ECM and Self Sensing Technology
Presented by Steve Thompson
VP - Residential Product Management – Taco Inc.
Mobile (401) 441-2934
E Mail: stetho@taco-hvac.com
## Commercial Energy Prices, by Year by Type

<table>
<thead>
<tr>
<th>Year</th>
<th>Electricity cents/kWh</th>
<th>Natural Gas Cents/therm</th>
<th>Distillate Oil $/gal</th>
<th>Residual Oil $/gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>9.58</td>
<td>85.91</td>
<td>2.41</td>
<td>3.28</td>
</tr>
<tr>
<td>2010</td>
<td>10.14</td>
<td>90.95</td>
<td>1.66</td>
<td>2.86</td>
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<td>2005</td>
<td>9.59</td>
<td>121.45</td>
<td>1.24</td>
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<td>2000</td>
<td>9.17</td>
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<td>1995</td>
<td>10.32</td>
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<td>0.64</td>
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<tr>
<td>1990</td>
<td>11.08</td>
<td>72.04</td>
<td>0.78</td>
<td>1.26</td>
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<tr>
<td>1985</td>
<td>13.06</td>
<td>95.96</td>
<td>1.21</td>
<td>1.56</td>
</tr>
</tbody>
</table>

* Includes distillate fuel oil, LPG, kerosene, motor gasoline and residual fuel

## Commercial Buildings Aggregate Energy Expenditures (2010 Billion)

<table>
<thead>
<tr>
<th>Year</th>
<th>Electricity</th>
<th>Natural Gas</th>
<th>Petroleum *</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>130.0</td>
<td>29.3</td>
<td>15.0</td>
<td>174.4</td>
</tr>
<tr>
<td>2010</td>
<td>134.8</td>
<td>29.9</td>
<td>14.5</td>
<td>179.2</td>
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<tr>
<td>2005</td>
<td>122.3</td>
<td>37.4</td>
<td>11.4</td>
<td>171.2</td>
</tr>
<tr>
<td>2000</td>
<td>106.3</td>
<td>26.6</td>
<td>8.3</td>
<td>141.2</td>
</tr>
<tr>
<td>1995</td>
<td>98.4</td>
<td>20.9</td>
<td>5.4</td>
<td>124.6</td>
</tr>
<tr>
<td>1990</td>
<td>92.9</td>
<td>19.4</td>
<td>9.2</td>
<td>121.5</td>
</tr>
<tr>
<td>1985</td>
<td>90.0</td>
<td>24.0</td>
<td>12.6</td>
<td>126.6</td>
</tr>
</tbody>
</table>

## Energy Expenditures per SF (2010)

<table>
<thead>
<tr>
<th>Year</th>
<th>$/SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>2.29</td>
</tr>
<tr>
<td>2010</td>
<td>2.44</td>
</tr>
<tr>
<td>2005</td>
<td>2.30</td>
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<tr>
<td>2000</td>
<td>2.06</td>
</tr>
<tr>
<td>1995</td>
<td>2.12</td>
</tr>
<tr>
<td>1990</td>
<td>1.98</td>
</tr>
<tr>
<td>1985</td>
<td>2.20</td>
</tr>
</tbody>
</table>
Energy Efficient Circulator Options

- European energy efficient circulator technology is becoming available today in U.S. but acceptance has been slow because:
  - U.S. hydronic heating installed base is much smaller than EU
  - A very small portion of new homes in the U.S. use hydronic heat.
  - U.S. hydronic systems typically only run for small portion of year
  - Electricity in U.S. is less expensive
  - Cost of energy efficient circulators is nearly double traditional wet rotor circulators.
Federal regulations mandate all states use ASHRAE 90.1 or IECC as a minimum efficiency standard
ASHRAE 90.1 - 2010

G3.1.3.8 Chilled-Water Design Supply Temperature (Systems 7 and 8). Chilled-water design supply temperature shall be modeled at 44°F and return water temperature at 56°F.

