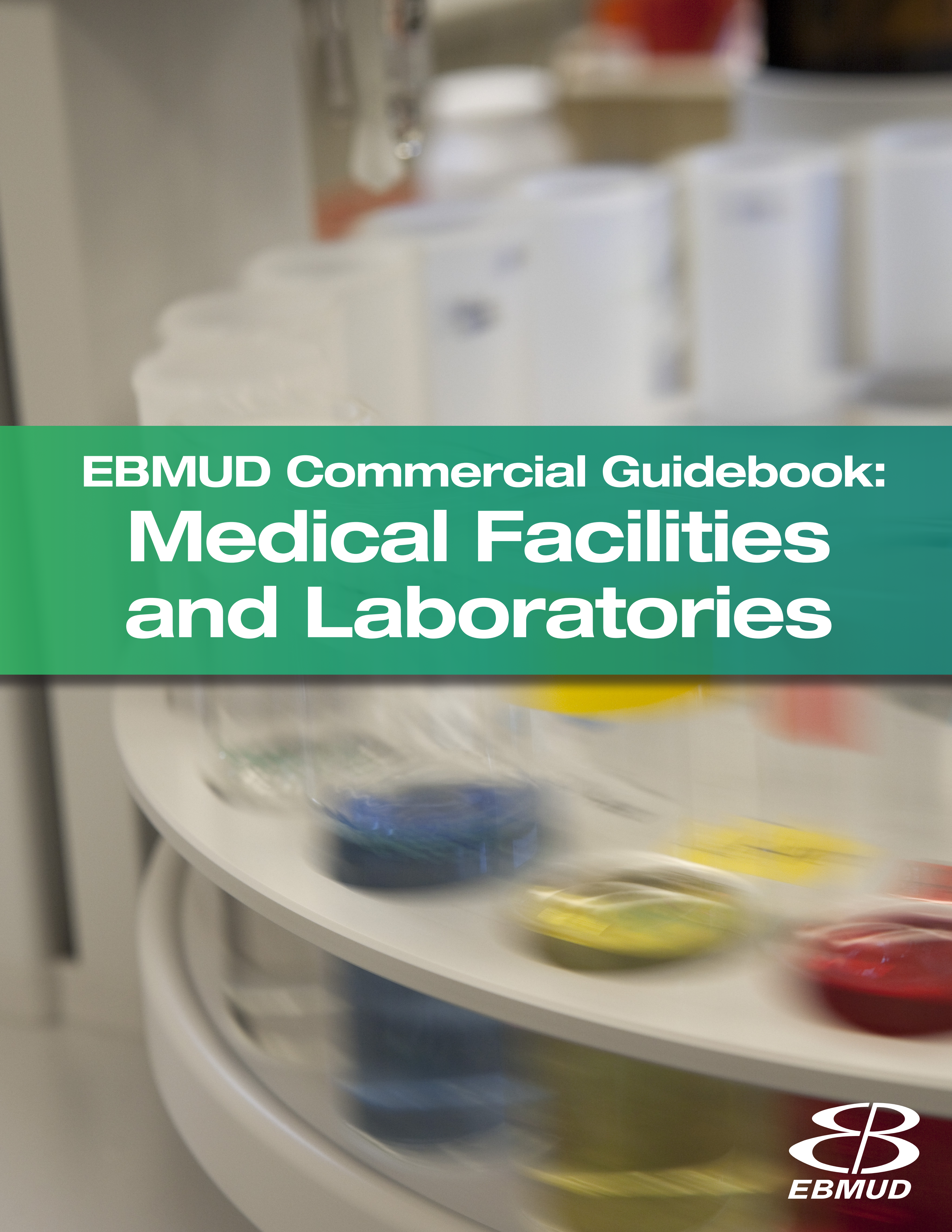


EBMUD Commercial Guidebook: Medical Facilities and Laboratories

EBMUD

MEDICAL FACILITIES AND LABORATORIES

Hospitals as well as medical, veterinary, and dental clinics along with medical laboratories use water in similar ways. Many factors can increase or decrease the amount of water that is being used in a medical facility such as on site laundry, food preparation, and landscape practices, just to name a few. There is a significant opportunity in this industry to design more water efficient facilities.

The US EPA estimates that “**implementing water-efficient practices in institutional facilities can decrease operating costs by approximately 11 percent and energy and water use by 10 and 15 percent**, respectively.” Additionally, the US EPA shows that just 28 percent of water is used directly in the lab, while the rest is accounted for in cooling, sanitation, and outdoor irrigation.[1]

Hospitals and laboratories also often have high rates of fresh air intake compared to other types of facilities, which means that their air conditioning systems often produce higher volumes of air conditioning condensate, especially in humid areas. This points to the substantial potential to capture and reuse condensate for non-potable uses. The chapter Alternate Onsite Water Sources covers options for recovery and reuse of this water source.

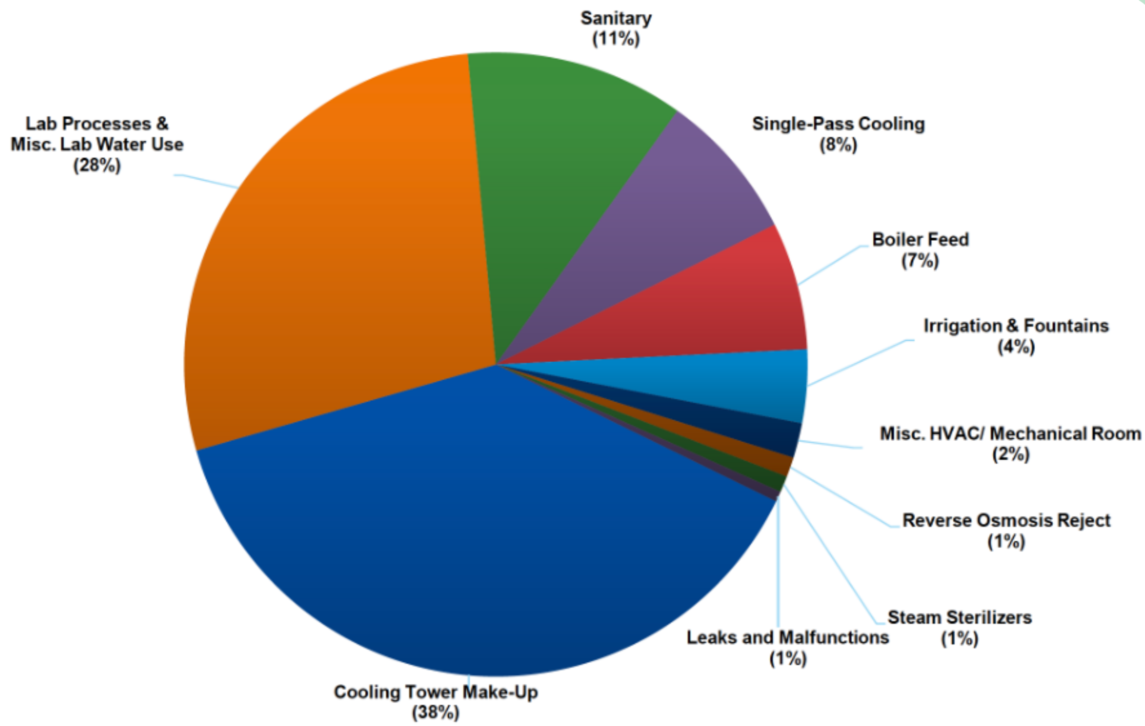
Equipment and Operations within Medical and Laboratory Facilities

1. **Medical instruments, glassware, cages, racks, and bottles washers**
   - Pre-sterilization washers
   - Glassware and equipment washers
   - Cage and bottle washers
2. **Sterilizers**
3. **Vacuum and compressor systems**
   - Whole building systems
   - Point-of-use systems
   - Ultra-high vacuum systems
   - Compressor systems
4. **Instrument and equipment cooling**
   - List of potential equipment using cooling
   - Water and energy efficient cooling methods
5. **Medical air and compressor systems**
   - Compressor types
6. **Laboratory fume hoods**
   - Perchlorate hoods
   - Scrubber hoods
7. **Vivarium and aquarium operations**
   - Vivariums
   - Aquariums
8. **Kidney dialysis and specialty laboratory or medical water treatment**
   - Kidney dialysis water treatment
   - Medical water treatment
   - Ultra-pure lab water treatment
9. **Humidification**
   - Types of equipment
   - Types of water use
10. **Medical therapeutic equipment**
    - Pools, whirlpools, whirlpool spas, hot tubs, and physiotherapy tanks
11. **Miscellaneous equipment**

Water Quality Testing Laboratory

1 https://www.epa.gov/system/files/documents/2022-08/ws-webinars-Laboratory-Water-Efficiency.pdf

Figure 11-1: Water Use Profiles of a Laboratory



Typical EPA laboratory building water use, based on data collected during water assessments conducted at EPA's laboratories between 2011 and 2019.

Graph source: I2SL, https://www.epa.gov/system/files/documents/2022-08/ws-webinars-Laboratory-Water-Efficiency.pdf

Medical Instrument, glassware, and cages, racks, and bottles washers

This section describes cleaning and washing methods including:

1. Pre-sterilization Washers
2. Glassware and Equipment Washers
3. Cage Washers and Bottle Cleaning
4. Types of Wash Water

Pre-sterilization washers:

Although not accounting for the most significant water use in hospitals and medical facilities, pre-sterilization washers are a critical part of cleaning instruments and equipment prior to sterilization. During pre-sterilization, the instruments and equipment are placed in an enzymatic detergent hand wash where heavy contamination is removed. This can be followed by both an ultrasonic cleaning and then washing in an instrument washer. The cleaned instruments are then sent to sterilization.

