# Fact Sheet on Steam Sterilizers at Stanford University

By: Environmental Quality and Water Efficiency Group, Stanford University; December 2013
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Background:

Sterilization is a common practice in medical and laboratory settings where it is vital to destroy microbial life that can cause contamination, infection, or disease (US EPA 2012). Many different types of sterilization are available, including dry heat, low heat (comprises two categories: gas and chemical), microwave, ozone, and steam (US DHHS 2008). This fact sheet focuses on steam sterilization, as it is the most commonly used method at Stanford University. Steam sterilizers (Figure 1), a subcategory of autoclaves, are routinely used by researchers in the Stanford University Department of Biology and School of Medicine to ensure all biological contaminants are removed from laboratory and medical equipment prior to use (Figure 2).

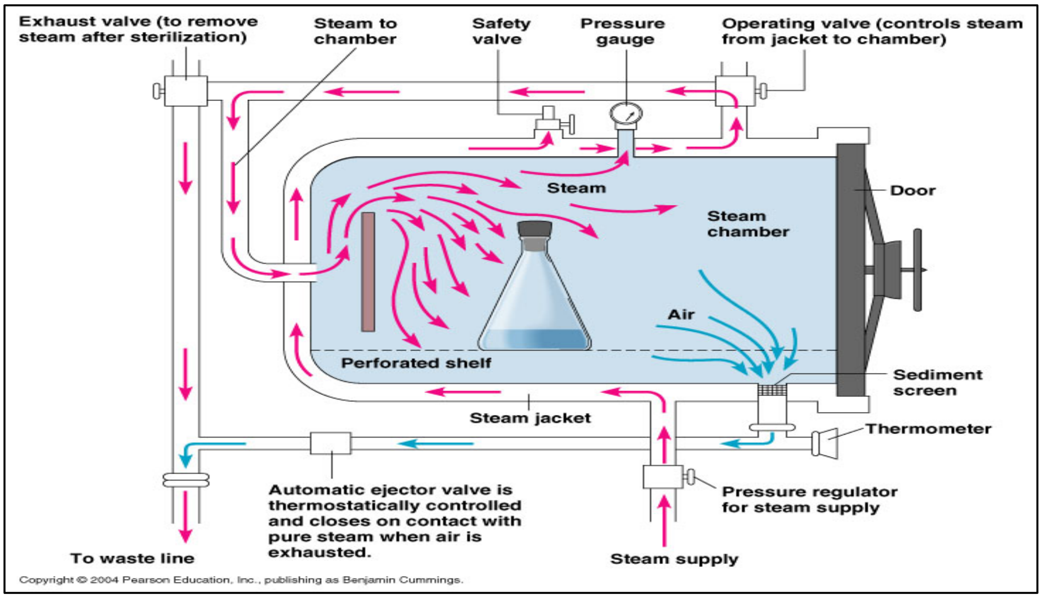



**Figure 1. An Autoclave. Source:** ***Tortora, Gerard J.; Funke, Berdell R.; Case, Christine L., Microbiology: An Introduction, 8th Edition, ©2004.*** **P. 187 Figure 7.2. Printed and electronically reproduced by permission of Pearson Education, Inc., Upper Saddle River, New Jersey.**


**Figure 2. Photographs of Steam Sterilizers at Stanford University: front of sterilizer (left), front of sterilizer with door open (middle), back of sterilizer (right).**

Steam sterilization employs pressurized steam to decontaminate articles within a sealed chamber. Steam is capable of eradicating microorganisms on surfaces and penetrating porous materials of equipment within the sterilization chamber. Successful sterilization depends on replacing the air inside the sterilization chamber with steam; residual air pockets can decrease the effectiveness of the steam.

Steam sterilizers have two different modes of operation: standby and active. Standby mode is when the sterilizer is not actively in use, but is kept ready to use. During standby mode, small amounts of steam are injected into the jacket and sterilization chamber to maintain a steady temperature and a sterile environment. Active mode is when sterilization is actively occurring (Koeller 2004).

Sterilizers are broken down into two main categories: gravity type and vacuum type, which use different methods of removing air from the sterilizer. The air removal method dictates which sterilization cycles are available to the operator and how certain operational phases are processed.

