VI. Steam Sterilizer Retrofits

1. Background

Steam sterilizers, a subcategory of autoclaves, are utilized in three major applications: hospitals, pharmaceutical manufacturers, and research institutions. They are used to disinfect (1) surgical instruments in hospitals and (2) instruments and apparatus used in the research and manufacture of products where sterilization is essential. The purpose of sterilization is to destroy all living microorganisms that include spores, viruses and bacteria including those that cause infection or disease (pathogens). Although other types of sterilizers exist, including dry heat, ethylene oxide, and radiation, steam sterilizers are by a large margin the most widely used form of sterilization. Sterilizers present a major opportunity for water conservation because water is used in these units when they are in operation and when they are at idle.

Water is used in sterilizers in two main areas: jacket and chamber trap cooling and in the ejector, which is used to create the vacuum. Depending upon the unit's usage pattern and size, water and sewer rates, operator practices, and other factors, trapway cooling and/or ejector vacuum water usage may be a candidate for water efficiency.

Sterilizer Classifications

Sterilizers are divided into two major categories: *tabletop,* which are small and do not represent viable water conservation candidates and the *freestanding type,* which are much larger, use large quantities of water in many installations, and where conservation opportunities exist. *Freestanding* sterilizers are further broken down into the *vacuum type*, where the chamber is subjected to a vacuum during the drying phase and the *gravity type,* where filtered air is drawn through the chamber during the drying phase. Air is removed from vacuum units to avoid stratification and coincident cold spots created by the presence of air in the chamber. Vacuum units sterilize much quicker than gravity units and are generally found in applications such as operating rooms where time is essential. Sterilizers generally range in standard size from about 3.8 cubic feet to 71 cubic feet; however, custom "walk-in" designs are as large as 2800 cubic feet.

Manufacturers

Two manufacturers lead the market in the United States and California in the sale of freestanding steam sterilizers: Amsco (Sterris) Corporation and Getinge-Castle. A third firm, ARS, builds customized sterilizers and ancillary systems for sterilizers. ARS is not a nationally distributed product but is a regional participant in Southern California.

All manufacturers utilize the same basic technologies to accomplish the sterilization task. First, inject low-pressure steam into the chamber when the sterilization process is taking place and, second, create a vacuum in the sterilization chamber during the dry phase cycle. Most all sterilization processes take place with temperatures ranging from 212º F on the low side up to about 275º F for certain load applications. Additionally, all manufacturers pass some steam into the chamber when the unit is in the standby mode in order to keep the unit ready to activate at a moment's notice.

Amsco (Sterris), the largest and most commonly found of the manufacturers, has the largest sterilizer product line. Sterris has approximately 4,700 units installed in California. Their approach to water efficiency is the retrofit of a vacuum pump[35] to eliminate the ejector and all ejector water consumption together with a control/solenoid valve arrangement for condensate trap cooling[36]. Both of these elements have added maintenance requirements and are considered unreliable and, thus, will not be discussed in this analysis.

Following are brief summaries of the two equipment approaches to water-efficiency analyzed in this report. More detailed descriptions may be found in Section 2.

> *Jacket and Chamber Condensate Drain Water Modification*
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> Continental Equipment Company is not a manufacturer of sterilization equipment but manufactures a water-efficient technology, the Water Mizer□ [37] that can be retrofitted onto almost any sterilizer for jacket and chamber condensate cooling. This technology reduces condensate cooling water flow by approximately 90 percent and is similar to the technology offered by ARS mentioned below.
>
> *Ejector Water Modification*
>
> Getinge-Castle, the second largest manufacturer in terms of market share with approximately 3,100 units installed in California, is more innovative in their approach to water efficiency. They offer their MP-129 Modernization Package[38] which lowers ejector water consumption by approximately 75 percent. Getinge-Castle does not offer a technology that addresses condensate trap cooling.
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> ARS, the smallest manufacturer, with about 600 units installed in Southern California, primarily builds highly customized sterilizers. However, ARS also offers the most flexible and comprehensive array of water-efficiency packages, including trap cooling and ejector packages as well as one package that completely eliminates all water consumption.