Instruments and equipment with many plastic parts require hand cleaning. Recommended manual cleaning procedure involves hand washing the instruments in a three compartment sink operation. Although tap water can be used in the first part of the washing sequence, distilled water and water treated by reverse osmosis (RO) is often required. The first sink is used to pre-rinse with cold water to remove any pretreatment product or biological contaminants. The second sink is used to pre-soak and physically wash instruments with an enzymatic or neutral detergent solution. The third sink is the final rinse sink and often uses distilled or RO water

Water conservation techniques for hand washing include making the most use of the water in sink and having efficient water treatment processes in place as discussed in the section on Water Treatment.

After manual cleaning, instrument cleaning is followed by either mechanical or automatic cleaning via ultrasonic cleaners, washer decontaminators, washer-disinfectors, or washer-sterilizers.

Tray of Surgical Instruments Ready for Sterilization

Image source: HW (Bill) Hoffman & Associates, LLC

Ultrasonic cleaning is used to penetrate hard to reach crevices, hinges, and lumens. The ultrasonic system produces extremely fine bubbles and ultrasonic waves to clean the instruments. For more information on softened or RO water used in this process, see Water Treatment section. Since these systems are a fill and dump type system, the water efficient approach is to only dump and refill when needed.

Washer-Disinfectors, often compared to high efficiency dish washers, are the typical next step in the process. These washers use high pressure sprays along with cleaning and disinfecting solutions to provide a more though cleaning. If enzymatic cleaners are used, the water temperature should be around 140°F and if surfactant cleaners are used, temperatures should be around 180°F. Wash cycle times and pressure setting can impact water use. The final rinse is typically done with RO water. The instruments are then ready for sterilization.

Recommendations:

1. When hand washing, only use the amount of water needed
2. Use softened or RO rinse water sparingly while following all proper cleaning methods
3. When using ultrasonic washers, only dump and refill when necessary
4. Operate instrument washer equipment only when needed
5. Wash full loads as a matter of practice
6. Follow recommended settings that minimize water use, such as wash time and pressure

Glassware and Instrument Washers

Laboratory Ware Washers:

The use of laboratory ware washers is reported to significantly reduce water use. The Labconco study[2] showed that hand washing used from 16 to 66 gallons per load while the automated ware washer used only 10 gallons and 27 minutes of labor. The mean water use by hand washing was a little over 34 gallons. By contrast, the automated ware washer only used 10 gallons and 19 minutes of labor. This is a water savings of 15 gallons per load. If two thousand loads are washed annually, this equals 30,000 gallons of water saved, and this is hot water that has been softened and of which some.

Most washers offer a five-step washing process, including pre-wash using softened water, a main wash cycle(s) using either softened hot water or deionized water, and two rinses, but special needs of the laboratory can require up to Five additional cycles. Water is used in several ways:

- Pre-rinse water which is typically softened water or water recycled from the final rinse cycles
- Wash water which can be either softened water or deionized water
- Rinse water
- Tempering water to cool discharge to below 140°F to meet plumbing codes
- Steam if steam heating is used
- Tempering water if the steam condensate is discharged to the sewer and not returned to the boiler

Ultrasonic Surgical Instrument Washer

Image source: HW (Bill) Hoffman & Associates, LLC

2 https://www.labconco.com/download/hand-washing-case-study/1836

Tunnel Surgical Instrument Washer and Thermal Disinfector Washer

Image sources: HW (Bill) Hoffman & Associates, LLC

Since water must be heated, up to as high as 203°F depending on the laboratory requirements, the reduction in water use is also the best way to reduce energy use.

Modern glassware washers are significantly more energy and water efficient than models even a decade ago. All modern glassware washing equipment can be set for different wash cycles depending on the laboratory's needs. Flask and beaker washer, pipet washers, and miscellaneous glass and plastic ware are the most common types of material washed, but specialty equipment such as bioreactors require special racks and cleaning procedures. High level analytical and many life science operations require extra levels of washing, thus higher water use settings.

Another major factor impacting water use is the size of the washing equipment. The equipment ranges from under-the-counter washers to large cabinet washers. Large cabinet washers require more water for each full washing cycle than small under the counter models do, but the cabinet washers can wash significantly more glassware at a time so total water use per item washed remains about the same for full loads.

A special consideration are pipette washers. The old fill and siphoned systems can use significant volumes of water by continuously filling and draining water. Most glassware washers can wash pipette. Some manufacturers offer systems that reduce water use by using compressed air and other ways of reducing water use compared to the old fill and siphon systems.

Rinsing equipment with a counter-current rinsing setup reduces water by using cleanest water only for the last rinse, and then used that water in a cascading manner for dirtier items. The basic premise is to use the cleanest water only for the final or last stages of a rinse operation; water for early rinsing tasks, when the quality of the rinse water is not as important, is obtained later in the process.

Lab Glass Water Washer and Pipette Washer

Image source: HW (Bill) Hoffman & Associates, LLC

Recommendations:

- Avoid hand washing where possible
- Ware washers are more water efficient when used appropriately:
  - Only run glassware washers when they are full; fill each glassware washer rack to maximum capacity
  - Operate the glassware washer near or at the minimum flow rate recommended by the manufacturer
  - Choose settings that minimize energy and water use while still cleaning the glassware to the desired level
  - If deionized water necessary, use only in final rise cycles where possible
  - Clean glassware as soon as possible so deposits do not dry on, thus requiring special cleaning
  - Choose water and energy efficient models; look for the WaterSense and EnergyStar labels
  - Select washer size that fits the needs of the laboratory; do not oversize
  - Choose models that have computer-controlled capability to minimize energy and water use.
  - Choose models that monitor the load and use only the fill water needed
  - Choose models that recycle the final rinse water for the first wash cycle
  - Most manufacturers offer "cool-down" tanks that cool the water prior to discharge thus eliminating the tempering water
  - Consider heat recovery systems available from many manufacturers that both conserve energy and eliminate the need for tempering water.
    - Tempering water uses potable tap water to mix with the discharge from the washer to reduce in-sewer temperatures to below 140°F
- If steam is used: install heat recovery systems to prevent the need for tempering water and return condensate to the boiler

Cage Washers and Bottle Washers

Vivariums and other research animal facilities must wash the cages and bottle and feeding containers used to nourish and hydrate the animals.

Labware Drying Rack

For vivarium operations (laboratory rats and mice), special "rack and bottle washers" are the most efficient way to clean rat cages and water bottles in large operations. These washers are large roll in systems that hold whole racks of rat cages and with special holders, watering bottles.

Cage, rack, and bottle washers, and cart and utensil washers are batch-type washers with racks.

A Lab Rat Cage Washer and the Inside of that Washer with a Rack of Cages Ready to Wash

Image source: HW (Bill) Hoffman & Associates, LLC

Choose modern washers using roughly 12 gallons to 50 gallons per wash cycle,[3] or no more than 50 to 100 gallons per load.

Traditional cage-and-rack washers are programmed with a pre-rinse, wash with detergents and chemicals, and a final rinse cycle. Softened water can be used in the pre-rinse and wash cycles, but deionized water is often uses in the final rinse. Rinse and often wash cycle washes typically use hot water heated to 180°F or more. Optional cycles using hydrogen peroxide, acid washes and special disinfection washes are available, each increasing water use.

Tunnel washers are conveyor-type washers that accommodate cages, racks, and other laboratory accessories at once.

Large Monkey Cage Tunnel Washer and Lab Rat Tunnel Cage Washer

Images source: HW (Bill) Hoffman & Associates, LLC

Some researchers note that, "cage and rack washers, while not the industry standard for large-scale animal cage washing, are more efficient and cost-effective to operate than tunnel washers.[4]"

Since many tunnel washers vent into the workspace, more air-conditioning may be required, thus potentially also increasing energy costs. Tunnel washers are typically found only in laboratories with a very large number of cages and other equipment to wash. There are typically four main cycles in the tunnel washer: pre-rinse, wash, first rinse, and final rinse. The final rinse uses only fresh water, while the other cycles can use water recycled from the wash, first rinse, or final rinse. Starting with the final rinse cycle, water moves countercurrent within the tunnel washer and is disposed of after the pre-rinse cycle.

Types of water used in all types of these washers varies with the laboratory needs, but can include:

- Tap water
- Softened water
- Water heated to 180°F or more
- Deionized water
- Steam if used, and
- Drain tempering water to reduce wastewater discharge to below 140°F

Recommendations

- Avoid washing partial loads
- Where possible, install modern washers with water-efficient cycles
- If needed, retrofit existing cage and rack washers to make use of counter-current flow systems to reuse final rinse water from one cage-washing cycle in earlier rinses in the next washing cycle
- With tunnel washers, use fresh water only for the final rinse; other cycles can use water recycled from the wash
- Install heat recovery features where possible
- Install water tempering kits, and if an energy recovery feature cannot be used that only flow cold tap water with water over 140°F is being discharged.

