Assessment of New Energy Efficient Circulator Pump Technology

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PRODUCT DESCRIPTION

Electric pumps are the workhorses behind several industrial processes that help in transferring liquids, gases, and slurries from one location to another. From simple water pumping systems to sophisticated oil refineries, electric pumps find their application in many different areas. From hot water circulation systems to pool pumps, electric pumps also are used in various capacities in commercial and residential sectors. This technical update provides a technical assessment of a new circulator pump technology that uses significantly less energy compared to conventional circulator pumps.

Results & Findings

This technical update presents laboratory test results of a conventional and an energy efficiency pump technology. These circulator pumps are quite prevalent in residential sector applications, such as domestic hot-water circulation and also in commercial buildings. There are approximately ten (10) million circulator pumps in the United States alone. The new circulator pump uses permanent magnet brushless dc motor and a microprocessor-based feedback controller. With the help of these features it can adjust the speed of the pump, similar to an adjustable speed drive, thereby finding an optimal efficient point to run the pump. Conventional circulator pumps, however, have no speed control, and they run at one speed and have induction motors to drive the shaft. There is significant energy savings opportunity, to the tune of about 3.5 TWh, available with the use of these pumps. The results and findings are described in detail in this technical update.

Challenges & Objective(s)

This technical update is oriented towards utility personnel who interface between the utility and end-use customers. It will help utility personnel answer customer questions regarding current trends in the electric motor market. Also, this technical update can serve as a quick reference guide to find out if the high efficiency pump technology described here would be a good fit for their customers' applications.

Applications, Values & Use

This work sets the tone for future work. More work is needed in the advanced motor/ pump technology area to demonstrate direct benefits, such as energy savings, reliability, and reduced downtime. The laboratory testing discussed in this report is just one example of how such demonstrations can help utilities and their customers see benefits of newer and advanced energy efficient technologies. With new legislation set to pass in December 2010 that requires motor manufacturers to meet higher efficiency levels, there may be significant value in such demonstrations.

EPRI Perspective

With several years of industrial experience in the electric motors and drives area, EPRI holds a unique position that could help utilities understand their customers' needs and respond to them in a very timely manner. EPRI has a huge inventory of technical documents on motor/drive efficiency, including the best-seller "ASD Applications Handbook." EPRI, as a vendor-neutral unbiased organization, can effectively coordinate efforts with organizations like the Consortium for Energy Efficiency (CEE) and the National Electrical Manufacturer's Association (NEMA).

EPRI also is in a great position to seek opportunities to work with motor or pump manufacturers and to establish demonstration projects to document quantifiable benefits of advanced energy efficiency pump or motor technologies.

Approach

The project team's goals were to investigate a new circulator pump technology, understand the working principle, and assess its efficiency levels against conventional circulator pump technology. Current applications of this new technology as well as possible other applications also are evaluated in this technical update.

Keywords

Electric pumps
Circulator pumps
Brushless dc motor
Microprocessor-controlled pumps
Variable speed pumps
Hydronic heating
Domestic hot water recirculation

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1
INTRODUCTION

Introduction

As a part of the 2010 research a new circulator pump technology that claims to consume less power than the conventional circulator pump was identified. The operational features of the new circulator pump and its performance characteristics were evaluated. These circulator pumps are quite prevalent in the residential sector applications such as domestic hot-water circulation and also in commercial buildings. There are approximately ten (10) million circulator pumps in the United States alone. The new circulator pump uses permanent magnet brushless dc motor and a micro-processor based feedback controller. With the help of these features it can adjust the speed of the pump, similar to an adjustable speed drive, there by finding an optimal efficient point to run the pump. The conventional circulator pumps, however, have no speed control and they run at one speed and have induction motors to drive the shaft. There is significant energy savings opportunity, to the tune of about 3.5TWh, available with the use of these pumps. The results and findings are described in detail in this technical update.

Pumps–Classification

From simple water pumping systems to oil refineries, the electric pumps find application in many different areas. From hot water circulation to systems to pool pumps, the electric pumps are also used in various capacities in the commercial and residential sectors also. In this technical update, one type of pump called the circulator pump will be discussed in detail.

Though there are many applications of electric pumps, they can be classified into two basic types based on the way they transmit energy to the fluid they carry. The first type of pump is known as a positive displacement pump while the second is referred to as a kinetic pump. Centrifugal pumps are the most common type of kinetic pumps.

Positive Displacement Pumps

Positive displacement pumps transmit energy to the fluid that passes through them by forcing a fixed volume of fluid from the inlet section of the pump to the discharge section of the pump.

Centrifugal Pumps

Centrifugal pumps transmit energy to fluid as it flows through the pump. Liquid first flows into the inlet or suction side of the centrifugal pump. This liquid is then captured by the impeller and thrown to the outside of the pump casing, or volute. The volute converts the velocity imparted to the fluid by the impeller into pressure, causing the fluid to flow through the system. Visual depictions of the both the positive displacement pump and the centrifugal pump can be found in Figure 1-1.

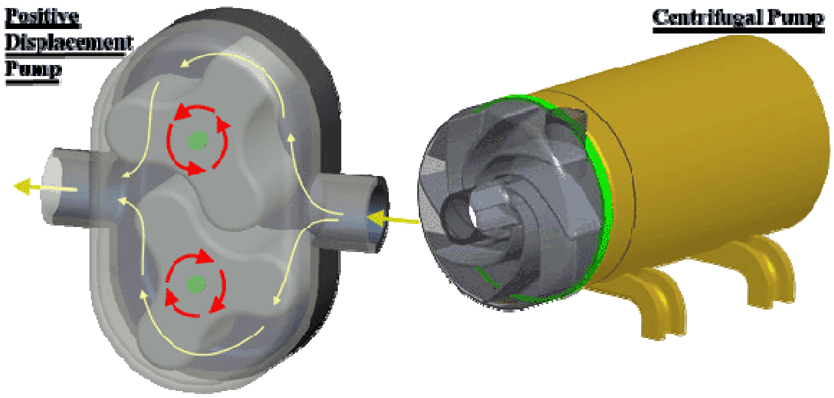

Figure 1-1
Positive Displacement Pump and Centrifugal Pump

Circulator pumps fall under the classification of centrifugal pumps. The circulator pumps are typically used in closed loop system to circulate liquids or gases. One such pump is a hot water circulator pump which is primarily used to circulate hot water in a closed loop pipe system.

These hot water circulator pumps provide hot water-on-demand at the faucets and sinks in some larger residential homes and commercial buildings. They are also used in industrial process systems for heat exchange applications. A visual depiction of the closed loop hot water circulation system setup is shown in Figure 1-2.

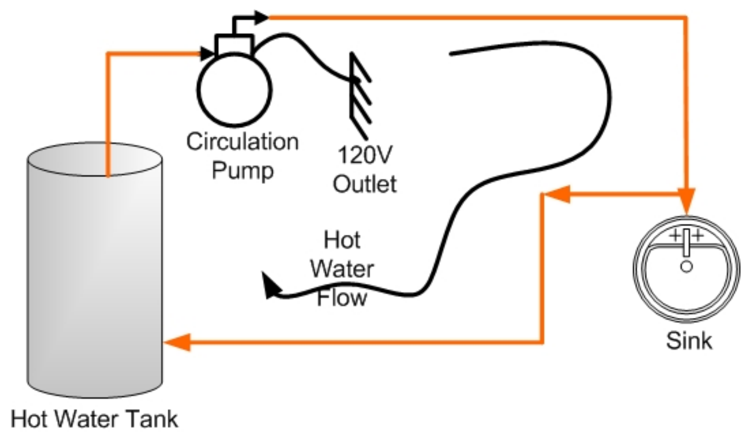

Figure 1-2
Visual of a Hot Water Circulation Pump in a Building

Typically these circulator pumps are oversized to accommodate future building expansion. An important point to note is that these pumps run at a constant flow (GPM[1]) during day and night every single day of the year.

---

[1] GPM stands for Gallons Per Minute

2
FUNDAMENTALS OF CENTRIFUGAL PUMPS

Since the circulator pump falls under the classification of centrifugal pump, the principles of operation, performance and efficiency of the centrifugal pumps will be described in this section. Pumps can be very complex; however, a simple centrifugal pump operation is presented here.

