WaterSense at Work

Laboratory and Medical Equipment

7.2 Vacuum Pumps

Best Management Practices for Commercial and Institutional Facilities

EPA WaterSense

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

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

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

- **Section 1. Getting Started With Water Management**
- **Section 2. Water Use Monitoring**
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This document is one section from *WaterSense at Work: Best Management Practices for Commercial and Institutional Facilities* (EPA-832-F-23-003). Other sections can be downloaded from www.epa.gov/watersense/best-management-practices. Sections will be reviewed and periodically updated to reflect new information. The work was supported under contract 68HERC20D0026 with Eastern Research Group, Inc. (ERG).

Overview

Laboratories, medical facilities, and dental offices use vacuum pumps to collect waste gases, liquids, or debris from a vessel or enclosure. These vacuum pump systems range in size, depending on whether they are used to supply a vacuum to several rooms or for point-of-use. Dental offices' pumps range from 1.0 to 4.0 horsepower (hp), while a central vacuum pump in a medical facility can be 5.0 to 20.0 hp.[1] Vacuum pumps can use water in two ways: to cool the pump and to create the vacuum seal in the rotating equipment, which generates the vacuum.

Generating the Vacuum

Vacuum pumps can either be "dry" or "wet"—based on how the vacuum seal is generated within the pump. Dry pumps do not use water to generate the seal for the vacuum. Instead, they create vacuums with turbines (i.e., fans) or use positive displacement (e.g., vane pumps, claw pumps, piston pumps). Wet pumps can be classified as either aspirators or liquid-ring vacuum pumps.

Liquid-ring vacuum pumps

In an aspirator, fluid (often water) flows through a narrowing tube, and a vacuum is generated by the Venturi effect. Water is used once and discharged to the drain, making the process very water-intensive. Due to their simple operation, water aspirators might be found most often in high school and college laboratories for educational purposes and are used infrequently. Since liquid-ring vacuum pumps are more common in commercial and institutional facilities, aspirators are not the focus of this section. If a facility has a water aspirator that is used frequently, it should consider replacing it with a dry, air-cooled vacuum pump as discussed below.

Liquid-ring vacuum pumps use a closed impeller that is sealed with water or other lubricants such as oil to generate the vacuum. The most common type of wet pump uses water to form a moving cylindrical ring inside the pump casing. In these pumps, the

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[1] East Bay Municipal Utility District (EBMUD). 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses.* Page MED2. www.ebmud.com/water/conservation-and-rebates/commercial/watersmart-guidebook.

vacuum is created by the changing geometry inside the pump casing as the impeller and liquid ring rotate. As the vacuum seal water rotates with the pump, it gains heat and gathers impurities from gases collected by the vacuum system.

In the simplest liquid-ring vacuum pump systems, the seal and cooling water are continuously discharged and replenished with fresh water to dissipate heat and remove impurities. Water requirements for both creating the vacuum and cooling the equipment range from 0.5 to 1.0 gallons per minute (1.9 to 3.8 liters per minute) per hp.[2] To save water, these pumps can be equipped with a partial or full recovery and recirculation system. In the full recovery system, all the seal water is recovered from the discharge side of the pump, passed through a heat exchanger, and reused for sealing and cooling. A small amount of recycled water is discharged to remove impurities, and the system is replenished with make-up water. Since it is designed to be self-contained and almost fully recirculate seal water, this full configuration recirculation system is estimated to reduce water use by nearly 100 percent.[3]

Partial recovery and recirculation systems recirculate part of the sealing water. Make-up water is added to ensure that impurity concentration is not too high. In these systems, consideration should be made to avoid heat build-up in the pump. Partial recovery systems can reduce water use by about 50 percent.[4]

Cooling the Vacuum Pump

Vacuum pumps can be water-cooled or air-cooled. Either wet or dry vacuum pumps can use water to cool the system. Water-cooled vacuum pumps use single-pass cooling or recirculated cooling. In single-pass cooling, water passes through the pump only once for cooling, then is discharged directly to the drain. A recirculated cooling system, on the other hand, passes the majority of cooling water through a heat exchanger, and the cooling water is reused. If the cooling water does not come in contact with the vacuumed gases or other impurities, it can be recirculated by connecting the pump to a larger building system chilled water loop or cooling tower water loop to remove the heat load. Air-cooled vacuum pumps use ambient air, rather than water, to remove the heat load from the vacuum pump.