Sterilizer Operation

Sterilizer operation is broken down into two modes or cycles of operation: *ready (standby)* and *active (sterilization)* mode.

> *Ready (Standby) Mode*
>
> Depending upon the application and the operator, many units will be turned off at night and other periods of time when no sterilization activity is anticipated. When these units are reactivated, they are run through a "flash cycle" which brings the unit up to temperature and sterilizes the internals of the unit. Most units are kept in a ready mode

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[35] Sterris Corporation, document number M1408.980529 Water Conservation Kit/Vacuum Pump Modification

[36] Sterris Corporation, document number M1407.011115 Rev. C Water Conservation Kit/Trap Cooling Modification.

[37] Continental Equipment Company brochure dated 2002.

[38] Getinge-Castle MP 129 Water saver Modification Package, Dated 1993.

during the day so that when multiple sterilization runs are required, the unit will not have to go through repeated “flash cycles” before it can be used for sterilization. Many units are kept in the standby mode 24 hours a day and therefore do not require a flash cycle during start-up.

To keep the unit in the standby mode, small amounts of low-pressure steam are passed into the chamber to maintain a specific temperature in the chamber to keep it sterile. As this steam condenses, it is bled off to a floor drain where it mixes with municipal water to cool it below 140º F before it goes into the sanitary sewer lines

Steam is also fed into the chamber jacket to keep it hot. By keeping the sterilizer jacket hot, less steam condenses in the chamber during the standby and sterilization modes. Additionally, when steam is now injected into the chamber it has a greater ability to sterilize rather than being consumed as waste by condensing on the chamber walls, thus partially defeating the sterilization process and lengthening the time needed for sterilization. By keeping the walls of the chamber hot, any potential condensation is nearly eliminated and, thus, less steam is required in the chamber. This steam eventually condenses in the jacket, similar to the steam in the chamber, and it is led to a trapway below the unit where it is also cooled below 140º F.

Code prohibits temperatures of water discharged to the sewer exceeding 140º F. To lower the temperature of the condensate leaving the two trapways, cold potable water is mixed with the condensate to lower the temperature to comply with code. Standby condition flow rates range from 0.5-gallons per minute (gpm) to as much as 6.0-gpm (or more) in this mode. The flow rate is a function of the size of the chamber and how well the needle valve is maintained and adjusted. In the vast majority of applications visited, trapway flow rates range between 0.5 and 2.5-gpm. However, the needle valves employed on many units are either not maintained or are set improperly and they therefore pass more water to drain than is necessary.

Active (Sterilization) Mode

This mode of operation occurs when the unit is actively sterilizing a load. Although there are several different types of loads, each with different temperatures and durations, the series of operational phases is the same for each:

(1) Ready Phase: Unit is up to temperature and is ready for automatic processing.

(2) Conditioning Phase: Steam enters the chamber and conditions the load. Air is removed from the chamber.

(3) Exposure Phase: Steam processes the load at a selected temperature and pressure.

(4) Exhaust Phase: Steam is removed from the chamber. The load is dried for a drying time selected by the operator.

(5) Complete: Control panel indicates that the processing cycles are complete.

Water is used extensively in the conditioning phase to remove air from the chamber and again in the exhaust phase to remove the steam and dry the load. This water passes through the ejector and goes directly to drain. Some water use occurs as the steam enters the unit and condenses, although the amount is very small.

The largest consumer of water in this mode is the ejector or venturi device which passes cold potable water through it to draw a vacuum in the chamber as seen in the figure which follows. The high velocity of water through the ejector creates a vacuum (low pressure) at that point, which is connected through a vent line to the chamber. Ejectors use approximately 5 to 6-gpm on small units and 10 to 15-gpm on the largest units. The initial conditioning phase (where a vacuum is drawn) lasts for about 2-3 minutes. The exhaust phase, again where the ejector is activated, can last anywhere from 12 minutes up to 2 hours depending upon load and operator discretion. The most common loads take about 24-30 minutes in the exhaust phase.

