ECM and Self Sensing Technology

Presented by Steve Thompson
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Commercial Energy Prices, by Year by Type

Year	Electricity cents/kWh	Natural Gas Cents/therm	Distillate Oil $/gal	Residual Oil $/gal
2015	9.58	85.91	2.41	3.28
2010	10.14	90.95	1.66	2.86
2005	9.59	121.45	1.24	2.07
2000	9.17	81.85	0.84	1.28
1995	10.32	66.99	0.64	0.88
1990	11.08	72.04	0.78	1.26
1985	13.06	95.96	1.21	1.56

Commercial Buildings Aggregate Energy Expenditures (2010 Billion)

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

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

Energy Expenditures per SF (2010)

Year	$/SF
2015	2.29
2010	2.44
2005	2.30
2000	2.06
1995	2.12
1990	1.98
1985	2.20

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.




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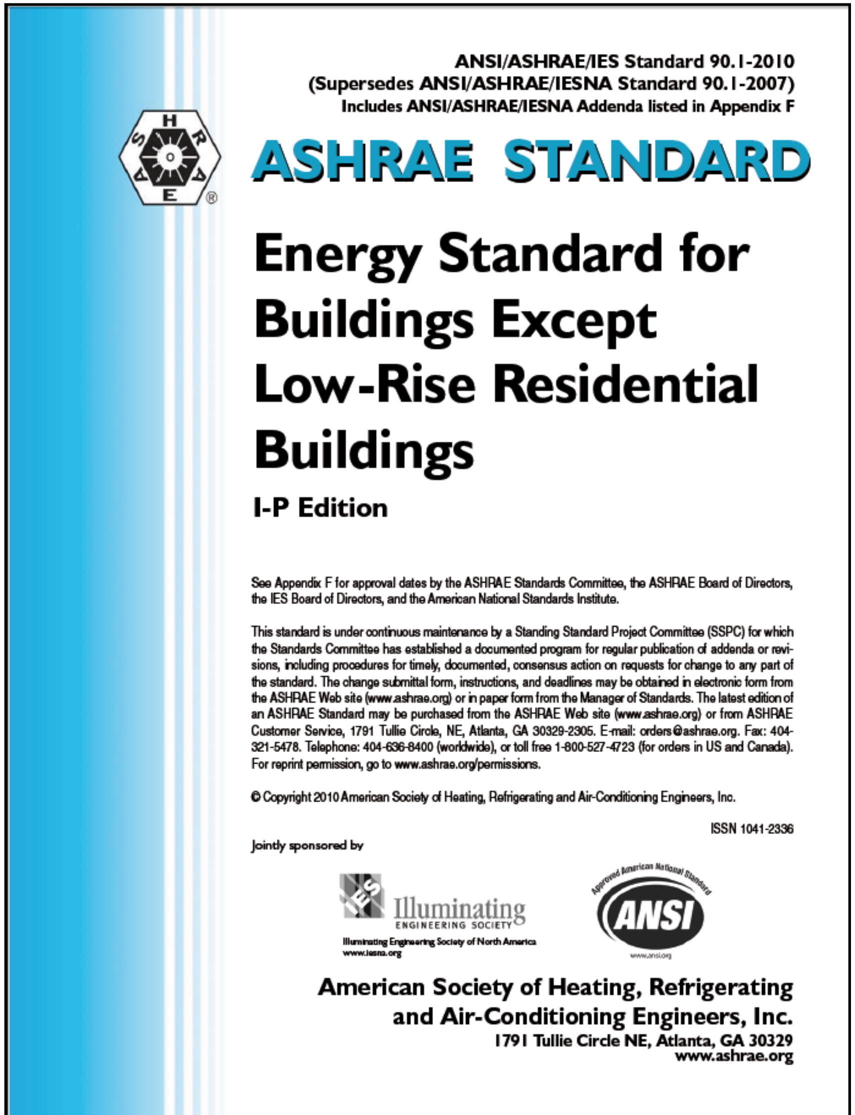
ANSI/ASHRAE/IES Standard 90.1-2010
(Supersedes ANSI/ASHRAE/IESNA Standard 90.1-2007)
Includes ANSI/ASHRAE/IESNA Addenda listed in Appendix F

ASHRAE STANDARD

Energy Standard for Buildings Except Low-Rise Residential Buildings

I-P Edition

See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the IES Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE Web site (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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Federal regulations mandate all states use ASHRAE 90.1 or IECC as a minimum efficiency standard

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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.

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.

← 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

DOE?

Regulation Due this fall – 5 years to comply

Washington, DC 20585–0121. *Phone:* (202) 586–2945. Please submit one signed paper original.

- *Hand Delivery/Courier:* Ms. Brenda Edwards, U.S. Department of Energy, Building Technologies Program, 6th Floor, 950 L'Enfant Plaza, SW., Washington, DC 20024. Phone: (202) 586–2945. Please submit one signed paper original.
- *Instructions:* All submissions received must include the agency name and docket number.

Docket: For access to the docket to read background documents or comments received, visit the U.S. Department of Energy, Resource Room of the Building Technologies Program, 950 L'Enfant Plaza, SW., Suite 600, Washington, DC 20024, (202) 586–2945, between 9 a.m. and 4 p.m., Monday through Friday, except Federal holidays. Please call Ms. Brenda Edwards at the above telephone number for additional information regarding visiting the Resource Room.

FOR FURTHER INFORMATION CONTACT: Mr. Charles Llenza, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program, EE–2J, 1000 Independence Avenue, SW., Washington, DC 20585–0121. Telephone: (202) 586–2192. E-mail: *Charles.Llenza@ee.doe.gov.*

In the Office of General Counsel, Ms. Elizabeth Kohl, U.S. Department of Energy, Office of the General Counsel, GC–71, 1000 Independence Avenue, SW., Washington, DC 20585–0121. Telephone: (202) 586–7796. E-mail: *Elizabeth.Kohl@hq.doe.gov.*

SUPPLEMENTARY INFORMATION:

1. Statutory Authority

Title III of the Energy Policy and Conservation Act (EPCA) of 1975, as amended (42 U.S.C. 6291 *et seq.*), sets forth various provisions designed to improve energy efficiency. Part C of EPCA includes measures to improve the energy efficiency of commercial and industrial equipment.[1] See 42 U.S.C. 6311–6316.

Section 6311(A) includes electric motors and pumps as "covered equipment." Section 6316(a) describes how provisions in Part A (which concerns "Consumer Products Other Than Automobiles") apply to industrial equipment, which includes pumps.[2]

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.

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 Energetics 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 this estimate (*http://www1.eere.energy.gov/industry/rd/footprints.html*) were primarily provided by the DOE Energy Information Administration's (EIA's) *Manufacturing Energy Consumption Survey* (MECS). The machine drive energy includes pump energy and reflects consumption in the year 2006, when the survey was last completed.

Another recent report for the United Nations ("Motor System Efficiency Supply Curves UNIDO," Dec. 2010),[3] also used the 2006 MECS data. The total industrial energy use was estimated to be 126,180 million kWh or 0.43 quads site energy use. Part of the reason for the lower estimate in this study is that the authors listed a lower value for the petroleum refining industry than any of the other three studies.

An earlier study conducted for DOE, "United States Industrial Electric Motor Systems Opportunities Assessment, December, 2002,"[4] estimated energy used by pumps in the manufacturing sector. This energy use estimate did not include agriculture, oil and gas extraction, water and wastewater, or mineral mining. Standard Industrial Codes (SICs) from 20–39 (except for 21 and 39) were included in the analysis. The site energy use estimated for the year 1994 was 142,690 million kWh or 0.49 quads site energy use. Table 2.1 lists the energy use for each industry analyzed.

TABLE 2.1—INDUSTRIAL SECTOR ELECTRICITY USE BY PUMPS

Industry	Pump electricity use (millions of kWh)
Food	6,218
Textile Mill products	2,949
Lumber and Wood	1,209
Furniture and Fixtures	27
Paper and Allied products	31,309
Printing and Publishing	84
Chemical and Allied Products	37,591
Petroleum and Coal Products	30,643
Rubber and Miscellaneous Plastics	9,211
Stone, Clay and Glass Products	90
Primary Metal Industries	7,646
Fabricated Metal Industries	903
Industrial Machinery and Equipment	968
Electronics and Other Electric Equipment	7,732
Transportation Equipment	5,517
Instruments and Related Products	594

The American Council for an Energy-Efficient Economy (ACEEE) 2003 report "Realizing Energy Efficiency Opportunities in Industrial Fan and Pump Systems" summarizes the energy use of pumps in a variety of industrial settings (including manufacturing,

[1] Part C was re-designated Part A–1 on codification of the U.S. Code for editorial reasons.

[2] It states that the provisions of section 6296(a), (b), and (d), the provisions of subsections (l) through (s) of section 6295, and section 6297 through 6306 shall apply with respect to electric motors and pumps to the same extent and in the same manner as they apply in part A. In applying the provisions in the sections cited above, section 6316(a)(1) states that references to sections 6293, 6294, and 6295 of this title shall be considered as references to sections 6314, 6315, and 6313 of this title, respectively; and section 6316(a)(3) states that the term "equipment" shall be substituted for the term "product."

[3] McKane, A. and A. Hasanbeigi, "Motor Systems Efficiency Supply Curves," United Nations Industrial Development Organization. (2010) (Available at: *http://industrial-energy.lbl.gov/files/industrial-energy/active/0/UNIDO%20Motor%20Systems%20Efficiency%20Supply%20Curves.pdf*)

[4] U.S Department of Energy, "United States Industrial Electric Motor Systems Market Opportunities Assessment." Office of Energy Efficiency and Renewable Energy, United States Department of Energy. (2002) Available at: *http://www.oit.doe.gov/bestpractices/*

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

DOE?