Elements of a Centrifugal Pump

A centrifugal pump is made up of two basic elements, namely, the stationary element and the rotating element called the impeller (refer to Figure 2-1). The stationary element consists of the pump casing, base plate, stuffing boxes and bearings. These parts provide support and enclosure for the rotating element. The case directs the flow of fluid into and away from the impeller, as well as providing the suction and discharge nozzles. The stationary element converts the kinetic energy generated by the impeller into pressure, or potential energy. Several examples of this pump application such as pool pumps, domestic hot water circulator pumps, industrial waste water systems, hydronic heating systems, geothermal systems can be found in residential, commercial and industrial sectors.

The rotating element is made up of a shaft and one or more impellers. The impeller(s) rotate, generating a flow of liquid and the head or pressure, of the pump.

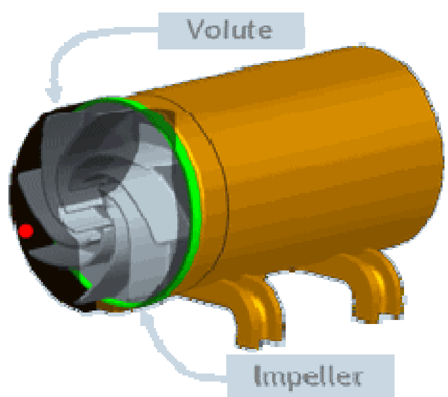

Figure 2-1
Elements of a Centrifugal Pump

The following terms and equations are essential to working with centrifugal pumps.

- **Head** is used as a measure of fluid energy in units of feet.
- **Friction Head (h_f)** is the energy required to overcome resistance to flow in the pipe, fittings, valves, entrances and exit.

Friction Head (h_f) is given by the following equation:

$$h_f = f\frac{L}{D}\frac{v^2}{2g}$$ **Equation 2-1**

Where (f) is friction factor, (L) is pipe length, (v) is fluid velocity, (D) is pipe inside diameter, and (g) is acceleration due to gravity.

- **Velocity head (h_v)** is the energy of a fluid as a result of its kinetic energy. It is given by the following equation:

$$h_V = \frac{v^2}{2g}$$ **Equation 2-2**

Where (v) is fluid velocity and (g) is acceleration due to gravity.

- **Pressure head (h_p)** is the pressure of the fluid being pumped. It is given by the following equation:

$$h_p = \frac{P}{\rho}$$ **Equation 2-3**

Where (P) is pressure and (ρ) is fluid density

- **Static suction head (h_s)** is the vertical distance in feet above the centerline of the pump inlet to the free level of the fluid source. If the free level of the fluid source is below the pump inlet, h_s will be negative and is referred to as a static suction lift.
- **Static discharge head (h_d)** is the vertical distance in feet above the pump centerline to the free level of the discharge tank.
- **Total dynamic head (H)** is equal to the net discharge head minus the net suction head. This is the total amount of energy added to the fluid by the pump.

Pump Performance Characteristics

Pump performance can be represented by plotting the head and capacity (flow rate). The head is measured in feet and the capacity is measured in gallons per minute or GPM. The resulting curve is referred to as the *performance curve*. Every pump will have a point on this curve where flow areas are optimized to *produce a given head and flow with minimal losses*. This point is called the *Best Efficiency Point (BEP)*.

Not all pumps have similar curves when plotted. Some pumps will gradually increase from run out to deadhead, and some will increase steeply. All curves, however, have a BEP, as indicated by the (+) on the curves shown in Figure 2-2. When a pump operates on either side of the BEP, losses affect the pump's performance.

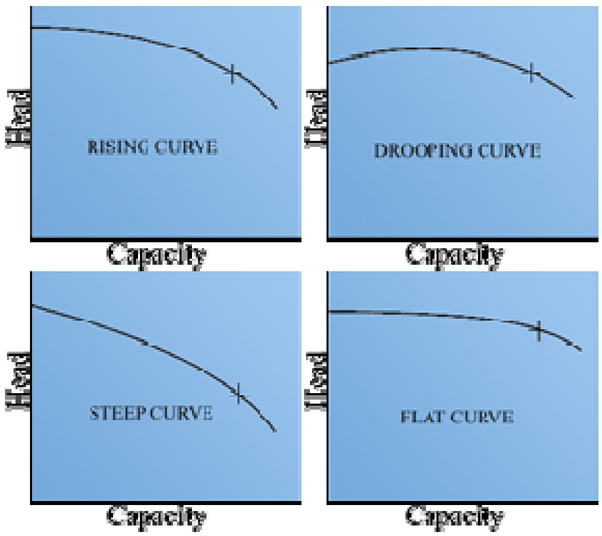

Figure 2-2
Performance Curves of Various Centrifugal Pumps (+ Denotes the Best Efficiency Point (BEP) of the Pump)

Pump Run-Out Conditions

Pump run-out refers to the maximum flow rate at the lowest anticipated system head. It is caused by a pump operating in an oversized system where system head loss is too low. Run out can occur even when a pump has been correctly sized (refer to Figure 2-3). This is most frequently a result of a rupture somewhere in the system that drastically reduces head loss. Run out can cause the following issues:

- Pump efficiency decreasing where run-out flow is typically much higher on the curve than the BEP
- Motor and/or pump overheating

Several actions can help prevent pump run-out including:

- Choosing the correct pump for the size and demands of your system
- Throttling (by means of mechanical valve) the discharge in order to prevent high flow rates
- Creating a minimum static head for the pump to discharge against
- Providing an alarm that will sound if/when flow rates reach a certain level

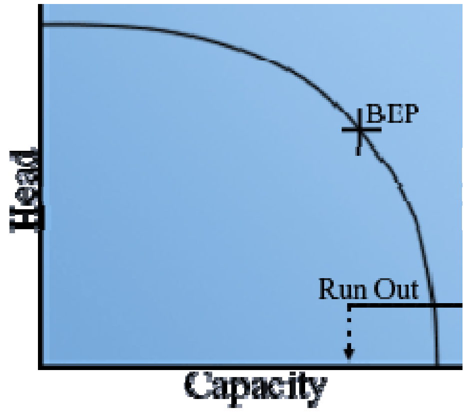

Figure 2-3
Pump Run-Out Condition

In some applications centrifugal pumps are specifically selected for their ability to withstand short periods of deadhead operation. ***Pump deadheading, or shutoff head, is when a pump runs with little or no flow.*** This typically occurs when *the pump discharge valve is closed* or the *system resistance is higher than the pump discharge pressure*. While a pump is deadheaded, the impeller still transfers energy to the fluid inside the pump (refer to Figure 2-4). Since the fluid is not leaving the pump casing, the energy in the fluid is converted into heat instead of pressure and the fluid temperature starts to rise.

If deadheading continues, the fluid may vaporize and cavitation may occur. Additionally, if temperature continues to rise, the pump materials may start to overheat and expand. Since a pump in deadhead has limited or no flow, and falls much lower than the BEP on the pump efficiency curve, the pump may also vibrate more than normal, further degrading the pump components. The individual design of the pump determines how long it can withstand this condition before it sustains permanent damage.

It is possible to prevent pump deadheading by providing a permanent flow path that will allow the manufacturer's suggested minimum safe flow rate.

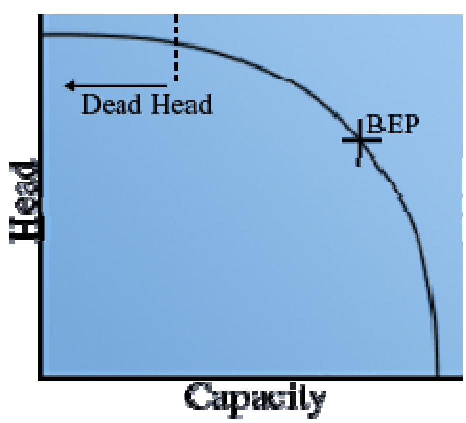

Figure 2-4
Pump Deadhead Condition

Pump Horse Power Calculations

The horsepower needed to develop the head and flow in a centrifugal pump depends on the flow rate of the pump. The relationship between horsepower, head and flow is stated as:

$$HP = \frac{H * Q * SG}{3960 * EFF}$$ **Equation 2-4**

Where (H) is head, (Q) is capacity, (SG) is fluid density or specific gravity of the liquid, and (EFF) is efficiency.

For most centrifugal pumps, required brake horsepower increases in proportion to the flow rate of the pump. Therefore, most centrifugal pump horsepower curves show a slight increase with increasing flow.

System Resistance and Pump Performance Curve

A pump will always operate at the intersection of the pump performance curve and the system resistance curve. When developing the system resistance curve, all of the system's operating conditions from minimum to maximum flow should be considered. For example, if a control valve is included in the system, the system curve must be evaluated with the control valve fully open and with the control valve fully shut. Figure 2-5 shows the pump performance and system resistance curve.