2. Water-Efficiency Measures

Jacket and Chamber Condensate Cooling Modification

This measure is designed to reduce the water consumed during "ready" or "standby" mode discussed earlier. This is the state during which the sterilizer operates most of the time. During standby mode, the sterilizer is kept at an elevated temperature by periodically introducing steam into the chamber to keep it sterile so that it can be utilized at a moment's notice without having to go through a "flash" cycle. The steam that is introduced eventually condenses and flows to the trap drain located beneath the sterilizer. The chamber jacket must be continuously heated to prevent cooling of the chamber walls and subsequent problems in the sterilizer when called upon. To prevent water at a temperature above 140º F from entering the sanitary sewer, water in the jacket and chamber traps is cooled by potable water. This water runs 24 hours a day at the flow rates set during start up by the adjustment of a needle valve. Needle valves should be changed out approximately once a year because of wear. Generally, replacement is not performed and most units flow cooling water at rates two to four times the manufacturer's recommended set point. Flow rates exceeding ten times the manufacturer's recommended set point have been observed in isolated cases. As mentioned earlier, recommended flow rates range from 0.5 to 3-gpm on most units but may range up to 5-gpm on units not maintained.

The condensate drain modification consists of a small tank and a thermostatically actuated valve. This is a simple technology that intercepts all the condensate from the chamber and jacket before it has a chance to go to drain. The tank is uninsulated and will transfer most of the excessive heat to (room) ambient atmosphere, which is kept, between 60º and 70º in most operating rooms. The quantities of water coming from the chamber and the jacket are relatively small so the tank will have enough time to cool the condensate well below the 140º F level before any cooling water must be added. No attempt is made to save the condensate. However, if the temperature does occasionally elevate above 140º F, the thermostatic valve will open and allow potable water to flow into the tank, thereby lowering its temperature below 140°F. The system operation is simple and easy to maintain. There is no electrical power needed. Most other technologies employ a logic controller and temperature sensors which can be complicated for service personnel and are sometimes unreliable, especially when the sensors fail or do not read the temperature of the water in the trap correctly.

The equipment associated with this technology is relatively small in size, consisting of a small tank and external thermostatic valve. The length is 12 inches, width is 7-1/2 inches, and height is 10 inches. The unit is small enough to fit beneath most sterilizer units or it can be mounted next to the support structure of the sterilizer if needed. Space constraints are not a major obstacle to the installation of this technology.

