WaterSense at Work

Laboratory and Medical Equipment

7.3 Steam Sterilizers

Best Management Practices for Commercial and Institutional Facilities

EPA WaterSense

March 2024

WaterSense® is a voluntary partnership program sponsored by the U.S. Environmental Protection Agency (EPA) that seeks to protect the nation's water supply by transforming the market for water-efficient products, services, and practices.

WaterSense at Work is a compilation of water efficiency best management practices intended to help commercial and institutional facility owners and managers from multiple sectors understand and better manage their water use. It provides guidance to help establish an effective facility water management program and identify projects and practices that can reduce facility water use.

An overview of the sections in *WaterSense at Work* is below. This document, covering water efficiency for steam sterilizers, is part of **Section 7: Laboratory and Medical Equipment**. The complete list of best management practices is available at www.epa.gov/watersense/best-management-practices. WaterSense has also developed worksheets to assist with water management planning and case studies that highlight successful water efficiency efforts of building owners and facility managers throughout the country, available at www.epa.gov/watersense/commercial-buildings.

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This document is one section from *WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities* (EPA-832-F-23-003). Other sections can be downloaded from www.epa.gov/watersense/best-management-practices. Sections will be reviewed and periodically updated to reflect new information. The work was supported under contract 68HERC20D0026 with Eastern Research Group, Inc. (ERG).

Overview

Steam sterilizer interior

Disinfection/sterilization is common in hospitals and research institutions where it is necessary to destroy microorganisms that can cause infection or disease. A steam sterilizer (a subcategory of autoclaves) is the most common type of system used to disinfect and sterilize laboratory equipment, surgical instruments, medical waste, and other materials requiring sterilization. Steam sterilizers can use water in three ways: to generate steam (i.e., the disinfecting/sterilizing agent); to cool steam condensate to appropriate temperatures before it is discharged down the drain; and to draw a vacuum through the sterilization chamber to expedite the drying process.

Several other types of autoclaves use different modes of sterilization, including dry heat, ethylene oxide, and radiation. However, these modes of sterilization are not typically recommended unless the material being sterilized has special requirements that make it adverse to steam or high temperatures. Because steam sterilizers are the most widely used form of sterilization, and because they use water, this section focuses on steam sterilizers only.

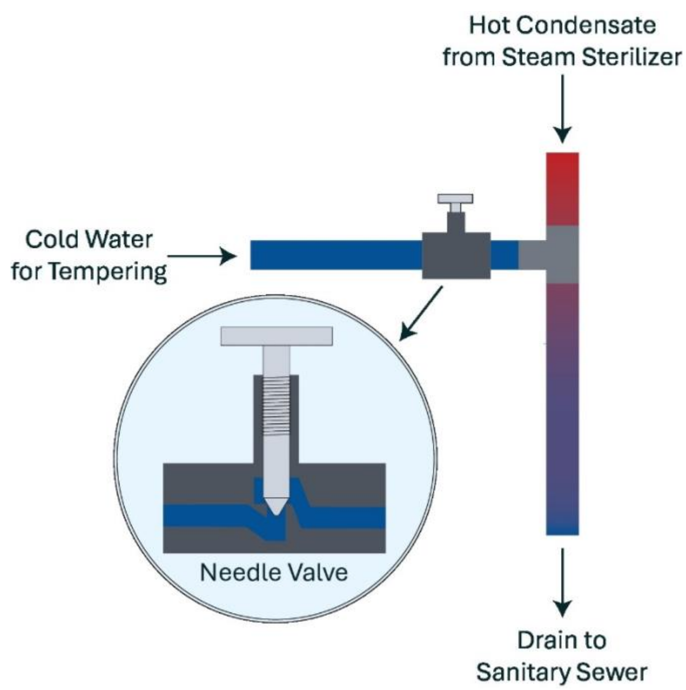
The water efficiency options discussed in this section do not address the water used to generate the steam that is used in the disinfection process and, therefore, do not impact the steam sterilizer's ability to disinfect and sterilize equipment. For information on optimizing a central boiler system that may supply steam to sterilizers, refer to *WaterSense at Work Section 6.5: Boiler and Steam Systems* at www.epa.gov/watersense/best-management-practices. Beyond the water used for steam generation, steam sterilizers generally use water in two ways: to temper hot steam condensate before it is drained to a sanitary sewer, and to create a vacuum to expedite the drying process.