[2] *Ibid.*
[3] California Urban Water Conservation Council (CUWCC). December 2012. *Water Use in Vacuum Pump Systems & Viability for a Water Conservation Best Management Practice in California*. Page 7. https://calwep.org/wp-content/uploads/2021/03/Water-Use-in-Vacuum-Pump-Systems-PBMP-2012.pdf.
[4] *Ibid.*, Page 6.

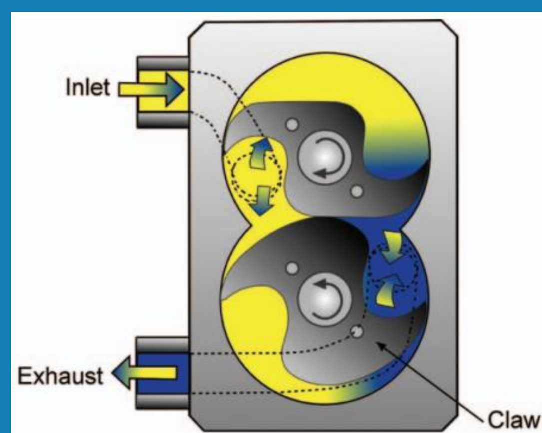
Operation, Maintenance, and User Education

For optimum liquid-ring vacuum pump efficiency, consider the following tips:

- Turn off the pump when it is not in use or needed.
- Ensure that the vacuum pump is set according to manufacturer specifications and is being operated in accordance with manufacturer-recommended control schemes to discharge only the amount of water necessary to remove impurities and cool the vacuum pump.
- Periodically check the vacuum pump's operational control schemes, if available, to ensure optimum efficiency (e.g., timers, float-operated switches, total dissolved solids controllers that initiate discharge and make-up water).

Claw Technology Eliminates Water Use While Reducing Energy and Maintenance

Some more energy-efficient vacuum systems use a claw technology to generate a vacuum. This technology incorporates two "claws" that rotate in opposite directions but do not come in contact with one another. Air is drawn in through an inlet and is compressed by the rotation of the claws, creating a pressurized air pocket. When the air pocket approaches the exhaust line (again, via the rotating claw movement), it leaves the vacuum chamber at a higher velocity and generates the vacuum. See the figure below. This technology does not require the use of oil or water and is typically lower maintenance.



Source: U.S. Department of Energy (DOE), Federal Energy Management Program (FEMP). 2011. *Water Efficiency Improvements at Various Environmental Protection Agency Sites*. www.nrel.gov/docs/fy11osti/48950.pdf.

Retrofit Options

If the facility is using a liquid-ring vacuum pump that continuously discharges water, the facility can consider equipping the pump with a full recovery and recirculation system to recover and reuse nearly 100 percent of the seal water.[5] The facility should consider the impurities gathered within the pump and other characteristics of the waste being removed when evaluating whether a full recovery and recirculation system is appropriate. A partial recovery and recirculation system could also be considered, and the facility could reduce water use by an estimated 50 percent.[6] If either recovery and recirculation system option is installed, ensure that it is

[5] *Ibid.*, Page 7.
[6] *Ibid.,* Page 6.

properly maintained per manufacturer instructions so that impurities are removed and hard water deposits do not remain in the system.

If the facility has any other type of vacuum pump that is cooled with single-pass, non-contact cooling water, a heat exchanger can be added, or it can be connected to a larger building system chilled water loop or cooling tower water loop. See *WaterSense at Work Section 6.2*: *Single-Pass Cooling* at www.epa.gov/watersense/best-management-practices for more information.

Replacement Options

When purchasing a new vacuum pump or replacing older equipment, facilities should choose a non-lubricated, dry vacuum pump that is air-cooled unless fire and safety codes for explosive, corrosive, or oxidative gases require a liquid-ring pump. Although they might be more expensive, dry, air-cooled vacuum pumps can be about 30 percent more energy-efficient than water-cooled or liquid-ring vacuum pumps since they do not have to pump water along with air.[7]

Dental facilities should note that new vacuum systems—wet or dry, and regardless of the type of cooling system—need to add amalgam separators and follow best management practices established by the American Dental Association to comply with EPA regulations to prevent mercury contamination in water bodies.[8]

Savings Potential

Retrofitting existing liquid-ring vacuum pumps with full or partial recovery and recirculation systems can result in significant water savings, while replacing existing water-cooled and/or liquid-ring vacuum pumps with air-cooled, dry vacuum pumps can entirely eliminate water use and result in energy savings as well.

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

Vacuum Pump Retrofit

Liquid-ring pumps that utilize water to create a vacuum can be retrofitted to recirculate sealing and cooling water rather than discharging to the drain.