G3.1.3.9 Chilled-Water Supply Temperature Reset (Systems 7 and 8). Chilled-water supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 44°F at 80°F and above, 54°F at 60°F and below, and ramped linearly between 44°F and 54°F at temperatures between 80°F and 60°F.

G3.1.3.10 Chilled-Water Pumps. The baseline building design pump power shall be 22 W/gpm. Chilled-water systems with a cooling capacity of 300 tons or more shall be modeled as primary/secondary systems with variable-speed drives on the secondary pumping loop. Chilled-water pumps in systems serving less than 300 tons cooling capacity shall be modeled as a primary/secondary systems with secondary pump riding the pump curve.

Exception: The pump power for systems using purchased chilled water shall be 16 W/gpm.

All about ∆T. Either control directly with a temperature reactive VFD pump or valves and a pressure reactive pump

VSD (VFD) pumps are mandated for use on secondary systems on larger systems
6.5.4 Hydronic System Design and Control.

6.5.4.1 Hydronic Variable Flow Systems. HVAC pumping systems having a total pump system power exceeding 10 hp that include control valves designed to modulate or step open and close as a function of load shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to 50% or less of the design flow rate. Individual chilled water pumps serving variable flow systems having motors exceeding 5 hp shall have controls and/or devices (such as variable speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow. The controls or devices shall be controlled as a function of desired flow or to maintain a minimum required differential pressure. Differential pressure shall be measured at or near the most remote heat exchanger or the heat exchanger requiring the greatest differential pressure. The differential pressure setpoint shall be no more than 110% of that required to achieve design flow through the heat exchanger. Where differential pressure control is used to comply with this section and DDC controls are used the setpoint shall be reset downward based on valve positions until one valve is nearly wide open.

Exceptions:

a. Systems where the minimum flow is less than the minimum flow required by the equipment manufacturer for the proper operation of equipment served by the system, such as chillers, and where total pump system power is 75 hp or less.

b. Systems that include no more than three control valves.

6.4.2.2 Pump Head. Pump differential pressure (head) for the purpose of sizing pumps shall be determined in accordance with generally accepted engineering standards and handbooks acceptable to the adopting authority. The pressure drop through each device and pipe segment in the critical circuit at design conditions shall be calculated.

6.4.3 Controls

6.4.3.1 Zone Thermostatic Controls

6.4.3.1.1 General. The supply of heating and cooling energy to each zone shall be individually controlled by thermostatic controls responding to temperature within the zone. For the purposes of Section 6.4.3.1, a dwelling unit shall be permitted to be considered a single zone.

Reducing pump flow by 50% > 10 Hp on systems with valves

30% wattage at 50% design flow descriptor

Δ P sensor location

LoadMatch systems are NOT required to have variable speed pumping as they have no more than 3 control valves
6.5.4.4.2 Hydronic heat pumps and water-cooled unitary air-conditioners having a total pump system power exceeding 5 hp shall have controls and/or devices (such as variable speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow.

6.5.4.5 Pipe Sizing. All chilled-water and condenser-water piping shall be designed such that the design flow rate in each pipe segment shall not exceed the values listed in Table 6.5.4.5 for the appropriate total annual hours of operation. Pipe size selections for systems that operate under variable flow conditions (e.g., modulating two-way control valves at coils) and that contain variable-speed pump motors are allowed to be made from the “Variable Flow/Variable Speed” columns. All others shall be made from the “Other” columns.

Exceptions:

a. Design flow rates exceeding the values in Table 6.5.4.5 are allowed in specific sections of pipe if the pipe in question is not in the critical circuit at design conditions and is not predicted to be in the critical circuit during more than 30% of operating hours.

b. Piping systems that have equivalent or lower total pressure drop than the same system constructed with standard weight steel pipe with piping and fittings sized per Table 6.5.4.5.
Regulation Due this fall – 5 years to comply

Sections 6314 and 6315 concern test procedures and labeling, respectively, for covered equipment. The provisions in these sections, in combination with section 6316(a), give DOE authority to establish test procedures and to prescribe a labeling rule for pumps. DOE will receive in response to this Request for Information, DOE will determine whether to initiate a rulemaking to establish a test procedure, energy conservation standard, or labeling requirement for commercial and industrial pumps.