Steam Condensate Tempering

Steam sterilizers are often operated 24 hours per day in either ready (standby) or active (sterilization) mode so that equipment remains sterile and ready to use at any time. These systems are commonly only actively sterilizing for eight hours per day or less and are idle for the remaining time. During standby mode, low-pressure steam is passed into the chamber to maintain a specific temperature and keep it sterile. During both standby mode and active sterilization, as the steam in the chamber condenses, it usually flows to a drain leading to the sanitary sewer, where it must be cooled to 140°F (60°C) or less before it can be discharged.

In older, conventional steam sterilizer models, hot condensate is tempered with utility-supplied cold water that continuously flows between 1.0 to 5.0 gallons per minute (gpm) (3.8 to 18.9 liters per minute [lpm]).[1] As illustrated in Figure 1, tempering water is controlled using a needle valve, which is able to precisely regulate the flow rate of the tempering water as it flows through an orifice in the valve that can be opened to a certain degree (or flow rate) by a plunger. These older systems can waste a significant amount of water; even set at a flow rate of 1.0 gpm (3.8 lpm), the resulting tempering water use can exceed 500,000 gallons (1.9 million liters) per year.

Figure 1. Continuously Flowing Tempering Water Controlled by Needle Valve in Conventional Steam Sterilizers[2]



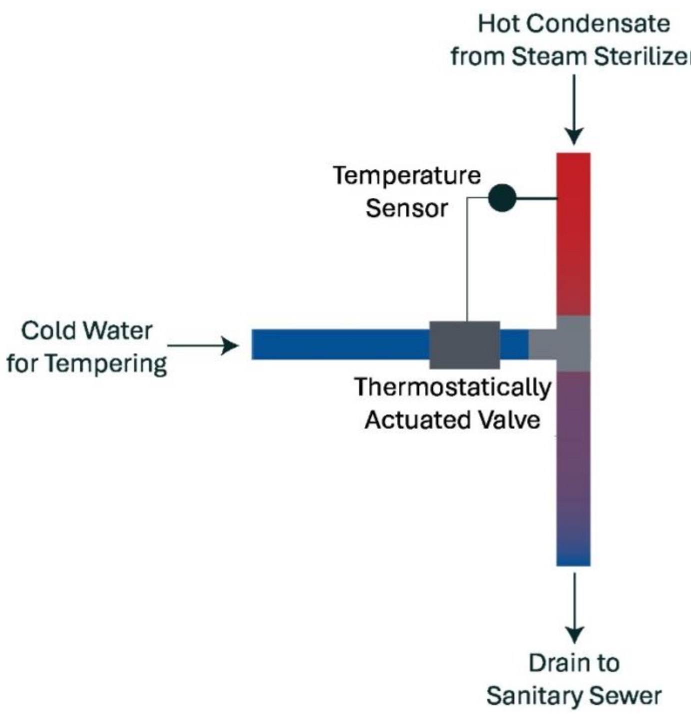
[1] U.S. Department of Energy (DOE), Federal Energy Management Program (FEMP). Water-Efficient Technology Opportunity: Steam Sterilizer Condensate Retrofit Kit. www.energy.gov/femp/water-efficient-technology-opportunity-steam-sterilizer-condensate-retrofit-kit.

[2] Recreated from image included in Fitch, J., et. al., Environmental Quality and Water Efficiency Group, Stanford University. December 2013. *Fact Sheet on Steam Sterilizers at Stanford University*. Page 3. https://suwater.stanford.edu/sites/g/files/sbiybj19876/files/media/file/sem_steamsterilizers_stanford_2013 .pdf. Permission provided by Tim Crow of Consolidated Steam Sterilizer Systems (www.consteril.com).

