General Services Administration
Public Buildings Service

GPG-035 | SEPTEMBER 2018

SMALL CIRCULATOR PUMPS WITH AUTOMATED CONTROL

Energy Savings and Positive Return-on-Investment from Two Applications

Because most small circulator pumps (< 2.5 horsepower) operate at a constant speed and use very little energy, they have typically been overlooked for energy efficiency upgrades. With over 30 million circulator pumps installed in U.S. commercial buildings, however, the opportunity for savings is significant. GSA's Proving Ground (GPG) program commissioned the National Renewable Energy Laboratory (NREL) to evaluate new high-performance variable-speed circulator pumps with automated control that adjust pump speed to meet changing demand. NREL researchers evaluated the new pumps' performance in two common applications: a domestic hot water (DHW) recirculation system and an air handler unit (AHU)—both at the Denver Federal Center (DFC), in Denver Colorado. When the new high-performance variable-speed circulator pumps were attached to the DHW system and compared with market-standard constant-speed baseline pumps, energy savings were between 90% and 96%. A savings of only 26% was achieved with the new AHU pump, because it was compared with a more efficient baseline pump. When compared with a market-standard constant-speed baseline pump, however, savings increased to 60%. Payback for both the DHW and AHU pumps was under 6 years, when annual maintenance savings were included. Deployment recommendations were simple and straightforward: small high-performance circulator pumps with automated control should be considered for end-of-life replacement for all constant speed pumps.

INTRODUCTION

> *"With the preset control modes, we met our conditions, ran the pumps efficiently, and eliminated ongoing maintenance."*
>
> —Stephen J. Guthrie
> Operations & Maintenance
> PMSC Solutions
> Denver, Colorado

TECHNOLOGY SPECIFICATIONS
Small Circulator Pumps with Automated Control

FEATURES

Pump size < 2 ½ HP
Energy efficiency index < 0.20
4-pole permanent magnet motor, ECM control
Sensors integrated into pump housing
Built-in control modes
1 analog input for 4-20 mA or 0-10-V DC
2 output relays for alarm, reading & operating
Wireless communication for 2-pump system
Communication range of 30 ft. without barriers
Maximum pressure 175 PSIG
Minimum media 14°F
Maximum media 230°F
Maximum sound pressure 43 dBA

What Is This Technology?

VARIABLE-SPEED CAPABILITY WITHOUT THE EXPENSE OF A VARIABLE FREQUENCY DRIVE

Circulator pumps propel fluid through closed-loop heating and cooling systems to regulate air or water temperature. The high-performance circulator pump with automated control represents an improvement over costly and complex variable frequency drives (VFD) because it controls motor speed with permanent magnet and compact stator motor technology. The pump's variable-speed electronically commutated motor (ECM) is governed by onboard algorithms, including a self-optimizing mode that finds the most efficient flow speed under different operating conditions. The pump also tracks and records temperature, flow rate, and energy use, providing operators with operational data and immediate feedback. Whereas an equivalent ad hoc setup would require separate pumps, meters, and communication equipment, which could introduce compatibility problems, this integrated pump is relatively easy to attach to an existing system. It can be controlled through a building automation system (BAS) or independently, via a desktop application, handheld device, or the pump's own user interface. Fourteen models of this specific circulator pump are available, with a maximum developed head of 60 feet and a flow rate of 340 gallons per minute (GPM).

What We Did

ASSESSED TWO COMMON CIRCULATOR PUMP APPLICATIONS

The high-performance circulator pump was evaluated at two buildings within the DFC, Building 67 and Building 810. Building 67 has two domestic hot-water recirculation pumps (DHWPs)—DHWP-1 serves the cafeteria, and DHWP-2 serves bathroom and kitchen sinks on floors 1 through 8. The two DHWPs were initially replaced with 0.37 HP high-performance pumps. Although these pumps reduced energy consumption by 90%, improved the power factor of the pump from 0.5 to 0.95, and successfully met the return water temperature set point, they were found to be oversized due to a low wire-to-water efficiency. Both DHWPs were replaced with smaller (approximately ¼ HP) and less expensive pumps when they became commercially available at the end of 2017. The DHWPs were monitored in series under two different control modes.

The high-performance pump was evaluated in conjunction with air handlers at the DFC's Building 810. The AHU pumps were monitored in parallel—AHU-19 was replaced with a high-performance circulator pump running with 0-10-V DC control mode, and AHU-17 pump was replaced with a market-standard pump.

Pump power and power factor, water flow rate, supply water temperature, and differential pressure were monitored on all pumps. In addition, researchers interviewed facility managers about the ease of installation and operability.

M&V FINDINGS

96% ENERGY SAVINGS FOR DHW PUMP, 60% NORMALIZED SAVINGS FOR AHU PUMP Energy savings varied significantly based on flow rate, differential pressure, and run time. Both ¼ HP DHW pumps reduced energy use by 96%; the DHW pump serving the cafeteria saved 587 kWh/yr and the DHW pump serving the bathroom and kitchen sinks on floors 1 through 8 saved 1,037 kWh/yr. The high-performance circulator pump on the AHU had very little run-time (4/hrs/day). When compared with a new baseline pump that was 32% more efficient than the typical constant-speed baseline pump installed before 2003, energy savings was 26% (45 kWh/yr). When normalized for baseline and usage (20/hrs/day), savings increased to 60% (688 kWh/yr).