2. Evaluation of Pumps as Covered Equipment

EPCA lists several specific types of “industrial equipment” as “covered equipment,” including electric motors and pumps. (42 U.S.C. 6311(1)) DOE estimates that commercial, industrial, and agricultural pumps consume approximately 0.63 quads per year of electricity and that technologies exist that can reduce this consumption by approximately 0.19 quads annually. DOE used industry and census data to calculate the average establishment energy use for pumps.

**Industrial Pumps**

Several estimates have been made of industrial pump electricity use. Four are discussed here. The most recent, made for the DOE Office of Energy Efficiency and Renewable Energy Industrial ‘Technologies program by incorporating Incorporated, states that the total industrial energy use of industrial pumps is estimated to be 185.000 million kWh or 0.63 quads site energy use. The machine drive energy data used in an estimate [https://www1.eere.energy.gov/industry/pumps.html] were primarily provided by the DOE Energy Information Administration’s (EIA) Manufacturing Energy Consumption Survey (MECS). The machine drive energy includes pump energy and reflects consumption in the year 2008, when the report was completed.

Another recent report for the United Nations (“Motor System Efficiency Supply Curves UNIDO,” Dec. 2010), same source as they apply in part A. In applying the provisions in the section 6316(a), section 6316(c) states that references to sections 6315, 6316, and 6316(c) shall be considered as references to sections 6315, 6316, and 6316(c) of this title, respectively; and section 6315(d) states that the term “equipment” shall be substituted for the term “product.”

The American Council for an Energy-Efficient Economy (ACCEE) 2003 report “Realizing energy efficiency Opportunities Industrial Fan and Pump Systems’ summarizes the energy use of pumps in a variety of industrial settings (including manufacturing).

<table>
<thead>
<tr>
<th>Industry</th>
<th>Pump electricity use (megawatt hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>6.218</td>
</tr>
<tr>
<td>Textile mill products</td>
<td>7.926</td>
</tr>
<tr>
<td>Lumber and Wood products</td>
<td>1.200</td>
</tr>
<tr>
<td>Fabricated Wood products</td>
<td>7.046</td>
</tr>
<tr>
<td>Paper and Allied products</td>
<td>31.250</td>
</tr>
<tr>
<td>Printing and Publishing</td>
<td>84</td>
</tr>
<tr>
<td>Chemicals and Allied prod.</td>
<td>37.021</td>
</tr>
<tr>
<td>Petroleum and Coal prod.</td>
<td>30.434</td>
</tr>
<tr>
<td>Paper and allied prod.</td>
<td>90</td>
</tr>
<tr>
<td>Plastics and related prod.</td>
<td>7.686</td>
</tr>
<tr>
<td>Metal fabricating prod.</td>
<td>963</td>
</tr>
<tr>
<td>Fabricated metal products</td>
<td>963</td>
</tr>
<tr>
<td>Electronic and Other Elec. Equipment</td>
<td>7.732</td>
</tr>
<tr>
<td>Transportation equipment</td>
<td>5.517</td>
</tr>
<tr>
<td>Instruments and Related prod.</td>
<td>5.944</td>
</tr>
</tbody>
</table>

**2006 MECS data**

The total industrial energy use was estimated to be 125.800 million kWh or 0.45 quad site energy use. Part of the reason for the lower estimate in this study is that the authors raised a lower value for the petroleum refining industry than any of the other three studies.

