Efficiency Vermont BBD BETTER BUILDINGS BY DESIGN

CONFERENCE THEME: Trends in Cold Climate Construction

Variable Flow Pumps – Control Strategies

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Variable Flow Pumps – Control Strategies

Agenda:

- Introduction
- General Descriptors
- VFD or not VFD – That is the Question (VFD Assessment Tool)
- System & Pump Curves
- Selfsensing Pumps
- Applications
- Balancing VFD Pumping Systems
- Delta T
- Warning!!!
- Efficiency
  - To trim or not to trim
  - ECM Permanent Magnet Technology
  - Affinity Laws
- Commissioning Tips
- DOE / ASHRAE / ACEEE

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General Descriptors

ΔT Differential Temperature
- Net temperature differential between two points (typically supply and return)
- 20 Deg F "Normal" differential temperature design for high mass, medium temperature systems
- 10 to 15 Deg F for radiant
- 10 to 12 Deg F for chilled water primaries

Setpoint Temperature
- Temperature sensed at single location
- If sensor built into the pump, the pump must be installed at sensing location
- Make-up air coil a good example

ΔP Differential Pressure
- Pressure measured or sensed across two points
- Typical closed loop system pup inlet pressure is relatively constant
- ΔPC – Differential Pressure Constant (flat pump curve)
- ΔPV – Proportional Pressure (inclining pump curve)

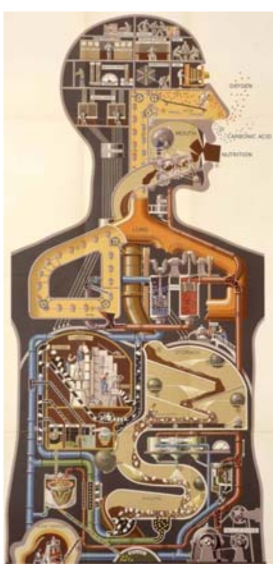
Self Sensing
- Pump (Circ) adjusts speed without any physical sensors
- Reacts to changes in impeller loading as a result of system flow change

Primary Circuit
- Dedicated to moving fluid to/from heating or cooling source

Secondary Circuit
- Supplies fluid to building conditioned space

Circulator vs Pump
- Pumps boost pressure (Well Pumps, Pressure Booster Pumps, Boiler Feed Pumps
- Circulators invoke fluid movement by overcoming friction loss (could be any Hp)

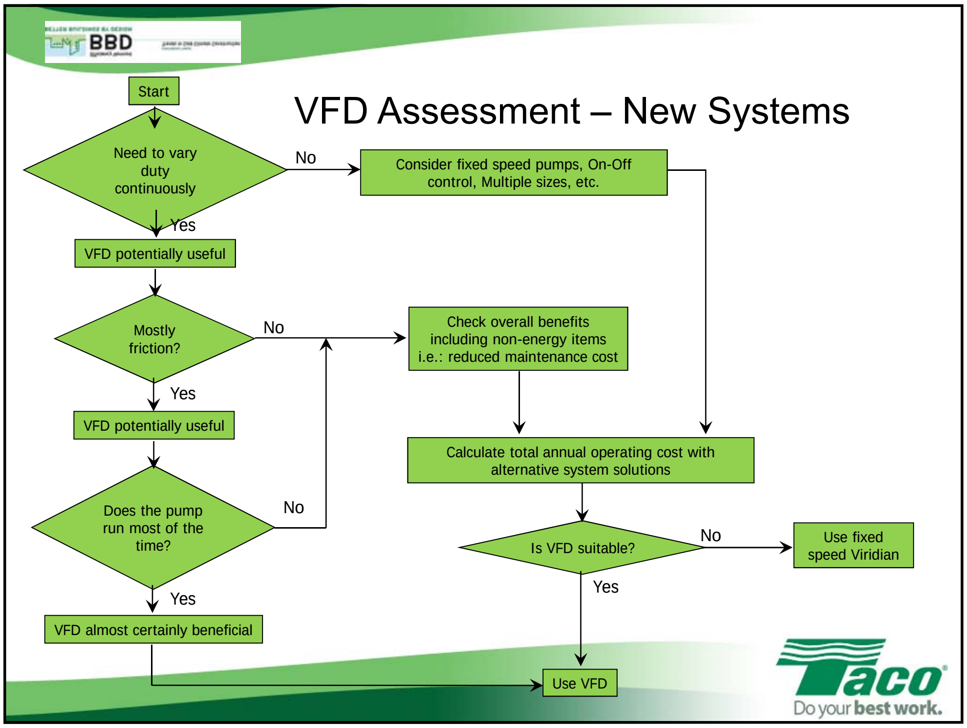
Residential vs Commercial



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!


VFD Assessment – New Systems
Start
Need to vary duty continuously
No
Consider fixed speed pumps, On-Off control, Multiple sizes, etc.
Yes
VFD potentially useful
Mostly friction?
No
Check overall benefits including non-energy items i.e.: reduced maintenance cost
Yes
VFD potentially useful
Calculate total annual operating cost with alternative system solutions
Does the pump run most of the time?
No
Is VFD suitable?
No
Use fixed speed Viridian
Yes
Yes
VFD almost certainly beneficial
Use VFD
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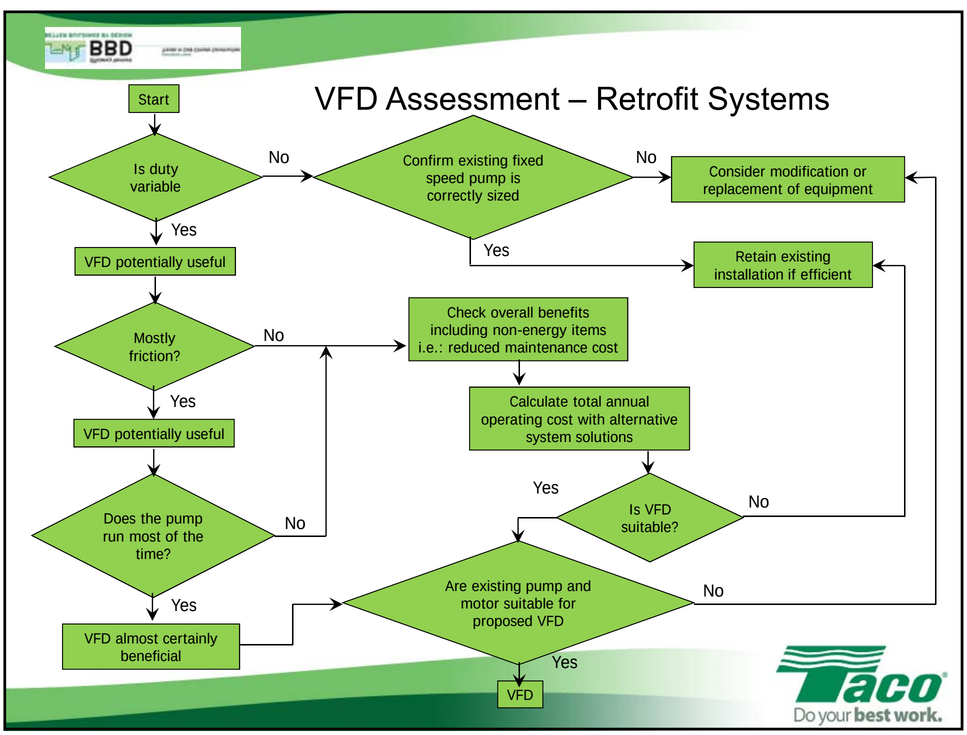
VFD Assessment – Retrofit Systems
Start
Is duty variable
No
Confirm existing fixed speed pump is correctly sized
No
Consider modification or replacement of equipment
Yes
Yes
Retain existing installation if efficient
VFD potentially useful
Mostly friction?
No
Check overall benefits including non-energy items i.e.: reduced maintenance cost
Yes
Calculate total annual operating cost with alternative system solutions
VFD potentially useful
Yes
Is VFD suitable?
No
Does the pump run most of the time?
No
Are existing pump and motor suitable for proposed VFD
No
Yes
VFD almost certainly beneficial
Yes
VFD
Taco
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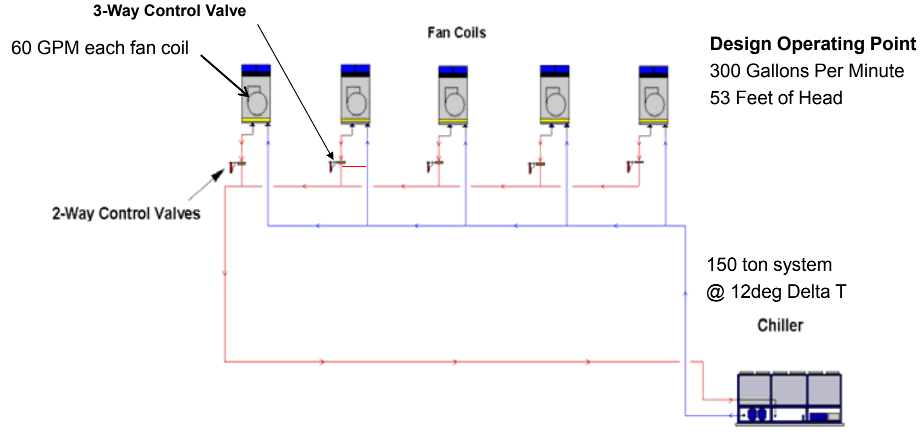
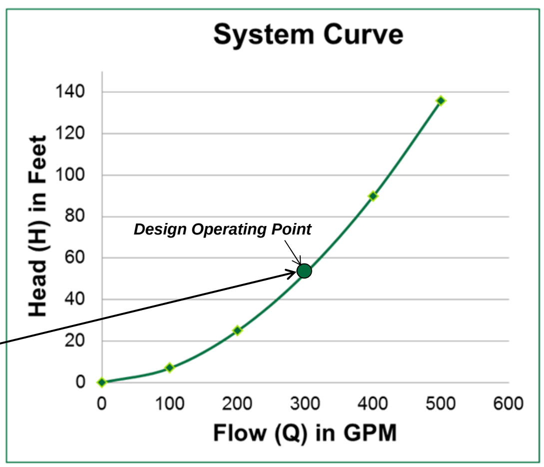
System Curves