Regulation Due this fall – 5 years to comply

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

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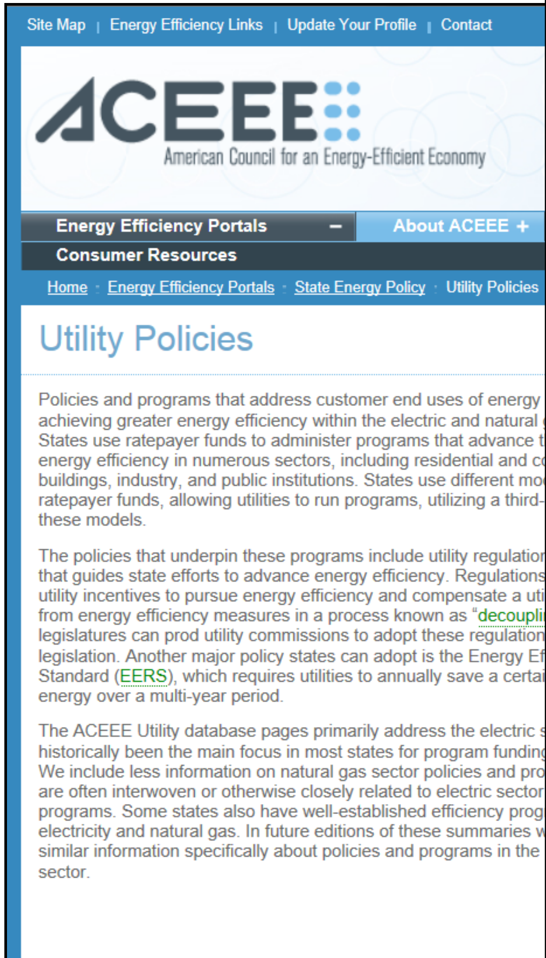
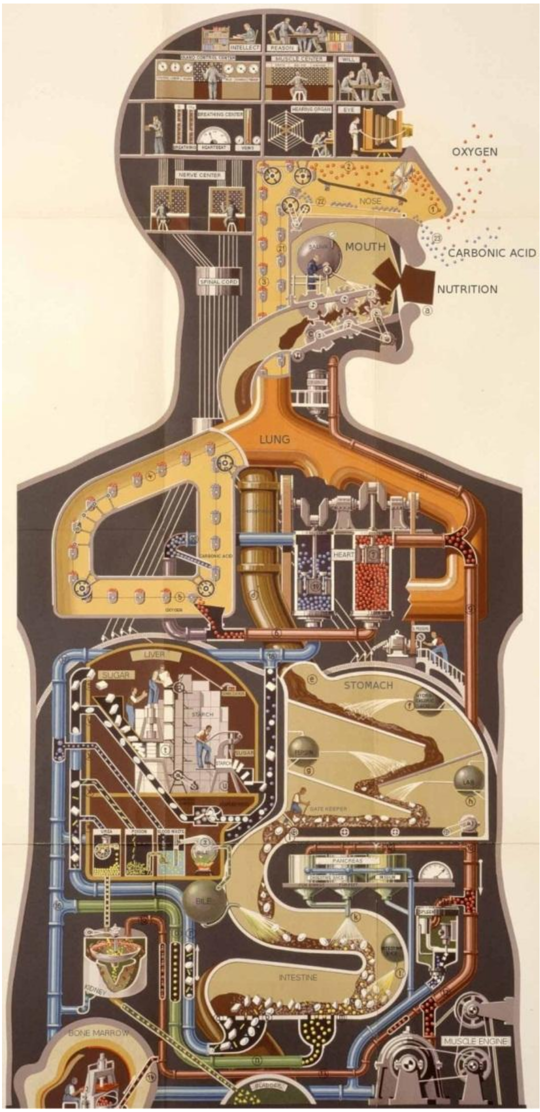
State Incentive Programs





What's a Variable Flow System Application And Why Does This Matter?

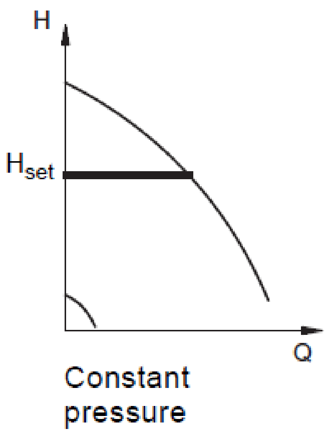
- An HVAC system is like our body
  - Brain = BMS (BAS) system
  - Heart = pump
  - Stomach = boiler or chiller
  - Arteries = piping system
- Working out - system under load
  - Body - heart rate up, increased blood pressure, consumes more energy
  - Building – more BTU's (flow), more head
- Sleeping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

Do your best work.

Integrated VFD with Sensorless Control

Constant Pressure Mode



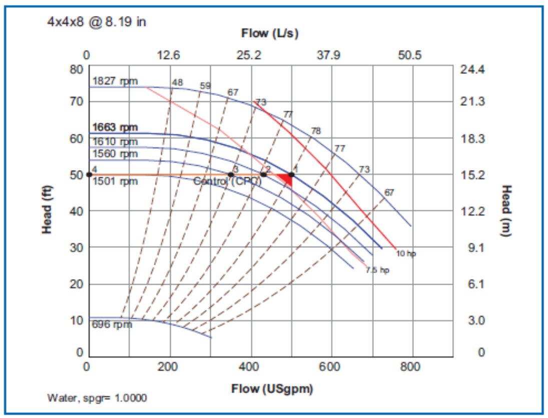
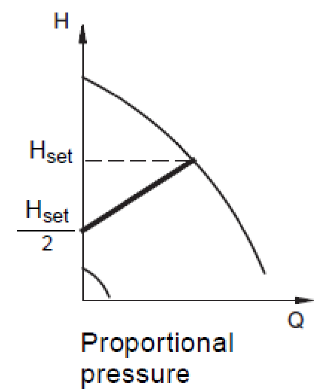