3 https://www.tecniplast.it/

4 https://www.tradelineinc.com/reports/2013-6/recommended-shift-away-tunnel-cage-washers

Figure 11-2: Aspirator in Lab and Venturi Vacuum on Sterilizer

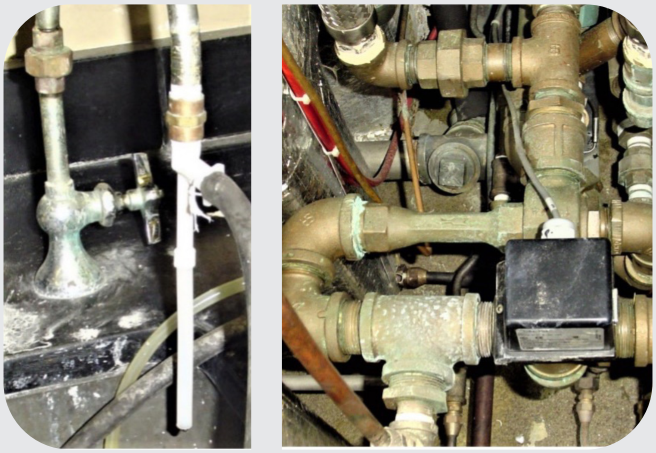


Image source: HW (Bill) Hoffman & Associates, LLC

Vacuum Systems

Vacuum systems are a common element of both medical and laboratory work. Because of the wide variety of vacuum system needs, this section is broken down into:

- Medical and dental systems
- Low-vacuum laboratory use
- High-vacuum laboratory use

Venturi aspirators should be replaced with dry vacuum systems wherever possible. These systems are found in many teaching chemistry labs and were previously used to create a vacuum to evacuate air from vacuum steam sterilizers. Sterilizer venturi systems can use 6.5 to 10 gallons per minute, with the vacuum phase lasting up to 30 minutes. Water use is in the range of 350 to 400 gallons per cycle.

As an alternative to laboratory aspirators, some labs use air aspirators like the one shown in Figure 11-2. Venturi aspirator vacuum systems in teaching laboratories where they are used only a few hours a year would be costly to convert to a dry system. If the system is run only a few hours a year, they do not use huge amounts of water.

Recirculating venturi aspirator vacuum systems are available that recirculate water to produce the vacuum such as the system in Figure 11-3. These are useful in settings such as biological laboratories where the gas being evaluated is not corrosive or otherwise a waste that should be sent to the sewer. Another option is to use a compressed air venturi system such as Figure 11-4, located in a university teaching laboratory.

Liquid-ring vacuum pumps were the mainstay of medical and dental vacuum systems until recently. They use a closed impeller that is sealed with water to form the vacuum. The water acts as both a seal and a once-through cooling system. Water requirements are typically in the range of 0.5 to 1.0 gallons per minute (gpm) per horsepower (hp). Dental clinics have historically used liquid ring vacuum pumps in the one to four horsepower range. The amount of water that may be saved varies with the type and size of equipment. According to product literature for several types of liquid ring dental pumps, these pumps use approximately a half gallon per minute per horsepower, so a two-horsepower pump would use approximately 1.0 to 1.5 gpm. An office that is open for eight hours would use 300 to 800 gallons a day. Medical facility central vacuum systems can be 5.0 to 20.0 hp. Therefore, medical facilities can use as much as 20 gpm of water.

Figure 11-3: Recirculating Venturi Vacuum System

Image source: HW (Bill) Hoffman & Associates, LLC

Figure 11-4: Compressed Air Venturi System

Image source: HW (Bill) Hoffman & Associates, LLC

Many cities do not allow liquid ring dental pumps. Dry vacuum pumps eliminate the need for water to create a vacuum. A small amount of water is needed at the end of each day to flush the "knock-out drum" that collects the waste.

Dry Vacuum Pump at a Dental Clinic

Image source: HW (Bill) Hoffman & Associates, LLC

Liquid Ring Vacuum Pump in a Large Hospital

Image source: HW (Bill) Hoffman & Associates, LLC

Dry Claw Vacuum Pump in a Hospital

Image source: HW (Bill) Hoffman & Associates, LLC

Central vacuum systems on hospitals are much larger than dental vacuum systems. One hospital had seven liquid ring vacuum pumps, five of which ran continuously. Each pump discharged 7.5 gpm, which is equal to each pump using 10,800 gallons a day. With five pumps running continuously, these liquid ring pumps were using over 19 million gallons of water a year.

Dry vacuum pumps offer real savings, both on water and energy. There are a number of dry vacuum systems that use from 20% to 40% less energy and no water to generate the vacuum. Using the above example with the five continuously running liquid vacuum pumps, at an assumed water rate of $10.18 per thousand gallons, the annual water savings that could be achieved by replacing the liquid ring system with a dry vacuum pump would be on the order of $193,000, not inclusive of energy savings.

The following is a list of the variety of dry vacuum pumps available. Each type of pump has its advantages and appropriate applications:

- Liquid-ring pumps
- Vane pumps
- Claw pumps
- Rotary pumps
- Scroll pumps
- Piston pumps

In the hospital example above, installing dry vacuum pumps to replace the seven liquid ring pumps would significantly cut yearly water, wastewater, and electricity costs. While the new vacuum systems are costly, the payback in water and other utility savings would be swift, with an estimate ROI of under two years.

Laboratory Vacuum Systems

There are many different vacuum needs in laboratories, but they fall into three basic categories. The first are lab bench type systems. These vacuum systems vary significantly, ranging from the aspirators discussed above to tabletop vacuum pumps which for the most part, do not use water. Examples of tabletop and laboratory hood vacuum systems are shown in Figures 12-5 and 12-6.

Figure 11-5: Dry Vacuum System in Water Quality Laboratory

Image source: HW (Bill) Hoffman & Associates, LLC

Figure 11-6: Dry Laboratory Vacuum Pump for Chemical and Biological Work

Image source: HW (Bill) Hoffman & Associates, LLC

Large laboratory facilities use vacuum systems for the whole building. The vacuum pump shown in Figure 11-7 is a lubricated vane dry vacuum pump. This type of pump find use in both laboratory and medical applications.

Figure 11-7: Lubricated Rotary Vane Dry Vacuum Pump

Image source: HW (Bill) Hoffman & Associates, LLC

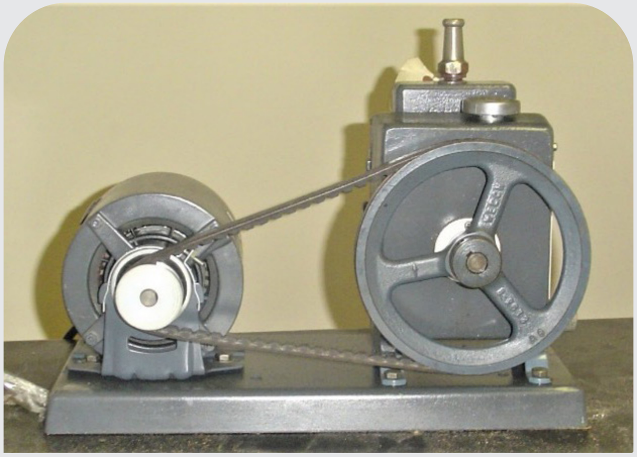
Again, one can find water and energy-inefficient liquid ring pumps. The liquid ring vacuum system shown in Figure 11-8 was installed in a university biological laboratory building.

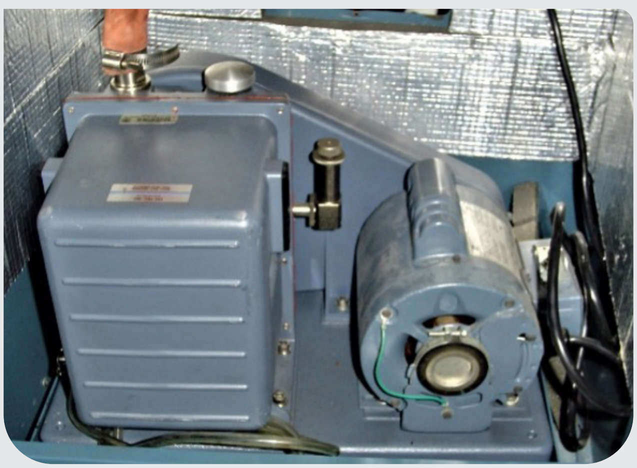
Figure 11-8: Lubricated Rotary Vane Dry Vacuum Pump

Image source: HW (Bill) Hoffman & Associates, LLC

Many laboratory applications require higher vacuum levels. The two pumps shown in Figure 11-9 are for evacuating vessels and other uses in laboratories. Again, these pumps do not use water.

Figure 11-9: Laboratory Higher Dry Vacuum Type Pumps





Images source: HW (Bill) Hoffman & Associates, LLC

Laboratories can sometimes require extremely high vacuums like diffusion pumps. These are found in industrial vacuum processing such as the production of microelectronics and in laboratories where mass spectrometry, analytical instrumentation, research and development for ion implantation, and nanotechnology.

Unfortunately, some of these pumps must be water cooled. However, a chilled water loop for the building's air conditioning system is often used in large systems such as universities. Again, all once-through cooling should be avoided.

Dry systems do not use water for the pump seal but can use water for cooling the pump. Water use rates for a liquid-ring pump range from 0.5 to 1.0 gallons per minute per horsepower. Even this will be totally eliminated if no cooling water is used. Pumps should never be cooled with a once-through system. If a water using system must be used, it should be connected to a closed-loop or radiator-type system. The typical dental unit with a 1.5 hp liquid-ring pump can use 360 to 720 gpd (Sable Industries). For a large medical facility with a 12 hp pump, the water used per day can range from 8,640 to 17,280 gallons. Newer liquid-ring pumps try to minimize water use, so their consumption would most likely be in the range of 8,600 to 10,000 gpd. Using a dry vacuum pump will save significant volumes of water or eliminate water use (Tuthill).

