lift non-slip mats to see hidden spills
  - » Check all stainless steel surfaces and clean any debris
  - » Check for any puddles of water on floors and surfaces and check whether they came from any leaks
  - » Check whether sinks are clean, clear scrapping traps
  - » Check sink faucets for leaks
  - » Check dish machine food traps for debris and throw away
  - » Clear all scrapping traps
  - » Take out trash
  - » Make sure all floor sinks are clean and unobstructed
- ☐ Shut down the dish machine
  - » Open doors
  - » Check for any obvious damage
  - » Remove any wares left in the machine
  - » Check all tanks for food or small wares
  - » Drain dish machine
  - » Clean fats oils or grease that remain in tanks or on other surfaces
  - » Turn dish machine off
- ☐ Shut off any pre-rinse operations equipment
  - » Remove any food debris and clean as appropriate
  - » Drain compartment sinks and clean as appropriate
  - » Turn off lights to the dish room

Other areas shutdown

- ☐ Mechanical room
  - » Fill mop bucket at mop sink and wash floors
  - » Check mop sink for leaks
- ☐ Food preparation area
  - » Make sure prep sink is clean and non-leaking
- ☐ Lavatories
  - » Make sure lavatory sinks are clean and non-leaking
  - » Turn off lights in lavatories
- ☐ Bar
  - » Clean all sinks and check for leaks
  - » Make sure all floor sinks are clean and unobstructed

3. Maintenance

The third key path to savings is to maintain hot water equipment overtime. Properly maintaining the fixtures on a hot water system will help the system achieve its minimum performance while keeping operating costs from rising. Maintenance issues commonly lead to hot water waste, which drives operating costs and can degrade performance and shorten equipment lifetimes. Just like regularly changing the oil in a car, maintenance of hot water systems should be an ongoing, periodic process.

This section first defines six steps to support good maintenance practices. It then presents a sample monthly maintenance checklist and further describes one important testing procedure to support maintenance procedures.

SIX STEPS TO MAINTAIN EQUIPMENT

Here is a sample maintenance program with steps most operators should follow.

1. Listen to staff

The staff onsite is often the first line of defense when it comes to identifying when equipment isn't working well. Operators who frequently talk to dish room staff about equipment are often quicker to notice changes in equipment performance such as when dish machines stop cleaning dishes as effectively, when pre-rinse spray nozzles seem to lose rinsing force, or when troughs run cold. Training dish room staff to report these issues quickly can help the operator decide when to change out equipment or when to call a technician.

2. Check your utility metering data

Utility meters are another source of information that can help identify when major issues are happening. It is recommended that at the very least, restaurant operators keep a log of water, electricity and gas bills and audit these bills somewhat frequently. Unexpected jumps in water usage could indicate major malfunctions like if a dish machine's drain is stuck open or if a toilet is broken. Many utilities and municipalities offer smart meters and have online resources where utility consumption can be viewed at hourly intervals. It is recommended that for sites that have this capability, the operator views a day's worth of water, gas, and electricity data to try to identify problems. In particular, if there is significant water and gas usage overnight, it likely means that there is a leak somewhere in the hot water system.

The more advanced version of this step is to check the water heater's onboard data log. Some modern water heaters sometimes feature built-in submetering, which can be used to see the building's hot water use more directly. This can be used to identify more granular problems, and operators could potentially use this to run various performance checks. For example, an operator could run a set number of rinse cycles at the dish machine and use the water heater's smart metering to identify whether the rinse flow rate matched the manufacturer's specifications. The onboard metering data could also be used to compare the energy usage from different days. An operator could compare the total daily energy usage from two days with a similar number of meals sold from two days spaced a few months apart. If the energy usage on the second day was much higher than the first, it could be an indicator that there is a maintenance issue somewhere in the system.

3. Identify and immediately address leaks

Leaks are pure hot water waste and should be addressed immediately. The table below highlights various types of leaks and the associated costs over the course of a year. As shown in Table 3, different types of leaks can have different cost implications. And if multiple leaks exist, the costs can add up. It is best practice to walk through the facility monthly and pay attention to common places for hot water leaks. Generally, leaks happen where fittings and orifices fail, including at fixture and equipment hot water connections as well as pipe couples, elbows, and bushings. In addition to monthly checks, it is recommended to check for leaks any time hot water equipment is moved or has maintenance performed on it.

