7.3 Vacuum Pumps

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 upon 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.[15] Vacuum pumps can use water in two ways: to cool the pump or to create the vacuum seal in the rotating equipment, which generates the vacuum.

Vacuum pumps at the Kansas City Science and Technology Center

An aspirator is a type of vacuum system that can consume water in the process of creating the vacuum. In an aspirator, fluid (e.g., liquid, gaseous) flows through a narrowing tube. As the tube narrows, the velocity of the fluid increases and the static pressure within the system decreases due to the Venturi effect, which creates a vacuum. The simplest type of aspirator uses water as the fluid medium, which is used once and discharged to the drain, making the process very water-intensive. Because of their simplicity, water aspirators might commonly be found in many high school and college laboratories, but their use can be limited to just a few hours each semester. Although water aspirators are available, they are not the focus of this section. Instead, this section focuses on vacuum pump systems, which are more commonly found in commercial and institutional facilities. If a facility has a water aspirator that is used frequently, it should consider the replacement options discussed in this section.

Generating the Vacuum

Vacuum pumps can either be "dry" or "wet"—based upon 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 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 vacuum pump is a liquid-ring vacuum pump, which uses water to form a moving cylindrical ring inside the pump casing. In these pumps, the 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 most simple liquid-ring vacuum pump systems, the seal and cooling water are continuously discharged and replenished with fresh water to dissipate heat and

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

remove impurities. Water requirements for both creating the vacuum and cooling the equipment range from 0.5 to 1.0 gallons per minute (gpm) per hp.[16] 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 (if the system configuration allows for heat removal), 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. This full configuration recirculation system is estimated to reduce water use by 80 percent.[17]

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 buildup in the pump. Partial recovery systems can reduce water use by about 50 percent.

Cooling the Vacuum Pump

Vacuum pumps can be water-cooled or air-cooled. Water-cooled vacuum pumps use single-pass cooling or recirculated cooling. Either wet or dry vacuum pumps can use water to cool the system. 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.

Operation, Maintenance, and User Education

For optimal 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 at manufacturer specifications 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).

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

[16] *Ibid*.
[17] U.S. Air Force Medical Service. *Dental Vacuum Systems*. Page 5. airforcemedicine.afms.mil/idc/groups/public/documents/afms/ctb_108329.pdf.

system, to reduce total water use by an estimated 80 percent.[18] 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 with its installation. If either recovery and recirculation system option is installed, ensure that it is 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 *Section 6.2: Single-Pass Cooling* for more information.

Replacement Options

When purchasing a new vacuum pump or replacing older equipment, a non-lubricated, dry vacuum pump that is air-cooled can eliminate the pump's water use altogether. When choosing a vacuum pump, it is important to consider all factors, including energy and water use. Although they might be more expensive, dry, air-cooled vacuum pumps can be as much as 25 to 50 percent more energy-efficient than water-cooled or liquid-ring vacuum pumps.[19]

Facilities should note that, in some cases, liquid-ring vacuum pump discharge can pose a biohazard risk. Therefore, a non-lubricated, dry vacuum pump that is air-cooled could be the best option. However, if explosive or corrosive gases are being removed with the vacuum system, the facility might only be able to consider a liquid-ring vacuum pump. Dental facilities should note that new vacuum systems—wet or dry, and regardless of the type of cooling system—often need to add amalgam separators to prevent mercury contamination in water bodies.[20]

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.

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.

[18] *Ibid*.
[19] EBMUD, *op. cit*.
[20] U.S. Air Force Medical Service, *op. cit*., Page 1.

Current Water Use

To estimate the current water use of an existing vacuum pump, identify the following and use Equation 7-1:

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

Equation 7-1. Water Use of Vacuum Pump (gallons per year)

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

Where:

- Vacuum Pump Discharge Flow Rate (gallons per minute)
- Daily Use Time (minutes per day)
- Days of Operation (days per year)

Water Savings

Full water recovery and recirculation systems can reduce water use by approximately 80 percent,[21] while partial systems can reduce water use by approximately 50 percent.[22] To calculate the 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 7-1 and use Equation 7-2, using 80 percent savings for a full system and 50 percent for a partial system.

Equation 7-2. Water Savings From Vacuum Pump Recovery and Recirculation System Retrofit (gallons per year)

= Current Water Use of Vacuum Pump x Savings (0.80 or 0.50)

Where:

- Current Water Use of Vacuum Pump (gallons per year)
- Savings (percent)

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 7-2, and the facility-specific cost of water and wastewater.

[21] *Ibid*. Page 5.
[22] Estimate based on manufacturer literature.

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

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, as well as the water used to cool the vacuum pump.

Current Water Use

To estimate the current water use of an existing vacuum pump, use Equation 7-1.

Water Savings

Because air-cooled, dry vacuum pumps consume no water to create a vacuum, water savings will be equal to the current water use. To calculate the water savings that can be achieved from replacing an existing vacuum pump, identify the current water use of the vacuum pump as calculated using Equation 7-1 and use Equation 7-3.

Equation 7-3. Water Savings From Vacuum Pump Replacement (gallons per year)

= Current Water Use of Vacuum Pump

Where:

- Current Water Use of Vacuum Pump (gallons per year)

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 7-3, 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 potential increase or decrease in energy use. Some dry vacuum pumps can save energy over the existing water-cooled or liquid-ring pump. The energy use will also affect the payback time and replacement cost-effectiveness.

Additional Resources

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

Sydney Water. October 2004. *The Liquid Ring Vacuum Pump*. www.sydneywater.com.au/Water4Life/InYourBusiness/FactSheets.cfm.

U.S. Air Force Medical Service. *Dental Vacuum Systems*. airforcemedicine.afms.mil/idc/groups/public/documents/afms/ctb_108329.pdf.