[7] *Ibid.*, Page 7.
[8] U.S. Environmental Protection Agency (EPA). Dental Effluent Guidelines. www.epa.gov/eg/dental-effluent-guidelines.

Current Water Use

To estimate the current water use of an existing vacuum pump, identify the following and use Equation 1:

- Flow rate of the discharged water from the existing vacuum pump.
- Average daily use time.
- Days of operation per year.

Equation 1. Water Use of Vacuum Pumps (gallons or liters per year)

= Vacuum Pump Discharge Flow Rate x Daily Use Time x Days of Operation

Where:

- Vacuum Pump Discharge Flow Rate: Gallons (or liters) per minute
- Wash Processes per Day: Minutes per day
- Days of Operation: Days of vacuum pump operation per year

Water Savings

Full water recovery and recirculation systems can reduce water use by nearly 100 percent,[9] while partial systems can reduce water use by approximately 50 percent.[10] To calculate water savings that can be achieved from retrofitting an existing vacuum pump, identify the current water use of the vacuum pump as calculated using Equation 1 and use Equation 2, using 99 percent savings for a full system and 50 percent for a partial system.

Equation 2. Water Savings From a Vacuum Pump Recovery and Recirculation System Retrofit (gallons or liters per year)

= Current Water Use of Vacuum Pump x Percent Savings

Where:

- Current Water Use of Vacuum Pump: Gallons (or liters) per year
- Savings: Percent

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[9] CUWCC, *op. cit.*
[10] *Ibid.*, Page 6.

Payback

To calculate the simple payback from the water savings associated with retrofitting an existing vacuum pump, consider the equipment and installation cost of the retrofit recovery and recirculation system, the water savings as calculated using Equation 2, and the facility-specific cost of water and wastewater.

The facility should also consider the energy impact of the vacuum pump retrofit. The recovery systems might use energy, which can affect the payback period and cost-effectiveness.

Vacuum Pump Replacement

Many existing liquid-ring vacuum pumps can be replaced with dry vacuum pumps that are air-cooled rather than water-cooled. This replacement entirely eliminates the water used to create a vacuum and cool the vacuum pump, and these pumps are also more energy-efficient.

Current Water Use

To estimate the current water use of an existing vacuum pump, use Equation 1.

Water Savings

To calculate water savings that can be achieved from replacing an existing vacuum pump, identify the current water use of the vacuum pump and the water use of the vacuum pump after replacement (using Equation 1) and input these values into Equation 3 below. If an air-cooled, dry vacuum pump is selected as the replacement model, water savings will be equal to the water use of the vacuum system being replaced.

Equation 3. Water Savings From a Vacuum Pump Replacement (gallons or liters per year)

= Current Water Use of Vacuum Pump – Water Use of Vacuum Pump After Replacement

Where:

- Current Water Use of Vacuum Pump: Gallons (or liters) per year
- Water Use of Vacuum Pump After Replacement: Gallons (or liters) per year

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Payback

To calculate the simple payback from the water savings associated with replacing an existing liquid-ring vacuum pump with an air-cooled, dry vacuum pump, consider the equipment and installation cost, the water savings as calculated using Equation 3, and the facility-specific cost of water and wastewater.

By replacing a water-cooled or liquid-ring vacuum pump with an air-cooled, dry pump, facilities should also consider the impact on energy use. Dry vacuum pumps can be about 30 percent more energy-efficient than water-cooled or liquid-ring vacuum pumps.[11] The energy use will also affect the payback time and replacement cost-effectiveness.

Additional Resources

American Dental Association. August 2022. Amalgam Separators and Waste Best Management. www.ada.org/resources/research/science-and-research-institute/oral-health-topics/amalgam-separators.

California Urban Water Conservation Council. December 2012. *Water Use in Vacuum Pump Systems & Viability for a Water Conservation Best Management Practice in California*. https://calwep.org/wp-content/uploads/2021/03/Water-Use-in-Vacuum-Pump-Systems-PBMP-2012.pdf.

East Bay Municipal Utility District. 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses.* Pages MED1-2. www.ebmud.com/water/conservation-and-rebates/commercial/watersmart-guidebook.

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

U.S. Department of Energy (DOE), Federal Energy Management Program (FEMP). March 2011. *Water Efficiency Improvements at Various Environmental Protection Agency Sites*. www.nrel.gov/docs/fy11osti/48950.pdf.

[11] *Ibid.,* Page 7.

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