Figure 5 - Constant Pressure Control

Proportional Pressure Mode



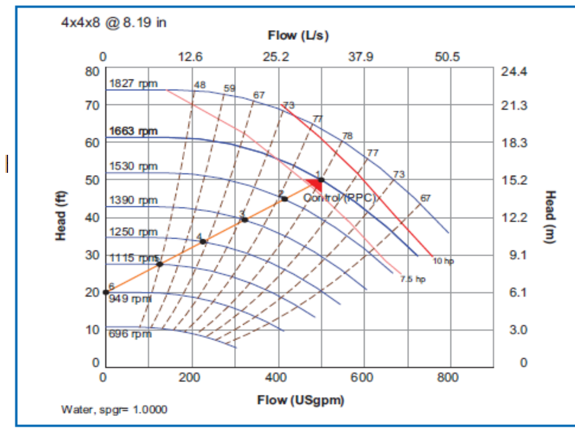


Figure 4 - Proportional Pressure Control

True System Curve Mode

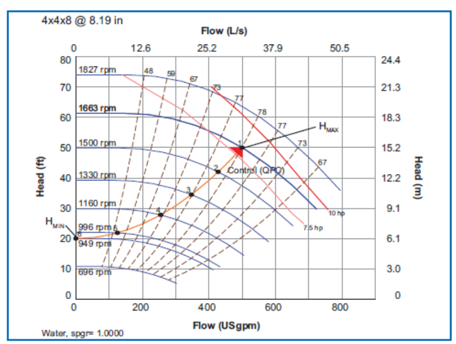


Figure 1 - System Control Curve

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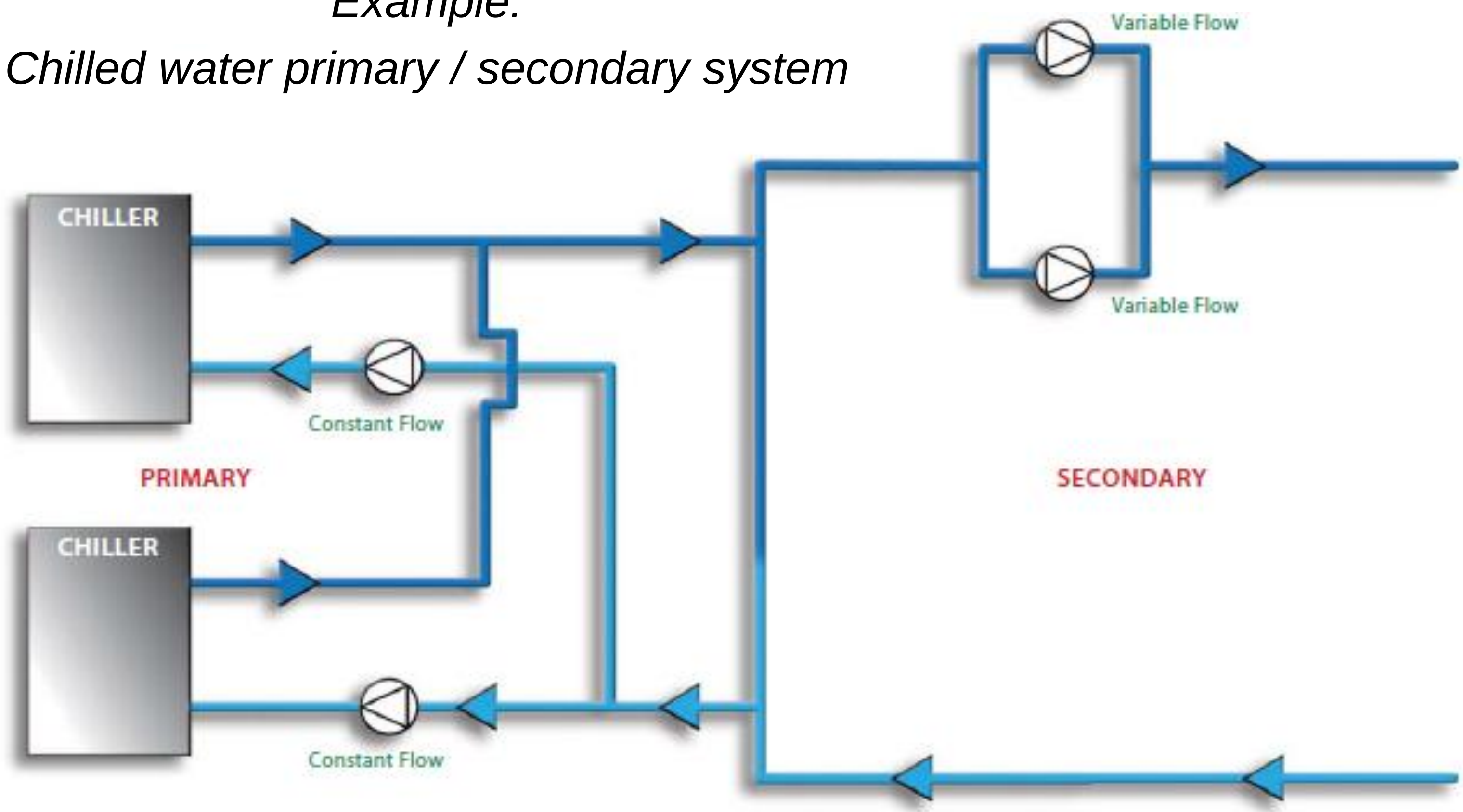
Applications

Example:

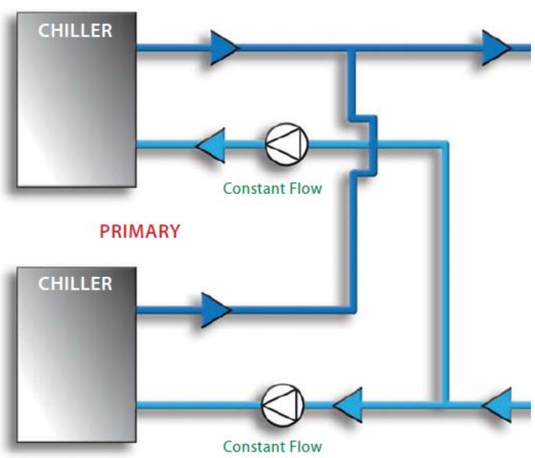
Chilled water primary / secondary system

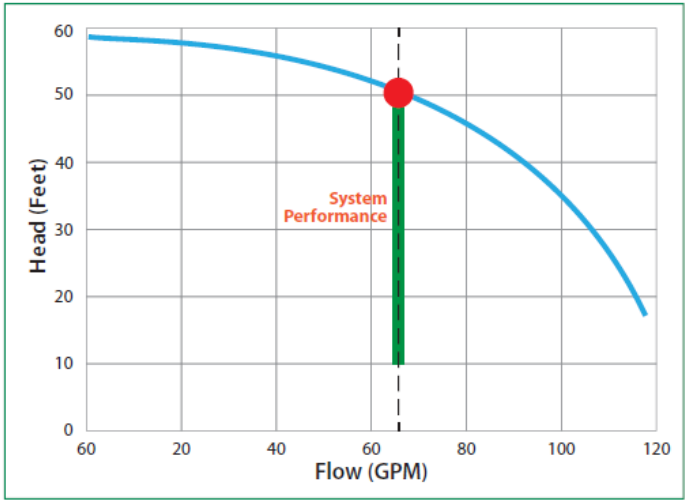


Constant Flow Mode

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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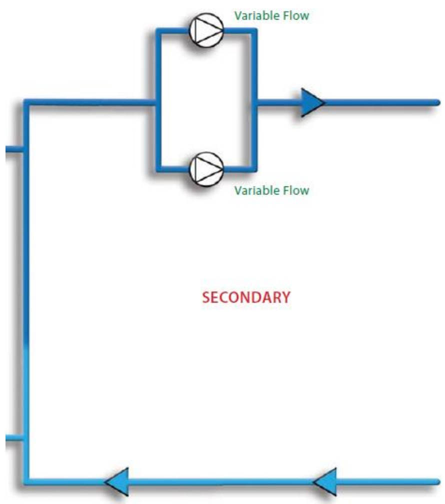
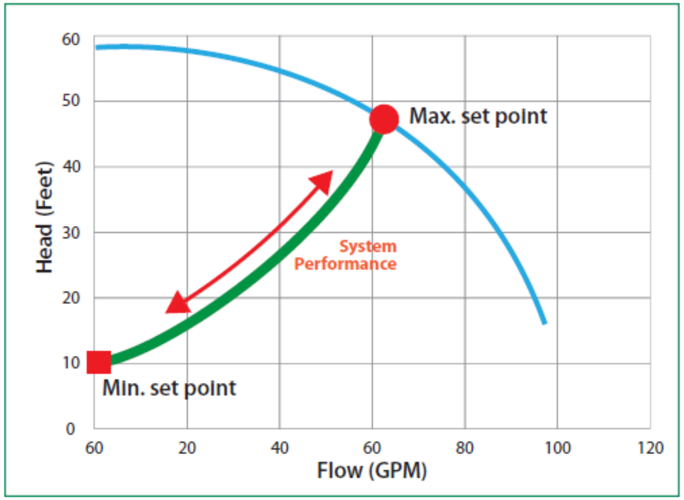
Variable Flow Mode