System Curves

$$H_2 = H_1 \left(\frac{Q_2}{Q_1}\right)^{1.85}$$

System	
Capacity (Q) in GPM	Head (H) in Feet
0.00	0
100.00	7
200.00	25
300.00	53
400.00	90
500.00	136



System Curves

Taco residential and commercial hydronic systems

Search for Taco Pump

① **PUMP TYPE** *(chose one)*

- (●) Variable Speed Pump
- ( ) Standard Pump

② **SEARCH** *(Variable Speed Pump)*

Design Flow	300	gpm
Design Head	53	ft

③ **OPTIONS** *(Variable Speed Pump)*

Fluid
Water @ 60 F

RPM All | **Motor** 60hz

Units US

Thumbnail Performance (

④ Choose Pumps *(Variable Speed Pump)*

/www.taco-hvac.com/

Pump Details

SKV/SKS4009

Specifications

Flow: 300	**Eff** 73%
Head: 53	**NOL HP** 7.50
RPM: 1760	**NPSH** 7 ft
Imp Dia.: 8.62	**Control Head** 21.2
Size: 4 x 4	**Control Head Hz** 32.41
Design Hz 54.48	

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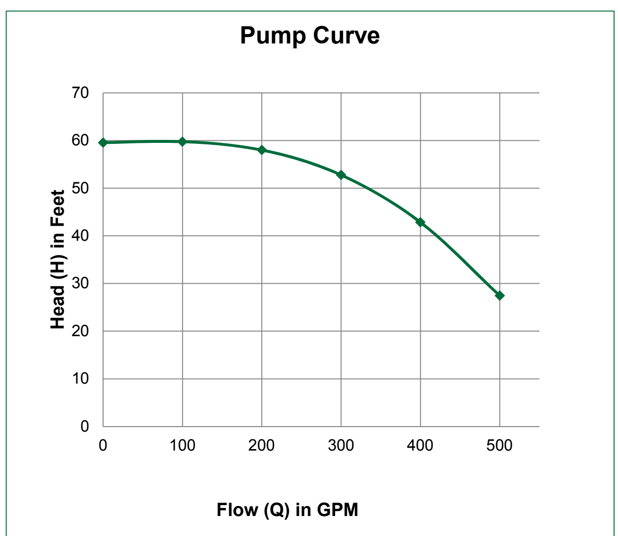
Pump Curves

KS Model 4009
Test Data at 1760 RPM

8.00" Diameter			
Capacity (GPM)	Head (Ft)	Efficiency (%)	BHP (HP)
0.00	59.55	-0.16	2.86
100.00	59.74	44.25	3.40
200.00	58.00	65.04	4.50
300.00	52.76	73.03	5.47
400.00	42.84	71.44	6.05
500.00	27.43	56.08	6.17



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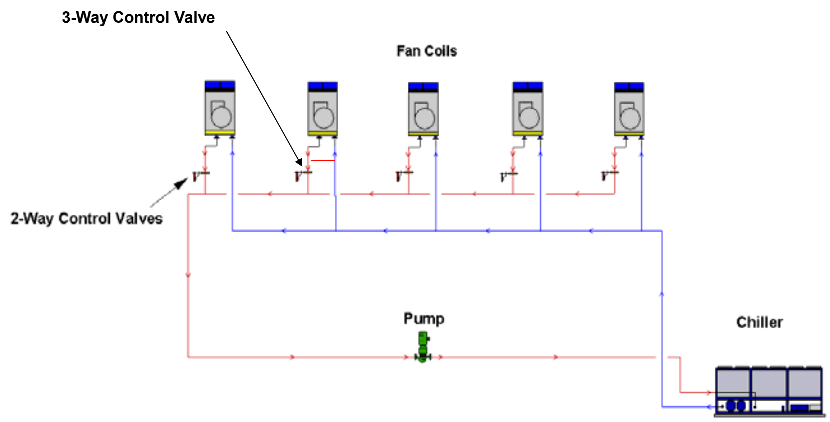
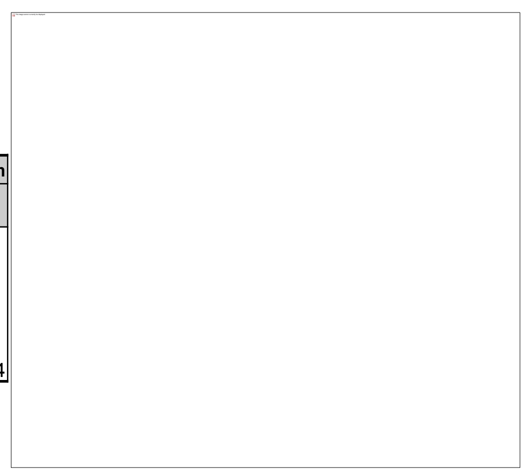
System Curves