Diffusion Pump

Images source: HW (Bill) Hoffman & Associates, LLC

Recommendations

- Avoid the use of non-recirculating venturi aspirators
- Chose systems that are sized to the need and capable of handeling the types of gases being evacuated
- Where possible, use dry vacuum systems
- If a liquid ring vacuum pump must be used because of corrosive conditions, use a non-potable source of water or water recirculation system if possible
- Where water cooling is needed, connect the vacuum system to the chilled water system for recirculation

Medical Air and Compressor Systems

Medical air and compressor equipment is used for a multitude of purposes in most dental and medical facilities. The only water use associated with this type of equipment is for cooling, done with once-through cooling, a radiator type system, or a closed loop system, such as a cooling tower or chilled water loop. Many air compressors today are air-cooled. For water efficiency, use air-cooled or closed loop systems.

Compressed air has a wide variety of applications in both medical and laboratory operations. There are four main types of air compressors:

- Rotary screw compressors
- Reciprocating air compressors
- Axial compressors
- Centrifugal compressors

Axial and centrifugal compressors are called dynamic systems. Rotary and reciprocating pumps work on the principle of positive displacement. The three main components of any compressed air system used by medical and laboratory systems are:

1. The compressor
2. The cooling system
3. The compressed air storage tank.

Reciprocating Piston Air-cooled Laboratory Compressor

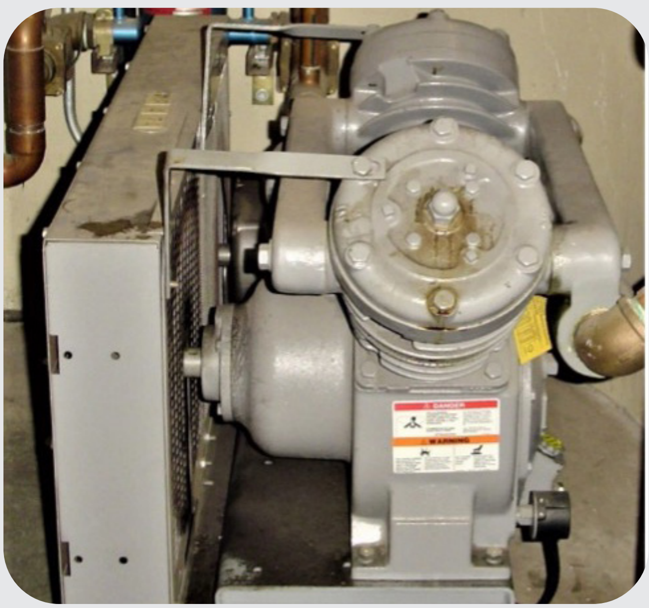


Image source: HW (Bill) Hoffman & Associates, LLC

When air is compressed, heat is generated in accordance with the following equation.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

This waste heat can be removed either by air or water. Air is the most common method of cooling compressed air systems. Where water is used, it should always be used in conjunction with chilled water or cooling tower cooling loop.

Hospital compressed air must be free of any oils, so oil-less systems are used. The air is filtered and dried. Air humidity control is important. All hospital and clinical applications must meet the National Fire and Protection NFPA -99 Code Standards since compressor operation produces heat. The uses of compressed air in medical application include:

- Driving incubators and ventilators and for controlled air flow with certain oxygen gas systems for patients
- As a carrier gas for anesthesia
- To operated certain physical therapy equipment
- As a power source for pneumatic surgical tools
- Dental compressed air systems are used to drive dental tools.

Laboratory compressor types will depend on the specific use for the air. However, the methods of cooling the compressor are the same as for medical applications.

Recommendations

- Use air-cooled systems wherever possible
- If a water-cooled compressor must be used, ensure it is connected to chilled water or cooling tower cooling loop
- Never use once-through cooling

Medical and Laboratory Equipment Cooling

Water cooled laboratory and therapeutic equipment have historically used once-through cooling. Connecting this equipment to a closed-loop system such as a cooling tower or chilled water loop is often impractical, but air-cooled chiller units are available. Cooling medical and laboratory equipment offers significant opportunities to save water.

A common practice in organic chemistry laboratories is to dry used solvents for recovery and reuse. Many labs use reflux condensers to dry the spent solvents. Labs using reflux condensers to dry solvents typically cooled the condensers with a continuous flow of tap water like the petroleum engineering example in Figure 11-10. The reflux column is used to strip oils out of a test block at a petroleum engineering teaching laboratory at a university. This system ran some 5,000 hours a year and the flow rate of the tap water cooling part of the apparatus was 1.5 gpm, which totaled 450,000 gallons of water a year.

Figure 11-10: Reflux Column Used to Strip Oils Out of a Test Block in Petroleum Laboratory

Image source: HW (Bill) Hoffman & Associates, LLC

These solve drying systems operate year around, have flow rates in the range of one to three gallons per minute and also present a fire hazard. For both water conservation and fire safety many laboratories have converted to desiccant systems such as the one pictured in Figure 11-11. Such systems use metal tubes filled with desiccant material that is regenerated by heating elements. This eliminates all water use and recovers valuable organic solvents while reducing fire hazards.

Additional examples of laboratory equipment that may require cooling are listed in Table 11-1:

Figure 11-11: Desiccant Drying System for Solvent Recovery

Images source: HW (Bill) Hoffman & Associates, LLC

There are three options to eliminate once-through cooling. The first is a recirculating chiller that chills the water circulating through the instrument such as a rotary evaporators, reflux condensers and similar laboratory devices and for the devices listed in Table 11-1.

Table 11-1: Examples Of Recommended Lab Equipment That May Need Cooling

Diffusion Pumps	Rotary Evaporator/Concentrators	Stills
Electron Microscopes	Extractors	Turbo Molecular Pumps
Spectrometers	Vacuum Systems	Air Compressors
Gas Chromatography	Mass Spectrometers	Centrifuges
Optics and Laser Equipment	Ion Implantation Equipment	Metallurgical Lab Equipment

This device mechanically cools the recirculating water and pumps it through system or equipment to be cooled. These systems have very wide application. The reduce water use to zero and are energy efficient.

These chillers are available for from $4,000 to $20,000 depending on capacity and special features. The following shows a laboratory hood with equipment using dry vacuum pumps and a recirculation chiller. Chillers also have the advantage of allowing researchers to precisely control temperatures.

Recirculating Chiller

Image source: HW (Bill) Hoffman & Associates, LLC

Example of a Laboratory Equipped with a Chilled Water Source and Return

Image source: HW (Bill) Hoffman & Associates, LLC

Many modern laboratory facilities are now equipped with chilled water loops to cool laboratory equipment. This totally eliminates the waste of water.

Some laboratory equipment requires that the cooling water be deionized water such as the mass spectrometer shown in Figure 11-12. To accommodate this, the deionized water loop is connected to a chilled water loop.

Laboratory Hood with Equipment Using Both a Dry Vacuum Pump and Recirculating Chiller

Image source: HW (Bill) Hoffman & Associates, LLC

Figure 11-12: Mass Spectrometer Requiring Deionized Water for its Cooling Loop and Connection to Building System Chilled Water Loop

Images source: HW (Bill) Hoffman & Associates, LLC

Another cooling method for laboratory reflux condensers, rotovaps, and distillation columns is to use compressed air.[5]

As an alternative, once-through cooling water from laboratory equipment can be collected directly for reuse. The University of Texas has a campus-wide system that collects air conditioning condensate, foundation drain water and chillers are not used, once-through cooling water for use in the campus cooling towers.

Cooling Water Collection System Chemistry Laboratory on the University of Texas Campus

Image source: HW (Bill) Hoffman & Associates, LLC

All these techniques can satisfy the requirements in areas that prohibit once-through cooling. Air-cooled condensers also reduce the risk of laboratory flooding, which can have costly consequences for the facility and research team.[6] They can also be easier to set up, as they do not require tubing or connectors for water cooling. This leaves more time and lab space for other research activities (Radleys).

Recommendations

- Eliminate all once-through cooling as soon as possible, In many areas it is prohibited by code.
- Use desiccant systems to dry organic solvents.
- Use stand alone chiller units for lab bench equipment.
- Connect to a chilled water system where possible.
- If once-through systems are the only option, capture and reuse the water.
    - Description
    - Compressor types - Rotary screw, vane and reciprocating
    - Recommendations

Autoclaves & Sterilizers

Autoclaves and central sterile operations are found in all medical facilities. Autoclaves are used to kill pathogens on instruments, equipment, and waste generated during routine lab operations, or, in a hospital setting, during medical procedures and surgery. Both steam and chemical sterilizers are used, depending upon the materials being sterilized. Chemical sterilization is used for instruments that are sensitive to heat, such as plastic and rubber products, and for instruments such as endoscopes. Steam is used for everything else.

Chemical sterilization has seen dramatic changes in recent years as ethylene oxide (EO) or glutaraldehyde (GA) systems, that are known carcinogens, are being replaced with non-polluting venturi vacuum systems. These systems can be found across a variety of systems including x-ray, laboratory, and pharmacy. Hydrogen peroxide has emerged as one of the most commonly used sterilization materials. Unlike the EO and GA systems, peroxide systems can use mechanical vacuum pumps that use no water. It is important to ensure that mechanical vacuum systems are used.[7]

Autoclaves kill harmful pathogens with live steam that is fed into a central pressure chamber in which instruments and equipment have been placed. There are three major classes of autoclaves:

- Table-top and stand mounted
- Gravity
- Vacuum

Table-top and stand mounted units use a small reservoir of water and electric heat to produce steam. They tend to be both water and energy efficient but are not large enough for the high rate of production needed in major lab or medical facilities.