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

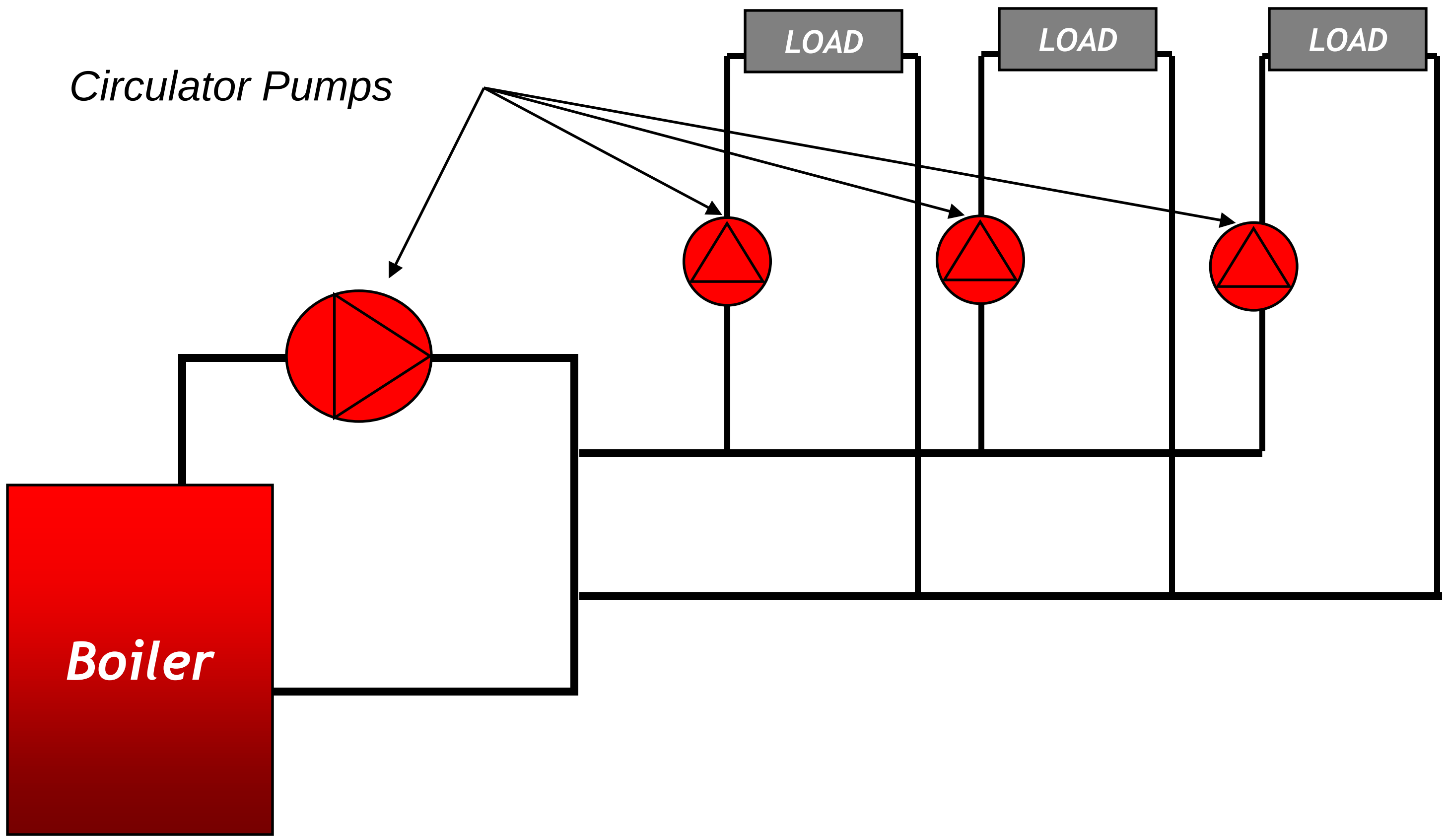




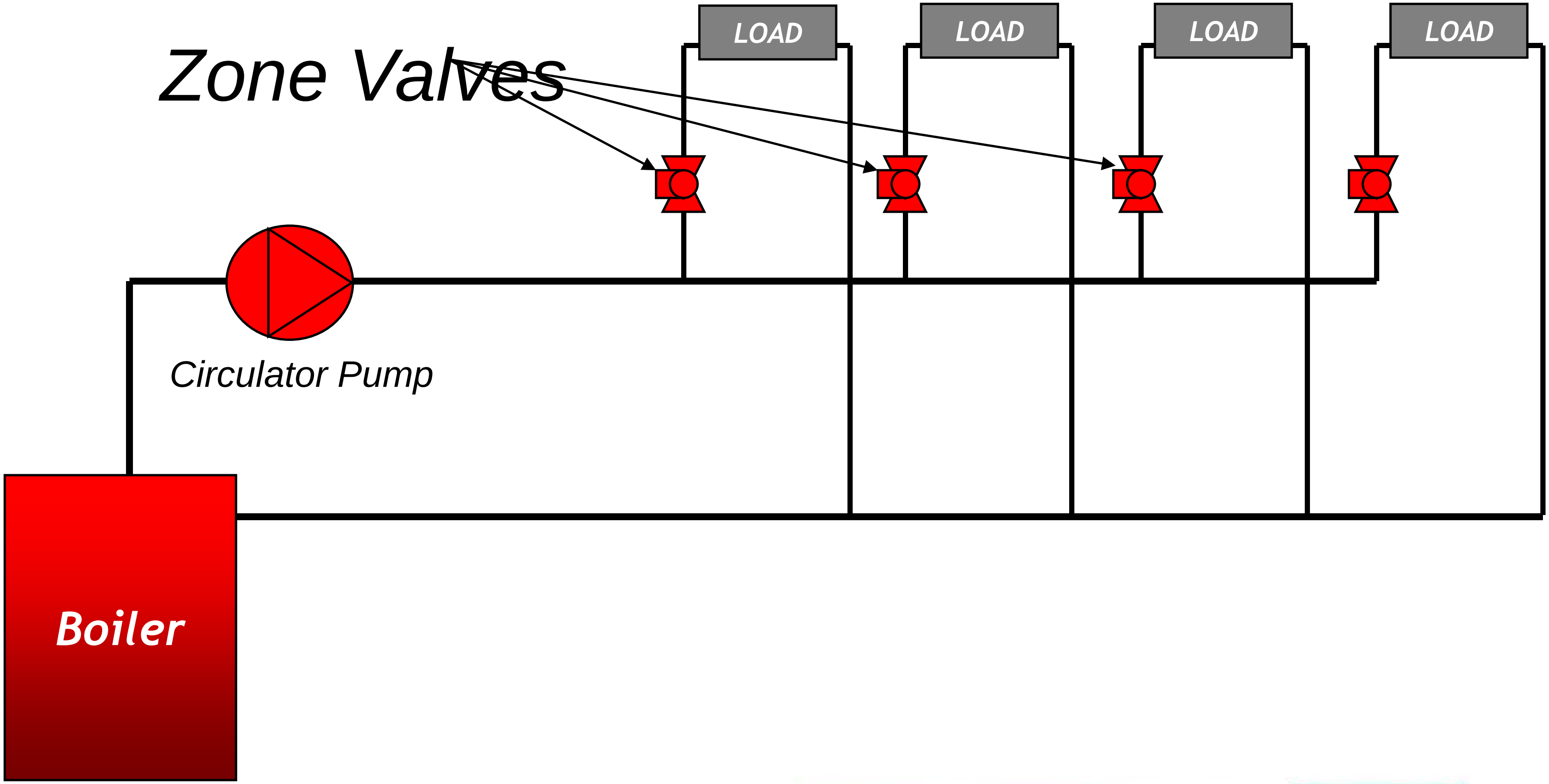
Benefits:

- *Lower install costs*
- *No error in setpoint*
- *Improved system efficiency and performance*
- *Reduced coordination and construction schedule*

Sample of zoning with Circulators



Example of zoning with Zone Valves



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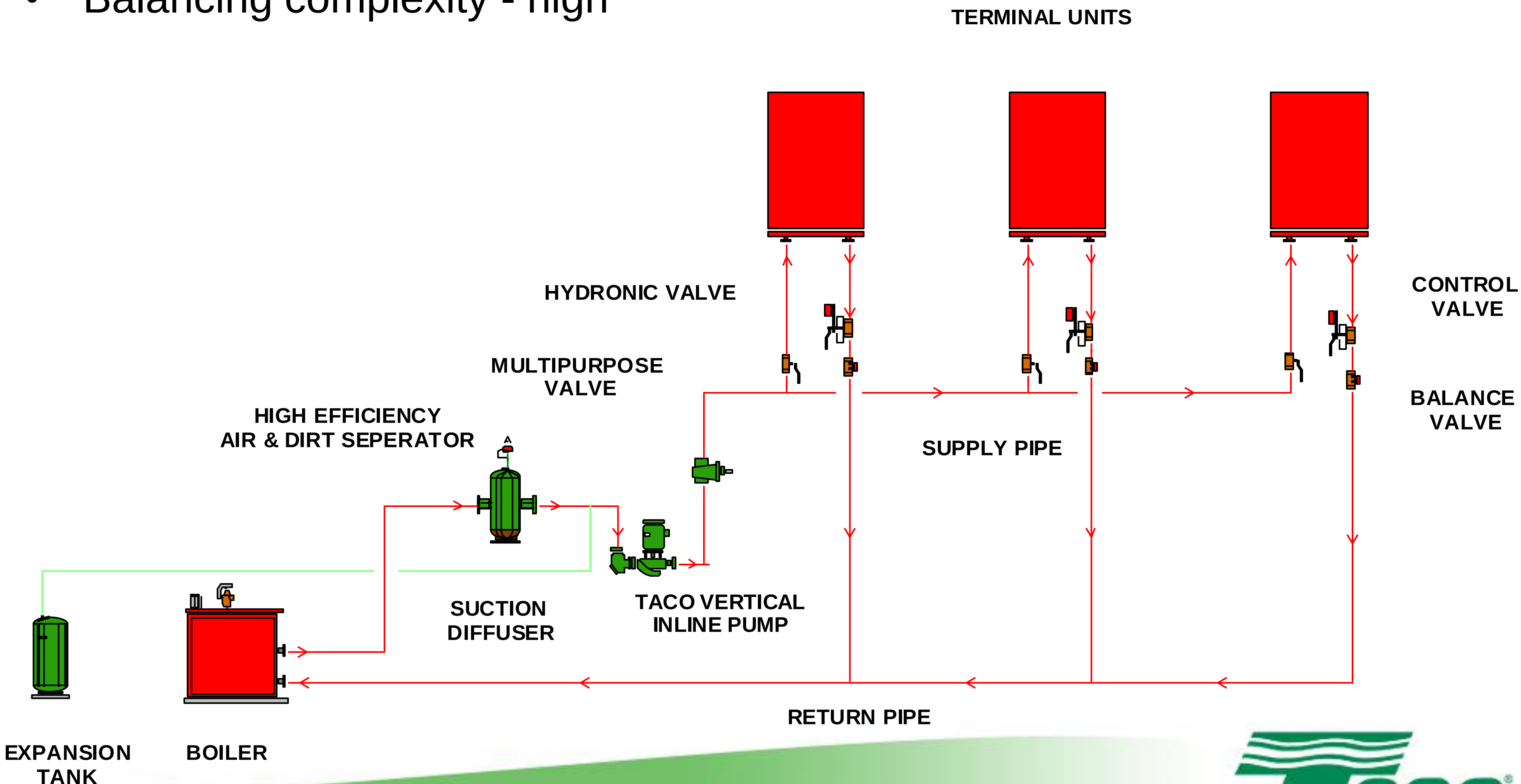
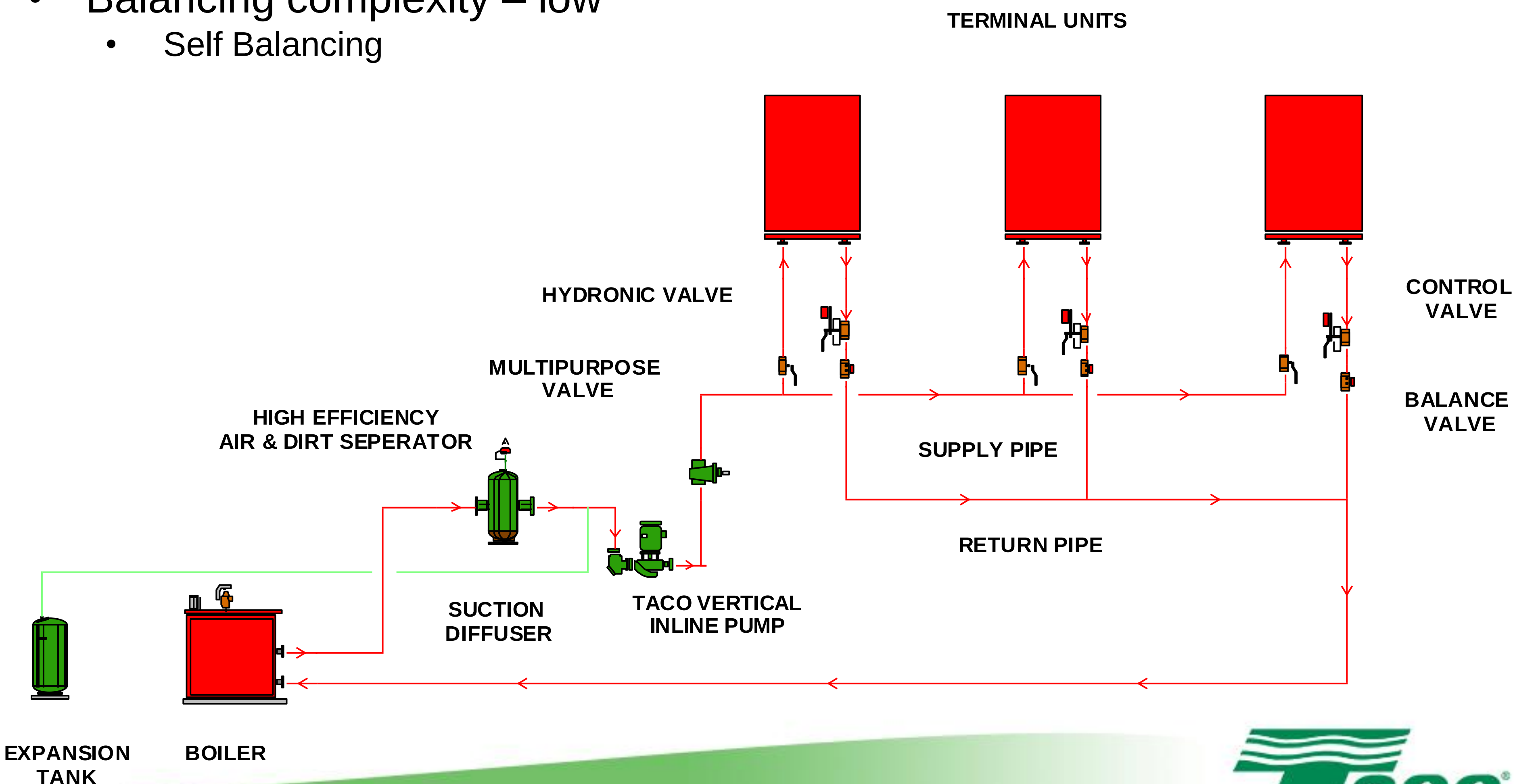
Direct Return Piping System
(first in / first out)