Table 3. The Potential Costs of Certain Leaks

Leak Type	Leak Size (GPM)	Cost Per Year
Quickly dripping compartment sink faucet	0.1	$ 25.72
Disposer recirculation starting to get clogged	0.25	$ 64.31
Stuck-open dish machine drain	0.4	$ 102.90
Failed-open Pre-rinse spray valve	0.5	$ 128.62

4. Identify burnt-out pre-rinse equipment

Using a catch-and-weigh test is useful in identifying whether equipment has burned out. An operator can perform a catch and weigh test to determine the flow rate of pre-rinse equipment. To perform this test, the operator should take an eight-cup-sized measuring cup, place it under the drain of the equipment (or under a pre-rinse spray nozzle) and time how long it takes to fill. Then, plug into the following formula to calculate the flow rate in gallons per minute.

$$\textit{Flow rate (gpm)} = \frac{60}{(2*\textit{time}\text{ (sec) })}$$

For example, if a pre-rinse spray valve fills one measuring cup in 120 seconds, it is running at 0.25 gallons per minute (gpm). If this number differs from the specifications sheet, it may be time to replace the equipment. This test should be used on all equipment once per month to evaluate whether the equipment is still running at its optimal flow rate.

5. Identify when dishwashers need maintenance

It is sometimes difficult to identify when dishwashers need maintenance. Common problems that drive maintenance are when they fail to meet the final rinse temperature, when racks of dishes come out of the dishwasher still dirty, when wash times take dramatically longer than expected, or when the dishwasher is completely non-functional. Once per month, the operator should check and log the following parameters if possible (these parameters should be easily found on the machine):

- Final rinse pressure
- Final rinse temperature
- Final rinse flow rate
- Tank temperature
- Drain temperature

An operator should also check to see if the dishwasher is constantly draining, which would indicate a failed drain valve. Finally, some dishwashers will overflow during the wash cycle if they have too high of an operating pressure, and this should drive a call to a technician.

In the event that a dish machine cannot perform adequately at the manufacturer's rated pressure, it is probably time to replace the dish machine or to perform service. Common symptoms of the rinse pressure being set too high include the dishwasher overflowing during the wash cycle, more steam generation during the wash cycle, and dishes coming out of the dishwasher hotter than normal. If a service technician turns down the rinse pressure and performs service (such as replacing worn rinse nozzles) and the machine fails to perform at the rated rinse, the technician might increase the rinse pressure. If this happens, it is time to specify a new machine.

6. Sample Maintenance and Replacement Schedules

One of the most powerful things that an operator can do is stick to a preventative maintenance schedule for all of the equipment on a hot water system. See Table 4 for an example schedule. Every facility will have different maintenance needs based on the age of the system and the installed equipment, the demand placed on the system, and the average number of meals served per day. As mentioned earlier in this guide, one of the advantages of leased dish machines is that the chemical company will perform service on the dish machine whenever chemicals are replaced. This may be a good schedule to follow for many facilities: when it's time to buy new chemicals, an operator can follow the steps outlined above and schedule a maintenance technician to diagnose whether the dish machine and water heater are functioning properly. Performing regular maintenance is also important for water heaters. Water heaters need to be flushed out, cleaned, and descaled periodically in order to maintain their performance and to prevent breakdowns: one of the most common burnout scenarios is when scale causes a critical component like a heating element or a lining to crack. The condensate neutralizer will need to be replaced with condensing water heaters periodically per manufacturer recommendations, and tankless water heaters will need their filters changed periodically.