Gravity type sterilizers use the **downward displacement air removal method**, which utilizes gravity to remove air from the sterilizer chamber. Steam rises as it enters the chamber, due to its density being lower than that of air. The steam then pushes the denser air downward and out through a drain in the bottom of the chamber (Figure 1). While in active mode there is a series of operational phases that the sterilizer goes through: 1) conditioning phase, steam enters and air is removed from the chamber; 2) exposure phase, steam is used to sterilize the load at a selected temperature and pressure; and 3) exhaust phase, steam is drained from the chamber and the load is dried by drawing filtered air through the chamber (dry time is selected by the operator). An ejector, which utilizes the venturi principle (explained below), is used during the dry cycle to draw atmospheric air into the chamber (Koeller 2004). Different cycle options are available to the operator which controls temperature, run time duration, dry time and is based primarily on load type. Available cycles include: liquid, gravity, and dry cycles.

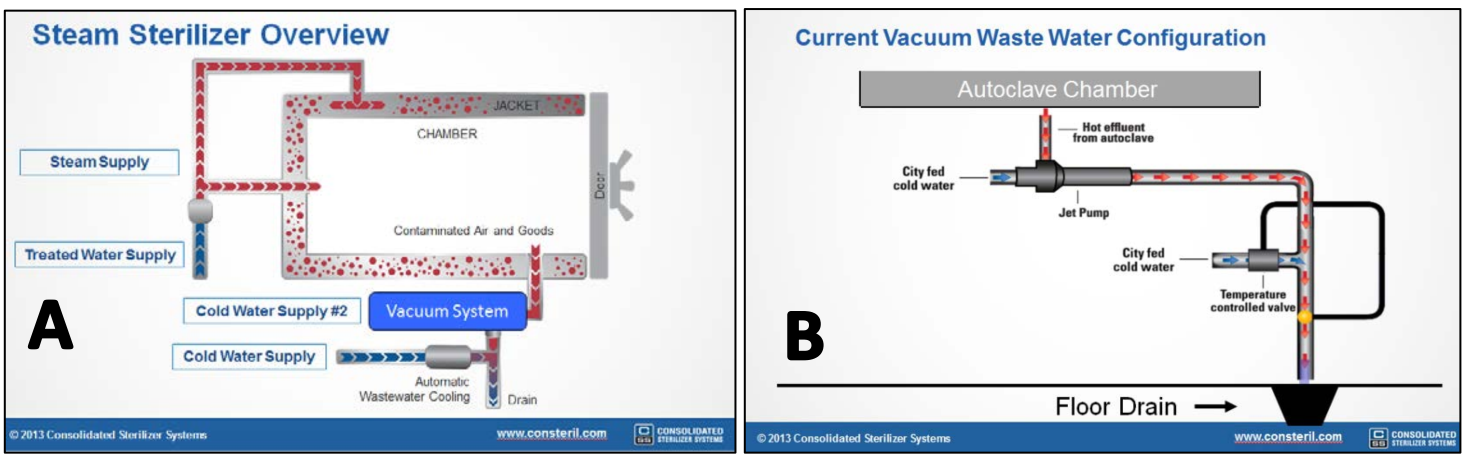
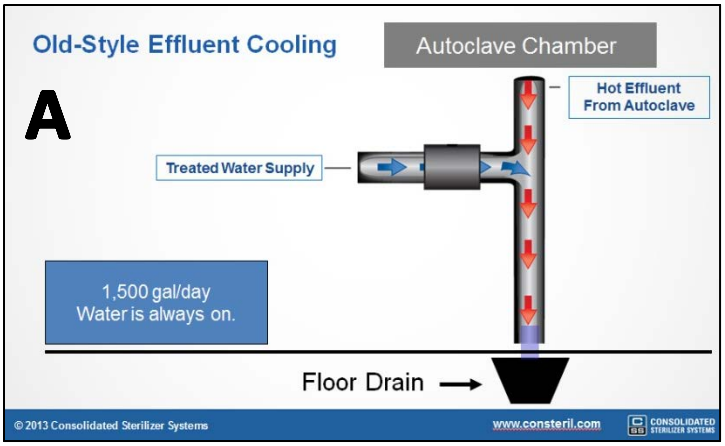