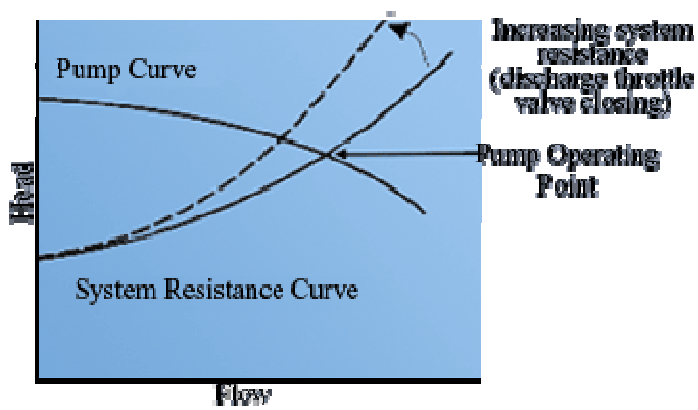

Figure 2-5
Pump Performance and System Resistance Curve

If the control valve is not considered, the system resistance curve could intersect the pump performance curve near or beyond pump run out. Then, the pump could experience cavitation due to insufficient net positive suction head (NPSH), or the motor could be overloaded.

Every pump has a minimum flow below which it should not operate. As a general rule, the minimum acceptable flow for a centrifugal pump is 25% of the flow at the BEP. The pump manufacturer should be consulted for a specific pump's exact requirements.

3
LABORATORY TESTING

Objective of Lab Tests

A new circulator pump technology has recently been introduced to the market. The new pump claims to consume less energy than the conventional circulator pumps. To evaluate the performance of this technology, a series of tests were performed on a sample of the new pump at the EPRI Knoxville, Tennessee Test Facility.

The objective of the laboratory tests are summarized as follows:

- To understand the physical operation of the new pump technology
- To characterize the pump based on the power consumption under various operating conditions
- To understand if there are any power quality related concerns associated with the pump
- To compare the test results with a traditional hot water circulator pump

The following sections describe the testing method and the test results in detail.

Test Setup Description

In order to evaluate the pump, a simple test setup was constructed. The test setup was able to test multiple pumps at the same time. Figure 3-1 shows the layout of the test setup. In order to operate normally, the circulator pumps require a head pressure. To create the head pressure in the lab environment, a sump pump was used. The circulator pump then re-circulates the water in the closed loop system. A power meter was installed to monitor the voltage, current, power factor and power consumed by the pump during normal operation. Also a hand held power quality analyzer was used to analyze the pump input voltage and current waveforms. A throttle valve was used to control the resistance and to adjust the head and GPM of the system. When the valve is completely closed no water can flow through the closed loop water system. The valve was kept in an optimal position so as to meet the inlet pressure (head) requirements set by the pump manufacturer. There is a water flow meter inline with the pump to monitor the water flow through the pump. Figure 3-2 shows the close up of the actual test setup. In the actual test setup, two circulator pumps, a traditional circulator pump and the new technology under test, are assembled side by side with identical measurement configurations. There is a switch to turn the pumps ON or OFF at the bottom of the test stand.

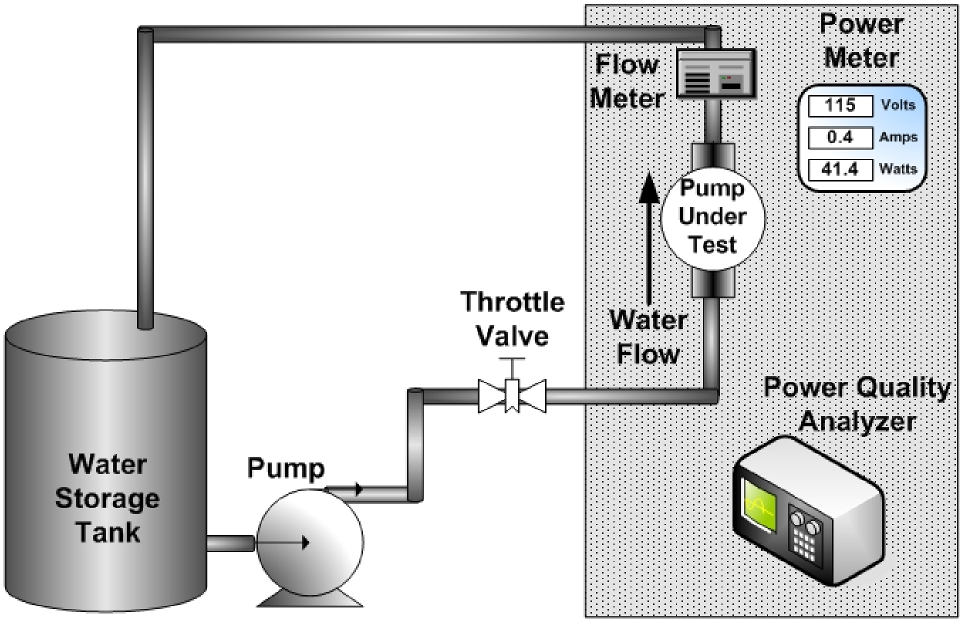

Figure 3-1
Simple Laboratory Pump Test Setup

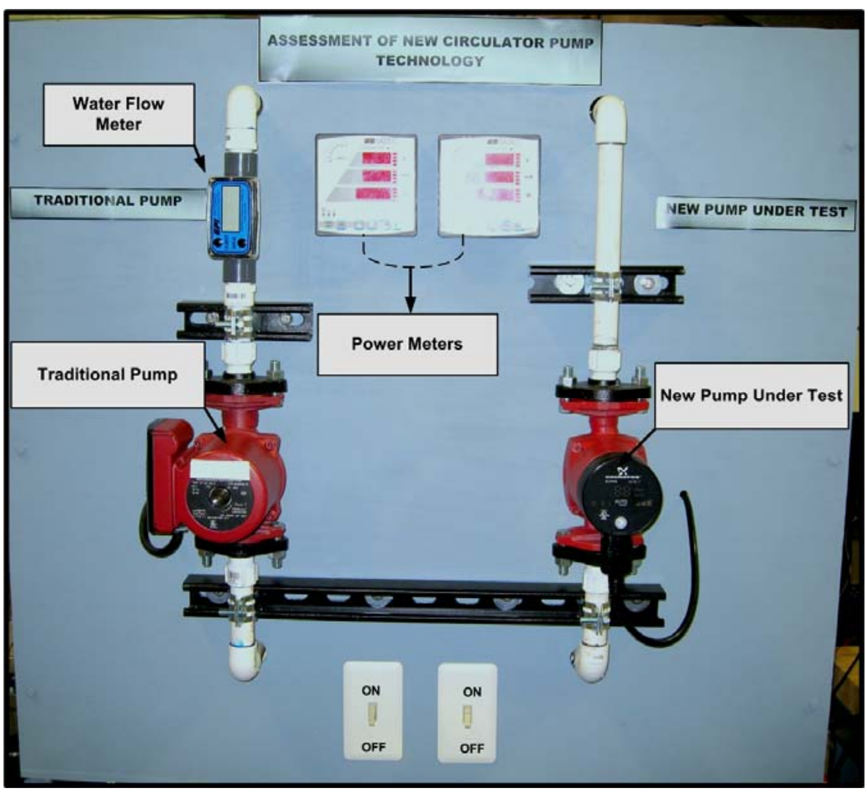

Figure 3-2
Close-up View of the Circulator Pump Test Stand

Instruments Used for Power and Flow Measurements

The instruments used for data measurement are summarized in the Table 3-1.

Table 3-1
Specifications and Description of Measurement Devices

S. No.	Meter Make	Model	Description	Accuracy
1	SATEC	PM110E	Measure single phase voltage, current and power.	0.3% Reading and 0.02% Full Scale for power measurement
2	Fluke	41B	Hand held power quality analyzer.	± (0.5%+3digits) for current harmonics measurement
3	GPI	TM075-N	Water flow (GPM) meter.	± 3.0% of reading
4	AEMC	MN306	AC Current Probe	• 2.5% Reading ± 0.1mV for (<0.5A) • 2.5% Reading for (0.5A - 1A) • 1% Reading for (1A - 12A)
5	Watts Up	Watts up? PRO ES	Data logger.	± 1.5% + 3 counts of the displayed value. For loads less than 60 watts, the current and power factor displays will have lower accuracy. However, the wattage and other displays will still be within 1.5%.