As an earlier study conducted for DOE, United States Industrial Electric Motor Systems Opportunities Assessment, December, 2002, estimated energy savings for the manufacturing and processing sector. This energy use estimate did not include agriculture, oil and gas extraction, water and wastewater, or mining, Standard Industrial Codes (SICs) from 20-29 (except for 21-23 and 25) were included in the analysis. The site energy use estimated for the year 1994 was 142.600 million kWh or 0.49 quad site energy use. Table 2.1 lists the energy use for each industry analyzed.
DOE?
Regulation Due this fall – 5 years to comply

<table>
<thead>
<tr>
<th>In Scope?</th>
<th>Pump Type</th>
<th>ANSI/Hi Nomenclature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>End Suction Frame Mounted/Own Bearings</td>
<td>OH0, OH1</td>
</tr>
<tr>
<td>Yes</td>
<td>End Suction Close Coupled</td>
<td>OH7</td>
</tr>
<tr>
<td>Yes</td>
<td>Inline</td>
<td>OH3, OH4, OH5</td>
</tr>
<tr>
<td>Yes</td>
<td>Radial Split (Multistage) Vertical</td>
<td>VS8</td>
</tr>
<tr>
<td>Yes</td>
<td>Submersible Vertical-Turbine (Multistage)</td>
<td>VS0</td>
</tr>
<tr>
<td>Maybe</td>
<td>Double Suction</td>
<td>BB1, OH4 double suction</td>
</tr>
<tr>
<td>Maybe</td>
<td>Axially Split</td>
<td>BB1 (2 stage), BB3</td>
</tr>
<tr>
<td>Maybe</td>
<td>Radial Split - Horizontal</td>
<td>BB2 (2 stage), BB4</td>
</tr>
<tr>
<td>Maybe</td>
<td>Radial Split – Vertical (Immersible)</td>
<td>N/A</td>
</tr>
<tr>
<td>Maybe</td>
<td>Vertical Turbine</td>
<td>VS1, VS2</td>
</tr>
<tr>
<td>Maybe</td>
<td>Circulators</td>
<td>CP1, CP2, CP3</td>
</tr>
</tbody>
</table>
State Incentive Programs

State Incentive Programs

Utility Policies

Policies and programs that address customer and uses of energy, achieving greater energy efficiency within the electric and natural gas sectors. State use ratepayer funds to administer programs that advance energy efficiency in numerous sectors, including residential and commercial buildings, industry, and public institutions. States use different methods for ratepayer funds, allowing utilities to run programs, utilizing a third-party provider. The policies that underpin these programs include utility rate regulation that guides state efforts to advance energy efficiency. Regulations for utility incentives to pursue energy efficiency and compensate a utility for energy efficiency measures in a process known as "decoupling" policies. Decoupling allows state legislatures to implement utility rate regulation that guides state efforts to advance energy efficiency. Regulations for utility incentives to pursue energy efficiency and compensate a utility for energy efficiency measures in a process known as "decoupling" policies. Decoupling allows state legislatures to implement utility rate regulation. Another major policy states can adopt is the Energy Star Standard (EERS), which requires utilities to annually save a certain amount of energy over a multi-year period.

The ACEEE Utility database pages primarily address the electric sector, historically been the main focus in most states for program funding. We include less information on natural gas sector policies and programs, which are often intertwined or otherwise closely related to electric sector programs. Some states also have well-established efficiency programs for electricity and natural gas. In future editions of these summaries we will begin to include similar information specifically about policies and programs in the gas sector.
What’s a Variable Flow System Application And Why Does This Matter?

• An HVAC system is like our body
  • Brain = BMS (BAS) system
  • Heart = pump
  • Stomach = boiler or chiller
  • Arteries = piping system
• Working out - system under load
  • Body - heart rate up, increased blood pressure, consumes more energy
  • Building – more BTU’s (flow), more head
• Sleeping - system under low load or setback
  • Body – heart rate and blood pressure down, consumes less energy
  • Building – less BTU’s, lower head

At least that’s the way it is supposed to work!
What if our heart and blood pressure didn’t change?
**Conclusion – all HVAC APPS are variable flow!**
Integrated VFD with Sensorless Control

Constant Pressure Mode

Proportional Pressure Mode

True System Curve Mode
Applications

Example:
Chilled water primary / secondary system
Constant Flow Mode

Self-sensing CONSTANT flow is self-balancing and automatically adjusts flow to maintain user-defined flow set point.