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



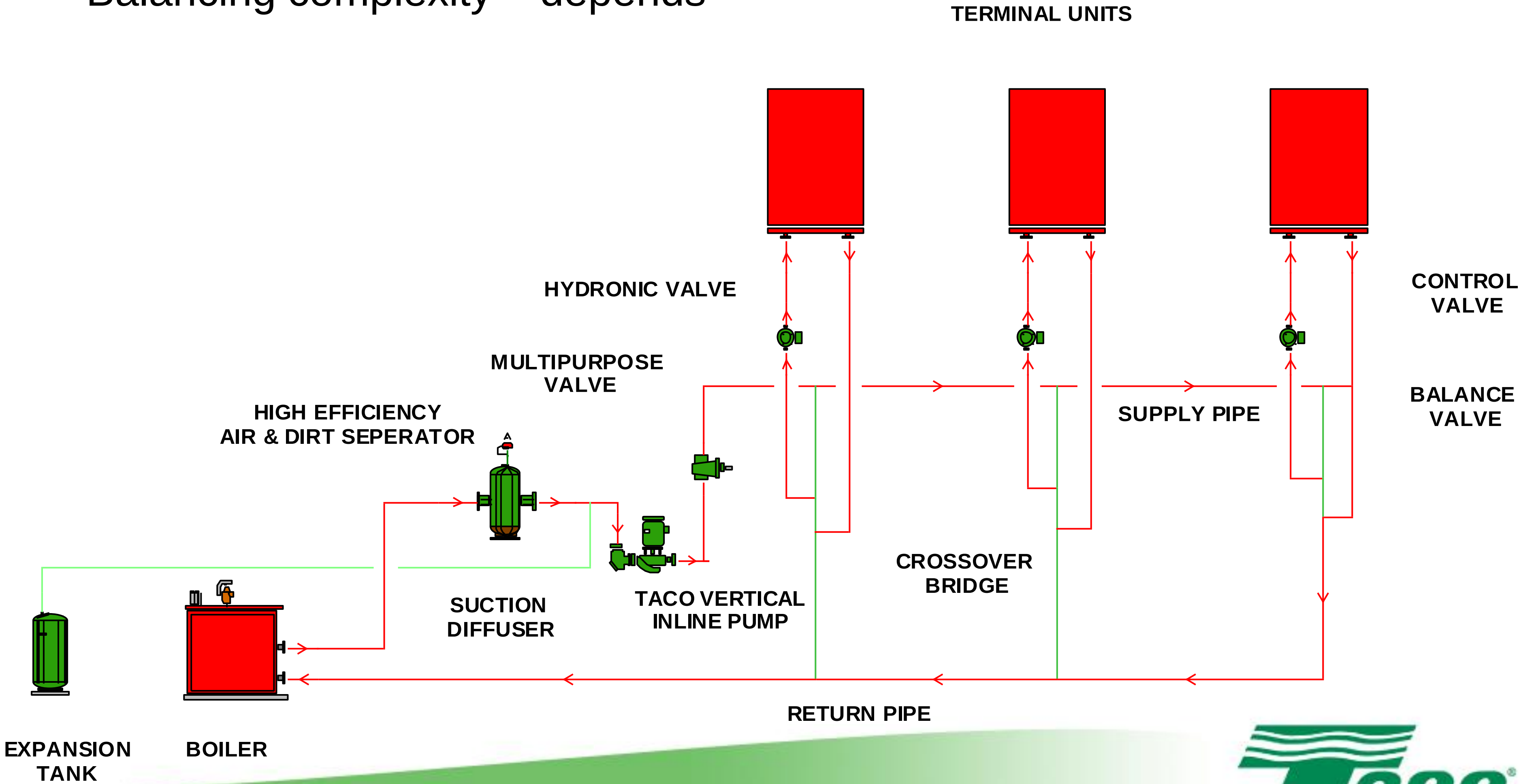
Reverse Return Piping System
(first in / last out)

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



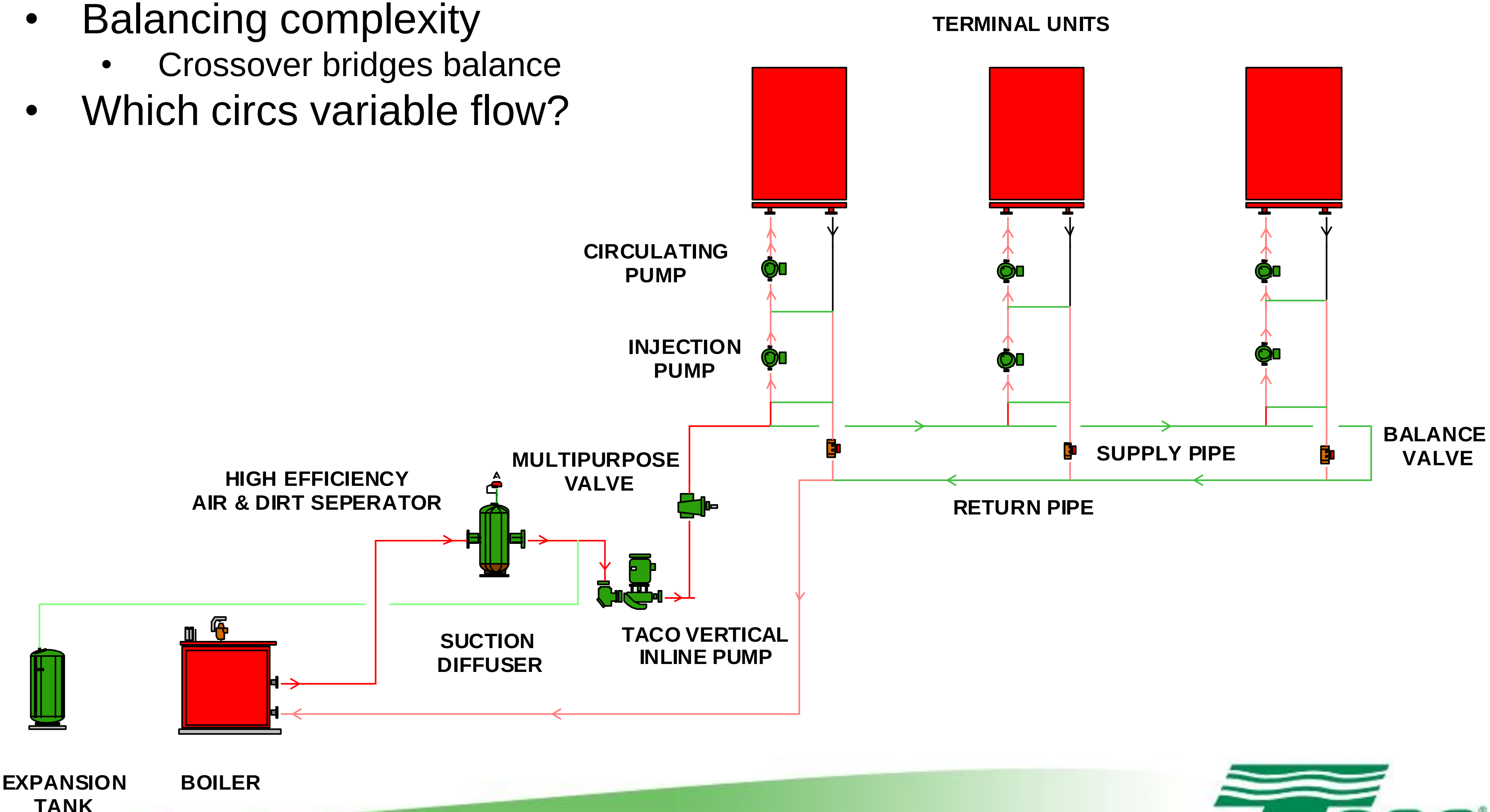
- Variable flow ✓
- Constant flow ✗
- Balancing complexity – depends

Primary Secondary Systems
(pumped secondary)



- Variable flow ✓
- Constant flow ✗
- Balancing complexity
  - Crossover bridges balance
- Which circs variable flow?