**Figure 3. Diagram of Steam Sterilizer with Vacuum System (left). Diagram of Effluent Flow from Steam Sterilizer with Vacuum System (right). Images provided by Arthur Trapotsis, Consolidated Sterilizer Systems.**

Vacuum type sterilizers use the **dynamic air removal method** (Figure 3, A). Dynamic air removal uses the venturi principal in design; domestic water is passed through a narrowed section of an ejector/jet pump which greatly increases the velocity of the water, and pulls air from the chamber to create a vacuum effect (Koeller 2004). As the air is removed, it is replaced with steam. While the dynamic air removal method removes air much faster and more thoroughly than downward displacement, it also uses substantially more water. During vacuum creation, domestic water is passed through the ejector venturi and flows to drain. Operational phases performed by the sterilizer include: 1) conditioning phase, air is removed and replaced by steam; 2) exposure phase, steam is used to sterilize the load at a selected temperature and pressure; and 3) exhaust phase, steam is drained from the chamber and the load is dried by creating a vacuum in the chamber (dry time is selected by the operator) (Koeller 2004).

Available cycles include: liquid, gravity, pre-vacuum, and dry cycles; dynamic air removal allows for a vacuum to be created during the pre-vacuum cycle and the dry cycle (where steam is pulled from the chamber).

Aside from vacuum creation, water is used in steam sterilizers for quenching (reducing the temperature of) hot effluent water and condensate. When sterilization is complete, condensate exits the chamber, and additional cold water is added to quench the condensate/effluent to an acceptable temperature (Figure 3, B). Effluent flow must be below 140°F prior to entering the sewer to comply with California Plumbing Code Regulation 810.1, and to prevent damage to sewer pipes. Inefficient sterilizers use a constant flow of cold water (even when equipment is not in use or is turned off), so that cold water is available at any time in case hot effluent is discharged (Figure 4, A). Newer sterilizers have the option of including a temperature actuated valve to monitor the temperature of effluent and add cooling water only if the temperature exceeds 140°F (Figure 4, B). This option is required on all new Stanford projects as it substantially reduces unnecessary water use.



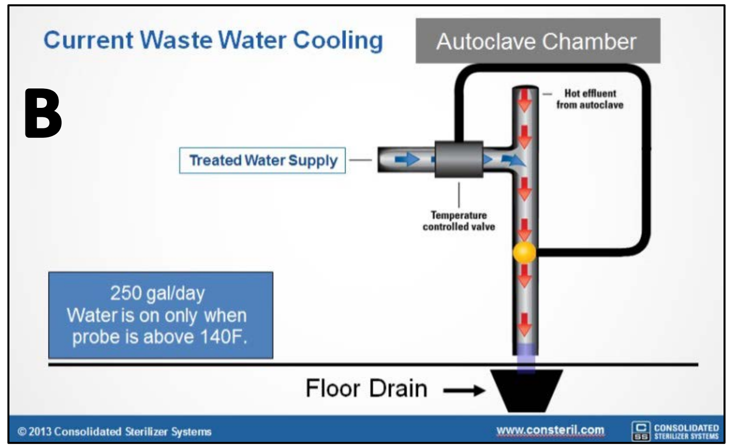




**Figure 4. Diagrams Showing the Change in Effluent Cooling Technology. Images provided by Arthur Trapotsis, Consolidated Sterilizer Systems.**

Water Use Reduction Strategies:

Technology is available to retrofit existing sterilizers to reduce water consumption. The sections below focus on water efficient retrofits, as well as recommendations for new sterilizers. Some options for water savings during quenching condensate/effluent water include (these options apply for all sterilizers, regardless of whether or not they have a vacuum system):

1) ***Temperature Actuated Valve***
A temperature actuated valve measures the temperature of the effluent water and allows cold water for quenching only when needed (when water exceeds 140°F) (Figure 4, B). This device prevents water from running 24/7 when the line is not in need of quenching. Water usage from one steam sterilizer can be reduced from approximately 1,500 gallons per day (1 gallon per minute, 24 hours/day) to approximately 250 gallons per day (Figure 4) with the installation of a temperature actuated valve (Trapotsis 2013). Proper maintenance of sterilizers prevents excessive water use. Some newer sterilizers come with the option of a built-in temperature actuated valve for quenching; this feature is required on all new Stanford projects.