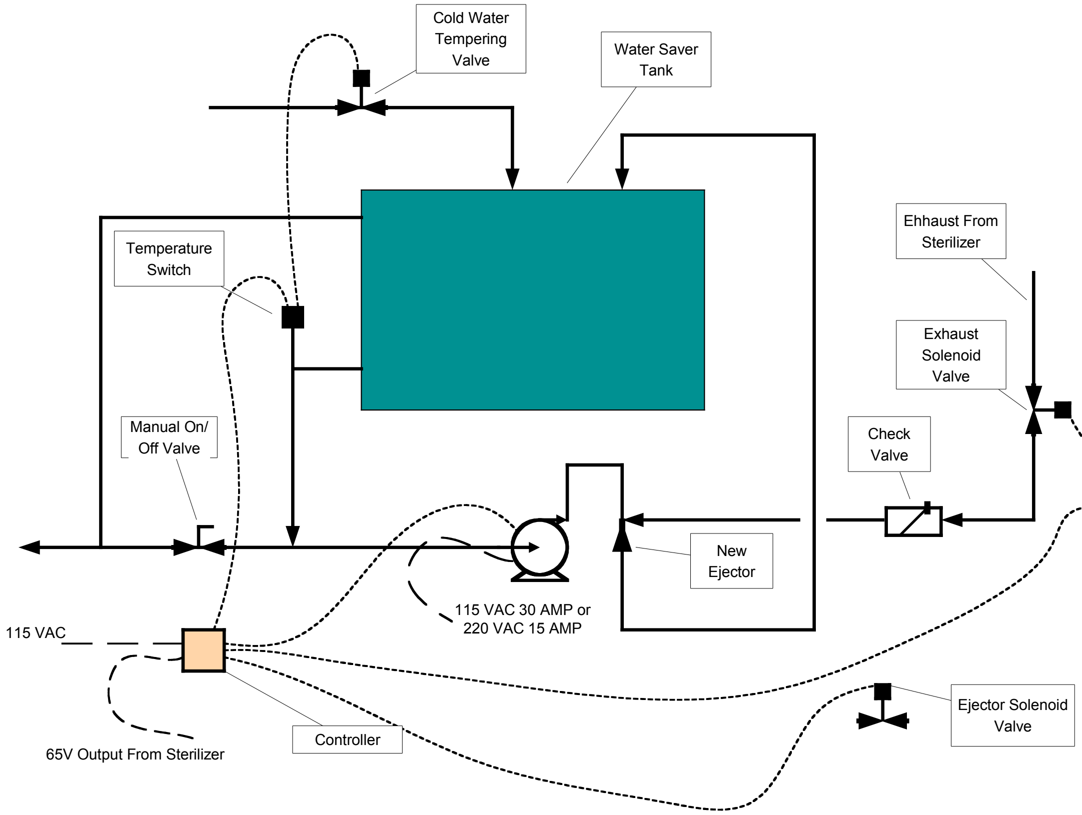
Ejector Water Modification

Vacuum units contain a device called an ejector that is used to create the vacuum in the sterilization chamber. Ejectors work on a venturi principle where potable water is passed through a narrowing in the ejector and the velocity of the water is greatly increased. A vacuum is created at this point by the high velocity water drawing off air.

Gravity (atmospheric) units also use this same ejector device to draw atmospheric air into the chamber after passing through HEPA filters. Drying times are lengthened when gravity units are used because of the presence of air. Therefore, on those units that are subjected to frequent use in the active sterilization mode, it is worthwhile to investigate opportunities to employ the more heavily engineered solution by modifying the water controls and piping being supplied to the ejector.

In either case, water passes through the ejector venturi one time and then flows to drain. The simple modification for single sterilizer applications takes a portion (50 to 75 percent) of the water flowing through the ejector and channels it into a small tank located under or behind the unit. The water cools in the tank due to the localized flow of ambient air (at 60º-70ºF) around the unit. On those sterilizers that see limited usage, the ambient air may provide all necessary cooling before the next sterilization cycle is called for. This modification is shown in the Figure 3.

Figure 3. Ejector Water Modification Schematic



The system incorporates a new water ejector with a pump and a water reservoir to recirculate a portion of the water that passes through the system. The system cannot be used on any sterilizer with a sealing flange, nor can it be installed on equipment that may process Bio Hazard material or Bio-contaminated waste.

When this ejector modification is employed, the system will determine whether the new or the standard ejector in the sterilizer provides the vacuum. A 115v, 30-amp or 220v, 15-amp pump is employed to circulate water through the ejector and into the new tank and then back to the suction side of the pump. This process repeats itself until the water reaches 120º F, at which point the temperature sensor activates the cold water tempering valve to open and allow cool potable water in the tank to reduce the temperature below 120º F. Excess water overflows through the drain connection on the upper side of the tank. The exhaust line from the chamber is retrofitted with a second line leading to the new ejector complete with it's own solenoid that is activated when the new system is energized and a check valve to prohibit water from being forced back into the chamber. The existing ejector solenoid valve is de-energized when the new system is in operation. A manual valve can be closed to allow maintenance or repair to the new system components, which allows normal (pre-modification) sterilizer operation when needed.

Space is a consideration in the implementation of this measure. The tank is physically larger than the Water Mizer mentioned earlier. More planning and effort must be given to the mounting of these systems and must be performed by experienced technicians familiar with the sterilizer technology. These units, which are specifically designed for the Getinge-Castle units, can also be adapted for use on Amsco sterilizers. They are often mounted to the support structure behind or next to the unit, rather than directly beneath the sterilizer.