Injection Pumping System



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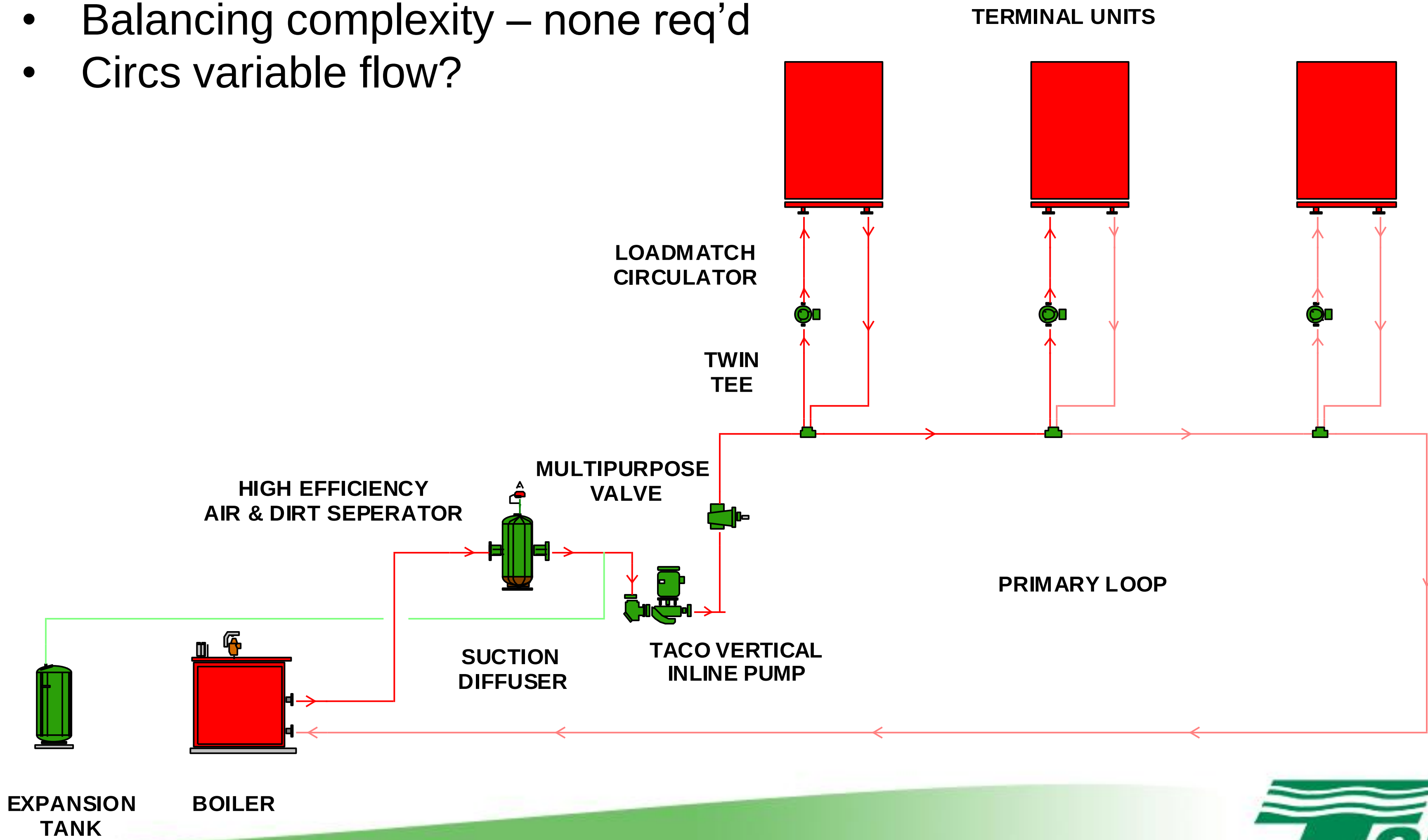
LoadMatch™ Single Pipe Pumping System

- Variable flow ✓
- Constant flow ✗
- Balancing complexity – none req'd
- Circs variable flow?



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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 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

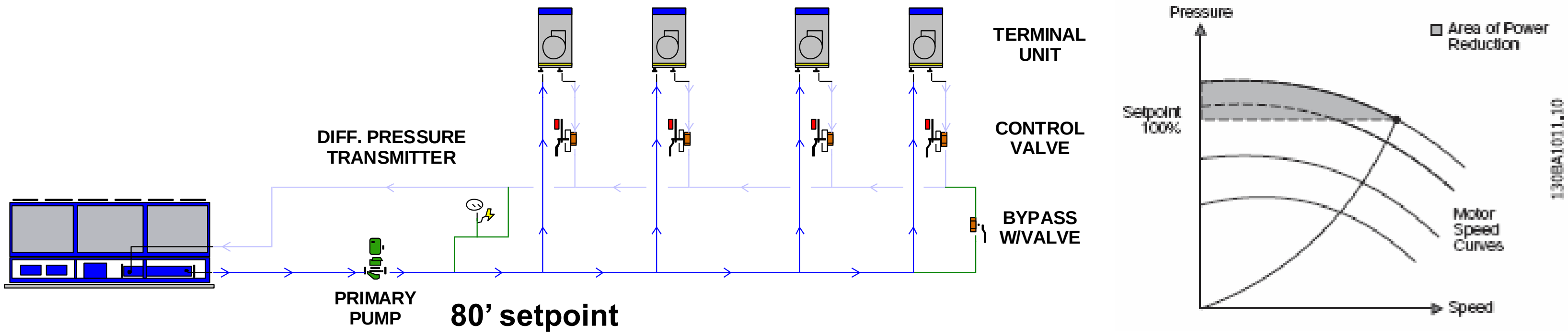
Run VFD’s at constant speed – balance then set pumps to AUTO

SelfSensing vs. Sensors

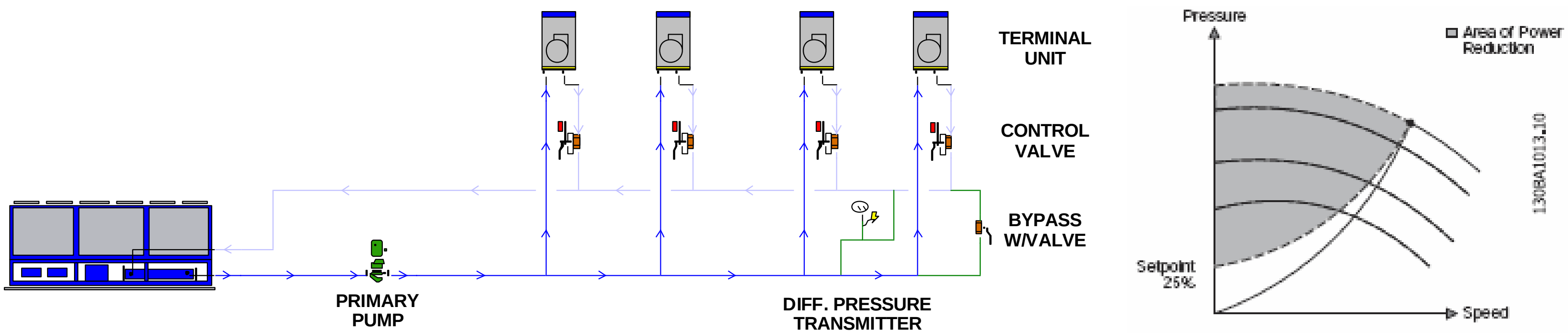
Do your best work.