Pump Curves

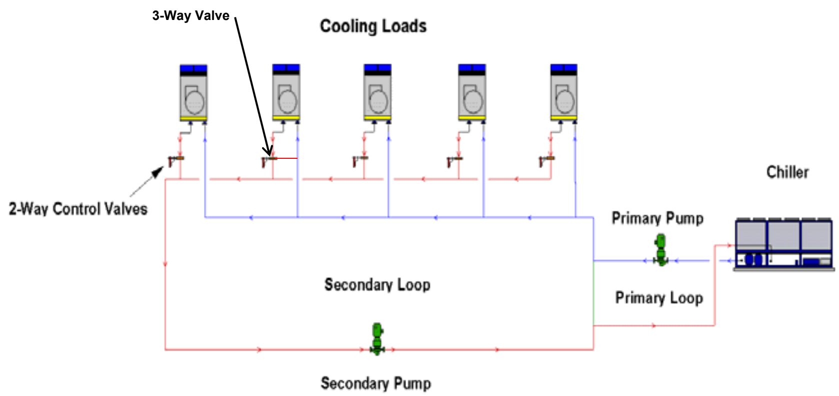
KS Model 4009
With an 8.00” impeller
Test Data at 1760 RPM

	Pump			System
Capacity (GPM)	Head (Ft)	Efficiency (%)	BHP (HP)	Head (Ft)
0.00	59.55	-0.16	2.86	0
100.00	59.74	44.25	3.40	6.91
200.00	58.00	65.04	4.50	24.91
300.00	52.76	73.03	5.47	52.76
400.00	42.84	71.44	6.05	89.83
500.00	27.43	56.08	6.17	135.74

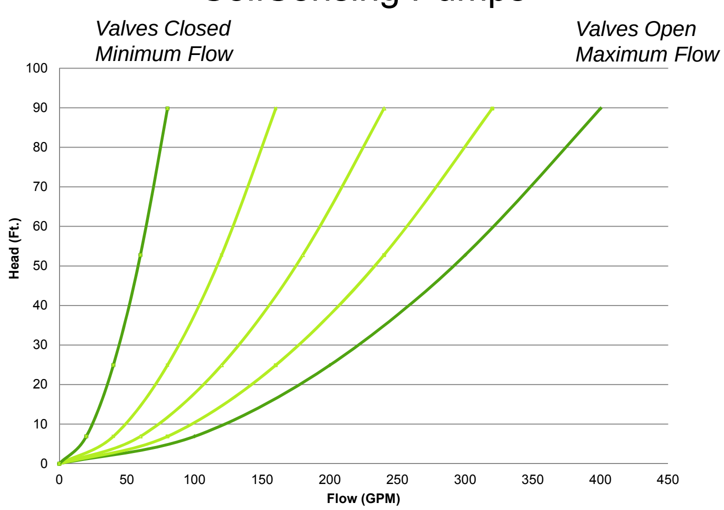


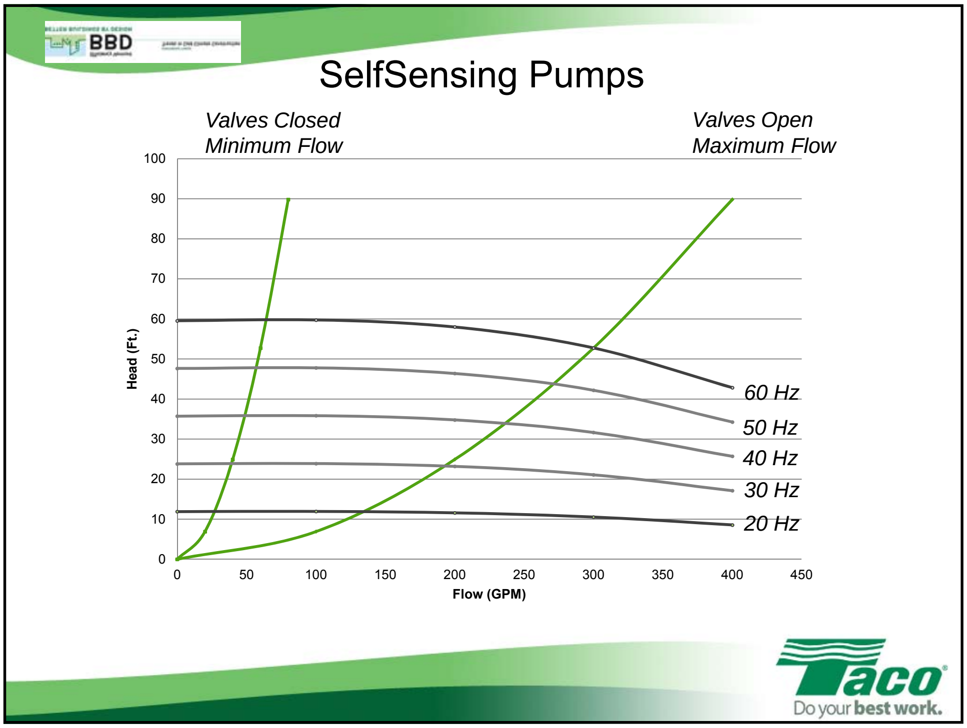
SelfSensing Pumps

Variable Loads (Zones Closing)

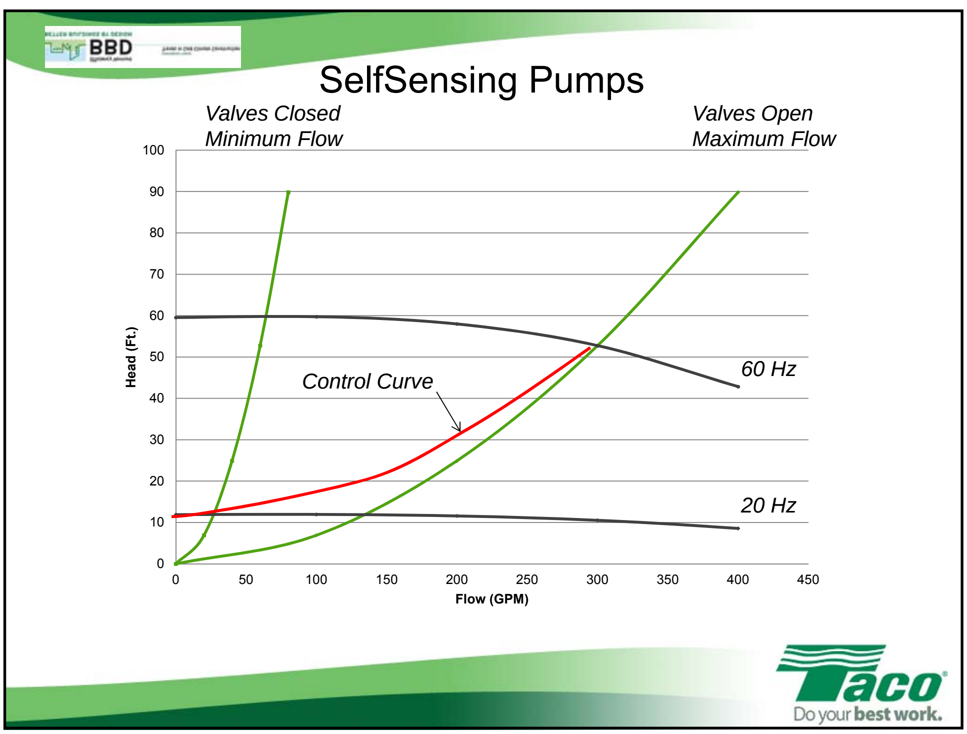


SelfSensing Pumps





SelfSensing Pumps
Valves Closed
Minimum Flow
Valves Open
Maximum Flow
Head (Ft.)
Flow (GPM)
60 Hz
50 Hz
40 Hz
30 Hz
20 Hz
Do your best work.