Table 4. Sample Maintenance Schedule

Fixture	Model Number	Technician Contact Information	Monthly Maintenance Checks	Tune Up Time Period
Dish machine	MFR-HTDEHR-180-42	Frank Fixer (XXX) XXX-XXXX	Rinse Temperature, Tank Temperature, Rinse Pressure, Rinse flow rate	Two months
Pre-Rinse Spray Valve	MFR-PRSV-08G	Frank Fixer (XXX) XXX-XXXX	Rinse Flow Rate	N/A
Scrapper	MFR-SCRP-120	Frank Fixer (XXX) XXX-XXXX	Drain Flow Rate	Six months
Recirculation Pump	MFR-CIRC-42	Joe Plumber (XXX) XXX-XXXX	Is it making any weird noises?	On Burnout
Recirculation Controller	MFR-CTRL-99	Joe Plumber (XXX) XXX-XXXX	Does it turn off when it's supposed to? Recirculation temperature when the pump is running	Upon perceived problem
Water Heater	MFR-WH-200	Joe Plumber (XXX) XXX-XXXX	Outlet Temperature/ Setpoint	Three months

In addition to defining and using a maintenance schedule, it is also good practice to keep track of expected burnout dates for equipment. This can help ensure equipment does not fail unexpectedly and cause an emergency repair, resulting in possible loss of kitchen use. It can also help buyers plan for purchases and stay ahead of purchasing needs, which can help ensure buyers have access a to full range of equipment options, including water and energy-efficient technologies. See Table 5 for a sample replacement schedule.

Table 5. Sample Replacement Schedule

Fixture	Model Number	Installation Date	Technician Contact Information	Expected Burnout Date	Date to specify and order new machine
Dish machine	MFR-HTDEHR-180-42	1/1/2020	Frank Fixer (XXX) XXX-XXXX	1/1/2027	7/1/2026
Pre-Rinse Spray Valve	MFR-PRSV-08G	1/1/2020	Frank Fixer (XXX) XXX-XXXX	1/1/2021	7/1/2020
Scrapper	MFR-SCRP-120	1/1/2020	Frank Fixer (XXX) XXX-XXXX	1/1/2024	7/1/2023
Recirculation Pump	MFR-CIRC-42	1/1/2020	Joe Plumber (XXX) XXX-XXXX	1/1/2024	7/1/2023
Recirculation Controller	MFR-CTRL-99	1/1/2020	Joe Plumber (XXX) XXX-XXXX	1/1/2024	7/1/2023
Water Heater	MFR-WH-200	1/1/2020	Joe Plumber (XXX) XXX-XXXX	1/1/2026	7/1/2025

SAMPLE MONTHLY MAINTENANCE CHECKLIST

Name of Reviewer: ______________________________

Date: ___________________

Dish machine

Rinse Pressure: _________________

Rinse Temperature: _____________

Tank Temperature: ______________

Rinse nozzles damaged? (Y / N)

Heat Exchanger Clean? (Y / N)

Overspray? (Y / N)

Damaged Curtains? (Y / N)

Maintenance recommended? (Y / N)

PRSV

Flow Rate: _____________

Spray OK? (Y / N)

Mechanical Room

Water Heater Setpoint: _________________

Heat Pump Air Filters clean (Y / N)

Master Mixing Valve Setpoint: ___________

Circulation Pump Functional (Y / N)

Circulation Controls Functional (Y / N)

If Tankless Water Heater: Water Filter clean? (Y / N)

If Condensing Water Heater: Is the condensate drain clogged? (Y / N)

If Condensing Water Heater: Is there rust on the drain? (Y / N)

If Heat Pump Water Heater: Is the condensate drain clogged? (Y / N)

Catch and Weigh Test Procedure

The catch and weigh test is useful in determining the flow rates of fixtures. The gist is this, take a five-gallon bucket (available for purchase in the paint sections of most major hardware stores) and see how long it takes to fill the bucket.

- For a Pre-Rinse Spray Valve (PRSV)
  - » Time how long the PRSV takes to fill the bucket in minutes
  - » On a calculator, calculate the flow rate by dividing five by the number of minutes
  - » E.g., a 1 gpm PRSV will take five minutes to fill the bucket, a two gpm PRSV will take two and a half minutes to fill the bucket, etc.
  - » Compare the calculated flow rate to the manufacturer's specifications

- For a Dishwasher
  - » Divert the drain to the bucket. This may require placing a shallow pan under the drain and then filling the bucket from the pan.
  - » Run the dishwasher the number of times necessary to fill the bucket
  - » Calculate the gallons per rack: divide five by the number of times the dishwasher was run
  - » Compare the calculated gallons per rack to the manufacturer's specifications

4. Retrofitting and Replacing Equipment

As described in the maintenance section, it is important to be prepared for when equipment needs to be retrofitted or replaced. Planning for equipment upgrades can help operators stay ahead of equipment failures and allow time to pick the most water and energy efficient equipment. This section defines water and energy retrofitting opportunities and considerations when replacing key components of hot water systems.