2) ***Cooling Reservoir System***
A cooling reservoir system (water miser) directs the hot effluent from the sterilizer into a reservoir with a temperature probe inside (Figure 5, A). When the probe senses that the water temperature exceeds 140°F, a temperature actuated valve adds cold water to the tank. When the tank is full, cooled water (below 140°F) flows to the sewer (US EPA 2012). Stanford University's Water Efficiency Program has installed 66 water misers on steam sterilizers from 2001 to 2012 saving an estimated 92,700 gallons per year (Figure 5, B).

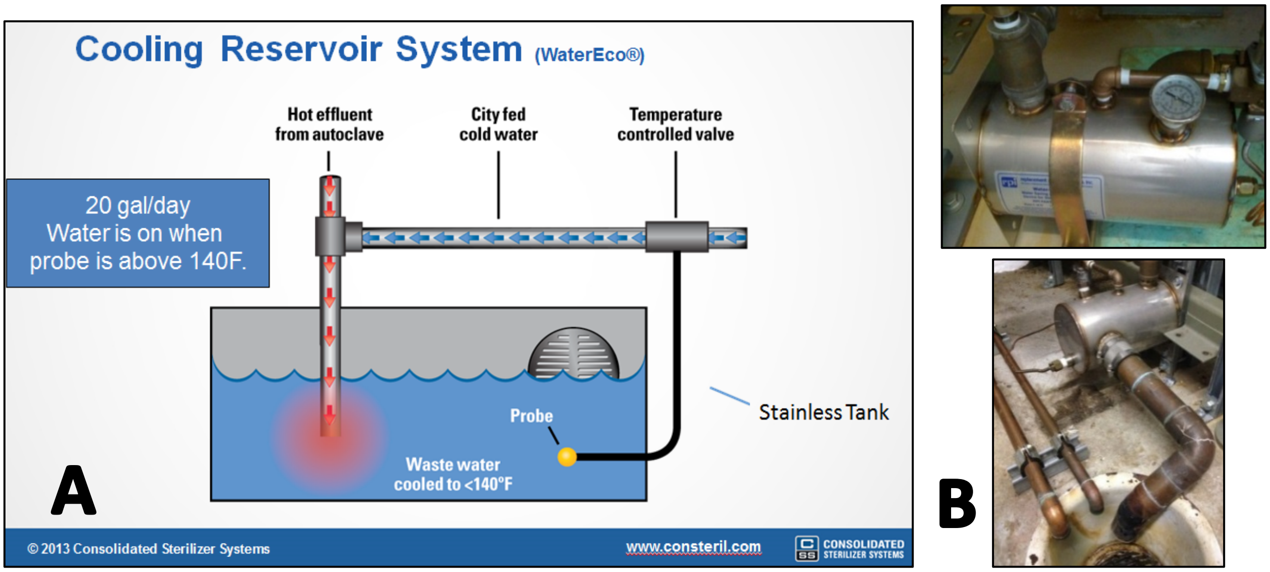



**Figure 5. Diagram of a Cooling Reservoir System (left). Image provided by Arthur Trapotsis, Consolidated Sterilizer Systems. Photographs of Cooling Reservoir System: water miser used at Stanford (top right), water miser connected to steam sterilizer and pipes going to sanitary sewer drain at Stanford (bottom right).**

3) ***Reuse of Reverse Osmosis (RO) Reject/Waste Water for Quenching***
Reuse of reverse osmosis (RO) reject/waste water for quenching is an excellent way to reduce domestic water use in steam sterilizers. RO filtration is commonly associated with Department of Biology and School of Medicine research buildings, and is also used for steam production in sterilizers. RO filtration generates large quantities of waste water that has no external additives and simply has a concentrated higher mineral content. Often, this water can be reused for quenching, saving domestic water for other uses. Stanford's School of Medicine completed a project in late 2012 to reuse RO reject water for quenching, generating an estimated savings of 181,000 gallons annually (Stanford 2013).