SelfSensing Pumps
Valves Closed
Minimum Flow
Valves Open
Maximum Flow
Head (Ft.)
Flow (GPM)
Control Curve
60 Hz
20 Hz
Do your best work.

Integrated VFD with Sensorless Control

Constant Pressure Mode

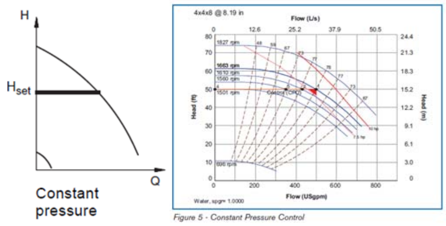


Figure 5 - Constant Pressure Control

Proportional Pressure Mode

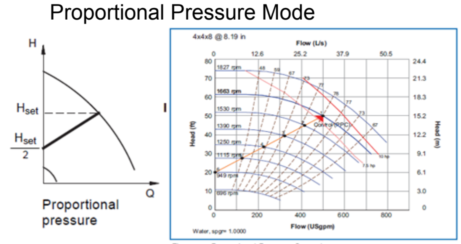


Figure 4 - Proportional Pressure Control

True System Curve Mode

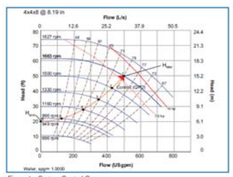
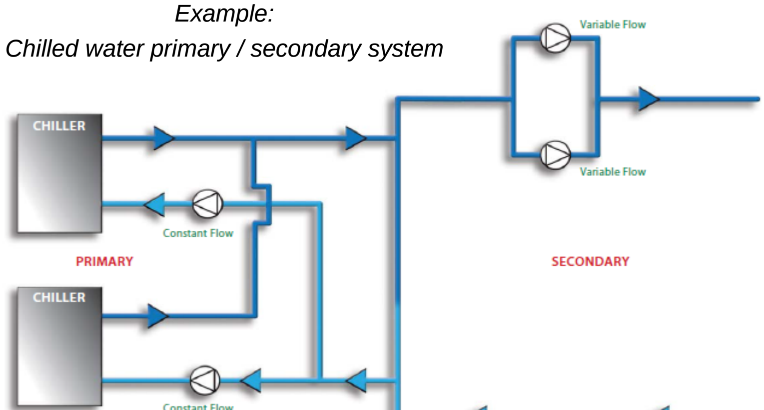


Figure 1 - System Control Curve

Applications

Example:

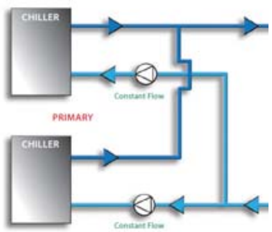
Chilled water primary / secondary system

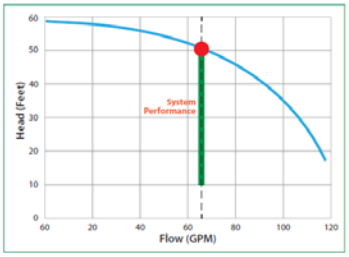


Constant Flow Mode

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*

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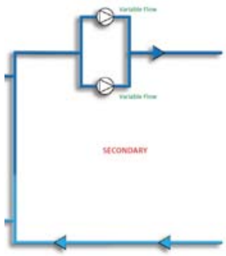
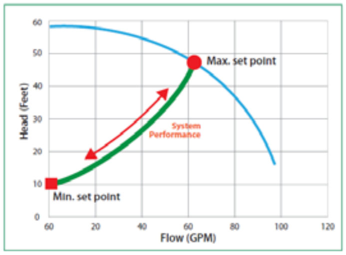
Variable Flow Mode

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*

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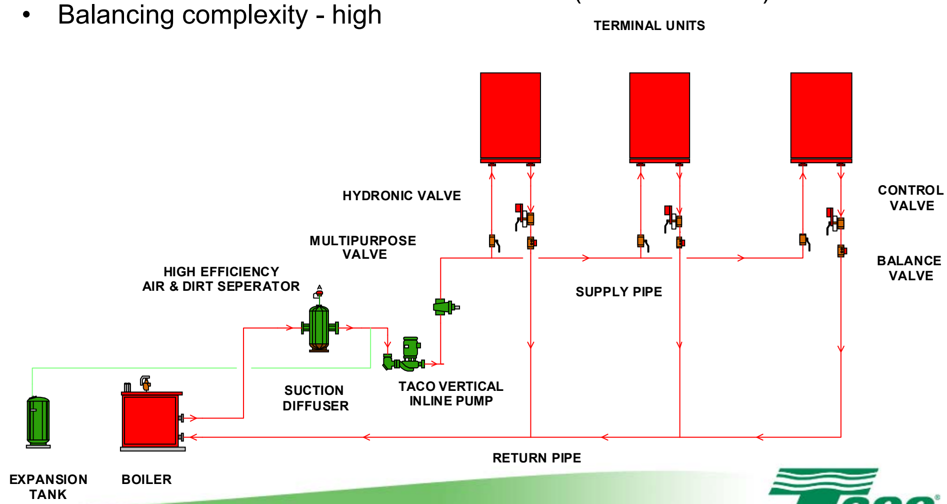
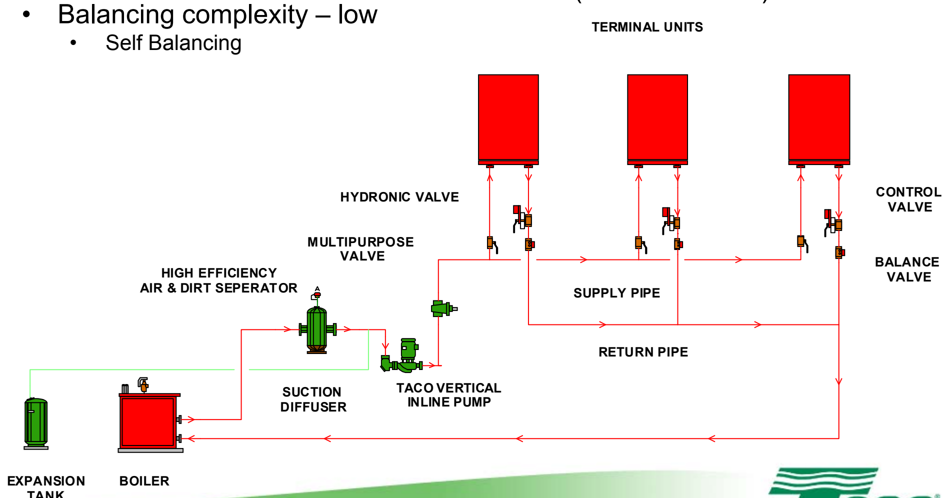
- Variable flow ✓
- Constant flow ×
- Balancing complexity - high

Direct Return Piping System
(first in / first out)



- Variable flow ✓
- Constant flow ×
- Balancing complexity – low
  - Self Balancing