Pre-Rinse Spray Valve (PRSV)

PRE-RINSE OPERATING (PRO) EQUIPMENT

The most important piece of pre-rinse operating equipment and the easiest to achieve savings through retrofit is the PRSV. The PRSV is a handheld device designed for use with commercial dishwashing equipment and multi-compartment sinks for removing food residue off dishes and flatware. Low-flow, high-performance PRSVs are the single most cost-effective piece of equipment for water and energy savings in commercial kitchens. Realizing that efficient spray valves have equivalent performance to inefficient or conventional higher flow counterparts, the federal government passed laws limiting their flow rate.

Prevailing efficient pre-rinse spray valves (with flows in the 1 to 1.2 gpm range) have been proven in a wide variety of kitchen applications, encouraging manufacturers to develop advanced models that use less than one gallon per minute. A busy, full-service restaurant can clock three hours total of pre-rinse use per service day. At just one hour of use per day, a best-in-class 0.65 gpm spray valve can save 70 Therms and $350 annually when compared to a federally regulated 1.2 gpm spray valve.

There are many different spray patterns available for pre-rinse sprayers, especially in the 1.2 gpm range. If many large cookwares are being washed, it may be useful to have a large spray area for faster spraying. If there are dishes that have heavy soil, a more concentrated spray pattern may be necessary. Generally, it is good practice to listen to staff and make any adjustments when the pre-rinse spray valves seem to cause dish backups.

The pre-rinse spray valve is usually the only piece of pre-rinse equipment installed in most quick-service and full-service restaurants, but it does not tell the whole story for large, cafeteria-style dish rooms. Corporate campuses, hotels and educational facilities can use scrappers, disposers and troughs that can significantly contribute to an operation's hot water consumption. More information on these pieces of equipment can be found in the technical design guide.

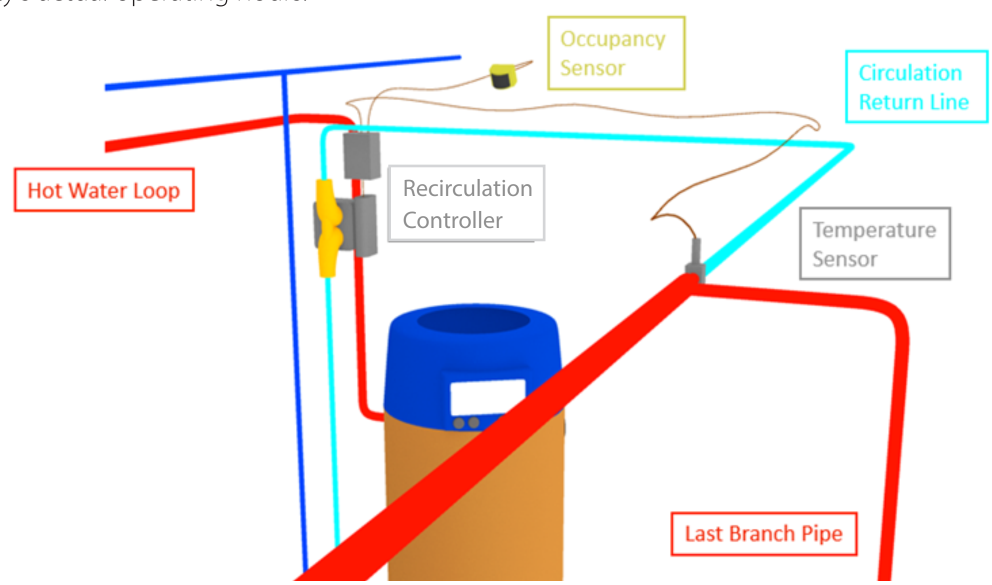
Staff training is the most important water and energy saving measure for pre-rinse operations. The most wasteful situations observed in the field involve the improper use of PRO equipment or the use of broken equipment by dish room staff. For example, it is a common occurrence for floor hoses to be used in place of a PRSV. Floor hoses can use as much as 10 gpm and still not provide enough pressure to properly rinse cookware, as can five gpm high flow pre-rinse spray valves (aka dog washers). Other poor practices include drilling out scaled-over, pre-rinse spray valves instead of descaling or replacing or leaving it always on. If the facility is large enough, consider specifying multiple pre-rinse spray valves or adding another one in an existing facility in the pre-rinse operating area that can allow more workers to scrap dishes at the same time and reduce the misuse of non-pre-rinse operating equipment like floor hoses.