For the vacuum creation process in dynamic air removal discussed previously, three main options are available for increasing water efficiency (these measures only apply to sterilizers that use dynamic air removal):

1) ***Liquid Ring Vacuum Pump***
Replacing the steam sterilizer's water ejector with a liquid ring vacuum pump (for vacuum creation) can greatly reduce water consumption during the pre-vacuum and dry cycles. The liquid ring vacuum pump eliminates the need to have water flowing through the ejector and directly to the sewer; water used to create a vacuum can be reduced by up to 75 percent with this type of modification (US EPA 2012). When purchasing a new sterilizer, selecting a model with an electric liquid ring vacuum pump is essential for water efficiency.

2) ***Second Water Ejector with a Reservoir and Pump***
If a sterilizer uses a water ejector to create vacuum, some of the water passing through the ejector can be captured and reused via installation of a second water ejector with a reservoir and pump. Water from the ejector can be captured in the added reservoir and allowed to cool through ambient air circulation, the addition of cold domestic water, or use of a heat exchanger. The water can then be reused for vacuum creation. This method reduces water use for sterilizer vacuum creation by approximately 50 percent (US EPA 2012). When purchasing a new sterilizer without a liquid ring vacuum pump, a model with a second ejector and a reservoir should be considered for increased water efficiency.

3) ***Recirculating water lines with a heat exchanger***

A recirculating water line with a heat exchanger (Figure 6) eliminates the need for effluent quenching; the effluent water that is cooled through the heat exchanger can be reused for vacuum creation. Hot effluent water from the sterilizer is piped into a large holding tank; from the tank the water goes through a heat exchanger. The heat exchanger uses a conductive panel to transfer heat from the effluent water to a closed-line of utility-provided chilled water (which is recirculated and cooled by the utility). Once the temperature of the effluent water has been reduced, it is recirculated and reused for vacuum creation. The effluent water never comes in direct contact with the chilled water. When the holding tank becomes full, water is discharged to sewer (temperature will be below the 140°F sewer limit). This option is the most water efficient, reusing condensate/effluent water from the sterilization process and eliminating the need for additional water to be used for quenching or vacuum creation.

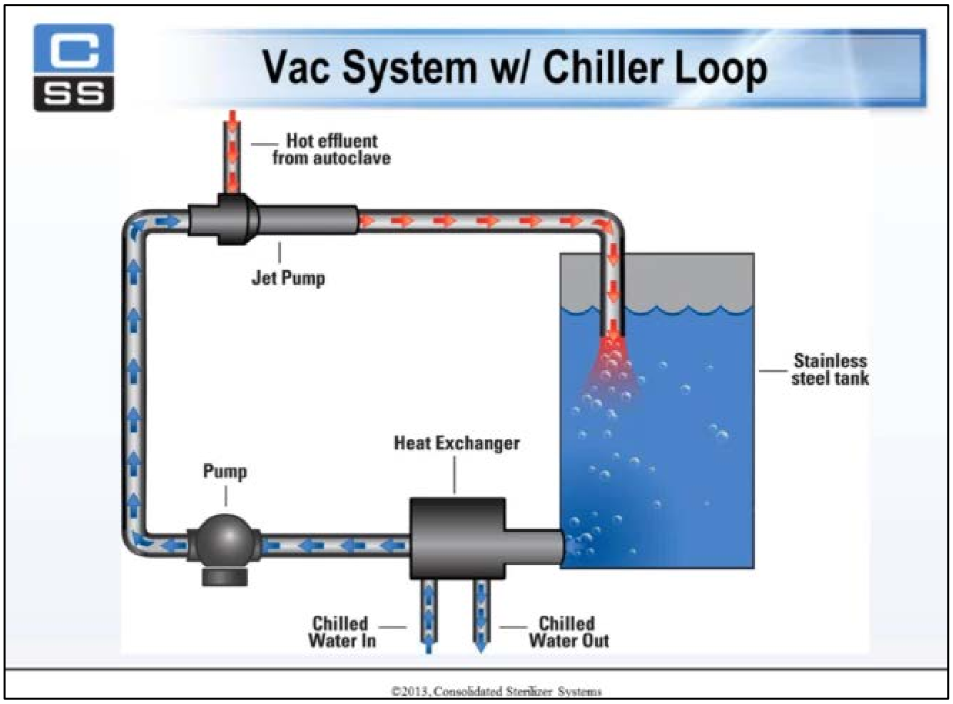



**Figure 6. Diagram of Recirculating Water Lines with a Heat Exchanger. Slide from webinar presentation by Arthur Trapotsis, Consolidated Sterilizer Systems.**