Location of ΔP Transmitters

<u>Effeciencies are dramatically affected</u>



80' setpoint



17' setpoint

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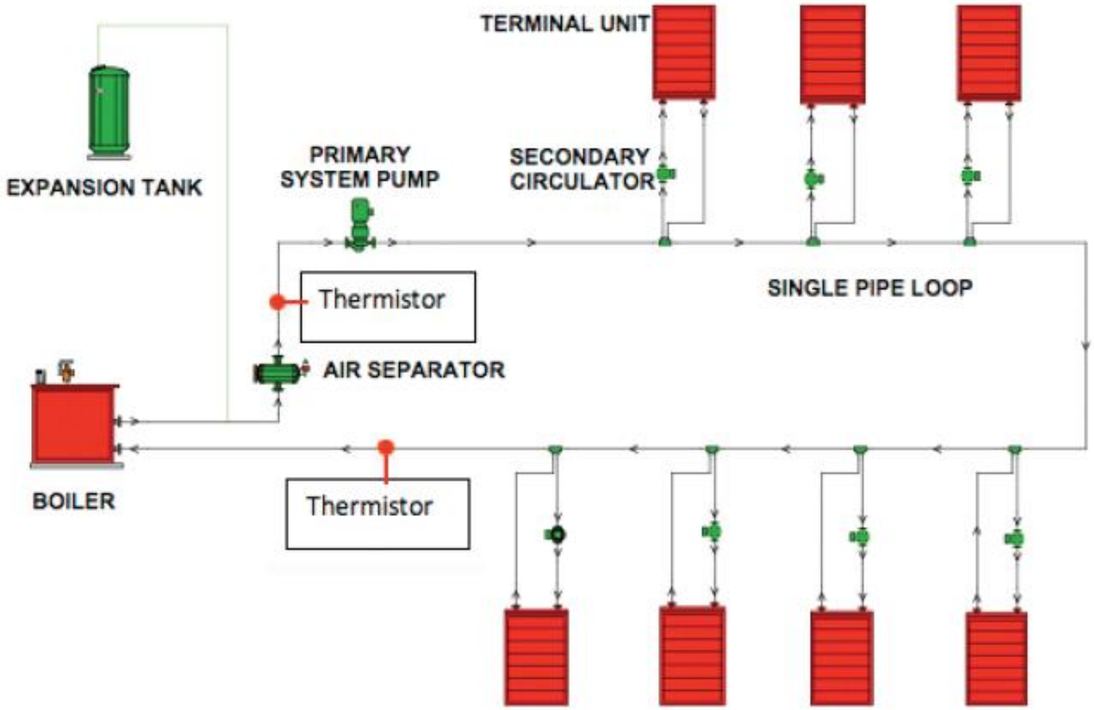
SelfSensing Pumps vs. Sensors

- 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 **BTUH = GPM x ΔT x 500**



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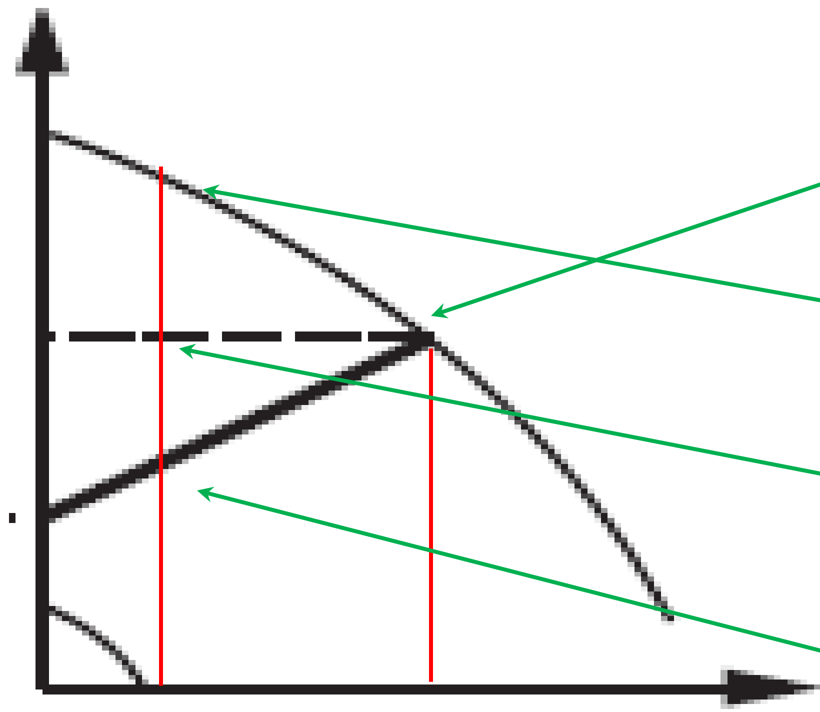
ΔPC vs Constant Speed

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

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



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

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

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

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

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

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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

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

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

"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

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Motor Efficiency – AC Motors

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

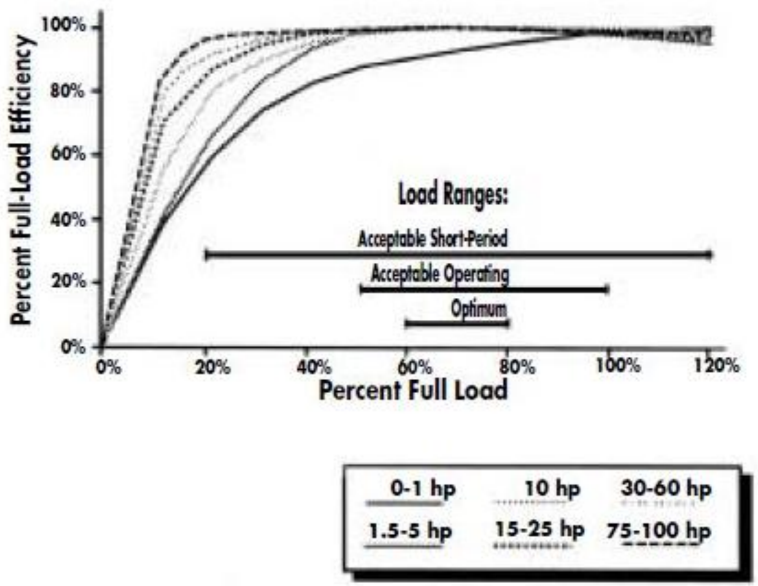
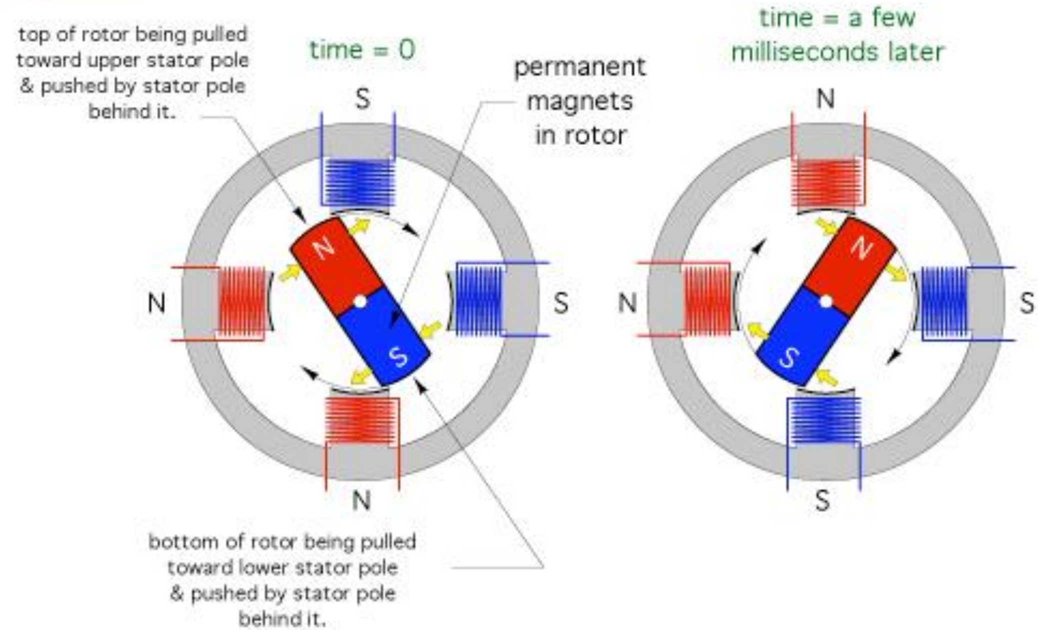


TABLE 10.8A Minimum Nominal Efficiency for General Purpose Design A and Design B Motors Rated 600 Volts or Less[a]

	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

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

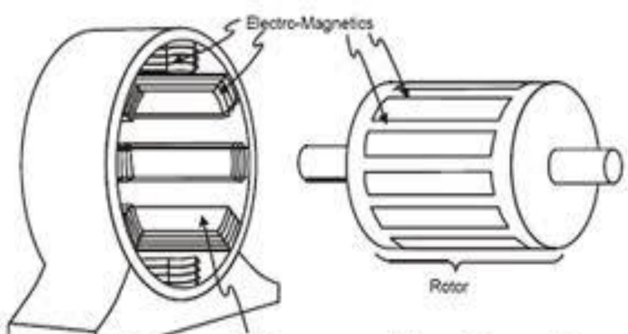
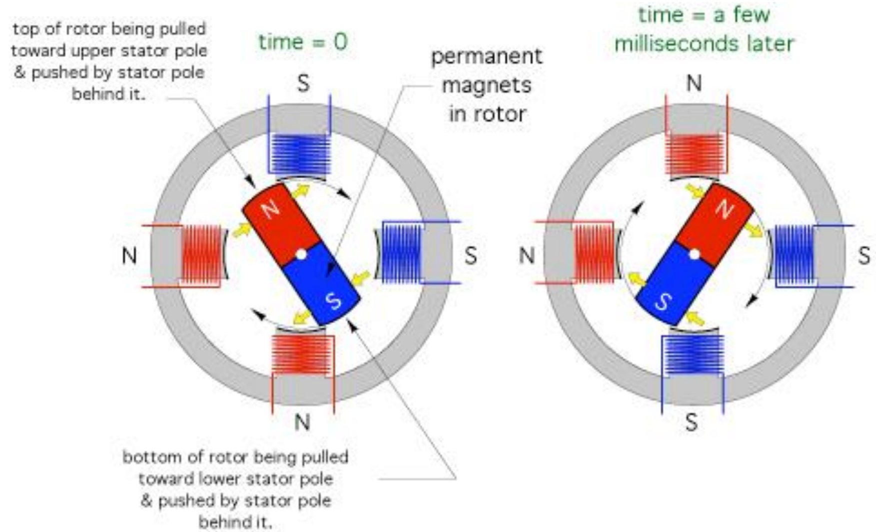


Figure 4: Rotor and Stator

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.