CONTINUOUS RECIRCULATION SYSTEMS

For California restaurants, environmental health guidelines state, "Where fixtures are located more than sixty feet from the water heater, a recirculation pump must be installed to ensure that water reaches the fixture at a temperature of at least 120°F." Recirculation systems are helpful in ensuring hot water delivery, but they can be a major energy drain because water in the recirculation pipe is constantly cooling, so the water heater needs to consume energy to keep up. Using technologies such as a pump timer, electric commutated motor (ECM) pumps, and demand circulation systems can save energy and can be cost effective in a retrofit scenario. The lowest cost retrofit is oftentimes the installation of pipe insulation. Any operator reading this guide should spend an afternoon tracing the hot water line from the water heater through the restaurant and ensure that all the hot water pipe is insulated. California's building code requires pipe insulation, but in practice, many commercial foodservice facilities operate with uninsulated pipe, leading to completely unnecessary energy waste.

Demand recirculation systems ensure that hot water is delivered quickly to fixtures (similar to a continuous recirculation system), but only lukewarm water is returned back to the water heater. Furthermore, the pump only runs when needed, saving 95 percent of the gas used to keep a continuous recirculation system operating around the clock. Pump run-time drops from 24 hours to 30 minutes per day, saving electricity. In addition, gas storage heaters can operate at higher efficiencies as temperature stratification in the tank is maintained. Demand systems can easily be designed in new facilities and retrofitted onto existing hot water systems that have a continuous recirculation system.

Another viable retrofit technology is a smart-plug style recirculation controller. As shown in the graphic below this device is installed on the electric line between the recirculation pump and the wall, and has a sensor installed on the hot water outlet. The sensor learns the facility's operating schedule and shuts off the recirculation pump when hot water is not needed. This is useful for any facility that doesn't run 24 hours per day because it will, at a minimum, reduce the recirculation time from 24 hours to the facility's actual operating hours.



DISH MACHINES

The most important piece of equipment in a commercial foodservice facility is the dish machine. The dish machine most likely consumes more hot water than any other appliance in the building. Every part of a commercial foodservice operation depends on the dish machine to function correctly. Additionally, health departments regulate the operation of dish machines (target rinse temperatures) and can shut restaurants down for running a malfunctioning machine.

Dish machines are also important from an energy and water perspective. In addition to using between 25 percent and 75 percent of a facility's hot water, dish machines with electric booster heaters and tank heaters can rival entire cooklines in terms of electric energy consumption. This is especially true of the larger classes of dish machine. Dish machines come in four main classes: undercounter, upright door-type, rack conveyor, and flight-type (rackless conveyor) machines. Undercounter and door-type units typically wash and rinse one rack at a time, functioning in a "batch-type" operation. Rack conveyor dish machines continuously wash wares placed in a rack on a conveyor belt, while flight-type conveyors have integrated pegs for placement of wares directly on the conveyor.

There are two types of commercial dish machines based on sanitation method: low- temperature chemical-sanitizing and high-temperature sanitizing. Low-temperature (or "low temp") chemical-sanitizing machines wash at 120 – 140°F and final rinse at 140°F with the aid of chemical sanitizing agents. A low-temp dish machine uses three chemicals: a washing agent, a rinse aid, and a sanitizer. Normally, low-temp machines are not required to be installed under a ventilation hood (check with your local authority having jurisdiction).