Newer steam sterilizers can be designed—or older systems retrofitted—with a thermostatically actuated valve or a cooling reservoir system to significantly reduce the amount of tempering water use. As illustrated in Figure 2, using a thermostatically actuated valve instead of a needle valve allows tempering water to flow only when the condensate reaches a certain temperature, which can reduce the amount of water used for cooling by 50 to 80 percent.[3]

Two steam sterilizers

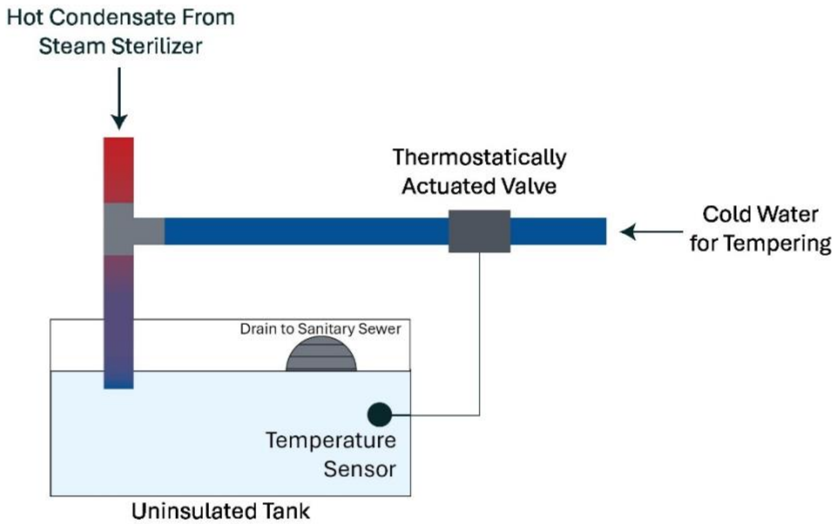
Figure 2. Steam Sterilizer Tempering Water Controlled by a Thermostatically Actuated Valve to Only Flow When Necessary



Alternatively, as illustrated in Figure 3 on the next page, sending hot condensate to an uninsulated tank allows heat to transfer from the condensate to the cooler, ambient atmosphere. Tempering water is added only if the water basin's temperature requires it, and when the tank is full, the cooled condensate is discharged to the sanitary sewer. Retrofitting older steam sterilizers with an uninsulated tank can reduce water needed for condensate cooling by up to 90 percent.[4]

[3] Fitch, J., et. al., *op. cit.*, Page 6.
[4] *Ibid*.

Figure 3. Steam Sterilizer Cooling Reservoir System[5]



To further reduce utility-supplied potable water use, facilities can also consider using reverse osmosis system reject water or other onsite alternative water sources for condensate tempering, if available. Refer to *WaterSense at Work Section 8.0 Onsite Alternative Water Sources* at www.epa.gov/watersense/best-management-practices for more information.

Another option is to use the closed building chilled water loop as a heat exchanger to cool hot condensate, removing some or all of the heat load so less tempering water is needed. These options depend on where in the building these processes are located and must be considered on a site-by-site basis. Often, it is easier to use onsite alternative water for tempering or the building chilled water loop as a heat exchanger for new steam sterilizer installations, as opposed to retrofits or direct replacements.

Steam Condensate Vacuum Systems

Some steam sterilizers also use water to draw a vacuum through the sterilizing chamber for the drying process. They can be retrofitted or designed to reduce the amount of water necessary to draw the vacuum through the sterilization chamber. In a conventional steam sterilizer, the vacuum is generated by passing water at a high velocity through an ejector at a flow rate of 5.0 to 15.0 gpm (18.9 to 56.8 lpm) and discharging it directly to the sanitary sewer.[6] To reduce this water use, a second pump and water reservoir can be added to capture and reuse a portion of the water.