Large labs and medical facilities must use large steam autoclaves fed by the facilities' boiler systems. The live steam injected into the pressure chamber is held for a period of time to ensure sterilization. The steam is then allowed to condense and exit through a steam trap. In busy facilities, fifteen to twenty loads can be sterilized per day. The process of sterilizing a load is called a cycle. In busy facilities, the jacket around the inner chamber is kept hot with live steam even when the chamber is empty, so instruments can be processed on an emergency basis as needed. As the steam in the jacket condenses, the water is released through a steam trap. Usually only a pint or

5 https://cen.acs.org/articles/91/web/2013/09/New-Condensers-Cool-Solvent-Without.html
6 https://www.science.org/content/blog-post/no-water-no-problem
7 https://www.sterrad.com/products_&_services/sterrad/index.asp

two of condensate is released and then only intermittently. This condensate must be cooled to below 140°F before it can be discharged to the sewer system. In older units, a stream of tap water was continuously run through a valve into the sewer connection to mix with the condensate. Most autoclaves are allowed to cool naturally, and the condensate drains from the chamber by gravity.

An Array of Autoclaves

Where volume is high or equipment needs to be sterilized quickly, a vacuum can be used to draw on the chamber and dry the instruments and evacuate moisture quickly. Historically, venturi aspirator equipment has been used to produce this vacuum. It works by passing water through a tube that tapers.

Typical flow rates are in the range of 5 to 10 gallons per minute, and the vacuum phase can last up to 30 minutes. Water use per cycle is in the range of 350 to 400 gallons per cycle.

Description of Medical Sterilizer Types - Sterilization of surgical instruments, fluids, pharmaceuticals, equipment, and bandages is an integral part of modern medical and laboratory practice. Over the years, different sterilization techniques have been used:

1. Chemical (ethylene oxide, peroxides, ozone, etc.)
2. Radiation
3. Dry heat
4. Steam sterilization

The first three techniques do not use water and are included as alternatives to steam sterilizers, but since they generally do not use water, they are not the topic of this discussion. However, they should be considered as alternatives to steam sterilizers. The following shows pictures of various types of steam sterilizers.

Small Sterilizer in Biological Laboratory

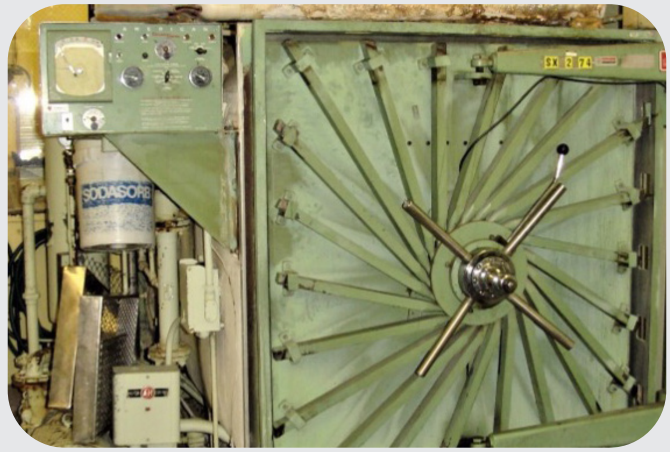


Image source: HW (Bill) Hoffman & Associates, LLC

Large Steam Sterilizer at a Laboratory to Sterilize Primate Cages

Image source: HW (Bill) Hoffman & Associates, LLC

Hospital Sterilizer and Cart with Items to Load Into Sterilizer

Image source: HW (Bill) Hoffman & Associates, LLC

Large Materials Autoclave at University Engineering Laboratory and Auto Clave for Polymer Work at Chemical Engineering Lab

Image source: HW (Bill) Hoffman & Associates, LLC

For medical and dental use, there are three major categories of steam sterilizers:

- Tabletop
- Gravity
- Vacuum

The two major configurations for steam sterilizers are tabletop and freestanding.

Tabletop-type sterilizers have a water reservoir that is heated by a heating element to make steam.

They use little water and are not considered further in this discussion.

Freestanding sterilizers include gravity displacement autoclaves and the high speed pre-vacuum sterilizer. For both freestanding gravity and vacuum type sterilizers, steam is injected into a closed sterilization chamber housing the instruments or equipment to be sterilized. Steam is also injected into the hollow jacket surrounding the sterilization chamber. Steam used for these purposes must be "clean steam" meaning that the water used to make the steam has been demineralized. Steam sterilizers are commonly found in medical, dental, pharmaceutical, medical laboratories, and in science and engineering laboratories.

In the gravity type, steam pushes air out of the chamber filling the top of the chamber with steam. The air is heavier than steam and can be “drained” by gravity out the bottom of the sterilizer with the vacuum type, a vacuum pump draws the air out. The vacuum type dries the sterilized materials more quickly than the gravity type.

In both cases, the sterilizer chamber is surrounded by an outer chamber that is also filled with steam to help keep the whole cavity hot. In many hospitals, a central boiler provides steam for the whole hospital for space heating, and for steam sterilizer use and other purposes. As the steam in the outer chamber condenses, it is often discharged through a steam trap to the sanitary drain. In years past, a constant flow of water was plumbed into the sanitary drain to dilute the quart of hot water discharged to keep temperatures in the sewer below 140°F. For older sterilizers, water tempering systems can be retrofitted to the sterilizer that only flows water when hot water is being discharged. For the last 20 years freestanding sterilizers have come equipped with a water tempering device.

Condensate Discharge to the Drain

Image source: HW (Bill) Hoffman & Associates, LLC

A study conducted in the 1990’s showed that water tempering kits significantly reduced water use (See Table 11-2). New sterilizers with built in tempering systems achieve similar savings.

Self-contained boiler systems are also available. With a self-contained system, a boiler is located at the sterilizer. The condensate is recirculated into the boiler directly. With these systems, there is no need for condensate tempering and the energy in the condensate is conserved. In other words, no water is needed for condensate tempering since the condensate is reused.

Vacuum sterilizers can also use significant volumes of water in the creation of the vacuum.

Table 11-2: Comparison of Condensate Retrofit Savings

Retrofit Equipment	Sterilizer Type	Before Retrofit (GPD)	After Retrofit (GPD)	Reduction %
Steris Corp	AMSCO 3021 Gravity	4,326	1,354	68%
	AMSCO 3023 Vac.	3,187	525	84%
Omega Medical	AMSCO 3021 Gravity	3870	305	92%
	AMSCO 3023 Vac.	3419	64	98%
Continental Equipment	AMSCO 3021 Gravity	1519	117	92%
	AMSCO 3023 Vac.	2510	267	89%

Water Tempering Retrofit Kit for a Steam Sterilizer

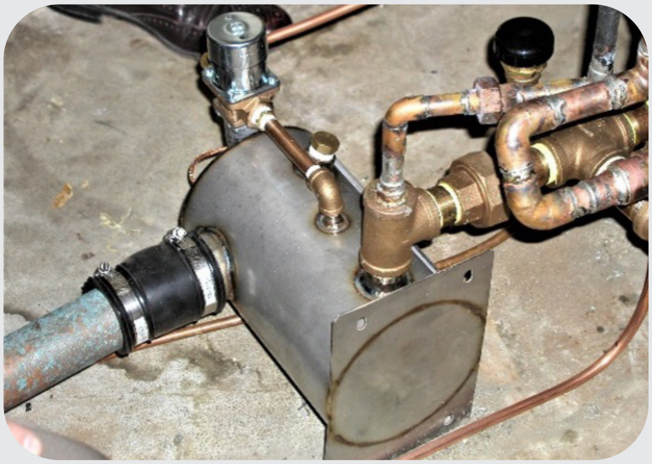


Image source: HW (Bill) Hoffman & Associates, LLC

For non-medical purposes, dry vacuum systems should always be used.

Where allowed by Federal Drug Administrator 510(K) regulations, dry vacuum systems should be used on medical vacuum sterilizers.[8] These savings are summarized in Table 11-3.

Recommendations

- Where feasible, choose something other than a free-standing steam sterilizer, such as a chemical, radiation, or dry heat sterilizer
- Where feasible, use small tabletop sterilizers
- Choose sterilizers with self-contained boiler systems that recycle all condensate
- Ensure that free standing steam sterilizers are equipped with water tempering devices, that the steam is returned to the boiler, or that it is condensed using a chilled water condenser
- Consider stand alone boilers on each autoclave
- Do not use venturi vacuum systems on vacuum sterilizers
- Use dry vacuum systems where FDA 510K regulations are not applied such as laboratory sterilizers

The US Green Building Council's LEED (Leadership in energy and environmental design) Version 4.0 draft contains the following additional requirement for steam sterilizers:

- For 60-inch sterilizers, water use cannot exceed 6.3 gal/U.S. tray.
- For 48-inch sterilizers, water use cannot exceed 7.5 gal/U.S. tray.

The guide can be found at the US Green Building Certification website.