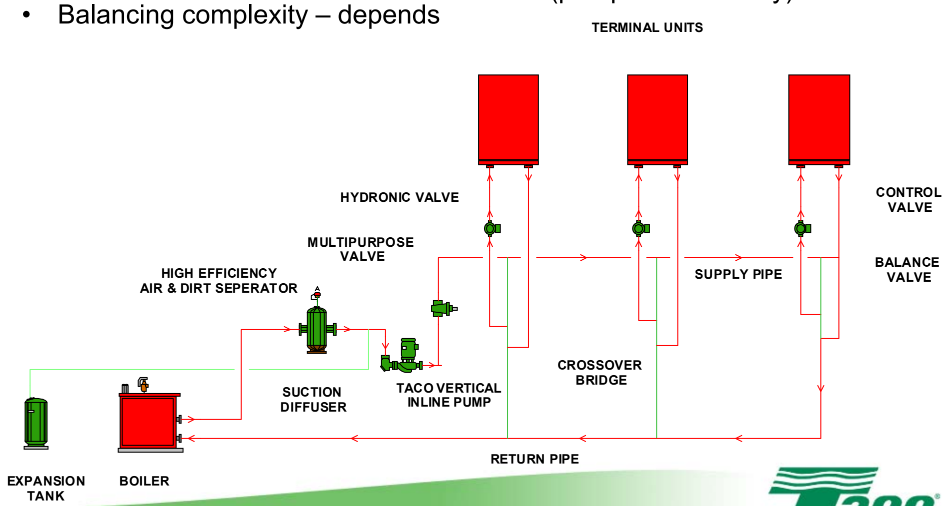
Reverse Return Piping System
(first in / last out)



Primary Secondary Systems

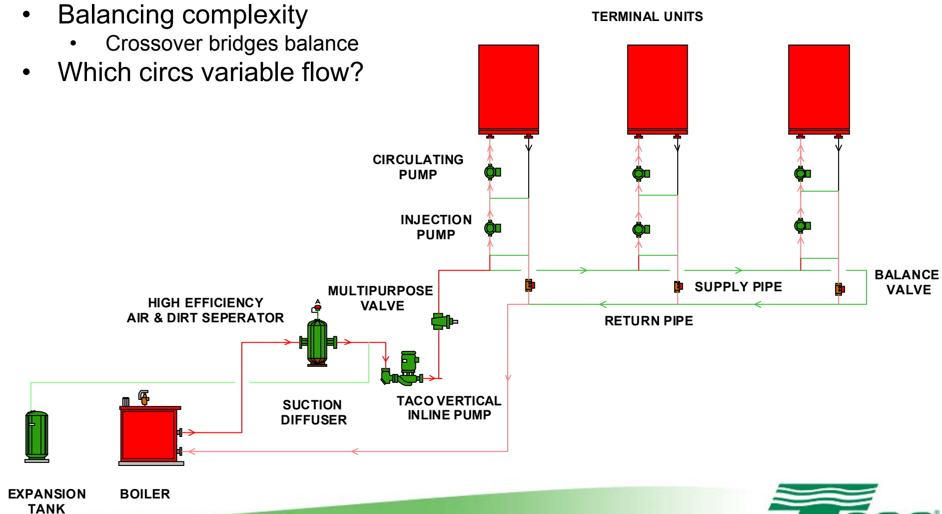
(pumped secondary)

- Variable flow ✓
- Constant flow ×
- Balancing complexity – depends



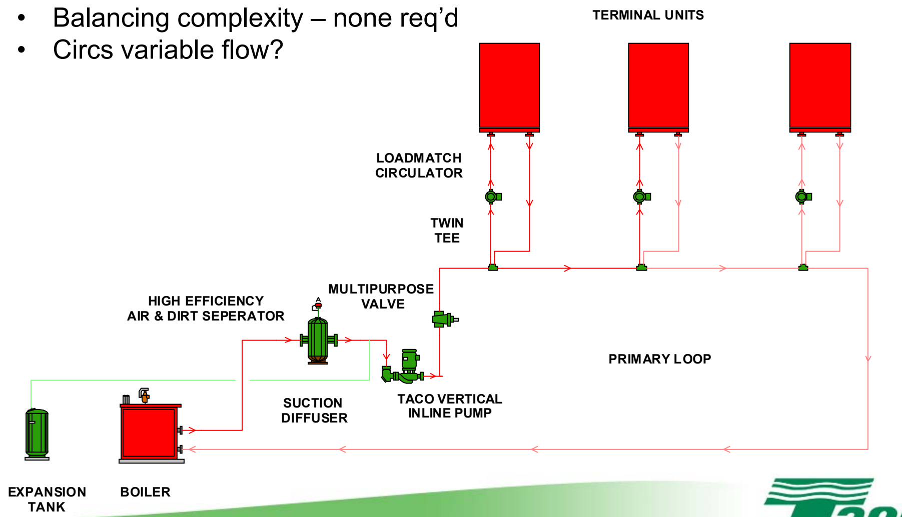
Injection Pumping System

- 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 (ASHRAE)

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 ft^2 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

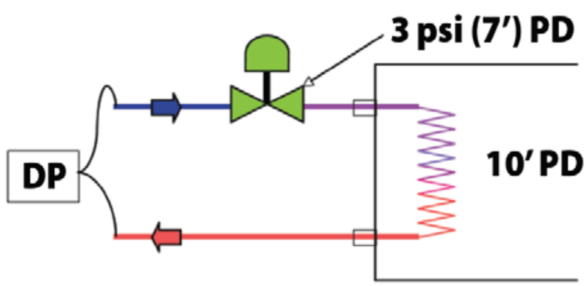
Do your best work.

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.

Determining the Set Point for the Differential Pressure Sensor

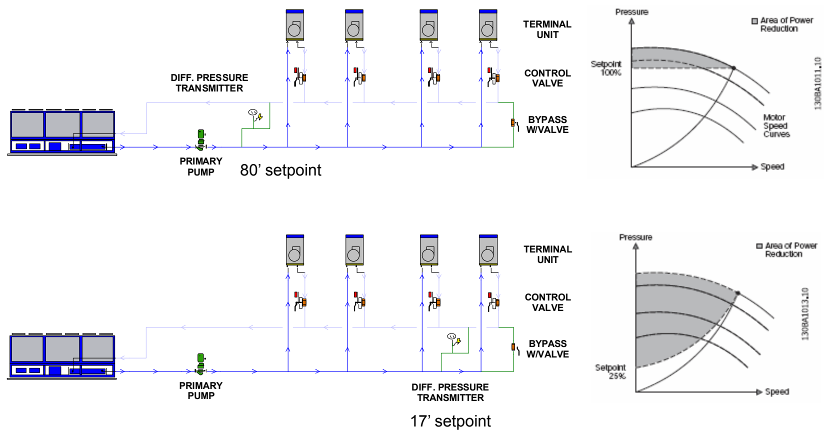
The sensor must keep enough pressure differential across the supply and return to "push" the design capacity flow through the coil and control valve.