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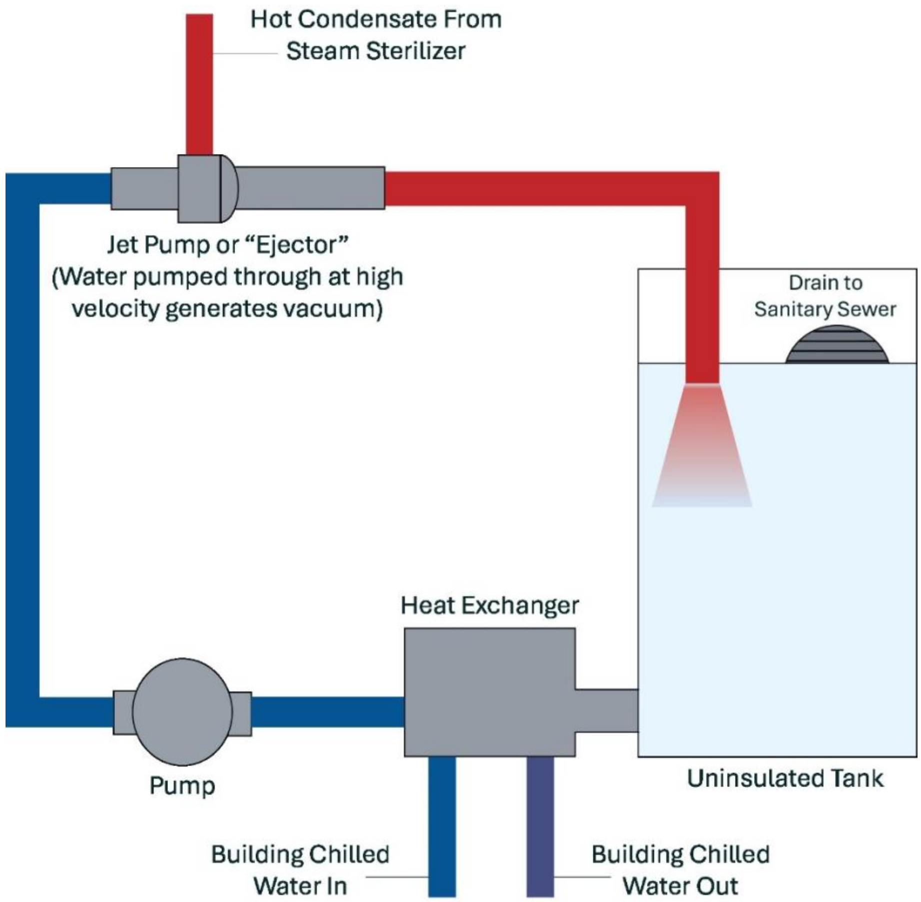
[5] Recreated from image included in *Ibid*., Page 4. Permission provided by Tim Crow of Consolidated Steam Sterilizer Systems (www.consteril.com).

[6] Koeller, John, et al. August 2004. *A Report on Potential Best Management Practices.* Prepared for the California Urban Water Conservation Council. Page 26. https://calwep.org/wp-content/uploads/2021/03/Steam-Sterilizer-Retrofit-PBMP-2004.pdf.

New steam sterilizers can use an electric liquid-ring vacuum pump or a dry vacuum pump. Generating a steam sterilizer vacuum using a liquid-ring vacuum pump instead of an ejector can reduce water use by up to 75 percent compared to the water used through the vacuum generation on a conventional steam sterilizer.[7]

To further improve the water efficiency of steam sterilizers, some newer models collect hot steam sterilizer condensate and send it through a heat exchanger, where heat is transferred to a closed building chilled water loop. The cooled condensate is then reused to generate the vacuum. This allows the condensate to be fully reused, eliminating the need for additional water for tempering or vacuum creation. This type of system is illustrated in Figure 4.

Figure 4. Steam Sterilizer Vacuum System Reusing Condensate by Utilizing a Heat Exchanger With the Building Chilled Water Loop[8]



[7] Consolidated Sterilizer Systems. Green Technology for Reducing Sterilizer Water Consumption. https://consteril.com/products/smart-options/water-saving-systems/.