8 https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-premarket-notification-510k-sterilizers-intended-use-health-care-facilities

Table 11-3: Comparison of Vacuum System Water Use for Steam Sterilizers*
Based on 10 uses a day, and 250 days per year

Venturi Ejector Water Use (gpm)	Gallons Used per Cycle	Venturi Vacuum Pump Gallons per Year	Liquid Ring Gallons per Year	Dry Vacuum Pump Gallons per Year
6	189	495,000	123,750	0
11	363	907,500	226,875	0
18	594	1,485,000	371,250	0
*Source: California Urban Water Conservation Council report, PBMP-Year One-Chapter VI-Sterilizer Savings Assessment				

Laboratory Fume Hoods

Fume hoods are found in most laboratories. Their primary purpose is to remove harmful fumes from the workspace. Many laboratory operations (e.g., those involving acid fumes, organic vapors, toxic materials, biological substances, and perchlorate) require hoods that remove contaminants through special treatment prior to the air being exhausted to the atmosphere. There are a variety of technologies that can provide this function, including some that do not require the use of water. For example, some filtration systems utilize inert adsorbents (e.g., activated carbon, activated alumina) or chemically active adsorbents (e.g., potassium permanganate). These dry filtration systems are effective for low concentrations of contaminants. Laboratories must make sure to check and maintain the adsorbent levels regularly.

Fume Hood in a Water Quality Lab

Systems that do require water include wet scrubbers or special wash-down equipment to remove potentially combustible products are the most common type of hood scrubbers. Within these scrubbers, contaminated air from the fume hood passes through a spray or wet packed column, where it is mixed with water, which dissolves water soluble gases, vapors, aerosols, and particulates.

The scrubbing liquid in the hood scrubber should always be recirculated back though the scrubber.

A small amount of the liquid will eventually need to be discharged, or blown down, to control total dissolved solids and other contaminants, and make-up water is added to maintain scrubber circulating water quality along with scrubber reagents. Mist and drift eliminators installed in the discharge from the scrubber both prevent the release of the scrubber fluid and save water.

Recommendations

- Turn off water flow when systems are not in use
- Always use water (scrubber fluid) recirculating systems
- Use non-potable water sources when possible
- Make sure liquid level controllers and water make-up valves are functioning properly
- Blowdown based on scrubber fluid chemistry, rather than allowing continuous blowdown or based on a timer
- Minimize air flow through the wet scrubbers. Reducing the amount of air passing through the scrubbers will reduce evaporation
- Size equipment to the task and install mist and drift eliminators

Perchlorate or perchloric acid wash-down systems are a specialty type of fume hood used for unstable or combustible compounds that tend to deposit on hood and ductwork surfaces. Wash-down systems are used to periodically wash these substances from the surface of the fume hood and associated ducts. Water is sprayed onto the hood and ductwork surfaces and discharged to the sewer. Fume hood systems and ducts should be designed to minimize surface area and thus the amount of water needed. Ductwork should be designed to take the shortest path to the outside. This specialized ductwork should also remain separate from other building ductwork. This both reduces the surface area that needs to be washed (thus saving water) and avoids perchlorate from coming into contact with organic fumes and other combustible substances. Applicable regulatory guidance can be found in ANSI/AIHA/ASSP Z9.5 –Laboratory Ventilation, and NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals.

Recommendations

- Continuous washers should never be used and should be retrofitted to include automatic shutoff valves when the hoods are not in use
- Establish operating procedures to schedule wash downs only when necessary to ensure health and safety. Reducing the runtimes of this equipment will save water
- Work with the provider of the equipment to design the most efficient system and operating procedures
- Energy considerations should also be considered for all ventilation systems that exhaust air from the room to the outside. In addition to reducing water used in wet scrubbers, minimizing air flow while still complying with air volume requirements should be considered to reduce the amount of conditioned air that is required in the laboratory

Vivarium and Aquarium Operations

The first consideration of any vivarium watering system is to provide an adequate volume of clean for the water for the desired purpose. During this delivery process, the prevention of transmission of pathogens requires careful consideration. One of the uses of water that must be considered is its pretreatment before its use by the animals. Choosing water efficient pretreatment processes should be part of the water efficiency consideration for all laboratory operations.

Although the majority of laboratory animal system are for rodents, primates, rabbits, and other animals are used in some circumstances. All of this will influence the type of watering system used. If pretreatment of the water is required, the water used by the treatment equipment such as softeners, reverse osmosis units require additional water use.

Both bottle and automated watering systems are in common use. Bottles must be washed and refilled on a routine basis. Washing involves the use of bottle washers, or cage and bottle washing equipment. Modern equipment uses much less energy and water. Consider new equipment that is more efficient.

Automated systems are typically found in larger operations. Automated systems can either flushing or recirculating systems or a hybrid of the two types.

For all automated vivarium system types, the distribution manifold needs to be flushed with adequate pressure to remove contamination and buildup in the system.

Recommendations

- Consider utilizing recirculating systems, which use less water during the proper treatment and recirculation process
    - For recirculating and hybrid systems, monitor water that is used or discharged in the recirculating treatment operations
- Continuous flushing systems should be replaced with automated systems

- Closely monitor flushing systems which can result in large volumes of water sent to the sewer

→ Hybrid systems reduce flushing, thus saving water, while maintaining water quality

→ Where bottle washing is used, choosing newer, energy and water efficient bottle and/or cage and bottle washing equipment (see the bottle and laboratory glassware washing sections [include section info here]

→ Flushing systems should be automated to reduce flushing cycles that flush only when water quality considerations dictate

→ Use air purge (instead of water) to help clean manifold lines where appropriate

→ Consider collecting and reusing wastewater from animal watering systems for irrigation and other purposes. Precautions against zoonotic diseases must be considered with such systems.

Aquariums are found in many research facilities and laboratories. Filtration systems such as cartridge filters can significantly reduce water use as smaller facilities. For larger aquariums, large sand filters like swimming pool filters are often used. As with all filtration systems, the Recommendations included in this document for water treatment should be followed.

Filtration System for Ichthyology Lab Aquariums

Image source: HW (Bill) Hoffman & Associates, LLC

Aquarium Sand Filters

Image source: HW (Bill) Hoffman & Associates, LLC

Recommendations

→ Best practices include the proper use of filtration equipment, using water treatment systems to remove specific contaminants that may be unique to the situation, and proper care and cleaning of aquarium surfaces.

→ The control of ammonia buildup in aquariums is beyond the discussion for this document.

Kidney Dialysis and Specialty Laboratory and Medical Water Treatment

Examples of a Total Treatment System of Laboratories

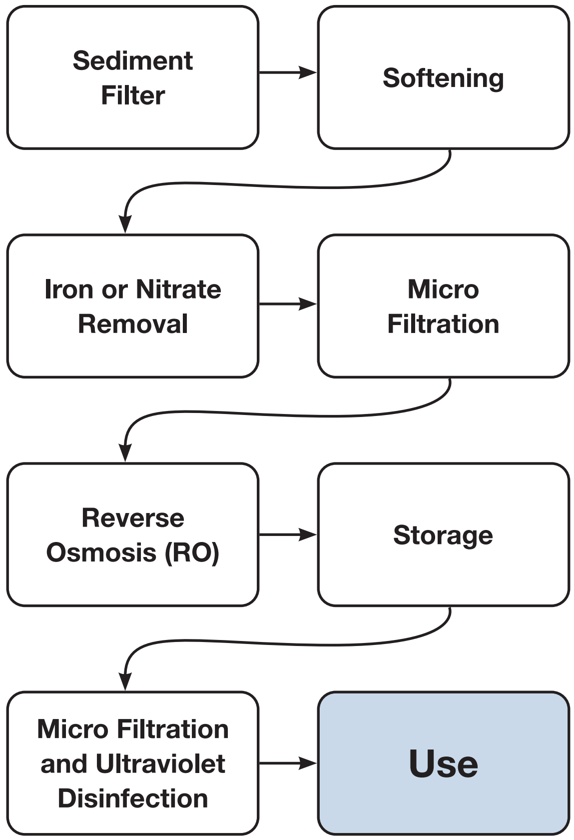
The level of treatment for laboratory water supply varies significantly depending on the end use of that water. Figure 11-13 shows the treatment for a water quality laboratory. It includes filtration, softening, reverse osmosis, and cation and anion exchange to produce water of extremely high quality.

Water used for all types of laboratory and medical operations must also be treated to levels required for that operation.

Examples of a Total Treatment System for Kidney Dialysis

Kidney Dialysis systems must produce ultra-pure, sterile water for the protection of the patient. To accomplish this, they use a combination of treatment systems.

The following shows a typical treatment train for this purpose:



The purity of water used for dialysis must be carefully controlled to protect the health of the patient. For most dialysis systems, the amount of product water produced is just about equal to the water rejected by the RO unit.

Figure 11-13: Treatment for a Water Quality Laboratory

Image source: HW (Bill) Hoffman & Associates, LLC

Recommendations

- The Recommendations found in the section on total water treatment should be followed.