Used on constant flow chiller / boiler pumps

Benefits:
- Balancing through reduced speed – not false head
- Reduced speed increases equipment life
- Balancing done internally and automatically
- Auto adjust over the life and fouling of the system
- Using full trim impellers
- Allows for design vs. reality differences
Variable Flow Mode

Self-sensing variable flow adapts to system pressure variations and automatically follows the system performance curve to meet demand.

*Used on secondary variable speed pumps*

**Benefits:**
- Lower install costs
- No error in setpoint
- Improved system efficiency and performance
- Reduced coordination and construction schedule
Sample of zoning with Circulators

Circulator Pumps

Boiler
Example of zoning with Zone Valves

Zone Valves

Circulator Pump

Boiler
- Variable flow ✓
- Constant flow ❌
- Balancing complexity - high

Direct Return Piping System
(first in / first out)

TERMINAL UNITS

EXPANSION TANK
BOILER
RETURN PIPE
SUPPLY PIPE
TERMINAL UNITS
CONTROL VALVE
BALANCE VALVE

EXPANSION TANK
BOILER
RETURN PIPE
SUPPLY PIPE
TERMINAL UNITS

HYDRONIC VALVE
MULTIPURPOSE VALVE
HIGH EFFICIENCY AIR & DIRT SEPARATOR
SUCTION DIFFUSER
TACO VERTICAL INLINE PUMP
Reverse Return Piping System
(first in / last out)

- Variable flow ✓
- Constant flow ×
- Balancing complexity – low
  - Self Balancing
• Variable flow ✓
• Constant flow ✗
• Balancing complexity – depends
- Variable flow ✓
- Constant flow ✗
- Balancing complexity
  - Crossover bridges balance
- Which circs variable flow?
• Variable flow ✓
• Constant flow ✗
• Balancing complexity – none req’d
• Circs variable flow?

LoadMatch™ Single Pipe Pumping System
Balancing VFD Systems

for fans with *fan system power* greater than 1 hp, fan speed shall be adjusted to meet design flow conditions.

6.7.2.3.3 **Hydronic System Balancing.** Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses; then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions.

**Exceptions:** Impellers need not be trimmed nor pump speed adjusted

a. for pumps with pump motors of 10 hp or less, or

b. when throttling results in no greater than 5% of the *nameplate horsepower* draw, or 3 hp, whichever is greater, above that required if the impeller was trimmed.

6.7.2.4 **System Commissioning.** HVAC control systems shall be tested to ensure that control elements are calibrated, adjusted, and in proper working condition. For projects larger than 50,000 ft² conditioned area, except warehouses and *semiheated spaces*, detailed instructions for commissioning HVAC systems (see Informative Appendix E) shall be provided by the designer in plans and specifications.

6.8 **Minimum Equipment Efficiency Tables**

6.8.1 **Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions**

6.8.2 **Duct Insulation Tables**

The main goal of the secondary chilled water system is to distribute the correct amount of water to satisfy the load. It must first accurately monitor the system for changes in load dynamics.

Secondly, it must respond to these load changes with the “correct” amount of flow

Run VFD’s at constant speed – balance then set pumps to AUTO
SelfSensing vs. Sensors
Location of $\Delta P$ Transmitters

Efficiencies are dramatically affected

80' setpoint

17' setpoint
SelfSensing Pumps vs. Sensors

• Sensors are frequently placed in the wrong location in the system; this incorrect sensor placement results in system inefficiency.

• In a typical system, trial and error must be used (i.e. physically moving the sensor) until the optimum location is determined.

• Another strategy is to use multiple sensors to increase the odds of correct placement.

• These strategies can become costly.