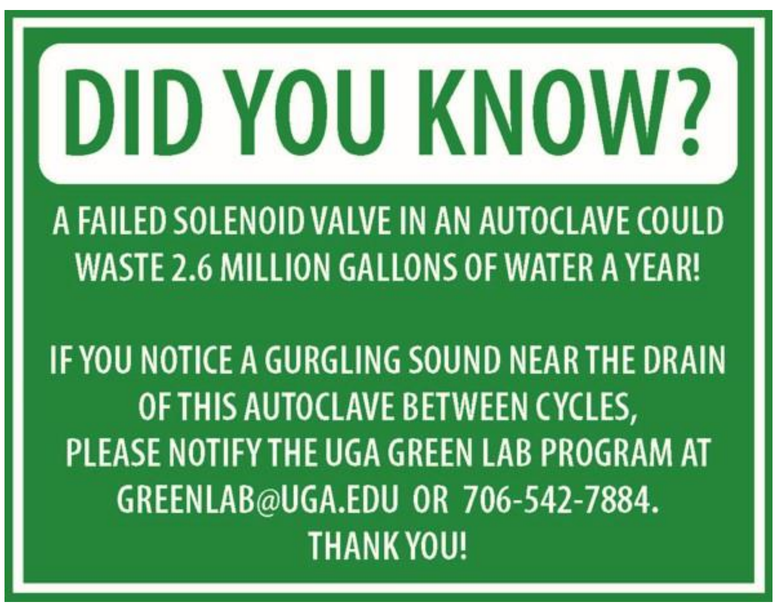
[8] Recreated from image included in Fitch, J., et. al., *op. cit.,* Page 5. Permission provided by Tim Crow of Consolidated Steam Sterilizer Systems (www.consteril.com).

Operation, Maintenance, and User Education

To optimize the water efficiency of a steam sterilizer, consider the following operation, maintenance, and user education techniques:

- Turn off the steam sterilizer when not in use or program the sterilizer to turn off at the end of the workday, on weekends, or after being idle for an extended period.
- If using a standard needle valve to control tempering water flow, adjust its flow rate to the minimum manufacturer recommendation and periodically review and readjust to ensure no unnecessary water is discharged to the drain.
- If used, change out the needle valve annually because they can wear quickly. Worn valves can discharge excess water.
- If the steam sterilizer is already equipped with a thermostatically actuated valve to control tempering water flow, periodically check the valve to ensure it is opening and closing properly so tempering water is not continuously discharged. Tempering water should only be applied while the steam sterilizer is operating.
- Include signage to help educate lab staff on how to identify a malfunctioning thermostatically actuated valve and whom to contact to get it fixed. Figure 5 shows an example of posted signage from the University of Georgia Green Labs program.

Figure 5. Example Signage on How to Identify a Malfunctioning Thermostatically Actuated Valve[9]



[9] Image included with permission from Star Scott, Green Labs Program Manager at the University of Georgia.

Retrofit Options

There are two retrofit approaches to reduce the water use associated with steam sterilizers. One approach addresses the use of tempering water, and the other addresses the water used to create the vacuum in the sterilization chamber. Depending upon the operational settings, frequency, and timing of sterilizer use and whether the tempering water flows continuously, retrofitting a conventional steam sterilizer to reduce its water use can be cost-effective.

Tempering Water Retrofit

To reduce the amount of tempering water necessary to cool the steam condensate that is discharged, replace the standard needle valve with a thermostatically actuated valve. This type of valve can monitor the temperature of the condensate discharge and will adjust and minimize the flow of cooling water necessary to maintain a discharge temperature below 140°F (60°C). In addition, consider diverting the steam condensate into a small, uninsulated tank prior to discharge. This tank will allow the condensate to cool through heat exchange with the ambient air to the point where little to no additional cooling water is required to meet the 140°F (60°C) temperature discharge requirement. These retrofits can reduce condensate cooling water use by as much as 90 percent.[10]

Facilities can also identify alternative sources of cooling water, such as reverse osmosis system reject water, that may be available in the lab to collect for use as tempering water.