Power Consumption at Various Operating Modes

During the first test, the traditional pump is turned ON while the new pump under test was turned OFF. Once the measurements are recorded from the first test, the traditional pump is turned OFF. For the second set of tests, the new pump under test is turned ON and the traditional pump is turned OFF. The data acquisition system was able to record the power consumption of both the pumps on a same time scale, which helps to visualize the difference in power consumption with better clarity. The specifications of both the circulator pumps tested are given in Appendix A.

Figure 3-3 shows the operation of traditional circulator pump of similar capacity. It can be seen from the figure that the traditional pump consumes over three times more power as compared to the new circulator pump. It should be noted that the traditional pump has only one operating mode or operating speed. However, the flow was controlled by adjusting the throttle valve. From no flow (0 GPM) to full flow (4 GPM) the pump was drawing 120 Watts to 146 Watts.

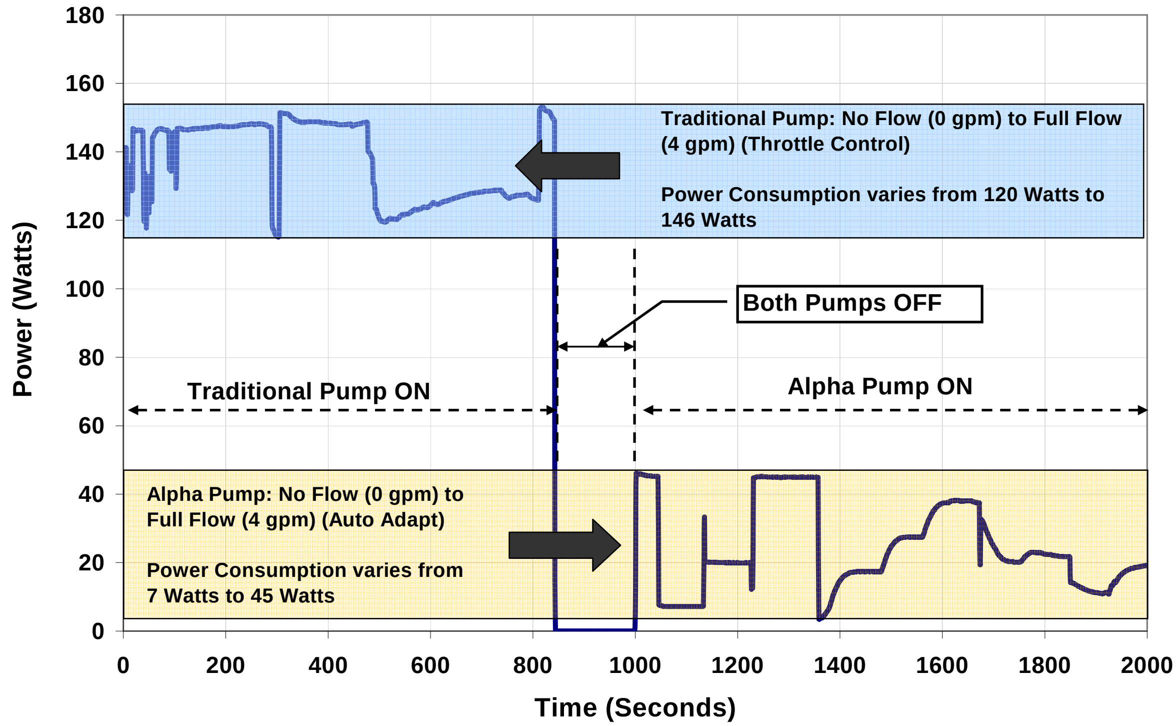

Figure 3-3
Power Consumption of Traditional Circulator Pump and the Evaluation Pump

Figure 3-4 shows the comparison of power consumed by the traditional circulator pump and the new pump under test. From no flow (0 GPM) to Full Flow (4 GPM) the pump was drawing 12 to 45 Watts. It can be noted from Figure 3-4, for similar flow rate, the new pump under test was drawing approximately 100 Watts less than the traditional pump.

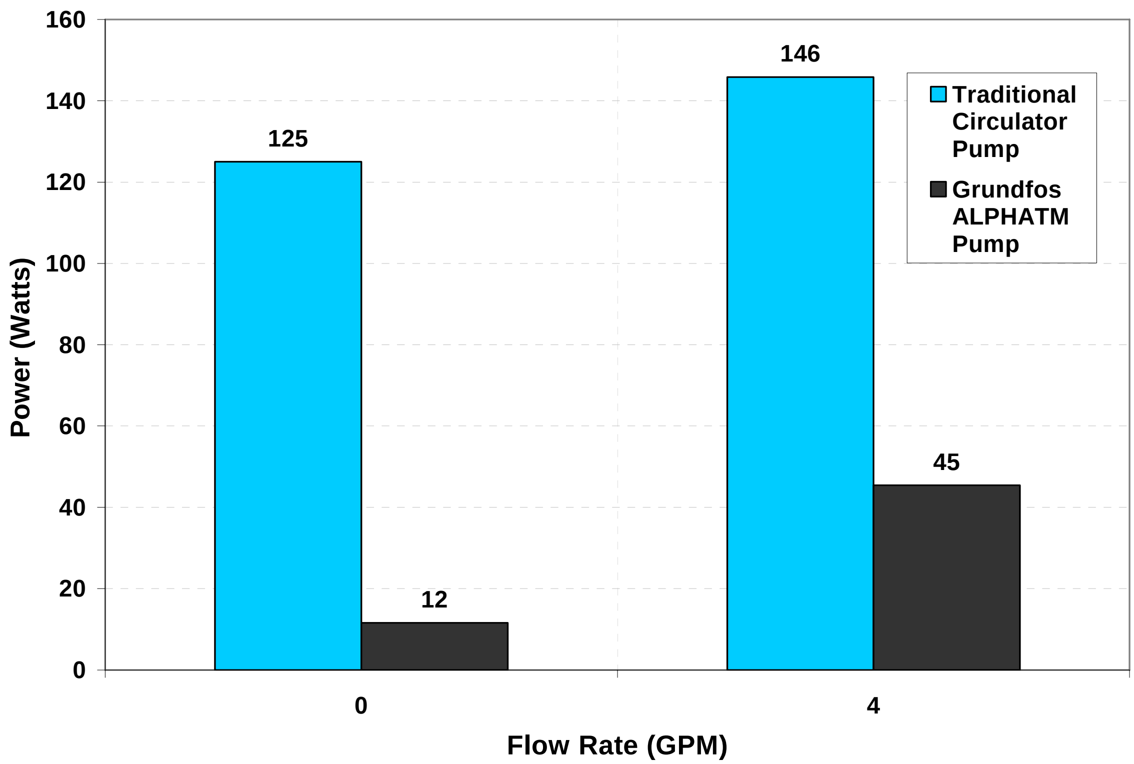

Figure 3-4
Power Consumption of Alpha Pump for Various Modes of Operation

Figure 3-5 shows the power consumed by the new pump under various operating modes. There are three (3) constant speed modes and three (3) constant pressure modes. Also there is a special mode called AUTO*ADAPT*™. In this mode, the ALPHA processor, a micro-processor in the pump, learns the system operating characteristics and optimizes the performance of the pump. In this mode the power consumption varies anywhere from 6 Watts to 25Watts.

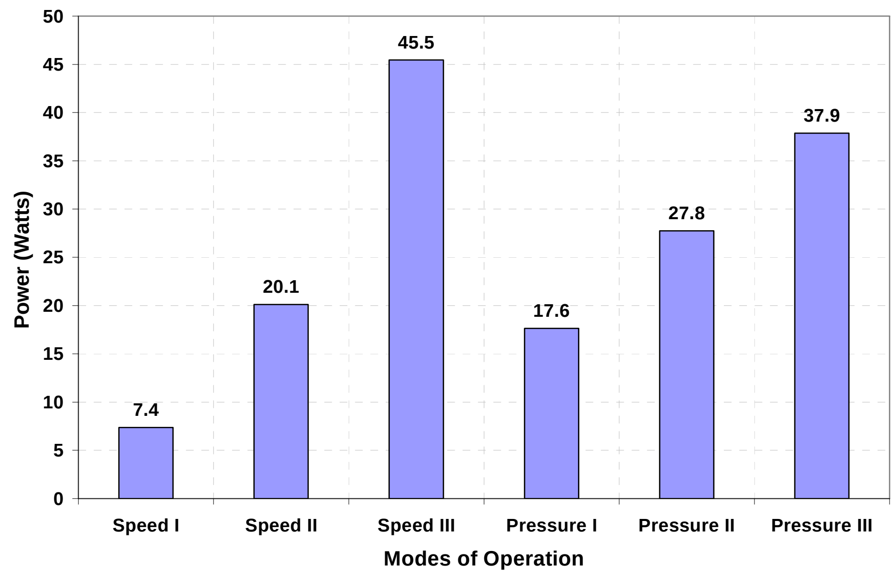

Figure 3-5
Power Consumption of Alpha Pump for Various Modes of Operation

Voltage and Current Waveforms

The voltage and current waveform of the traditional circulator pump is shown in Figure 3-6. It can be seen that the pump exhibits the characteristics of an inductive load, where the current lags behind the voltage waveform.