On those applications (primarily hospitals) with "central sterilization" or "central processing" centers, another strategy can be employed where all of the ejector and trapway water is fed back to a central tank and stored. Heat is removed from this water via a cooling coil with chilled water supplied from the building's central chilled water system, located in the tank. Because of the expense of these systems, complexity of their design and installation challenges, these should only be considered on multiple unit installations. Space is at a premium in many hospital applications. This system requires about 6-8 square feet for skid-mounted components, electric power for a small recirculation pump, and a piping connection into the central chilled water system. The system is simple and reliable and is engineered to switch back to potable water in case of system failure.

The benefits of this approach are that 100 percent of the ejector and trapway water is saved. The first cost to retrofit several units in this manner (one system) may have a lower first cost than multiple installations of the previous technology discussed.

Performance Requirements and Specifications

At this time there is no governing authority that sets the standards for sterilizer performance or efficiency. Personnel working in "central sterilization", laboratory and R&D departments, and industrial production departments are generally trained in the field of sterilization and infectious disease control. Therefore, sterilization effectiveness is largely up to the operating personnel and the accuracy of information gained from the sterilizer control/feedback system. Sterilizer operational efficiency is left to the maintenance personnel of the facility and service contractors.

Useful Life

Sterilizers last up to 20 years with proper maintenance and repair. Of course, this figure varies greatly depending upon the time in use, operator practices, maintenance and repair practices, water conditions, steam quality, and atmospheric conditions in the sterilizer room. We have chosen conservation strategies partly based upon the maintainability and reliability of the product. Most of the strategies discussed have minimal control devices or moving parts that would otherwise be the components that would cause problems on any piece of machinery. Therefore, it is reasonable to expect that the water-efficiency strategies discussed in this report will remain operational (with reasonable maintenance and occasional service) with the same life expectancy as the sterilizers that they are serving.

3. Water Savings Estimates

Jacket and Chamber Condensate Cooling Modification

The calculations below assume the unit is retrofitted with the Continental Water Mizer□. The effectiveness of this water-efficiency measure is entirely dependent upon the time that the unit sits in the ready or standby mode. Standby time can generally be divided into three use classifications for analytical purposes :

- unit is turned on 12 hours a day.
- unit is turned on 18 hours a day.
- unit is never turned off.

Also, when the unit is going through a sterilization cycle, this time must be deducted from the standby time.

According to the only third party study done on the performance of the Water Mizer technology, the average idle flow for trapway cooling was 2.4 gpm. It was decided to use the data as presented from this study as the basis for our analysis because it is the best qualitative study containing useful information available[39]. Table 3 shows the spectrum of savings relating to hours of usage and sterilization time per day for one sterilizer.

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[39] Ibid.

Table 3. Savings: Jacket and Chamber Condensate Cooling Modification (Water Mizer□)

Hours of Operation per Day	Average Cooling Water Flow (gpm)	Condensate Cooling Water Consumption (gpd - 4 hours per day of sterilization)	Days of Operation per Year	Pre-Retrofit Consumption (gpy)	Post-Retrofit Consumption (gpy)	Savings (gpy)
12	2.4	1,152	250	288,000	28,800	259,200
18	2.4	2,016	250	504,000	50,400	453,600
24	2.4	2,880	250	720,000	72,000	648,000

gpm – gallons per minute
gpd – gallons per day
gpy – gallons per year
Pre-retrofit consumption = (hours per day – hours per day of sterilization) x average flow of 2.4-gpm x days of operation per year
Post-retrofit consumption = Pre-retrofit consumption x. 0.10 (representing a 90% reduction in consumption)
Savings = Pre-retrofit consumption – post-retrofit consumption

Ejector Water Modification

This water-efficiency measure is entirely dependent upon the time that the unit is running in the sterilization mode and, more specifically, how much time the unit is programmed to spend in the conditioning and exhaust phases. The calculations below assume Getinge-Castle units of varying sizes with actual ejector flow rates and average conditioning and exhaust phase times set at 3 minutes and 30 minutes, respectively. Table 4 shows savings based upon 4 and then 10 sterilization runs per day, a critical factor in defining the return on initial investment for this measure.