Setpoint=Sum of coil pressure drop + control valve pressure drop at design conditions (17')

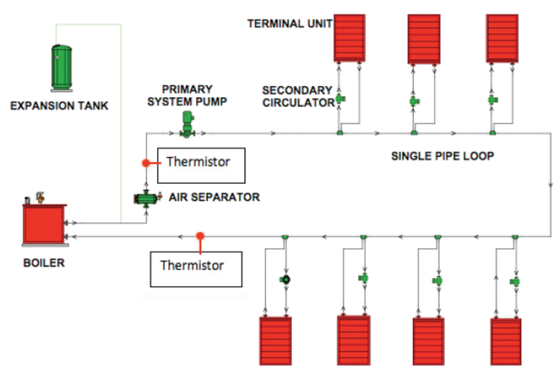
Location of ΔP Transmitters

Effeciencies are dramatically affected



Differential Temperature

Delta-T lends itself to even more cost effective variable speed pumping.
The issues associate with placement and of Delta-P sensors is replaced with ease and simplicity of thermisters.
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 **BTUH = GPM x ΔT x 500**

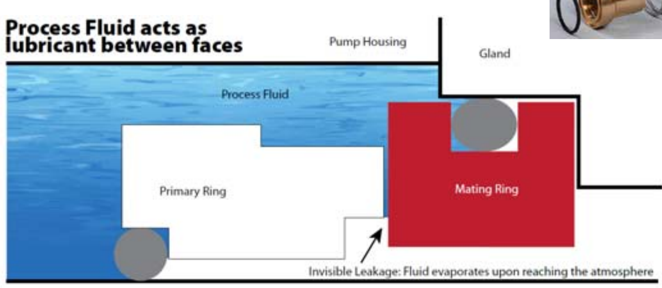


Caution

Boiler Temperature Sensor Location Consideration

- Be careful with sensor location for boiler plant control
- Sensors right at plant discharge can cause boiler short cycling because of lack of thermal mass
- The short cycling can significantly hurt system efficiency.
- Newer lower mass high efficiency boilers are very sensitive to low flow rates in the system (VFDs) and need a thermal flywheel. (Buffer tank)

Variable Speeds and Mechanical Seals – CAUTION!



Minimum Speeds Effect Mechanical Seals
- Noise (remember the noise when you turn a pump off during the last few revolutions – it's dry a dry running seal
- Seal face lubrication

Rules of Thumb
- 4 Pole (1,750 RPM) min 15 Hz, preferably 20 Hz
- 6 Pole (1,150 RPM) min 25 Hz

Causes of Excess System Flow

- Poor / excessive balancing
- Poor control valve selection (oversizing)
- Improper installation of control sensors
- Set point too high on DP transmitters
- Oversized pumps (with/without VFD's)
- ∆P transducers in the wrong location is a common mistake (see next slide)

Universal Problems

- The secondary system will try to distribute more chilled water than is needed. This is inefficient and used excess horsepower
- Higher flow causes low system temperature differentials, excess flow and change in flow direction in the crossover bridge
- The chiller plant must keep more chillers on-line than is required by the load. The chillers and their chiller pumps are brought on just to keep up with excessive system flow
- Solution: Designing and installing a variable speed pumping system can help eliminate these problems. A well designed and commissioned system can greatly improve an owners chiller plant utilization and life cycle cost.

Do your **best work.**

Chiller Plants – Things to Consider

- The flow rate of the chiller plant should be equal to or greater than the system flow rate
- Changes in the direction of flow in the cross over bridge can be used for chiller staging
- Control valve problems (or balancing) can result in artificially high flows, low temperature differentials, and the need to rerate chillers
- Watch out for the physical configuration of the cross over bridge, especially 6" and above.
- Make sure that chiller plant loop has sufficient volume to cover chiller minimum run times.

Boilers – Things to Consider

- The flow rate of the primary boiler plant does not need to be greater than the system flow rate
- Boiler plants and distribution loops can be designed with different temperature differentials to take advantage of smaller pipe sizes and mixing in the bridge
- The mixing in the bridge can be used to protect non-condensing boilers in a water source heat pump system.

Do your **best work.**

Benefits of Variable Speed Pumping

Energy Savings

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: Q2 = Q1 X (N2/N1)

Head: H2 = H1 X (N2/N1)2

Horsepower: BHP2 = BHP1 X (N2/N1)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.

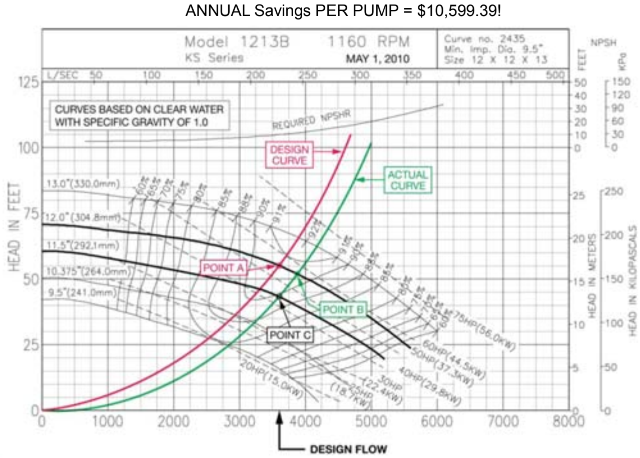
Speed	Flow	Head	BHP
100%	100%	100%	100%
75%	75%	56%	42%
50%	50%	25%	12.5%
25%	25%	6%	1.2%

Do your best work.

To Trim or Not To Trim

Design Point A - 3,600 USGPM @ 55' TDH, 12" Dia, ɳ 90.7% - BHP = 55.13
Actual Operating Point B - 3,900 USGPM @ 52' TDH (throttle), 12" Dia, ɳ 90.5% - BHP = 53.91
Actual Operating Point C (57.5 Hz) – 3,600 USGPM @ 44' TDH, 12" Dia, ɳ 90.7% - BHP = 44.10

Annual Operating Cost PER PUMP (Hospital @ 8,736 Hrs/Year, $0.11/kWh)
Point A - Full Trim, no Balance = $52,977.73 (not including chiller efficiency decrease)
Point C - Full Trim, Speed Reduction = $42,378.34
ANNUAL Savings PER PUMP = $10,599.39!



Do your best work.

ΔPC vs Constant Speed

Design load 1,600,000 BTU's or 160 USGPM @ 20 deg ΔT
25% load (shoulder heating season) 400,000 BTU or 40 USGPM

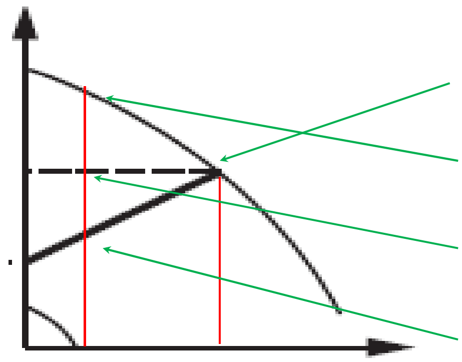
$$BHP = \frac{H\ (Ft) \times Q\ (Usgpm)}{Eff\ (0.?) \times 3960}$$

$$BHP\ Design = \frac{35\ Ft \times 160\ Usgpm}{0.6 \times 3960} = 2.4$$

$$BHP\ \ 25\ \% = \frac{43\ Ft \times 40\ Usgpm}{0.4 \times 3960} = 1.2$$

$$BHP\ \Delta pc = \frac{35\ Ft \times 40\ Usgpm}{0.6 \times 3960} = 0.6$$

$$BHP\ \Delta pv = \frac{13\ Ft \times 40\ Usgpm}{0.6 \times 3960} = 0.2$$



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

Let's Talk About Efficiency

Flow (% of BEP)	100%	75%	50%	25%
Motor Load (% Full Load)	15 Hp (100%)	7 Hp (42%)	2 Hp (13%)	0.3 Hp (2%)
Motor Eff*	93%	92.6%	85%	78%
Drive Eff**	96.5%	93.5%	84.5%	44%

* 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

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

$$0.745 \times \frac{500 \times 81 \times 1.0}{0.74 \times 0.93 \times 0.96.5 \times 3960}$$

"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

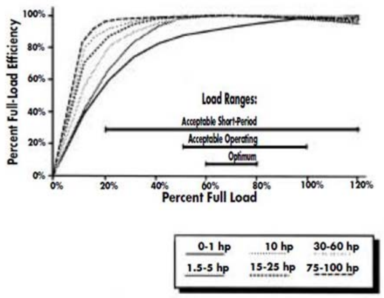


TABLE 10.8A Minimum Nominal Efficiency for General Purpose Design A and Design B Motors Rated 600 Volts or Less[a]