Treated Water Piped to Labs

Image source: HW (Bill) Hoffman & Associates, LLC

Point of Use Treatment System

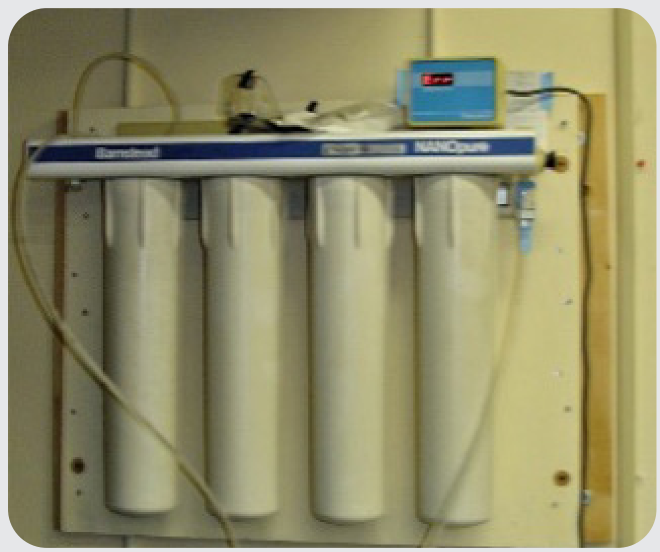


Image source: HW (Bill) Hoffman & Associates, LLC

Dialysis Equipment and Treatment System

Image source: HW (Bill) Hoffman & Associates, LLC

Humidifiers

Humidification of the laboratory working space is necessary, especially in the colder months, to maintain proper humidity both for creature comfort and to control the growth of harmful organisms such as mold, viruses, bacteria, and mites. Most laboratories try to keep relative humidity between 40 percent and 60 percent for the above reasons. Since many laboratories require significant fresh air turnover rates, proper humidification is required. Two basic types of humidification processes are available:

- Isothermal systems use an external heat source to boil water which is injection as steam or water vapor directly into the circulating air.
- Adiabatic systems which either spray water into the air space (atomizers) or those that cause the air in the room to evaporate water with the aid of wetted medial or mechanical energy.

By design, humidifiers consume water to add moisture to conditioned air. However, additional water use can occur from either 1) blowdown or discharge to prevent a buildup of minerals in the system; or 2) treatment of the incoming water supply. Like with cooling towers and boilers, blowdown is required in humidifiers to periodically control the levels of TDS and minerals in the system. The only exception to the need for blowdown is atomizer systems that spray treated water directly into the room. Direct steam injection from a central boiler system does not require additional treatment or blowdown at the point of use, but blowdown and treatment are required at the central boiler. Very pure water produced by reverse osmosis or deionization is recommended for many types of humidifiers, and even then, some water must be blown down or flushed out. Atomizers typically require purified water many laboratories since tap water contains minerals and other contaminants that would be sprayed into the indoor air. Also, wet media, ultrasonic, centrifugal, and hybrid spray systems need the water in them to be controlled for bacteriological growth through the addition of biocides, even when high purity water is used. When operating humidifiers or selecting new equipment, laboratories should examine the water that is required for blowdown, as well as waste generated through generation of reverse osmosis and deionized water.

Energy is also a consideration when selecting or operating humidifiers. Isothermal humidification requires the generation of steam or hot water, which can be energy intensive. Since centralized boiler systems are usually operated more efficiently than stand-alone steam boiler humidification systems, direct steam injection tends to be both more energy and water efficient. Adiabatic systems require the evaporation of water which has a cooling effect on the air in the space being humidified. This is beneficial in warm, dry climates where cooling is needed in addition to humidification. In colder climates, or in winter more energy will be required for space heating, however energy savings may still be achieved by not having to generate steam or hot water, as is required for isothermal humidifiers.

Table 11-4: ASHRAE (Chapter 22, 2016 ASHRAE Handbook—HVAC Systems And Equipment) List of Humidifiers

Isothermal	Adiabatic
Steam heat exchanger	Ultrasonic atomizer
Hot-water heat exchanger	Centrifugal atomizer
Direct-injection steam	Pressurized-water atomizer
Electrode steam	Compressed air atomizer
Electric resistance steam	Wetted media
Gas-fired steam	Hybrid spray/media
Electric infrared steam	

Recommendations

- All humidification operations should be properly controlled with instrumentation to measure relative humidity and keep the levels typically between 40 and 60 percent. This ensures that only the water and energy needed to control humidity is used and comfortable, safe conditions are maintained.
- All humidifier equipment and operating conditions should be carefully chosen and sized for type of laboratory in which it is being installed. Work with a qualified vendor to select equipment and controls designed for energy and water efficiency.

Medical Therapeutic Water Using Equipment

Hydrotherapy and related treatment methods are used for a multitude of purposes ranging from recovery from muscular skeleton injuries and illnesses to therapy for burn victims. Equipment ranges from small vessels for hand and foot injuries to hole body whirlpools and swimming pools.

Therapy pools operate like swimming pools and the Recommendations for pools apply. For special baths, strict medical procedures are used to prevent transmission of infections. The Center for Disease Control (CDC) has strict protocols for the cleaning, disinfection and maintenance of this equipment. Among other things special baths and treatment tanks must be drained and disinfected after each use. The only recommendation is that institutions should follow the CDC guidelines.

Alternative Water Sources

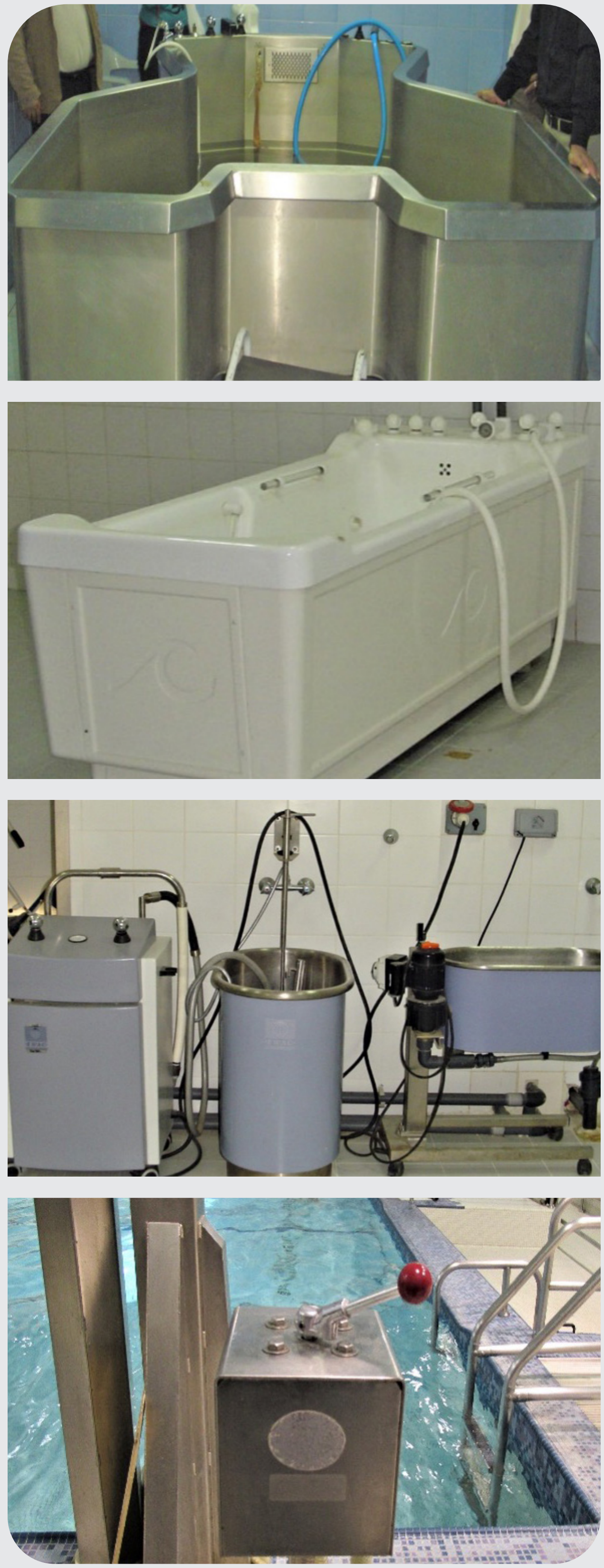
Before beginning a discussion of the water savings potential of the technologies described above, it is important to remember that the potential to collect and reuse clean but non-potable water is significant in larger medical and laboratory facilities. This approach is promoted by "Labs for the 21st Century," a joint program of the US EPA and the Department of Energy.

Possible sources of water include, but are not limited to:

- Once-through cooling water discharge
- Water from reverse osmosis units
- Foundation drain water
- Rainwater

Using reclaimed water from municipal sources is also possible for irrigation and cooling tower makeup, as well as toilet and urinal flushing.

Examples of Therapeutic Equipment (Top to Bottom): Physiotherapy Tank, Whirlpool Bath, Whirlpool, Pool



Images source: HW (Bill) Hoffman & Associates, LLC

Figure 11-4 is for illustrative purposes only. Such a system must be equipped with proper backflow prevention and pumps where pressurized output is needed. Learn more in the Alternate Onsite Water Sources chapter.

Water Savings Potential

For the equipment described in the section above, the following water savings are possible:

Vacuum Systems

Dry systems do not use water for the pump seal but can use water for cooling the pump. Water use rates for a liquid-ring pump range from 0.5 to 1.0 gallons per minute (gpm) per horsepower (hp). Water use can be eliminated entirely if no cooling water is used. Pumps should never be cooled with a once-through system. If a water-using system must be used, it should be hooked to a closed-loop or radiator-type system. The typical dental unit with a 1.5 hp liquid-ring pump can use 360 to 720 gpd.[9] For a large medical facility with a 12 hp pump, the water used per day can range from 8,640 to 17,280 gallons. Newer liquid-ring pumps try to minimize water use, so their consumption would most likely be in range of 8,600 to 10,000 gpd. Using a dry vacuum pump will save significant volumes of water or eliminate water use (Tuthill).