Table 4. Savings: Ejector Water Modification – 4 and 10 Sterilizing Runs Per Day

Model Number	Flow Rate (gpm)	Water Consump-tion – Conditioning Phase (gpc)	Water Consumption – Exhaust Phase (gpc)	Total Pre-Retrofit Consump-tion (gpc)	Machine Uses per Day	Days per Year	Pre-Retrofit Consump-tion (gpy)	Post-Retrofit Consump-tion (gpy)	Water Savings (gpy)
3533	6	18	180	198	4	250	198,000	49,500	148,500
3633	11	33	330	363	4	250	363,000	90,750	272,250
4233	18	54	540	594	4	250	594,000	148,500	445,500

Model Number	Flow Rate (gpm)	Water Consump-tion – Conditioning Phase (gpc)	Water Consumption – Exhaust Phase (gpc)	Total Pre-Retrofit Consump-tion (gpc)	Machine Uses per Day	Days per Year	Pre-Retrofit Consump-tion (gpy)	Post-Retrofit Consump-tion (gpy)	Water Savings (gpy)
3533	6	18	180	198	10	250	495,000	123,750	371,250
3633	11	33	330	363	10	250	907,500	226,875	680,625
4233	18	54	540	594	10	250	1485,000	371,250	1113,750

gpm – gallons per minute
gpc – gallons per cycle
gpy – gallons per year
Savings = Pre-retrofit consumption – post-retrofit consumption

4. Product Cost

Jacket and Chamber Condensate Cooling Modification

The estimated cost of the Water Mizer device, including installation, is shown below. It takes approximately 8 hours to install.

Continental Water Mizer	$1,850
Installation Labor	$600
Miscellaneous Parts	$50
Total Installed Cost	$2,500

Ejector Water Modification

The estimate below is based upon the Getinge-Castle MP129 Water Saver Modernization Package.

Getinge-Castle MP129	$13,500
Installation Labor	$1,200
Total Installed Cost	$14,700

5. Cost Effectiveness

Jacket and Chamber Condensate Cooling Modification

At the low range of water savings of approximately 259,000 gallons per year and a physical (useful) life of 20 years, aggregated savings would amount to about 5,180,000 gallons per installed Water Mizer (15.9 acre-feet). Assuming implementation through a direct install program (installation included), the undiscounted cost per acre-foot of water saved is approximately $157 per acre-foot.

At the high range of savings of 648,000 gallons per year, aggregate savings over a 20-year life would amount to about 40 acre-feet of water, yielding an undiscounted value of approximately $63 per acre-foot.

Ejector Water Modification

At the low range of water savings estimated at approximately 148,500 gallons per year, together with a physical (useful) life of 20 years, aggregated savings would amount to about 2,970,000 gallons per installed MP 129, or about 9.1 acre-feet of water. Again, assuming implementation through a direct install program (installation included), the undiscounted cost per acre-foot of water saved would be approximately $1,614 per acre-foot.

At the higher end of the savings range (approximately 1,113,750 gallons per year) and a physical (useful) life of 20 years, aggregated savings would amount to about 22,275,000 gallons per installed MP 129, or about 68 acre-feet of water. The cost per acre-foot of water saved would be about $215 per acre-foot.

These are conservative estimates of water savings. In reality, however, there are many applications that run more than the 4 and 10 sterilizer loads per day assumed in the examples shown above.

From the viewpoint of the end-user, the water savings achieved through sterilizer retrofits in a large medical facility potentially yields two significant benefits: reduced water consumption and reduced flows to the sanitary sewer. Depending upon the frequency and timing of sterilizer use, peak flows could be reduced as well.