Vacuum Retrofit

In conventional steam sterilizers, vacuum units contain an ejector that creates the vacuum in the sterilization chamber. Water is typically passed through the ejector at a very high flow rate before it is discharged down the drain. To capture and reuse a portion of the water passing through the ejector, a second, additional ejector with a pump and a water reservoir can be added. This modification channels 50 to 75 percent of the water flowing through the ejector into an uninsulated tank, where it is allowed to cool before being reused through the pump and ejector.[11] If the captured water does not cool fast enough, a thermostatically actuated valve allows cold water to flow into the tank, and any overflow is sent to the drain. One limitation to this type of system is that it cannot be used on sterilizers with a sealing flange or any sterilizer that processes biohazardous material.

Replacement Options

When looking to purchase a new steam sterilizer or replace older equipment, look for models that use the building's chilled water loop as a heat exchanger to cool tempering

[10] Fitch, J., et. al., *op. cit.,* Page 6.
[11] Koeller, et. al., *op. cit.*, Page 27.

water, models that use onsite alternative water sources instead of utility-supplied potable water, models that cool condensate using an uninsulated tank, and/or models with thermostatically actuated valves that control tempering water to flow only when needed.

Multiple steam sterilizer models in an EPA laboratory

If the facility needs a steam sterilizer with a vacuum system, look for models that use the building chilled water loop to cool tempering water and reuse it for vacuum generation, significantly reducing or eliminating the need for tempering water and additional water to create a vacuum. If using the building chilled water loop as a heat exchanger is not possible, look for models that offer an electric liquid-ring vacuum pump or a dry vacuum that can significantly reduce the water used to establish a vacuum. If these models aren't available and an ejector must be used, look for models that have a vacuum unit with a second ejector and a reservoir to capture and reuse a portion of the water passing through the ejector.

Finally, look for models with features that can further reduce water use and improve efficiency, such as an automatic shut-off, or a programmable control system that shuts down the sterilizer during periods of non-use (e.g., non-business hours) and restarts the unit so it is ready for use when needed. Models are also available with improved chamber jacket cladding (i.e., insulation) to reduce sterilizer heat loss and ambient heat gain.

Savings Potential

Water savings can be achieved through steam sterilizer retrofit or replacement in two ways: reducing the amount of water required to temper the condensate, or reducing the water used to create the vacuum.

To estimate facility-specific water savings and payback, use the following information.

Steam Sterilizer Retrofit or Replacement to Reduce Tempering Water Use

Existing steam sterilizers can be retrofitted or new steam sterilizers can be purchased with a thermostatically actuated valve or a cooling reservoir system to reduce the amount of tempering water used to cool the steam condensate.

Current Water Use

To estimate the current tempering water use of an existing steam sterilizer, identify the following information and use Equation 1 on the next page:

- Flow rate of the sterilizer's tempering water. Most steam sterilizers use tempering water with a flow rate of 1.0 to 5.0 gpm (3.8 to 18.9 lpm).[12]
- Average daily operating period of the steam sterilizer. Note that some older models have tempering water that flows constantly, even if the unit is turned off or in idle mode. In this case, an average daily use of 24 hours should be used instead of the daily operating period to calculate daily water use.
- Days of sterilizer operation per year. If the tempering water is flowing constantly, even when the sterilizer is not in use and the facility is closed, 365 days per year should be used.

Equation 1. Steam Sterilizer Tempering Water Use (gallons or liters per year)

= Tempering Water Flow Rate x Daily Operating Period x Days of Operation

Where:

- Tempering Water Flow Rate: Gallons (or liters) per minute
- Daily Operating Period: Minutes per day
- Days of Operation: Days of sterilizer operation per year

Water Savings

A steam sterilizer retrofit or replacement that addresses tempering water can reduce tempering water use by up to 90 percent, depending upon how long the sterilizer is in idle mode.[13] To calculate tempering water savings that can be achieved from retrofitting or replacing an existing steam sterilizer, identify the current water use of the equipment, as calculated using Equation 1, and use Equation 2:

Equation 2. Water Savings From Steam Sterilizer Tempering Water Retrofit or Replacement (gallons or liters per year)

= Current Steam Sterilizer Tempering Water Use x Water Savings Potential

Where:

- Current Steam Sterilizer Tempering Water Use: Gallons (or liters) per year
- Water Savings Potential: Percent

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[12] DOE, FEMP, *op. cit.*
[13] Fitch, J., et. al., *op. cit.*

Payback

To calculate the simple payback from the water savings associated with the tempering water retrofit or replacement, consider the equipment and installation cost of the retrofit or replacement, the water savings as calculated using Equation 2 on the previous page, and the facility-specific cost of water and wastewater. If the steam sterilizer was replaced, use the cost of the new steam sterilizer or the incremental cost of the efficiency upgrades.

Steam sterilizer

Steam Sterilizer Vacuum Retrofit or Replacement with Additional Ejector

To reduce the water used by a sterilizer to produce a vacuum, existing steam sterilizer equipment can be retrofitted or new units purchased with an additional ejector with a pump and water reservoir to capture and reuse a portion of the water passing through the ejector. Purchasing a new steam sterilizer with this vacuum configuration would result in a longer payback period than retrofitting.

Current Water Use

To estimate the current water use of an existing steam sterilizer's vacuum, identify the following information and use Equation 3 on the next page:

- Flow rate of water needed to pull the required vacuum. This will be dependent upon the size of the unit.
- Number of sterilization cycles run each day.
- Duration of the conditioning phase. The average conditioning phase lasts 3 minutes.[14]
- Duration of the exhaust phase. The average exhaust phase lasts 30 minutes.[15]
- Days of sterilizer operation per year.

[14] Koeller, John, et al., *op. cit.* Page 26.
[15] *Ibid.*

Equation 3. Steam Sterilizer Vacuum Water Use (gallons or liters per year)

= [Vacuum Flow Rate x (Duration of Exhaust Phase + Duration of Conditioning Phase)] x Sterilization Cycles x Days of Operation

Where:

- Vacuum Flow Rate: Gallons (or liters) per minute
- Duration of Exhaust Phase: Minutes per cycle
- Duration of Conditioning Phase: Minutes per cycle
- Sterilization Cycles: Sterilization cycles per day
- Days of Operation: Days of sterilizer operation per year

Water Savings

On average, a vacuum retrofit or replacement that modifies the ejector can reduce vacuum water use by at least 50 percent.[16] To calculate water savings that can be achieved from this type of modification, identify the current water use of the equipment as calculated using Equation 3 and use Equation 4.

Equation 4. Water Savings From Steam Sterilizer Vacuum Retrofit or Replacement With Additional Ejector or Liquid-Ring Vacuum Pump (gallons or liters per year)

= Current Steam Sterilizer Vacuum Water Use x Water Savings Potential

Where:

- Current Steam Sterilizer Vacuum Waer Use: Gallons (or liters) per year
- Water Savings Potential: Percent

Payback

To calculate the simple payback from the water savings associated with retrofitting or replacing an existing steam sterilizer vacuum, consider the equipment and installation cost of the retrofit or replacement, the water savings as calculated using Equation 4, and the facility-specific cost of water and wastewater.

By retrofitting an existing steam sterilizer vacuum with an additional ejector, facilities should also consider the potential energy impact. The pump and other equipment included

[16] *Ibid*. Page 27.

with the retrofit or replacement can use additional energy. The energy use can affect the payback time and cost-effectiveness.

Steam Sterilizer Ejector Replacement With Liquid-Ring Vacuum Pump

When replacing a steam sterilizer, facilities can also select models that have an electric liquid-ring vacuum pump instead of a high-velocity ejector. Liquid-ring vacuum pumps can reduce vacuum water use by 75 percent compared to the water used through the vacuum generation on a conventional steam sterilizer.[17]

Current Water Use

To estimate the current water use of an existing steam sterilizer's vacuum, use Equation 3 on the previous page.