	Minimum Nominal Full-Load Motor Efficiency (%) prior to December 19, 2010					
	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
Number of Poles ⇒	2	4	6	2	4	6
Synchronous Speed (RPM) ⇒	3600	1800	1200	3600	1800	1200
Motor Horsepower						
1	NR	82.5	80.0	75.5	82.5	80.0
1.5	82.5	84.0	84.0	82.5	84.0	85.5
2	84.0	84.0	85.5	84.0	84.0	86.5
3	84.0	86.5	86.5	85.5	87.5	87.5
5	85.5	87.5	87.5	87.5	87.5	87.5
7.5	87.5	88.5	88.5	88.5	89.5	89.5
10	88.5	89.5	90.2	89.5	89.5	89.5
15	89.5	91.0	90.2	90.2	91.0	90.2
20	90.2	91.0	91.0	90.2	91.0	90.2
25	91.0	91.7	91.7	91.0	92.4	91.7
30	91.0	92.4	92.4	91.0	92.4	91.7
40	91.7	93.0	93.0	91.7	93.0	93.0
50	92.4	93.0	93.0	92.4	93.0	93.0
60	93.0	93.6	93.6	93.0	93.6	93.6
75	93.0	94.1	93.6	93.0	94.1	93.6
100	93.0	94.1	94.1	93.6	94.5	94.1
125	93.6	94.5	94.1	94.5	94.5	94.1
150	93.6	95.0	94.5	94.5	95.0	95.0
200	94.5	95.0	94.5	95.0	95.0	95.0

[a] 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

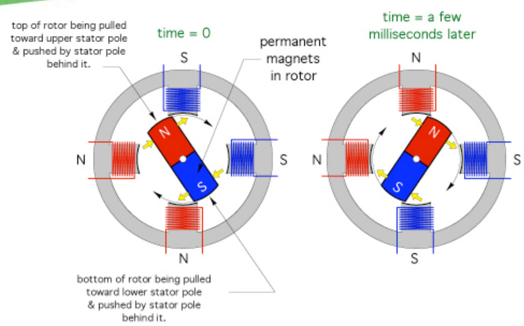
Do your best work.

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.

Do your best work.

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

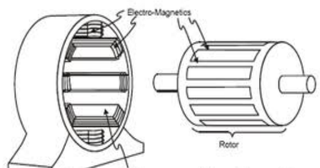


Figure 4: Rotor and Stator

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.

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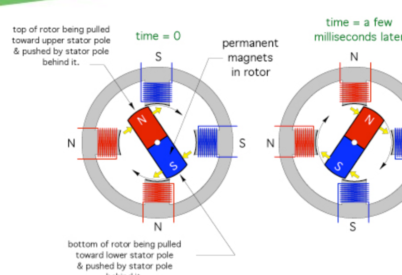
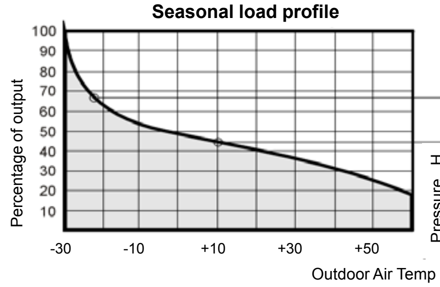


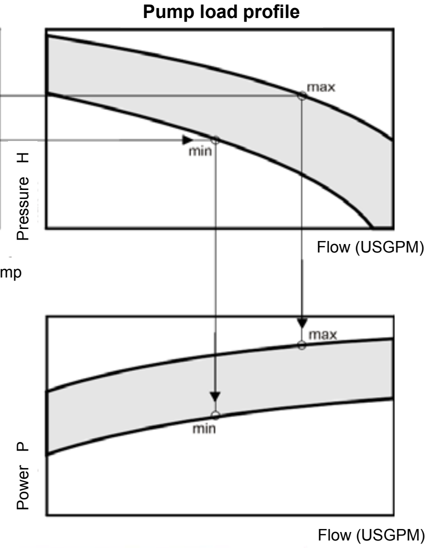
Benefits of ECM Technology

- 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

Taco
Do your best work.

(HVAC systems are DYNAMIC – loads / flows continually change)



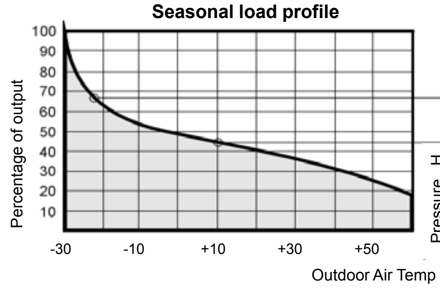


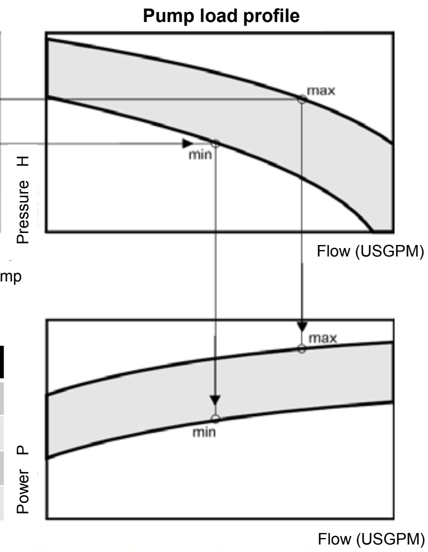
Heating - Pump Operation:

6% time at design load (max)
15% time at 75% design load
35% time at 50% design load
44% time at 25% design load

Do your best work.

(HVAC systems are DYNAMIC – loads / flows continually change)





AC Part Load Analysis - ARI Standard

% Load	Old % Hrs	Current % Hrs
100	17	1
75	39	42
50	33	45
25	11	12

Do your best work.

Energy Savings Calculator – Chilled Water

CW Load Profile and 8000 Hours, $0.11 / kWh

Chilled Water - Constant Speed Pumps, Throttling Valves (no VFD's)										
% Load Conditions ARI Standards	% Load	GPM (USGPM)	Head (ft)	Eff Pump	Eff Motor	Drive NIC	Wire to water eff	P1 to P4 Hp	Annual KW	Annual Cost
1%	100%	500	80.65	74%	93%	100%	69%	14.76	1181	$130
42%	75%	375	87.51	70%	91%	100%	64%	13.01	43711	$4,808
45%	50%	250	92.75	59%	78%	100%	46%	12.72	45805	$5,039
12%	25%	125	95.97	37%	62%	100%	23%	13.21	12677	$1,395
								Totals	103375	$11,371.25

Chilled Water - Variable Speed Pumps										
% Load Conditions ARI Standards	% Load	GPM (USGPM)	Head (ft)	Pump Eff	Motor Eff	Drive Eff	Wire to water eff	P1 to P4 Hp	Annual KW	Annual Cost
1%	100%	500	80.7	74%	93%	97%	66%	15.34	1227	$135
42%	75%	375	45.4	74%	93%	94%	64%	6.71	22546	$2,480
45%	50%	250	20.2	74%	85%	85%	53%	2.40	8638	$950
12%	25%	125	5	74%	78%	44%	25%	0.62	597	$66
								Totals	33008	$3,630.88

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Energy Savings Calculator - Heating