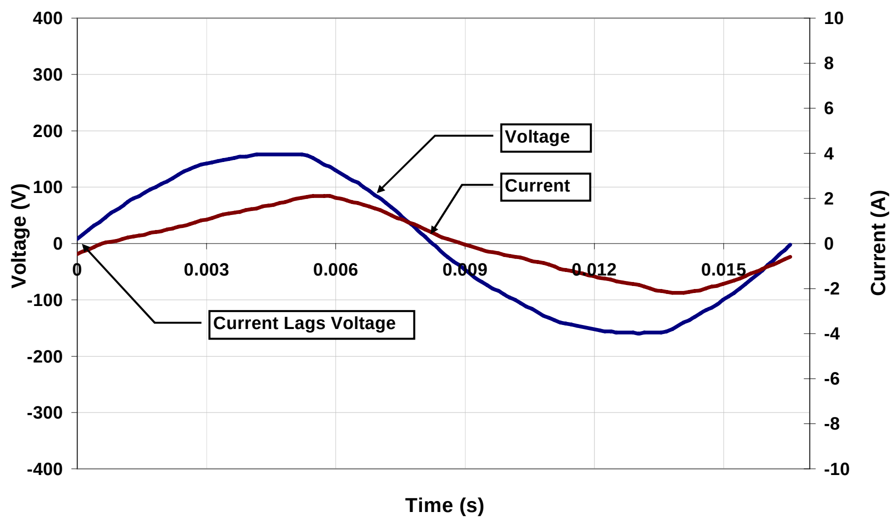

Figure 3-6
Current and Voltage Waveform of Traditional Circulator Pump

The voltage and current waveform of the new circulator pump exhibit the characteristics of a rectifier front end power supply. Since this pump has the capabilities to adjust the speed of the impeller, the pump has a rectifier front end and behaves like a motor-drive system where the motor speed is controlled electronically by the drive than through mechanical brakes.

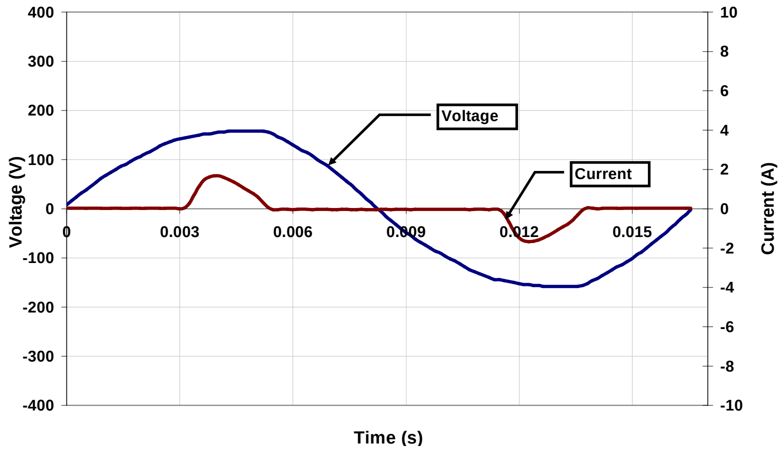

Figure 3-7
Voltage and Current Waveform of Evaluation Pump

Harmonic Distortion

The harmonic[2] current distortion for the traditional pump is lower as compared to the new circulator pump. <u>*However, the power consumption savings for the new pump is great enough that any harmonic concerns would be completely negated.*</u> Figure 3-8 shows the harmonic content of the current waveform of the traditional pump. It shows a very low 3rd harmonic presence in the waveform, however, other harmonics are very negligible.

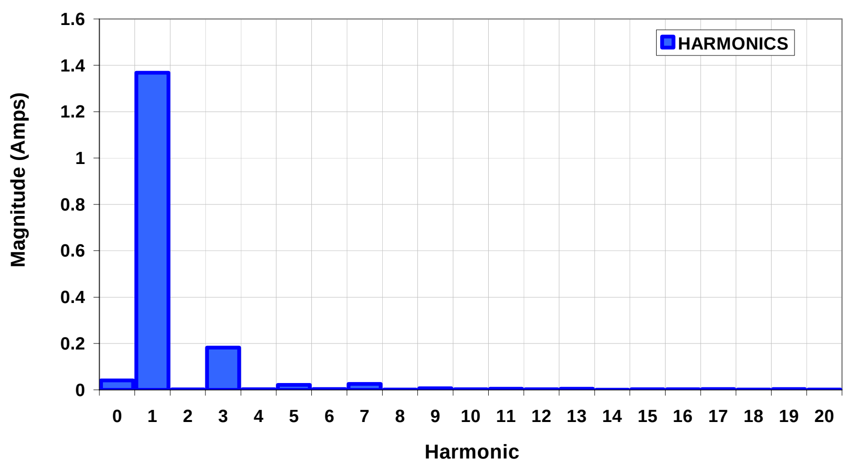

Figure 3-8
Harmonic Content of Traditional Circulator Pump

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[2] A harmonic of a waveform is a component frequency of the signal that is an integer multiple of the fundamental frequency of the waveform. In this case the fundamental frequency is 60Hz. So n^{th} harmonic = n x 60Hz. E.g. 3^{rd} harmonic corresponds to 3x60Hz=180Hz.

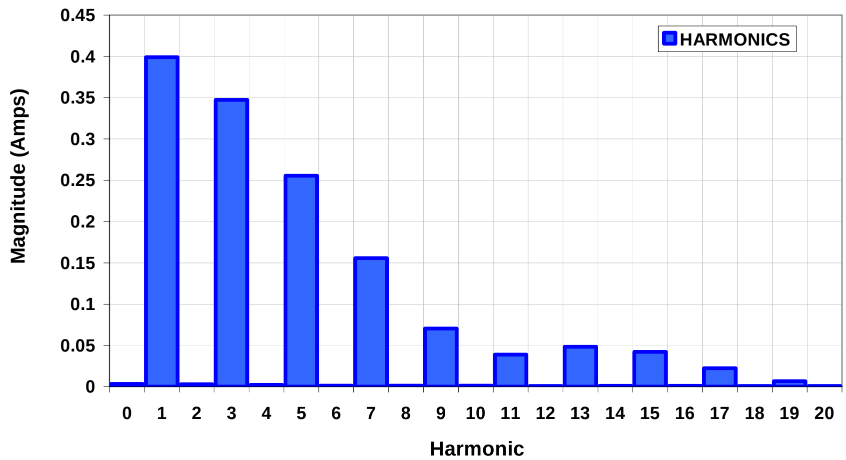

Figure 3-9
Harmonic Content of the New Circulator Pump

Referring to Figure 3-9, the harmonic current distortion of the new circulator pump shows it has more odd-harmonics (3rd, 5th, 7th etc.). This is because of the distortion in the current waveform due to the rectifier front end. This is a typical current waveform for an ac-dc power supply where the ac input voltage is converted to a dc input voltage. The current and voltage waveform of a single phase ac-dc power supply is shown in Figure 3-10.