OVERSIZED PUMPS STILL SAVE ENERGY BUT ARE NOT AS COST-EFFECTIVE It took longer to install the high-performance variable-speed circulation pumps (five hours instead of three), due to two hours of programming time. High-performance pumps that were larger than necessary for the required flow saved energy, but had higher installed costs and lower wire-to-water efficiencies than right-sized pumps.

LESS MAINTENANCE AND MORE OPERATIONAL VISIBILITY Because the high-performance circulator pumps do not require the greasing of bearings or replacing of pump seals, facility staff estimated annual maintenance savings of 1 hour per pump. A smart-phone-based application can be used to monitor pump operations. Due to IT security concerns and the timeline of the project, this capability was not evaluated. Operators can obtain the same data via a display on the pump itself.

LIFE-CYCLE COST EFFECTIVE FOR BOTH PUMPING APPLICATIONS Payback was under 10 years, with normalized energy savings between $65 and $114 at the GSA average utility rate ($0.11/kWh) and incremental costs for the smallest (¼ HP) pump between $500 and $575. When annual maintenance savings were included, payback was under 6 years. Higher flow rates combined with smaller pump sizes offered the best return on investment.

CONSIDER FOR END-OF-LIFE REPLACEMENT Pumps used for DHW recirculation, small heating systems, small chilled-water systems, solar hot water systems and small geothermal heat pump applications are all candidates for the high-performance circulator pump.

Payback and Savings Compared to Baseline Standard Pumps

Higher flow rates combined with smaller pump sizes offered the best return on investment

	% Savings	Annual Energy Savings (kWh/yr)	Annual Energy Cost Savings @ 0.11 kWh ($)	Annual O&M Savings ($)	Incremental Cost ($) over market standard pump	Simple Payback	Savings-to-Investment Ratio (SIR)
DHWP #1: ¼ HP, 77 watts (duty point) **Baseline:** ¼ HP, 280 watts (duty point)	96%	587 kW	$65	$75	$575	4.1	3.6
DHWP #2: ¼ HP, 97 watts (duty point) **Baseline:** ½ HP, 370 watts (duty point)	96%	1,039 kW	$114	$75	$575	3.0	4.9
AHU 19 : 0.36 HP, 186 watts (duty point) **Baseline:** ½ HP, 223 watts (duty point) 4 hrs/day run-time	26%	45 kW	$5	$75	$500	6.3	2.4
AHU 19: 0.36 HP, 186 watts (duty point) **Baseline:** ½ HP, 330 watts (duty point) 20 hrs/day run-time	60%	688 kW	$76	$75	$500	3.3	4.5

CONCLUSIONS

These Findings are based on the report, "High-Performance Circulator Pump Demonstration," which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact GSA's GPG program gpg@gsa.gov

Technology for test-bed measurement and verification provided by Grundfos.

What We Concluded

LIFE-CYCLE COST-EFFECTIVE FOR BOTH PUMP APPLICATIONS

Based on energy savings alone, small high-performance circulator pumps with automated control were life-cycle-cost effective for DHW applications and for the AHU application running 20/hrs/day. When annual maintenance savings are taken into consideration, payback decreased to less than 5 years. Small high-performance circulator pumps with automated control should be considered as an end-of-life replacement for all constant speed pumps..

LESSONS LEARNED

Convert three-way bypass valves to two-way valves At a minimum, the flow through the bypass loop must be closed for the pumps to operate correctly.

Correctly size the pump Because differential pressure and accurate flow readings are not readily available for smaller constant-volume circulator pumps, use one of the following methods to right-size the pumps:

- Determine pipe sizes and lengths and then calculate actual head loss from the pipes to estimate the flow (GPM) and head required for the pump.
- Observe supply and return temperature differentials to make an educated guess about the existing pump's suitability for that system. For example, if the Delta-T is extremely small (2°F to 5°F), the pump is most likely too big.

BAS integration can more than double a pump's installed cost To avoid additional costs, use the pump's pre-programmed internal control modes and rely on the BAS for on/off control.

DEPLOYMENT RECOMMENDATIONS

DHW recirculation pumps Bathroom and cafeteria sinks, like those at the Denver Federal Center, are ideal candidates for DHW pumps because of the irregular loads that result from intermittent hand and dish washing. The economics are favorable for end-of-life replacement with as little as 40 hours per week of pump operation at Denver's low electric rates. Using the constant return-water temperature control mode with the pump's internal temperature sensor is recommended.

Small heating system pumps Because of intermittent operation, longer run times and increased flow rate requirements, small heating pumps that serve multiple heating coils will likely have greater energy savings. Sites with older constant-volume pumps and standard induction motors that are less than 2 ½ HP in size and that operate for more than 8 hours per day, 8 months per year, with electric rates of $0.6 kWh or higher should be targeted first. For small heating systems, all three-way control valves should be converted to two-way valves. Use one of the control modes internal to the pump, following the manufacturer's recommendations, or a simple 0-10-V DC signal from the BAS.

Other applications Small chilled-water system pumps and solar hot-water system pumps require systems conditions similar to those of DHW applications. Small geothermal heat pumps may be more cost-effective than separate heating and cooling applications because they typically operate all year long.