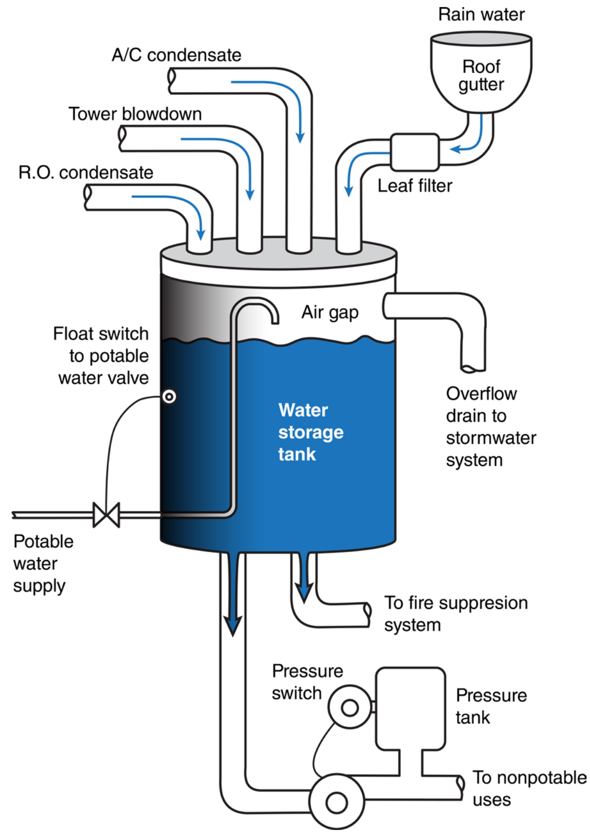
Medical Air and Compressor Equipment

Compressors generate significant heat as they compress the air. Smaller units, such as those used in dental and smaller medical facilities, can easily be air-cooled. Compressors larger than 10 or 15 hp (Tuthill), however, often require water cooling. Ten hp equals 7.5 kW, and a once-through-cooled compressor that size would require a constant stream of 5 to 6 gpm to cool it when in operation. When water cooling is necessary, the compressor cooling system must be hooked to a looped cooling system. If not, water demands for this example could exceed 8,000 gpd.

Sterilizer Operations

Water use per cycle for large vacuum steam sterilizers ranges from 350 to 400 gallons per cycle (TDK Consulting). Now new equipment often comes equipped with condensate-tempering systems (CTS). Mechanical vacuum pumps and other equipment can be retrofitted with after purchase equipment (Continental Equipment). To reduce water use per cycle to less than 80 gallons.

Figure 11-4: Reclaimed Water Reuse Example



The use of CTS on gravity and vacuum sterilizers also reduces water use significantly. Since the typical flow rate for tempering is 0.3 to 1.0 gpm, water use can be in the range of 450 to 1,500 gpd. The installation of a CTS can reduce this water use by 85 percent to 65 to 200 gpd.

Water-cooled Laboratory and Therapeutic Equipment

Daily water use depends upon the type of equipment being cooled and the length of time the equipment is used daily. Flow rates of 0.5 to 5.0 gpm are possible for each piece of equipment. Connecting larger stationary equipment to a closed-loop system is the first logical step in reducing water use to near zero. Recirculating water systems also minimize water use.

Laboratory Hood Scrubbers

Flow rates in scrubbers can be high. Recirculating systems reduce this use to a few gallons per minute when operating.

9 www.sableindustriesinc.com

Cost-Effectiveness Analysis

Vacuum Systems

Because liquid-ring vacuum systems must move both air and water, they are inherently less energy efficient and use significant amounts of water. However, they also tend to be the least expensive vacuum systems, based upon size and capacity (from a search of web sites for such equipment), so there is a true trade off between initial cost and operating cost.

Several dry vacuum systems are available for dental applications. The cost for a new dry vacuum pump in the one to two hp size is $5,000 to $10,000. By comparison, a liquid ring pump of the same hp costs $2,000 to $7,000. However, because dry systems are more efficient, a one hp dry system can often replace a 1.5 to 2.0 hp liquid ring system. This partially offsets this cost difference. On an annual basis, dry systems use one-third to one-half less electricity than a liquid-ring pump and have zero water use (Tuthill). As an example, compare a system that requires a 1.5 hp liquid ring pump with a 1.0 hp dry pump. In an eight-hour day, the liquid ring pump will use 540 gallons of water and 9 kWh of energy. The dry pump will use no water and only 6 kWh. Depending on where the facility is, the business will not only save on water costs but wastewater costs as well.

If the liquid ring system of a large medical center requires a 23 hp pump, a comparable dry system (piston, vane, or non-lubricated) would require only 12 to 15 hp. Liquid-ring pumps require as much as twice the horsepower of equivalent dry vacuum pumps because both water and air must be pumped. Liquid ring pumps in continuous operation use water at a rate of 16,000 to 30,000 gpd.

In one example from a firm that sells all four kinds of pump systems, a 23 horsepower pump will use about 2.9 million gallons of water per year and 152,000 kWh of power (Tuthill). In contrast, the same tasks could be accomplished by a 12 hp vane pump, which would use no water and only 80,000 kWh of power (Tuthill). The costs for operating these systems will be dramatically different. The liquid-ring system cost would be about $8,000 to $20,000, while vane and piston pumps would cost twice that. Liquid ring and dry vane pumps have about the same life span of 10 years or fewer, while piston pumps can last several decades (Tuthill). As an example, one medical facility replaced a liquid ring pump with a dry 10 hp vacuum system. The savings in energy and water were over $60,000 per year (Deckkler).

Another major cost savings with dry systems is that they do not have to be plumbed for water or have a backflow system. These costs can be from $200 to over $5,000, depending upon how much plumbing must be done. Dry systems also eliminate the costs of annual inspections of backflow equipment, which typically cost from $50 to $300 depending on who the water utility is.

Medical Air and Compressor Equipment

Air-cooled systems do not use water, while once-through systems will use half a gallon to one gallon per horsepower-hour. Hooking up to a closed loop system can be relatively inexpensive if the water line is readily available or expensive if long runs must be made. Typical costs of a few hundred to one to five thousand dollars can be expected.

Sterilizers and Central Sterile Operations

Most new sterilizers are equipped with water tempering equipment at the factory, and medium and large vacuum systems come equipped with mechanical vacuum pumps, according to Steris's information on their web site (www.steris.com/).

Water cooled Laboratory and Therapeutic Equipment

Cooling any piece of equipment with air is always the least expensive method. Where water must be used, hooking to a closed loop system is the next best option. The cost for doing this is dependent upon the location and availability of chilled water for cooling tower loop piping.

Laboratory Hood Scrubbers

Equipment and operating costs for scrubbers vary with application, and case-by-case analyses are necessary. Remember that dry hoods are always less expensive than systems that require scrubbers, because they require no water or sewer hookups and backflow preventers, consume less electricity, and use no water. Typical costs of a few hundred to one to three thousand dollars can be expected.

Recirculating chillers are also available. This equipment has the advantage of very precise temperature control and the ability to achieve low water temperatures if needed. Equipment is rated in watts of energy removed and can vary in size from 1,000 to 10,000 watts. The cost for this equipment ranges from $2,000 to more than $15,000, depending upon capacity and brand. The price per watt will vary depending on the region and fluctuate with the time of the day and year but the overall price is 20.06 cents per kilowatt hour, compared with an average 16.06 cents statewide and 10.48 cents nationally. There is also an electricity cost based upon the electrical-rating wattage of the equipment. For example, a 5,000-watt machine will consume 6.4 kWh in continuous operation, including the heat input from the motor of 3.5 watts removed per watt of motor energy input. Most units will not run continuously and will operate only when there is a heat load from the laboratory or therapeutic equipment being used.

The water savings are also based upon the amount of heat removed. Using the example above, a 5,000-watt machine with once-through cooling and a temperature rise of 10 degrees will use about 6.33 gpd in continuous operation.

Recommendations

Proven Best Practices for Superior Performance

- Use dry vacuum systems in medical, dental, and laboratory facilities
- Air cool or use a radiator cooler or a chilled-loop or cooling tower system with all vacuum and compressor systems. Once-through cooling with potable water should be prohibited
- Equip all stand-alone steam sterilizers with condensate tempering systems
- Equip all vacuum sterilizers with mechanical vacuum systems
- Cool laboratory equipment with a closed-loop system, such as a chilled water or cooling tower system, or with a recirculating chiller unit
- Equip all hood scrubbers with recirculating systems
- Perchlorate hoods on fume hood washdown systems should have self-closing valves
- Consolidate loads. Don't run an autoclave to sterilize a small amount of equipment
- Right-size your autoclave. If you don't need a large autoclave, use a smaller one instead
- Consider a water and energy efficient “Green” autoclave when purchasing autoclaves
- Install water saving devices on existing autoclaves whenever possible

Additional Practices That Achieve Significant Savings

- Use dry hood-exhaust systems wherever possible
- Promote the use of digital X-ray equipment
- Recover and reuse water from sources such as RO reject water, air conditioner condensate, rainwater, foundation drain water, and any other applicable source for use as irrigation water, scrubber water makeup, and cooling tower makeup
- Use dry cooling for all equipment where possible
- Promote use of condensate return systems for sterilizers

Resources

1. ANSI/AIHA/ASSP Z9.5 –Laboratory Ventilation, and NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals.
2. ASHRAE (Chapter 22 - 2016 ASHRAE Handbook – HVAC Systems and Equipment) lists the following types of humidifiers.
3. Arizona Municipal Water Users Association, Black and Veatch. March 2003. Facility Managers Guide to Water Management. Version 2.3.
4. Beckinghausen, David. October 1, 2006. "Energy-Efficient Washing Systems." ALN Magazine. *www.alnmag.com/article/energy-efficient-washing-systems.*
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East Bay Municipal Utility District

375 11th Street, Oakland CA 94607

Phone: 1-866-403-2683

E-mail: waterconservation@ebmud.com