Because water and sewer rates vary significantly throughout the state, the economic benefits would likewise vary. Over a range of rates, however, benefits to the sterilizer operator would be as shown in Figures 4 and 5 on the following page.

Figure 4. Cost Savings-Jacket and Chamber Condensate Cooling Modification

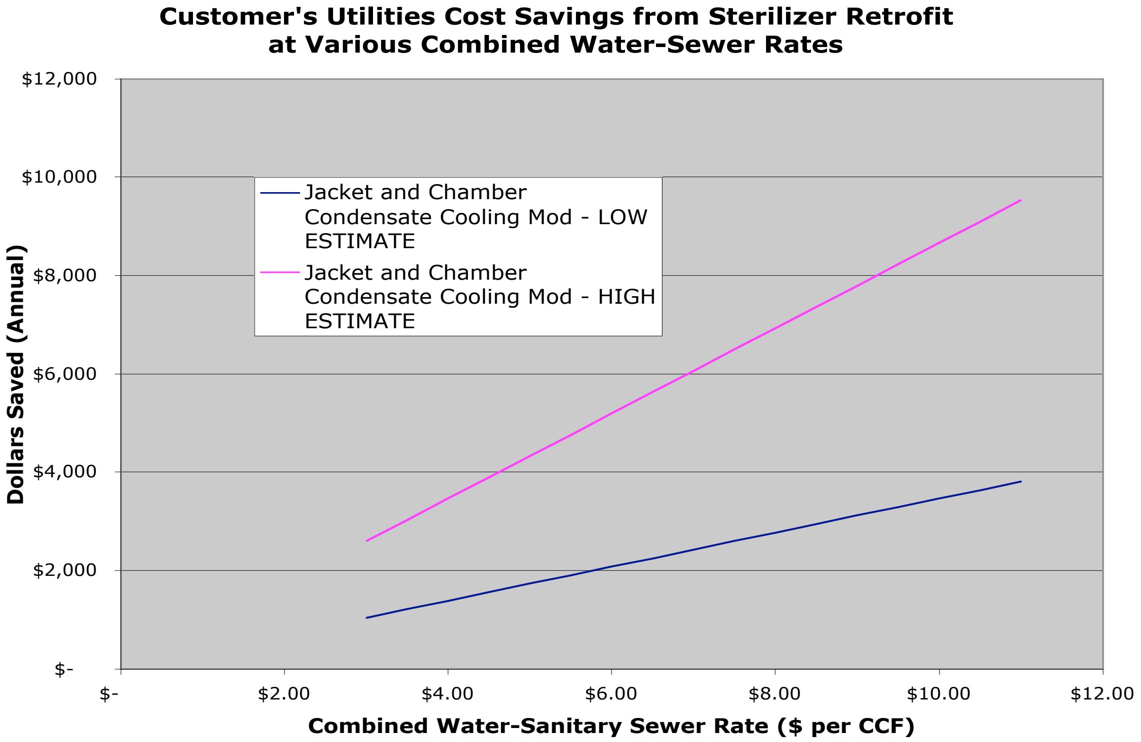
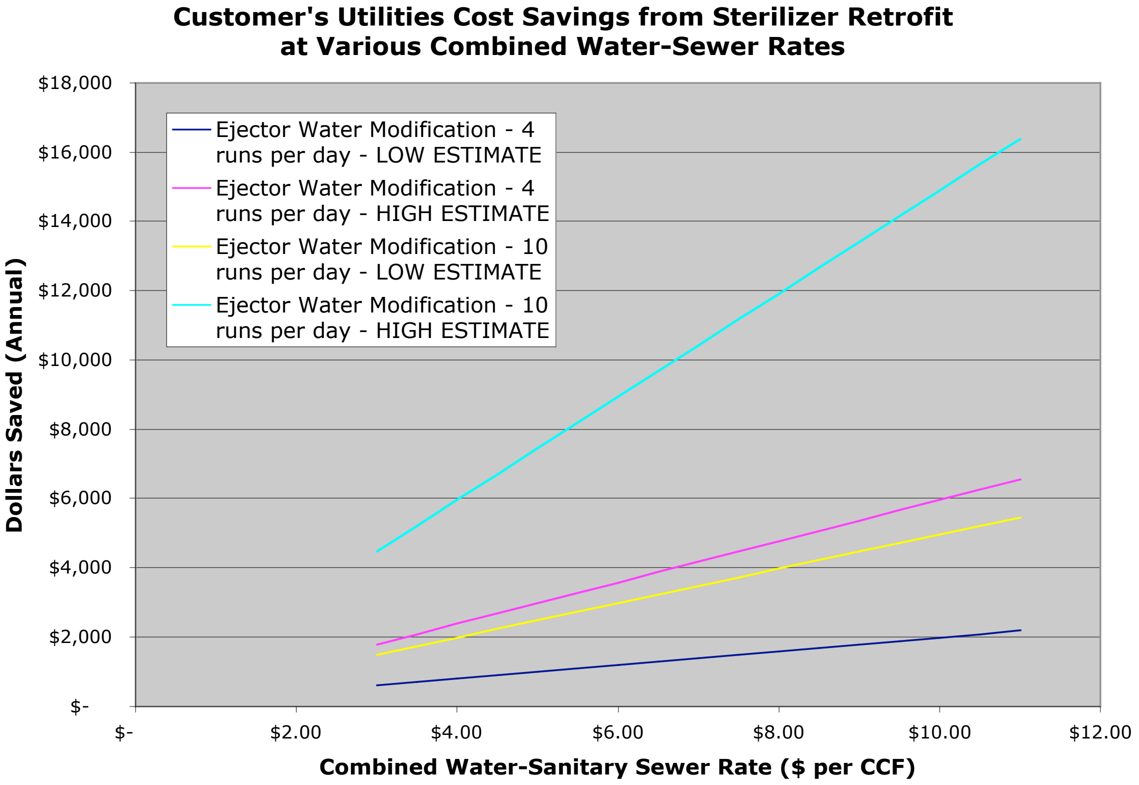