High-temperature (or "high temp") machines wash dishware at 150 – 160°F with a final rinse at 180°F, which is a high enough temperature to sanitize wares without the need for chemical sanitization. High-temp machines only use a washing agent and a rinse aid. The high rinse temperature is achieved by either an internal or external booster heater that "boosts" the incoming 140°F water supply from the facility's main water heater to achieve the minimum 180°F rinse temperature. Due to the intense heat generation, high-temp dish machines are required to be direct vented or installed under a ventilation hood.

HEAT RECOVERY DISH MACHINES

By capitalizing on waste heat to preheat incoming hot water, energy recovery systems reduce both water heating and ventilation loads associated with dish machine operation. Manufacturers offer energy recovery models for all types and sizes of high-temp machines (heat recovery is not a cost-effective option on a low-temp machine due to a lower difference between incoming cold water and rinse water temperatures). Energy recovery machines typically cost about 25 percent more up front than an ENERGY STAR® unit of the same size category, but they can use as little as half the total energy (at the water heater and the machine) of a standard machine. Heat recovery dish machines also support decarbonization because they can be fed with only cold water. This allows the largest hot water load to be taken off of the hot water system entirely, which means that the water heater doesn't have to use as much gas throughout the day. It also allows for a smaller/cheaper heat pump water heater when the facility is ready to fully decarbonize.

To understand the impact of dish machines on operating costs, Table 6 compares three dish machines. The baseline machine was a seven-year old ENERGY STAR® high-temp dish machine monitored for water and energy use. This unit was replaced with a current ENERGY STAR® dish machine, then replaced again with an exhaust-air heat recovery dish machine. Of the three machines, the exhaust-air heat recovery dish machine performed the best, used the least amount of water per rack and exhibited the lowest overall cost to operate.

Table 6. High-Temperature Door-Type Dish machine Field Comparison

Machine	Rinse Pressure (psi)	Water Use (gal/rack)	Cost per Rack[1]	Annual Operating Cost[2]
Baseline (fed by water heater)	Est. 20 psi	1.4	$0.28	$22,800
ENERGY STAR® Dish machine	12	0.9	$0.23	$18,500
Exhaust-Air Heat Recovery Dish machine	Pumped Rinse	0.75	$0.20	$16,600

[1]Based on $14.13/HCF, $1.80/therm, $0.32/kWh.
[2]annual operating costs based on an average 225 racks per day.

Replacing a dish machine is a complex process, whether it is a mid-life replacement or a replace-on-burnout situation. An operator selecting a new machine for retrofit needs to consider the following factors when replacing a dish machine:

- Footprint of the existing and replacement machines
- Layout of the stainless-steel tables and fixtures in the dish room and the size and shape of the tables that connect to the dish machine
- Height of the counter for undercounter dish machines
- The water pressure in the dish room on both the hot and cold side
- The available electric capacity in the dish room
- The length of the wash cycle
- Whether the chemicals for the old machine can be used with the replacement machine

Some of these considerations will be more important than others based on the desired outcome of the replacement. Swapping a low-temperature sanitizing rinse machine for a high-temperature sanitizing rinse machine will necessitate a larger power draw, so the available electric capacity will be the limiting consideration for this replacement. Likewise, swapping a conventional dish machine for a heat recovery dish machine will necessitate a larger cold water draw, so if the facility has low cold water pressure in the dish room, this retrofit may not be possible. Additionally, some of the considerations listed above have the potential to make a retrofit very costly. If the stainless-steel tables need to be replaced with the dish machine, it can as much as double the cost of the retrofit in some cases, and the need to raise a counter to accommodate an undercounter dish machine is usually a non-starter for most facilities.

Replacing a dish machine will also require a plan check through a local health department. Usually, the retrofit will require the machine to drain to a floor sink with an air gap, and the health department will need to approve the use of detergent or rinse chemicals. Health departments will also usually perform an inspection of a new dish machine once it has been commissioned to check whether it is functional and meets its final rinse temperature requirements.