Heating Load Profile and 6000 Hours, $0.11 / kWh

Heating - Constant Speed Pumps, Throttling Valves (no VFD's)										
% Load Conditions EU Standards	% Load	GPM (USGPM)	Head (ft)	Eff Pump	Eff Motor	Drive NIC	Wire to water eff	P1 to P4 Hp	Annual KW	Annual Cost
6%	100%	500	80.65	74%	93%	100%	69%	14.76	5315	$585
15%	75%	375	87.51	70%	91%	100%	64%	13.01	11708	$1,288
35%	50%	250	92.75	59%	78%	100%	46%	12.72	26720	$2,939
44%	25%	125	95.97	37%	62%	100%	23%	13.21	34863	$3,835
								Totals	78606	$8,646.67

Heating - Variable Speed Pumps										
% Load Conditions EU Standards	% Load	GPM (USGPM)	Head (ft)	Pump Eff	Motor Eff	Drive Eff	Wire to water eff	P1 to P4 Hp	Annual KW	Annual Cost
6%	100%	500	80.7	74%	93%	97%	66%	15.34	5523	$608
15%	75%	375	45.4	74%	93%	94%	64%	6.71	6039	$664
35%	50%	250	20.2	74%	85%	85%	53%	2.40	5039	$554
44%	25%	125	5	74%	78%	44%	25%	0.62	1641	$180
								Totals	18242	$2,006.60

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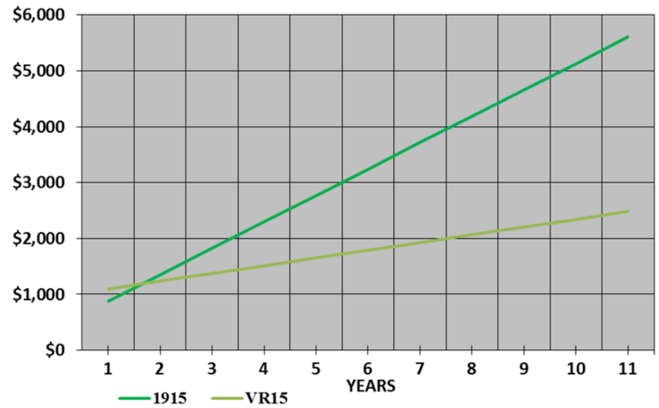
Payback Analysis

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 vs1900 Series



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ECM and Self Sensing Technology

FAQs:

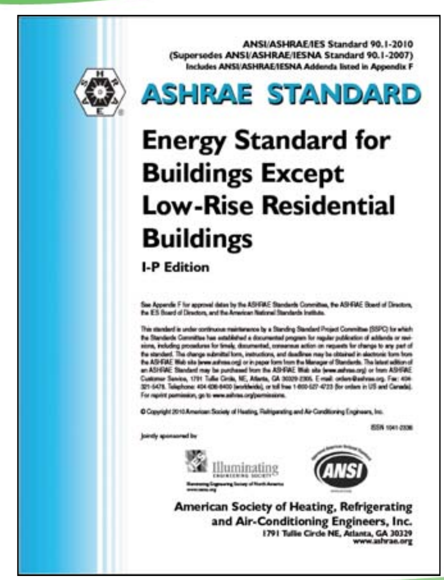
•Availability of larger ECM motors
•ECM motors in Residential markets
•ECM/Variable Flow in Solar – why/why not?
•State Incentive Programs – residential and commercial
•ECM Failure Modes
•Available Voltages
•Sensor Lessons Learned
•ASHRAE and DOE Activities

Do your best work.

ASHRAE?

DOE Regulations?

Incentives?



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.

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

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.

← VSD (VFD) pumps are mandated for use on secondary systems on larger systems

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

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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

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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.

← 30% wattage at 50% design flow descriptor

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.

Higher velocities (smaller pipes) with VFD!

TABLE 6.5.4.5 Piping System Design Maximum Flow Rate in GPM

Operating Hours/Year	≤2000 Hours/Year		>2000 and ≤ 4400 Hours/Year		>4400 Hours/Year	
Nominal Pipe Size, in.	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed
2 1/2	120	180	85	130	68	110
3	180	270	140	210	110	170
4	350	530	260	400	210	320
5	410	620	310	470	250	370
6	740	1100	570	860	440	680
8	1200	1800	900	1400	700	1100
10	1800	2700	1300	2000	1000	1600
12	2500	3800	1900	2900	1500	2300
Maximum Velocity for Pipes over 12 in. Size	8.5 fps	13.0 fps	6.5 fps	9.5 fps	5.0 fps	7.5 fps

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Federal Register / Vol. 76, No. 113 / Monday, June 13, 2011 / Proposed Rules 34193

DOE?

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.

Based on the information DOE receives 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 0.190 quads annually.

DOE used industry and census data to calculate the average establishment energy use for pumps.

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DOE?

Full Effect 2019?

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

Extended Product – Pump/Motor/Drive
- Probable regulation evaluates variable load line to water efficiency

Pump/Motor
- Probable regulation evaluates constant load line to water efficiency

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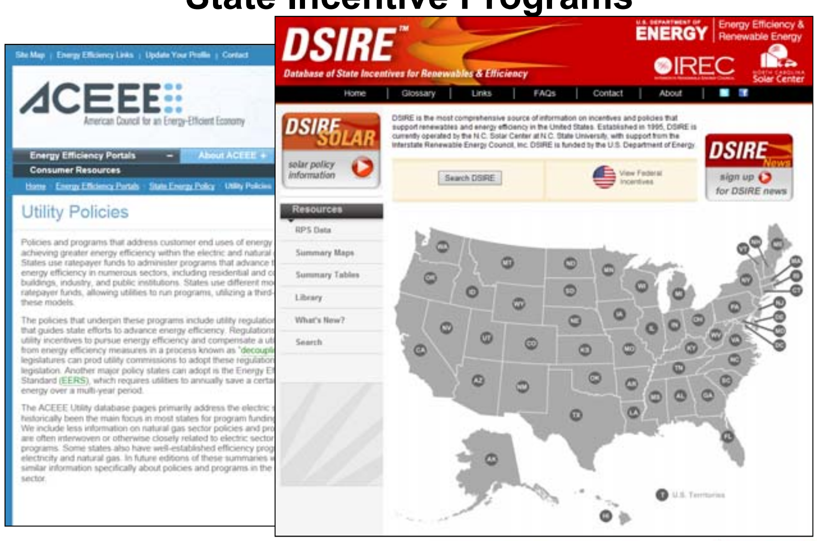
State Incentive Programs



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Facts and Figures

2000 Figures

- 40 Quads (1 Quad = quadrillion Btu's) of electricity is produced annually in the USA
- 13 Quads (3,800 billion kWh) of electricity is delivered from the source to the point of use – balance is lost via thermal waste heat to the environment!
- Approx 40% of the energy consumed in the USA is used in Commercial Buildings
- 25% of the energy consumed by a commercial building used for fans and pumps (1.5 Quads)
- Of the 1.5 Quads:
  - 5% for heating water pumps
  - 2% for condenser water pumps
  - 2% for chilled water pumps
- Where did the electricity come from?
  - Coal generated 51% (1.968 billion kWh)
  - Nuclear 20% (754 billion kWh)
  - Natural Gas 16.1% (1.141 billion kWh)
  - Hydroelectric 7% (273 billion kWh
  - Petroleum (oil) 3% (109 billion kWh)

Source – USGBC & EIA Annual Energy Outlook 1998, ref 1

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Efficiency Vermont BBD BETTER BUILDINGS BY DESIGN

CONFERENCE THEME: Trends in Cold Climate Construction

Variable Flow Pumps – Control Strategies

BBT Conference – Feb 4/5, 2015

Presented by Steve Thompson
VP - Residential Product Management – Taco Inc.
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