• Even if correct placement is achieved, correct setpoint is rarely used.
Differential Temperature

- As the Delta-T falls below setpoint, the pumps would slow down.
- As the Delta-T rises above setpoint, the pumps speed up.
- Remember that $\text{BTUH} = \text{GPM} \times \Delta T \times 500$
$\Delta PC$ vs Constant Speed

Design load 1,600,000 BTU’s or 160 USGPM @ 20 deg $\Delta T$
25% load (shoulder heating season) 400,000 BTU or 40 USGPM

Design flow – 160 USGPM
25% load flow – 40 USGPM

BHP = \frac{H (\text{Ft}) \times Q (\text{USGPM})}{\text{Eff (0.?) \times 3960}}

\text{BHP Design} = \frac{35 \text{ Ft} \times 160 \text{ USGPM}}{0.6 \times 3960} = 2.4

\text{BHP 25\%} = \frac{43 \text{ Ft} \times 40 \text{ USGPM}}{0.4 \times 3960} = 1.2

\text{BHP } \Delta pc = \frac{35 \text{ Ft} \times 40 \text{ USGPM}}{0.6 \times 3960} = 0.6

\text{BHP } \Delta pv = \frac{13 \text{ Ft} \times 40 \text{ USGPM}}{0.6 \times 3960} = 0.2
Let's Talk About Efficiency

<table>
<thead>
<tr>
<th>Flow (% of BEP)</th>
<th>100%</th>
<th>75%</th>
<th>50%</th>
<th>25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Load (% Full Load)</td>
<td>15 Hp (100%)</td>
<td>7 Hp (42%)</td>
<td>2 Hp (13%)</td>
<td>0.3 Hp (2%)</td>
</tr>
<tr>
<td>Motor Eff*</td>
<td>93%</td>
<td>92.6%</td>
<td>85%</td>
<td>78%</td>
</tr>
<tr>
<td>Drive Eff**</td>
<td>96.5%</td>
<td>93.5%</td>
<td>84.5%</td>
<td>44%</td>
</tr>
</tbody>
</table>

* 15 Hp Premium Efficiency
** VFD interpolated from “Energy Tips – Motor (Motor Tip Sheet #11) July 2008

Calculating Annual Electrical Cost to Operate a Pump – need to know:
- Information above on motor (driver) and drive (VFD) – efficiency at various loads
- # of operating hours at each flow (load) condition (load profile – heating or cooling)
- Average cost of electricity (USA average is $0.11 per kW)
- Head, flow and efficiency of the pump (wet end) - assume constant with VFD

Line to Water kW = \[ \frac{H \text{ (Ft)} \times Q \text{ (Usgpm)} \times SG}{\eta P \times \eta M \times \eta D \times 3960} \]

0.745 x \[ \frac{500 \times 81 \times 1.0}{0.74 \times 0.93 \times 0.965 \times 3960} \]

“Knowns”
- 500 USGPM @ 81’ (100% load or flow)
- Pump efficiency @ H/Q “design” = 74%
- Motor efficiency @ design = 93%
- Drive efficiency @ design = 96.5%
- Assume SG 1.0
Motor Efficiency – AC Motors

- Optimum operating range 60% to 80%!
- EISA, NEMA and ASHRAE only refer to FULL LOAD minimum efficiency

<table>
<thead>
<tr>
<th>Motor Horsepower</th>
<th>0-1 hp</th>
<th>1.5-5 hp</th>
<th>10 hp</th>
<th>30-60 hp</th>
<th>15-25 hp</th>
<th>75-100 hp</th>
</tr>
</thead>
</table>

### TABLE 10.8A  Minimum Nominal Efficiency for General Purpose Design A and Design B Motors Rated 600 Volts or Less

<table>
<thead>
<tr>
<th>Number of Poles</th>
<th>Open Drip-Proof Motors</th>
<th>Totally Enclosed Fan-Cooled Motors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Synchronous Speed (RPM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3600</td>
<td>75.5</td>
<td>75.5</td>
</tr>
<tr>
<td>1800</td>
<td>82.5</td>
<td>82.5</td>
</tr>
<tr>
<td>1200</td>
<td>80.0</td>
<td>80.0</td>
</tr>
</tbody>
</table>

*Nominal efficiencies shall be established in accordance with NEMA Standard MG1. Design A and Design B are National Electric Manufacturers Association (NEMA) design class designations for fixed-frequency small and medium AC squirrel-cage induction motors. NR—No requirement.
**Comparison AC / EC Motor**