Water Savings

Purchasing a new steam sterilizer with an electric liquid-ring vacuum pump can reduce vacuum water use by approximately 75 percent.[18] To calculate water savings that can be achieved from replacing an existing steam sterilizer with one that has an electric liquid-ring vacuum pump, identify the current water use of the equipment, as calculated using Equation 3, and use Equation 4 on the previous page.

Payback

To calculate the simple payback from the water savings associated with replacing a steam sterilizer with one with a liquid-ring vacuum pump, consider the equipment and installation cost of the replacement, the water savings as calculated using Equation 4, and the facility-specific cost of water and wastewater.

By replacing a steam sterilizer with one with a liquid-ring vacuum pump, facilities should also consider the potential increase or decrease in energy use. The energy use will also affect the payback period and replacement cost-effectiveness.

Steam Sterilizer Replacement With Vacuum Pump Using the Building Chilled Water Loop as a Heat Exchanger

When replacing a steam sterilizer, facilities can select models that utilize the building chilled water loop as a heat exchanger to cool steam condensate and use it to generate vacuum. These systems can nearly eliminate the need for additional water for tempering or vacuum creation.

[17] Consolidated Sterilizer Systems, *op. cit.*
[18] *Ibid.*

Current Water Use

To estimate the current tempering and vacuum generation water use of an existing steam sterilizer, add the results from Equation 1 on page 9 and Equation 3 on page 11.

Water Savings

Installing a steam sterilizer that utilizes the building chilled water loop to cool condensate and reuse it to create a vacuum can nearly eliminate additional water needed for tempering and vacuum generation (a savings of 99 percent or more).[19] Therefore, the water savings that can be achieved from this replacement is nearly equal to the current water use of the system calculated by combining Equation 1 and Equation 3.

Payback

To calculate the simple payback from the water savings associated with replacing a steam sterilizer with one utilizing the building chilled water loop to reuse steam condensate, consider the equipment and installation cost of the replacement, the water savings as calculated by adding Equation 1 and Equation 3, and the facility-specific cost of water and wastewater. Adding heat load to the building chilled water loop may have energy implications that should also be considered.

Additional Resources

Consolidated Sterilizer Systems. Green Technology for Reducing Sterilizer Water Consumption. https://consteril.com/products/smart-options/water-saving-systems/.

Fitch, J., et. al., Environmental Quality and Water Efficiency Group, Stanford University. December 2013. *Fact Sheet on Steam Sterilizers at Stanford University*. https://suwater.stanford.edu/sites/g/files/sbiybj19876/files/media/file/sem_steamsterilizers_stanford_2013.pdf.

International Institute for Sustainable Laboratories (I2SL) and U.S. Environmental Protection Agency (EPA). May 2022. *Best Practices Guide: Water Efficiency in Laboratories*. www.epa.gov/system/files/documents/2022-06/ws-I2SL-Laboratory-Water-Efficiency-Guide.pdf.

Koeller, John, et al. August 2004. *A Report on Potential Best Management Practices*. Prepared for the California Urban Water Conservation Council. https://calwep.org/wp-content/uploads/2021/03/Steam-Sterilizer-Retrofit-PBMP-2004.pdf.

[19] Fitch, J., et. al., *op. cit.,* Page 5.

U.S. Energy Department (DOE), Federal Energy Management Program (FEMP). *Water Efficiency Improvements at Various Environmental Protection Agency Sites*. www.nrel.gov/docs/fy11osti/48950.pdf.

DOE, FEMP. Water-Efficient Technology Opportunity: Steam Sterilizer Condensate Retrofit Kit. www.energy.gov/femp/water-efficient-technology-opportunity-steam-sterilizer-condensate-retrofit-kit.

van Gelder, Roger E. and Leaden, John. University of Washington. 2003. *Field Evaluation of Three Models of Water Conservation Kits for Sterilizer Trap Cooling at University of Washington*. www.sterilizer.net/wp-content/uploads/2018/07/Van-Gelder-R-2003-Field-Eval-of-Water-Cons-Kits-for-Sterilizer-Trap-Cooling.pdf.

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