## Best Management Practice, Efficiency Features for New Equipment, and Most Important Retrofits for Old Equipment:

Management Practice:

1). Shutting sterilizer units off at night can reduce water usage by 20% to 40%

2). Replacing needle valves (which control the flow of quenching water) once per year prevents use of excess water due to wear or adjustment (Koeller 2004)

Efficiency Features for New Equipment, and Most Important Retrofits for Old Equipment:

<table>
<tr><th></th><th colspan="2">Retrofits</th><th colspan="2">New Sterilizers</th></tr>
<tr><th></th><th>Gravity Displacement Sterilizers</th><th>Pre-Vacuum Sterilizers</th><th>Gravity Displacement Sterilizers</th><th>Pre-Vacuum Sterilizers</th></tr>
<tr><td rowspan="5">more water efficient<br><br>less water efficient</td><td>Addition of a temperature actuated valve with a cooling reservoir (water miser) can reduce cooling water by up to 90%. ($)</td><td>Addition of a temperature actuated valve with a cooling reservoir (water miser) can reduce cooling water by up to 90%. ($)</td><td rowspan="2">Only purchase new sterilizers with temperature actuated valves. Optimal selection is an actuated valve with a cooling reservoir (water miser) ($)</td><td>Including closed recirculating water lines with a heat exchanger will eliminate the need for additional water for quenching or vacuum creation. ($$$$ - $$$$$)</td></tr>
<tr><td>Addition of a temperature actuated valve can reduce water needed for cooling by 50% to 80%. ($)</td><td>Addition of a temperature actuated valve can reduce water needed for cooling by 50% to 80%. ($)</td><td>Only purchase new sterilizers with temperature actuated valves. Optimal selection is an actuated valve with a cooling reservoir (water miser) ($)</td></tr>
<tr><td>*Reuse of reverse osmosis reject water for quenching. **($$$ - $$$$$)</td><td>*Reuse of reverse osmosis reject water for quenching. **($$$ - $$$$$)</td><td rowspan="3">*Reuse of reverse osmosis (RO) reject water for quenching. Utilize a design that locates new sterilizers close to RO tanks. Cost may vary; estimated cost for recycled water pipes are about 10% of the building plumbing cost when installed into a new building. **($$$ - $$$$$)</td><td>For new sterilizers, select option with liquid ring vacuum pump. ($$$)</td></tr>
<tr><td rowspan="2"><table><tr><th colspan="2">Key</th></tr><tr><td>$</td><td><$3,000</td></tr><tr><td>$$</td><td>$3,000 - $5,000</td></tr><tr><td>$$$</td><td>$5,000 - $10,000</td></tr><tr><td>$$$$</td><td>$10,000 - $20,000</td></tr><tr><td>$$$$$</td><td>$20,000 - ≥ $30,000</td></tr></table></td><td>Retrofit existing sterilizers with liquid ring vacuum pumps. This retrofit can decrease water use for vacuum creation by 75%. ($$$)</td><td rowspan="2">*Reuse of reverse osmosis (RO) reject water for quenching. Utilize a design that locates new sterilizers close to RO tanks. Cost may vary; estimated cost for recycled water pipes are about 10% of the building plumbing cost when installed into a new building. **($$$ - $$$$$)</td></tr>
<tr><td>Inserting an additional ejector and a reservoir to capture and reuse water can reduce water use for vacuum creation. This retrofit can reduce vacuum water use by up to 50%. ($$$$)</td></tr>
</table>

*Note: percent savings would be determined by amount of RO water created/rejected and the number of sterilizers present

**Pricing information is based on estimates from a specific project at Stanford University (2013) and is likely to vary at other project locations

## Selected References:

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