Another consideration is that dish machines are often leased from a chemical supply company rather than owned outright by the operator. The chemical supply company will usually charge a monthly service fee which will include the machine's maintenance and a rental fee on the unit, and the company will sell the operator chemicals. The maintenance plan will usually include on demand emergency maintenance to the operator, which is important because usually commercial foodservice facilities can't operate without a functioning dish machine. Broadly, leased dish machines are low-temperature sanitizing rinse models that have relatively high water usage. Low-temperature machines use more chemicals than high-temperature machines and are usually less efficient. Because the chemical supply company doesn't have to pay for utilities, they have no incentive to lease high-performing or efficient equipment to the operator. The benefits of a leased machine to an operator are that they don't have to invest in the high capital cost of a dish machine and they have relatively easy access to maintenance. The downside is that the operator can't select a high-performance or high-efficiency dish machine and pays more in utility costs compared to operators who own their dish machines. For more discussion on dish machine heat recovery technologies and dish room HVAC implications, please refer to the Sizing Dish Room Ventilation design guide. (https://caenergywise.com/design-guides/CKV-Dishroom-Sizing-Design-Guide.pdf)

WATER HEATERS

This section will discuss water heater technologies for commercial foodservice to give background information and to describe potential replace-on-burnout efficiency gains. Ultimately, the goal of this section is to show the benefits of replacing burnt-out conventional water heaters with high efficiency water heaters.

Primary Water Heater Technologies

Conventional Gas-Fired Tank-Type Water Heaters — These water heater designs are relatively simple with a burner mounted beneath a tank of water with the flue going through the center of the tank. Gas-fired storage tank-type heaters have thermal efficiencies of 80 percent or lower and lifespans in commercial kitchens of about five years.

The cost scales directly with tank and burner size, but most conventional commercial water heaters can be purchased for between $2,000 and $5,000. Some conventional water heaters come equipped with active flue dampers designed to close the flue when the burner is not running, which can raise efficiency and save utility costs. Other water heaters will provide greater efficiencies, but selecting a water heater with an active flue damper is the lowest cost efficiency upgrade available to users who are unable to install a condensing water heater for lack of an ability to install a condensate drain or who lack the electrical capacity to install a heat pump water heater.

Condensing Water Heaters — High-efficiency, condensing water heaters condense water vapor contained in the exhaust gases, producing liquid condensate as a byproduct. A pipe must be connected from the base of the exhaust flue to route the condensate to a drain in proximity to the heater. Alternately, a condensate pump can be used to discharge the liquid to a remote drain. Gas-fired condensing water heaters typically have thermal efficiencies between 90 percent and 95 percent. An important caveat is that the operating efficiency depends on the temperature of the recirculation return.

Typical first costs for condensing water heaters vary by manufacturer, but specifiers can expect to pay between three percent and 50 percent on top of the initial cost of a standard efficiency water heater, and an additional five to ten percent for the installation of a demand control system if one doesn't already exist in the building. This can lead to between 15 and 20 percent energy savings. Additionally, operators can specify a digital master mixing valve for additional savings.

Tankless Water Heaters – These water heaters are growing in popularity because they take up less footprint, but many facilities struggle with adequate hot water delivery because they can struggle to keep up with demand. If you are using a tankless water heater and have hot water delivery issues or the tankless heaters are breaking down frequently, consider installing a storage water heater if the footprint allows.

Electric Resistance Water Heaters – These water heaters are usually only used in facilities that don't have a natural gas hookup. They generally should not be specified for a simple water heater retrofit because they are much more expensive to run than gas water heaters.

Heat Pump Water Heaters – This water heating technology is emerging in the commercial foodservice industry. If your facility needs a water heater upgrade and can handle the electrical demand from one of these units, considering a heat pump water heater or a heat pump assist heating plant might be a viable way to save energy in a replace-on-burnout scenario. Heat pump water heaters are also the key to decarbonizing hot water systems for commercial foodservice facilities. Please reference the technical design guide for more information and design examples.

Key Takeaways

- ✓ The first step to running an efficient hot water system is making sure your system is commissioned properly
- ✓ Staff should be trained in efficient use of hot water system equipment, especially the practice of dry scrapping as much as possible
- ✓ Daily startup and shutdown procedures save water and energy and also prevent mechanical failures of devices
- ✓ Staff should be trained to be the first line of defense in reporting mechanical problems
- ✓ Regular and frequent maintenance should be performed on all major fixtures
- ✓ Equipment lifespans should be planned for, and replacements at end-of-life shouldn't be an emergency upon burnout