Figure 5. Cost Savings-Ejector Water Modification



6. California Potential

The approximate number of installed sterilizer units in California for each of the three manufacturers is as follows[40]:

Amsco (Sterris)	4,700
Getinge-Castle	3,100
ARS	600
TOTAL	8,400

It is estimated by the manufacturers that approximately 2 percent of the units are already retrofitted with water saving technology. We estimate the total potential and capturable water-savings benefit of implementing the described measures to be as follows:

Jacket and Chamber Condensate Cooling Modification

- *Potential Savings*

  Low range: 98% x 8,400 units x 15.9 acre-feet = 130,900 acre-feet
  Or ….approximately 6,500 acre-feet per year

  High range: 98% x 8,400 units x 40 acre-feet = 329,200 acre-feet
  Or ….approximately 16,500 acre-feet per year

- *Capturable Savings*

  Capturable savings will depend, to a large extent, upon the technical skills and water agency priority given to the implementation of the measure. However, working aggressively with the industry that markets the modifications, a reasonably conservative estimate of capture rate would be 50 percent. As such, capturable savings would generally range between 3,200 and 8,200 acre-feet of water per year in California.

Ejector Water Modification

- *Potential Savings*

  Low range: 98% x 8,400 units x 9.1 acre-feet = 74,900 acre-feet
  Or….approximate 3,750 acre-feet per year

  High range: 98% x 8,400 units x 68 acre-feet = 560,000 acre-feet
  Or….approximately 28,000 acre-feet per year

- *Capturable Savings*

  With the same caveats as noted above, potential capturable savings would amount to between about 1,900 and 14,000 acre-feet per year. This large range of savings is representative of the uncertainty with regard to the hours of use of the currently installed sterilizer base. Before any decision is made to consider this measure for full BMP status, further independent investigations of the usage patterns of the installed base would be required.

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[40] Data was gathered from vendor sources deemed reliable, but cannot be guaranteed.