**AC-motor**
Non controlled or VFD controlled

Asynchronous-squirrel-cage motor
Rotor is a sheet steel pack with nail like rods parallel to the rotor shaft
The rotor movement is caused by the rotating stator magnetic field

**EC-motor**

- Viridian ECM Technology
  - Brushless electronically commutated synchronous motor using a permanent magnet rotor
  - The rotor magnetic field “grabs” the rotating stator magnetic field, causing rotor rotation
  - Rotor (impeller) speed is determined by the pre-programmed drive software.
**Benefits of ECM Technology**

- Viridian is 15 to 20% more efficient than pump / VFD
- Permanent magnet (ECM) motors have flatter torque / efficiency curves than AC motors (better motor efficiency at low motor loads)
  - PM rotor is driven by magnetic field created by the motor windings
  - Opposite polarity attracts, similar polarity attracts at the same time!
- Higher “turn down” ratios (max vs. min speed relationship – Viridian is 6.8 to 1!)
- PM motors have 300 to 400% higher starting torque
- Viridian is soft start (no power surge)
- Doesn’t consume any energy in order to magnetize the rotor
- Creates continuous thrust
HVAC systems are DYNAMIC – loads / flows continually change

### Heating - Pump Operation:

- 6% time at design load (max)
- 15% time at 75% design load
- 35% time at 50% design load
- 44% time at 25% design load
(HVAC systems are DYNAMIC – loads / flows continually change)

### Seasonal load profile

<table>
<thead>
<tr>
<th>Outdoor Air Temp</th>
<th>Percentage of Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30</td>
<td>100</td>
</tr>
<tr>
<td>-10</td>
<td>90</td>
</tr>
<tr>
<td>+10</td>
<td>80</td>
</tr>
<tr>
<td>+30</td>
<td>70</td>
</tr>
<tr>
<td>+50</td>
<td>60</td>
</tr>
</tbody>
</table>

### Pump load profile

- **Pressure H**
- **Flow (USGPM)**

### AC Part Load Analysis - ARI Standard

<table>
<thead>
<tr>
<th>% Load</th>
<th>Old % Hrs</th>
<th>Current % Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>75</td>
<td>39</td>
<td>42</td>
</tr>
<tr>
<td>50</td>
<td>33</td>
<td>45</td>
</tr>
<tr>
<td>25</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>
Payback Analysis
Based on 6,480 annual operating hours, pump costs and $0.11/kWh cost of power
Data from LCL Excel file for energy comparison – Viridian vs.. 1900 Series
ECM and Self Sensing Technology

FAQs:

• Availability of larger ECM motors
• ECM motors in Residential markets
• ECM/Variable Flow in Solar – why/why not?
• State Incentive Programs – residential and commercial
  • ECM Failure Modes
  • Available Voltages
  • Sensor Lessons Learned
• ASHRAE and DOE Activities
Variable Speed Pumping
Questions???
The Pump Affinity Laws are a series of relationships relating, Flow (Q), Head (H), Horsepower (BHP), and Speed (N in units of R.P.M.)

The **Affinity Laws Relating to Speed Change Are:**

**Flow:** \( Q_2 = Q_1 \times \left( \frac{N_2}{N_1} \right) \)

**Head:** \( H_2 = H_1 \times \left( \frac{N_2}{N_1} \right)^2 \)

**Horsepower:** \( BHP_2 = BHP_1 \times \left( \frac{N_2}{N_1} \right)^3 \)

Reducing the speed has a cubed effect on HP 1/2 Speed = 1/8 HP

Most systems operate at reduced capacity most of their lives.

<table>
<thead>
<tr>
<th>Speed</th>
<th>Flow</th>
<th>Head</th>
<th>BHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>75%</td>
<td>75%</td>
<td>56%</td>
<td>42%</td>
</tr>
<tr>
<td>50%</td>
<td>50%</td>
<td>25%</td>
<td>12.5%</td>
</tr>
<tr>
<td>25%</td>
<td>25%</td>
<td>6%</td>
<td>1.2%</td>
</tr>
</tbody>
</table>