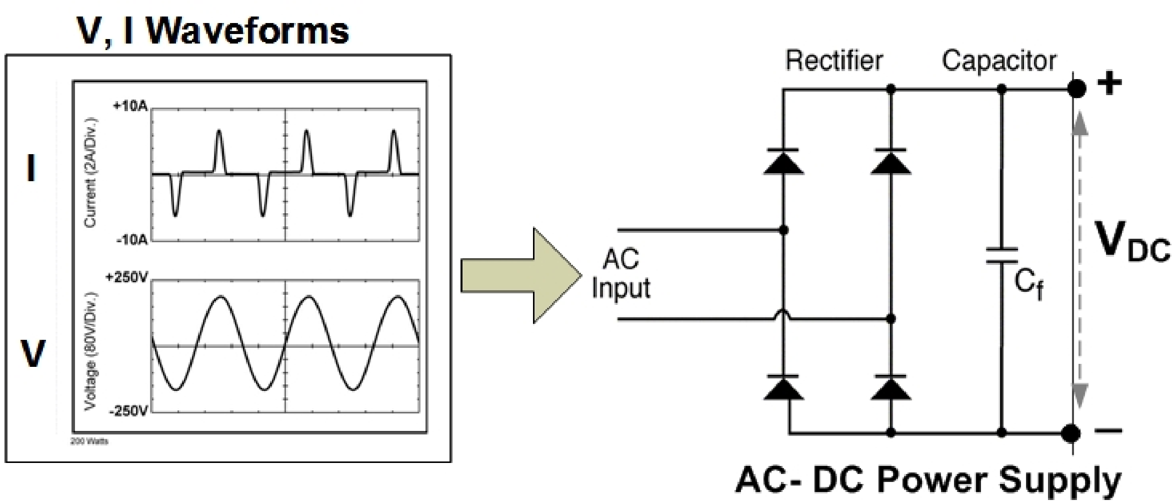

Figure 3-10
Simple AC-DC Power Supply Schematics (Waveforms Not to Scale)

Figure 3-11 compares the power factor of the traditional pump and the new circulator pump. Because there is distortion of current in the new circulator pump, the power factor is not close to unity. The low power factor in the new circulator pump is attributed to the odd-harmonics present in the current waveform.

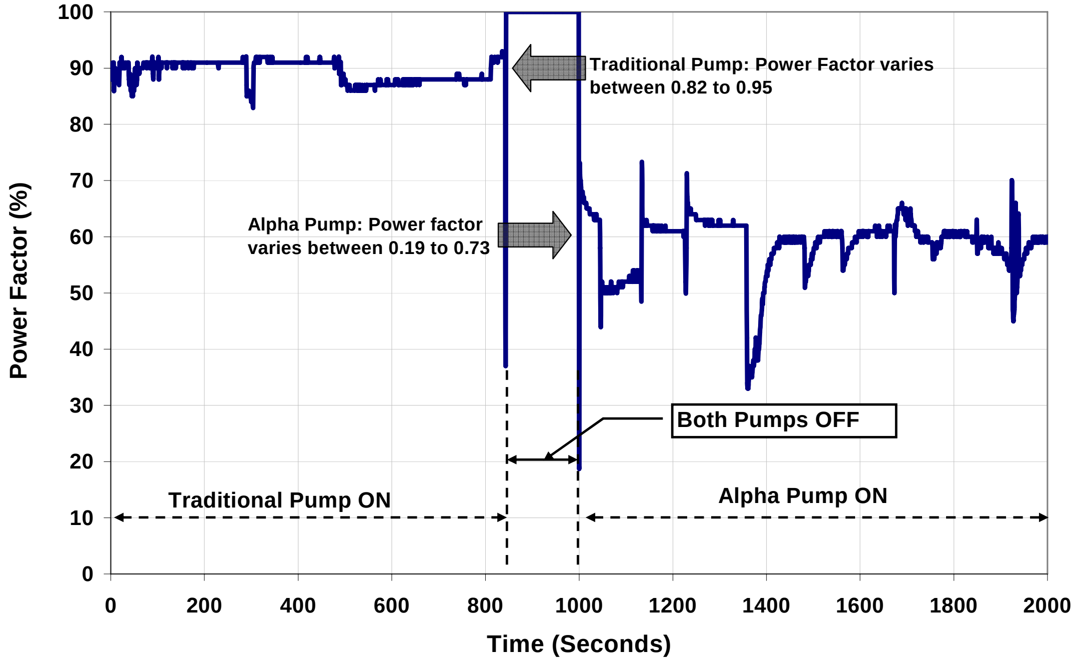

Figure 3-11
Comparison of Power Factor

Summary of Lab Tests

A traditional hot water circulator pump and a new circulator pump technology were evaluated in the lab. The hot water circulators typically run 24 hours a day, 365 days a year. The laboratory tests met all the objectives set forth before the beginning of the tests. The test results can be summarized into three major findings which are given below.

Findings – 1: Operation of the Pump

The testing of the new circulator pump showed that the pump has a rectifier front end and it has adjustable speed control. The pump behaves and operates like an adjustable speed drive. The pump has a micro-processor that can adjust the pump characteristics by sensing the flow requirements of the system.

Findings – 2: Power Consumption

A traditional pump and the new circulator pump are tested on a test stand side by side. The test results show that, for a similar size pump, the new circulator pump consumes less power than the traditional pump. The new circulator pump, Grundfos ALPHA™ pumps uses permanent magnet brushless dc motor construction which has higher efficiency than typical induction motor. Also it has a micro-processor based controller that uses feedback loop control. This controller can actively monitor the flow requirement and adjust the pump operating characteristics to operate at lower power mode. Another feature of this pump is the variable speed operation which also contributes to the lower power consumption.

Findings – 3: Power Quality Concerns

The current waveform and the harmonic contents of the new circulator pump show that there is significant odd-harmonic presence in the waveform. *However, the power consumption savings for the new pump is great enough that any harmonic concerns would be completely negated*. The odd harmonic content is typical of any ac-dc rectifier power supply current characteristics. A power factor correction circuit in the front end of this pump would easily alleviate the harmonics.

4
APPLICATIONS

Applications

The new circulator pump technology finds application in many areas where circulation of hot or cold water is needed. The following are few examples of the applications:

Residential applications include, circulation of hot or cold water in

1. Heating systems
2. Domestic hot water systems
3. Cooling and air-conditioning systems

Other commercial and industrial applications include:

4. Geo-thermal heat pump application that uses circulation pumps to circulate water/glycol or other refrigerant (please refer to Figure 5-1)
5. Industrial circulation systems with high gallons per minute requirement
6. Solar water heating applications

This type of pump can not only be used for residential and commercial sectors but in many other industrial processes also.

Features and Benefits

Efficient Motor Design

The Pump is constructed with permanent-magnet motor with compact stator and wet-rotor technology. There are fewer connections inside the motor that makes it robust and reliable.

ALPHA™ Processor

The pump has a micro-processor, called ALPHA processor, which constantly monitor the flow rate and the speed of the pump and adapts to the changing system conditions.

AUTOADAPT™

The pump keeps track of the usage pattern every day and adopts itself to the flow requirements. It optimized the speed of the water flow for the best possible efficiency with the help of microprocessor. It also uses integrated electronics and software algorithms to fine tune the speed control. Figure 4-1 shows the performance and operating modes of the ALPHA™ pump. It can be seen that the pump can operate up to 22 gallons per minute (GPM).

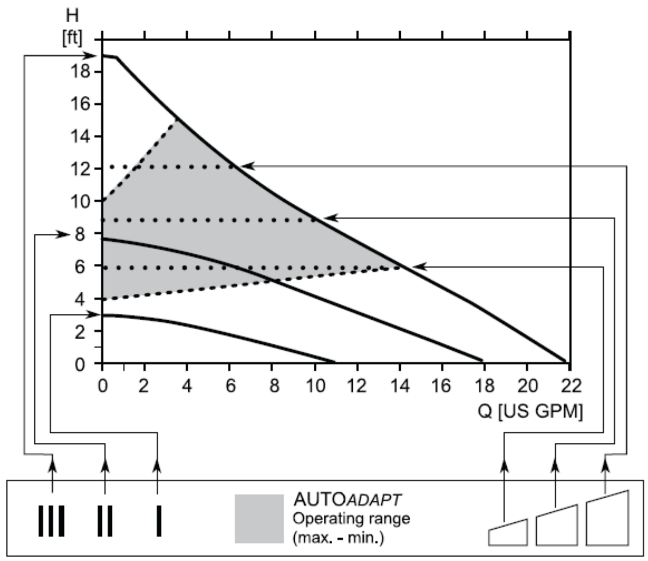

Figure 4-1
Operating Modes and Performance Curves of ALPHA™ Pump

Other Benefits

Some of the benefits of using the new circulator pump may be summarized as follows:

1. Lower energy consumption than traditional circulator pumps
2. May have less maintenance because of lower power consumption and lower power dissipation.
3. Lower noise compared to traditional pumps because of adjustable speed control.
4. Wide performance range
5. It has potential for “demand response” or “demand management” controllability.

Application Issues

The laboratory testing of the new circulator pump from Grundfos shows that it has current harmonic distortion. This may cause some issues with other equipment that are connected to the circuit. But if the circulator pumps are distributed in the electrical building network there may be enough diversification of the loads in the building that can negate this issue.

The circulator pump needs a minimum pressure at the inlet (that varies with temperature) for its operation. So in places where there is no pressure in the loop, for example, lifting oil or water from an underground tank, these circulator pumps cannot be used. They cannot be used in sump pumps or submersible pump applications.

Energy Savings Potential

How much energy can these small circulator pumps save? This is a question that naturally comes to the mind of the reader who has just reviewed the test results. To answer this question a small computation has been completed which is summarized in the Table 4-1. There are few assumptions made in order to calculate the savings and they are:

- The total US pump population is assumed to be 10 million (based on Frost and Sullivan research in 2005)
- The utilization factor, the percentage of time the circulator pump runs in a year is 40%
- The percentage of old circulator pumps replaced by the new circulator pumps is 100%
- According to Energy Information Agency (EIA), the annual net electric power generation is **4,119 TWh** in 2008

Table 4-1
Estimation of Potential Energy Savings Achieved by Replacing Existing Circulator Pumps with New Circulator Pumps

Description	Quantity	Units
Number of Circulator Pumps in US market: (approximate)*	10,000,000	Units
Average power consumed by a conventional circulator pump:	146	Watts
Hours of operation: (24 hr x 365 days):	8760	Hours
Utilization Factor: (assumptions)	40%	
Total annual energy consumption of existing conventional circulator pumps population in US (=Power consumption of a conventional circulator pump x Operating hours x Utilization factor x Number of Units):	**5.12**	**TWh**
Average power consumption of one energy efficient circulator pump:	45	Watts
Hours of operation: (24 hrs x 365 days):	87f60	Hours
Average annual energy consumption of a new circulator pump:	394.2	KWh
Percentage of old pumps replaced: (assumption)	100%	
Utilization Factor:	40%	
Total annual energy consumption of new circulator pumps in US (=Power consumption of new circulator pump x Operating hours x Percentage of old pumps replaced x Utilization factor x Number of Units):	**1.58**	**TWh**
Potential Energy Savings:	**3.54**	**TWh**
Potential Energy Savings as a % of total annual energy usage of existing pumps:	**69%**	
Energy consumption of Circulator Pumps as a percentage of Total US Annual Electricity Generation:**	**0.12%**	
Potential Energy Savings of New Circulator Pumps as a % of Total US Annual Electricity Generation:**	**0.09%**	
* Frost and Sullivan estimates		
**Source: http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html		

From Table 4-1 it can be seen that there is a significant energy savings potential, in the order of 3.54 TWh or approximately 69% of the total energy consumption of the existing conventional circulator pumps. To put this in perspective, this energy savings is equivalent to the energy produced by three (3) 250 MW power plants running at 50% of their rated capacity in a year.

Payback Calculations – A Case Study

The energy savings potential varies from one facility to another based on the circulator pump being used and the usage pattern. The energy savings potential for an example light-commercial building facility is described here. This site location has a circulator pump that is used to circulate hot water inside the building. Please refer to Figure 4-3 for the existing setup. The existing circulator pump consumes 146 Watts (180 Watts (max)) during its operation. Replacing this pump with an ALPHA™ pump would offer a significant reduction in the power usage as well as annual energy consumption.

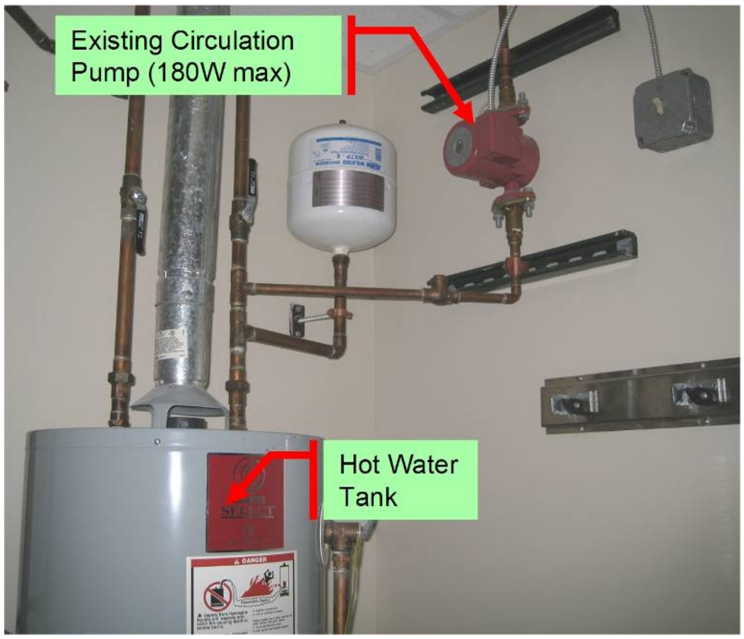

Figure 4-2
Circulator Pump Located in a Commercial Building

For example, let us consider a simple energy calculation. The pump runs 24 hours a day for 365 days; let us consider a power draw of 146 Watts for the existing pump (Pump-1) and 45 Watts for the ALPHA™ pump (Pump-2, shown in Figure 4-2). Then,

Annual Energy Consumption for Pump-1 (E_{P1}) = 365 x 24 x146/1000 = 1279 kWh

Annual Energy Consumption for Pump-2 (E_{P2}) = 365 x 24 x45/1000 = 394 kWh

Annual Energy Savings (E_{P1}-E_{P2}) = 885 kWh

Possible Annual Energy Savings = (885/1279) x100 = ~70%

These calculations suggest a significant opportunity to save energy by switching to the more pump technology described in this technical update. Clearly, the other aspect of the savings opportunity will be the payback period. To expand on this aspect the following calculations show the comparison of the cost of doing nothing to the cost of installing the replacement pump.

Table 4-2 shows an example of the simple payback calculations and can be modified based on the pumps utilization factor, actual cost of the pump and the installation costs. The new pump in this example pays for itself in a span of just four (4) years.

Table 4-2
Simple Payback Calculation for Retrofit Option

Payback Calculations for Replacing One Pump		
Cost of new circulator pump (approximate)	$250	
Installation costs (assumption)	$100	
Total retrofit costs (=Pump cost +Installation cost)	**$350**	
Old pump power consumption	146	Watts
Utilization factor (assumption)	100%	
Operating Hours (24hrs x 365 days x Utilization factor)	8760	Hours
Annual energy consumption of old circulator pump (E_{old})	**1279**	**kWh**
New pump power consumption	45	Watts
Annual energy consumption of new circulator pump (E_{new})	**394**	**kWh**
Cost of electricity (assumption)	10	cents/kWh
Energy Savings (E_{old} – E_{new})	**885**	**kWh**
Annual cost savings (approximate)	$89	
Pay back { =Total retrofit cost/ Savings(in $)}	**~4**	**Years**

Other Manufacturers

Internet research shows that there are other manufacturers apart from Grundfos who make circulator pumps with advanced energy efficient technology. The German pump manufacturer WILO has two product lines called Stratos ECO (residential) and Stratos (Commercial) that are high-efficiency circulator pumps. Both these product lines use electronically commutated motor (ECM) technology which essentially comprises of synchronous motor with a permanent magnet rotor. The unique rotor-can assembly made of synthetic composite carbon-fiber avoids eddy-current losses, thus considerably increasing overall efficiency. Additionally, the WILO Stratos can be used in commercial applications where the flow rate can go up to 200 gpm (gallons per minute) such as industrial circulation systems, closed cooling circuits and geothermal applications.

US manufacturer, TACO, is also developing a highly efficient circulator pump called “Bumble Bee.” This highly efficient circulator pump is not yet commercially available in the US market. It is expected to become available in 2011.

Summary

From the above discussions it can be seen that energy efficient pump technologies are available and they offer significant energy reduction potential to residential, commercial and other industrial applications. The use of this pump technology to other applications such as Variable Refrigerant Flow (VRF) technologies needs to be explored.

5

SUMMARY AND NEXT STEPS

In this technical update, a new circulator pump technology has been identified. The operating principles and the performance characteristics were evaluated in the lab. The new circulator pump from Grundfos shows that it consumes less power than a similar sized conventional pump. The permanent magnet brushless dc motor along with feedback loop control using micro-processor based controller helps in reducing the overall power consumption of this circulator pump. The micro-processor constantly studies the system requirements and adjusts the speed of the pump by changing the pump performance curve. By lowering the speed and reducing the flow the pump can significantly reduce the power consumption.

This circulator pump finds wide applications such as:

- Residential closed loop hot water heating systems (also known as hydronic heating)
- Domestic hot-water re-circulation
- Geo-thermal heat pump application that uses circulation pumps to circulate water/glycol or other refrigerant (please refer to Figure 5-1)
- Industrial circulation systems with high gallons per minute requirement
- Solar water heating applications

Since these circulator pumps have microprocessor based controller and integrated variable-speed drive, they can be modified for demand response (DR) ready application. The algorithm can be written in such a way that the microprocessor can optimize the fluid flow based on the demand response signal from the utility. Currently, this feature is not available with the circulator pumps. However, discussion with manufacturers on the merits of demand response would lead into development of DR-ready circulator pumps in the future.

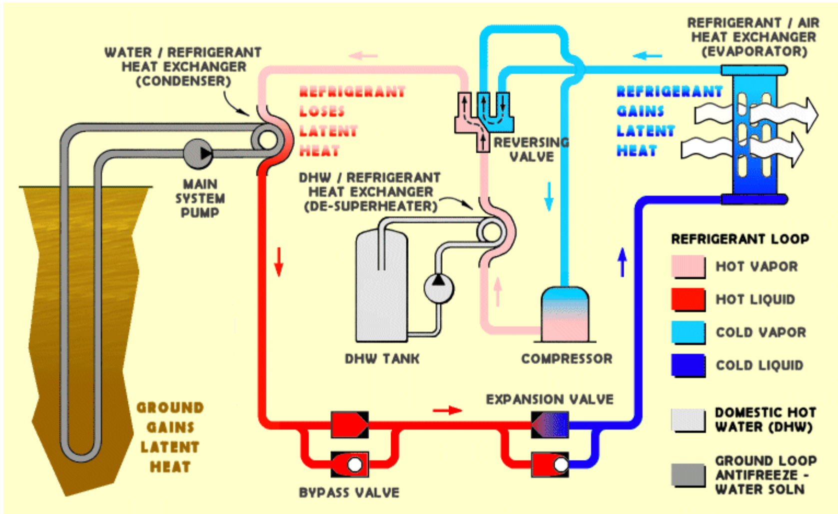

Figure 5-1
Visual of Geo-thermal Heat Pump

The next steps are to a) identify the commercial/ industrial applications that can potentially use this circulator pump and b) demonstrate this technology in a commercial or industrial site to show the actual energy and cost savings.

A minor drawback of this technology is the current distortion and harmonics produced during the pump operation, but the amount of energy saved negates this drawback. Overall the new pump technology has met the manufacturer's specifications.

A

PUMP DATA SHEET

Table A-1
Specifications of the Traditional Pump Used in Lab Test

Make/ Model:	Grundfos/ UP26-99F
Material:	Cast Iron
Amperage:	2.15 Amps
Application:	Heating
Voltage:	115 V
Max PSI:	145 PSI
Type:	Pump
Horse Power:	1/6
Connection Size:	1/2
Flow Range:	0-34 GPM
Head Range:	0-32 ft.
Hertz:	60.0
Phase:	1.0
RPM:	3000.0
Temperature Range (F):	36°-230°F
Connection Type:	Flanged
Applications	Hydronic heating, Fan coil heating, Solar heating, and Radiant heating systems

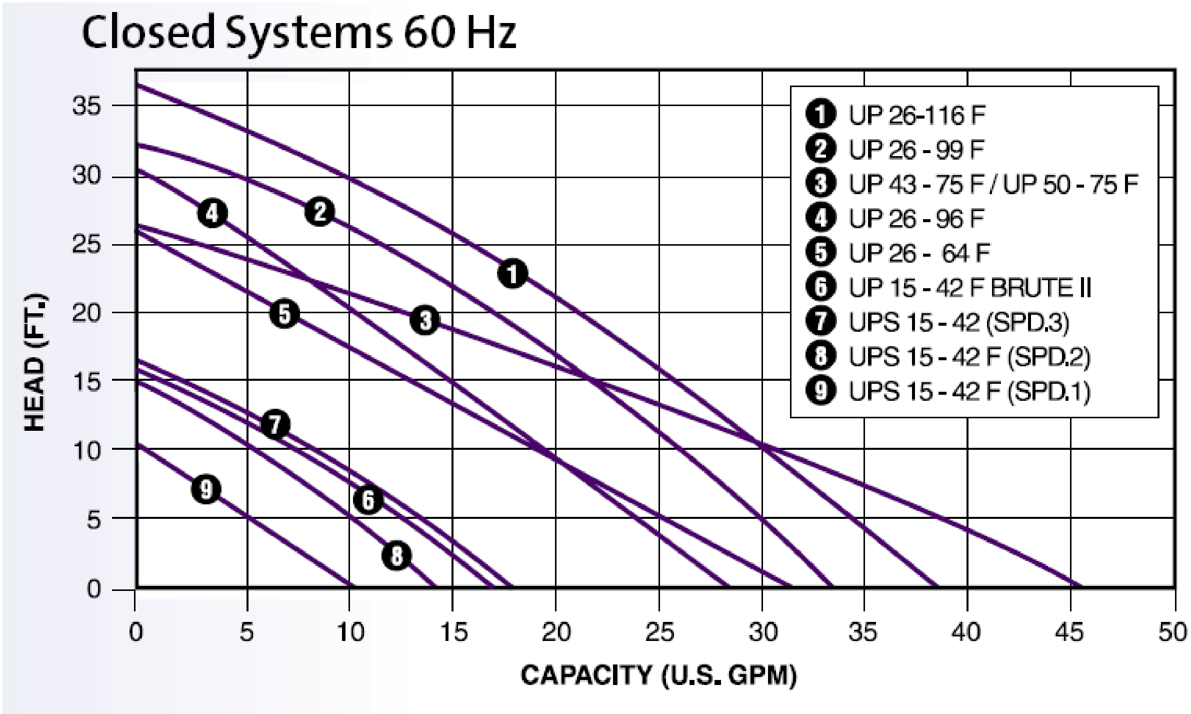

Figure A-1
Performance Curves of UP26-99F Pump

Table A-2
Specification of New Circulator Pump (Grundfos ALPHA™ Pump)

Material:	Cast Iron
Flow Range:	0-21 GPM
Head Range:	0-19 ft.
Min Temp (F):	36oF
Max Temp (F):	230°F
Max PSI:	150 PSI
Phase:	1.0
Voltage:	115 Volts
Amperage:	0.65 A
Power	5-45 Watts
Special Features:	1. Speed Control 2. AUTOADAPT measures system changes automatically and maximizes energy savings 3. Select a mode with the touch of a button 4. Easy-to-read LED display shows flow indication and power consumption

Performance Curve:

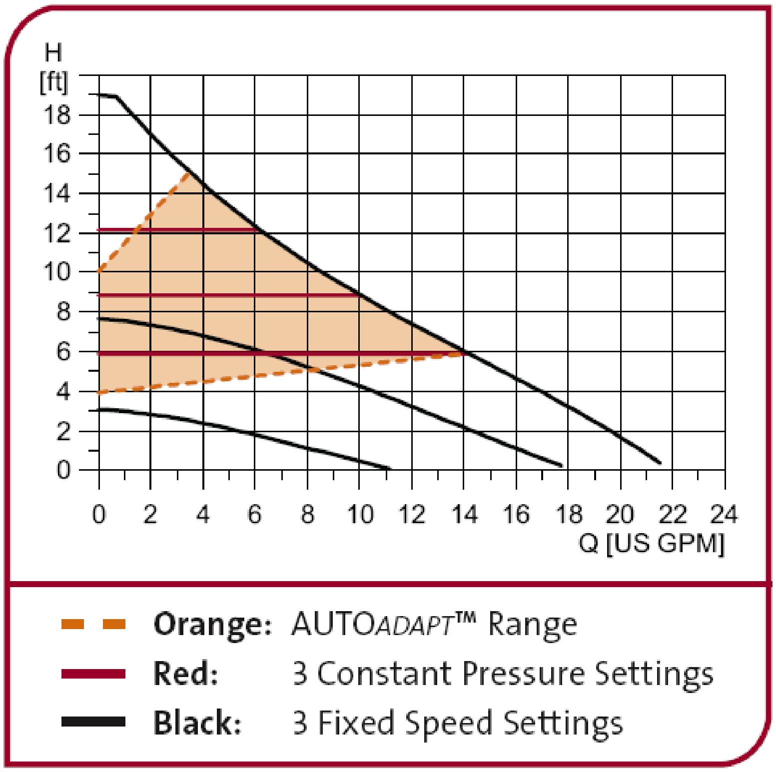

Figure A-2
Performance Curve of Grundfos ALPHA™ Pump

B
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