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

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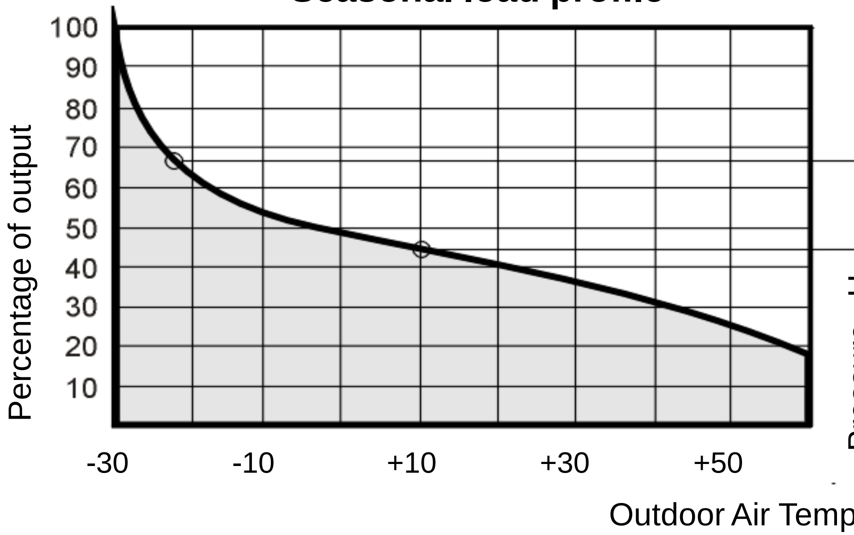
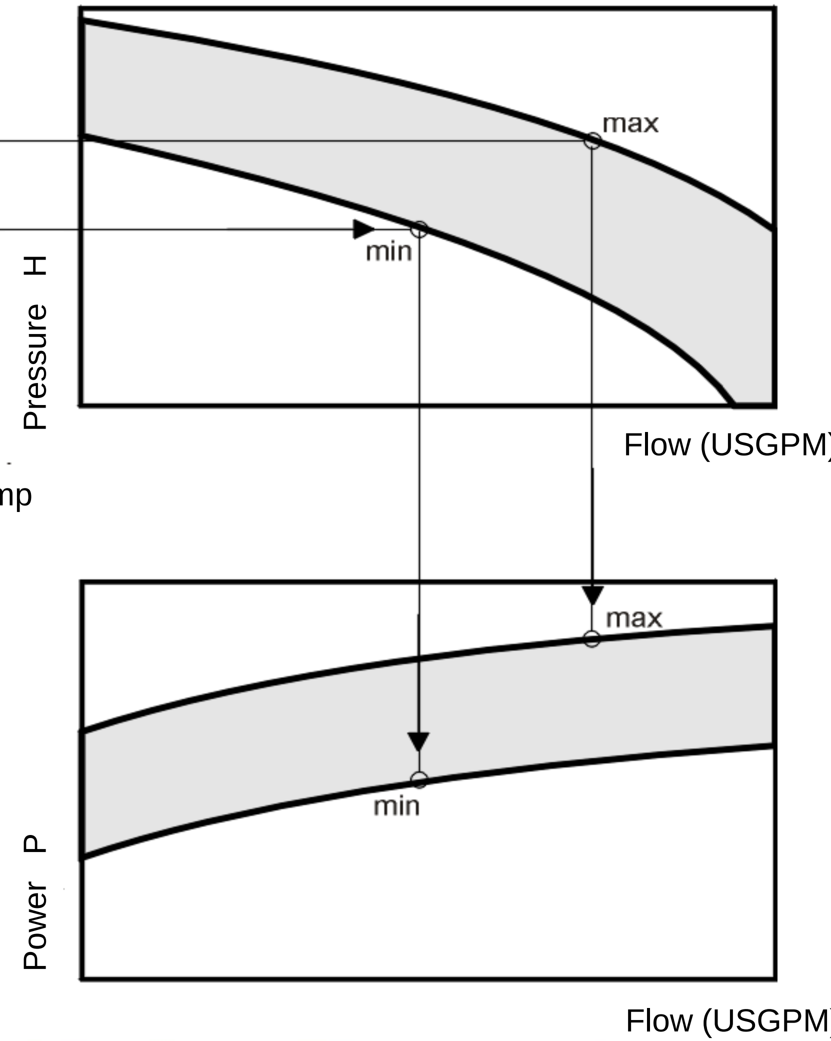
(HVAC systems are DYNAMIC – loads / flows continually change)

Seasonal load profile



Pump load profile



Heating - Pump Operation:

6% time at design load (max)

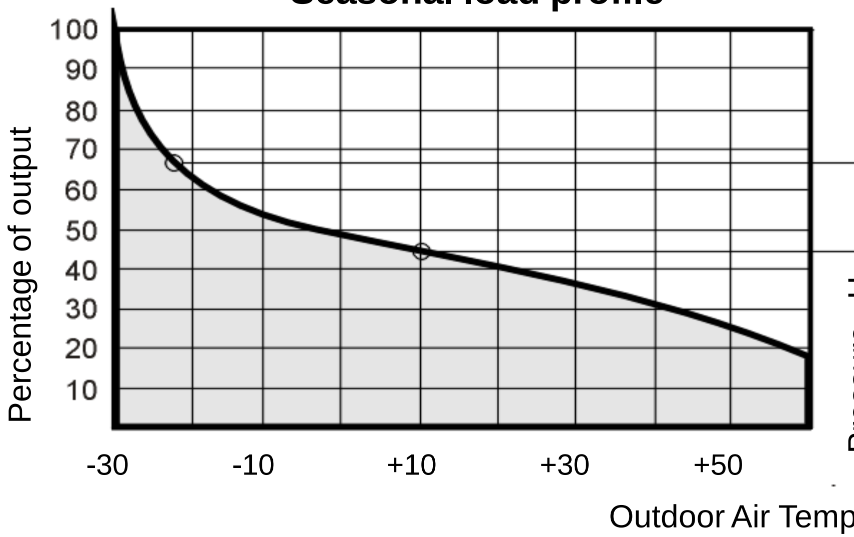
15% time at 75% design load

35% time at 50% design load

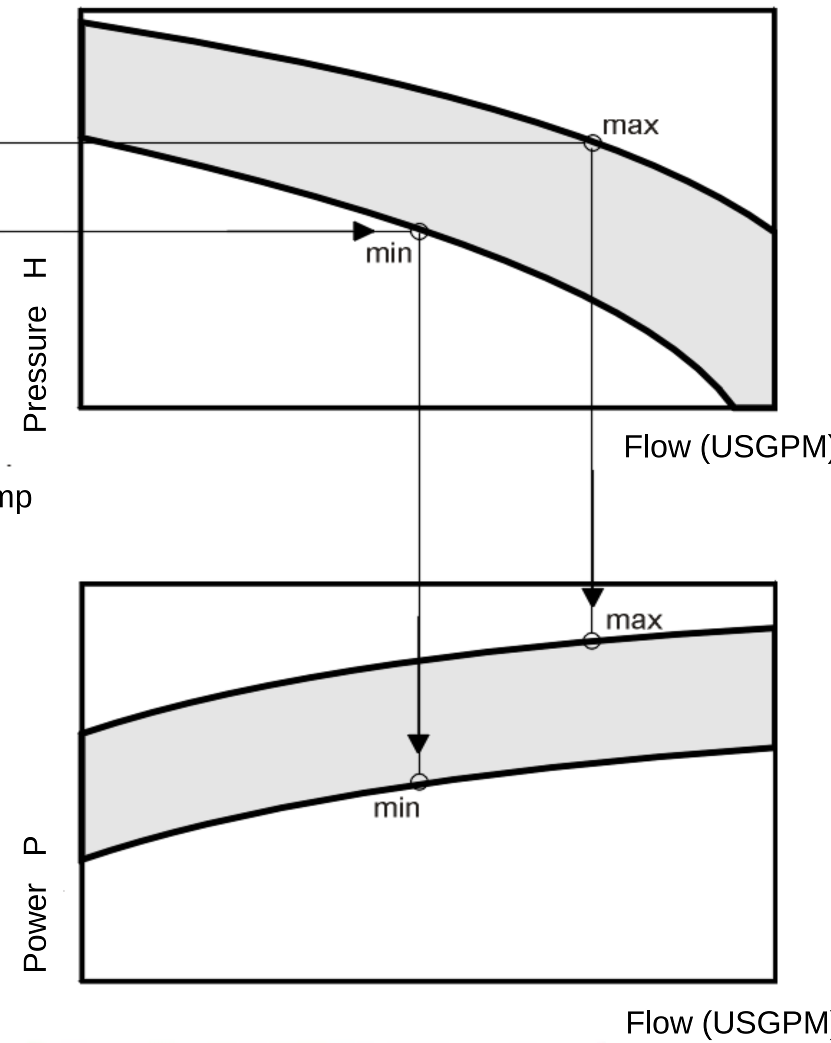
44% time at 25% design load

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

Seasonal load profile



Pump load profile

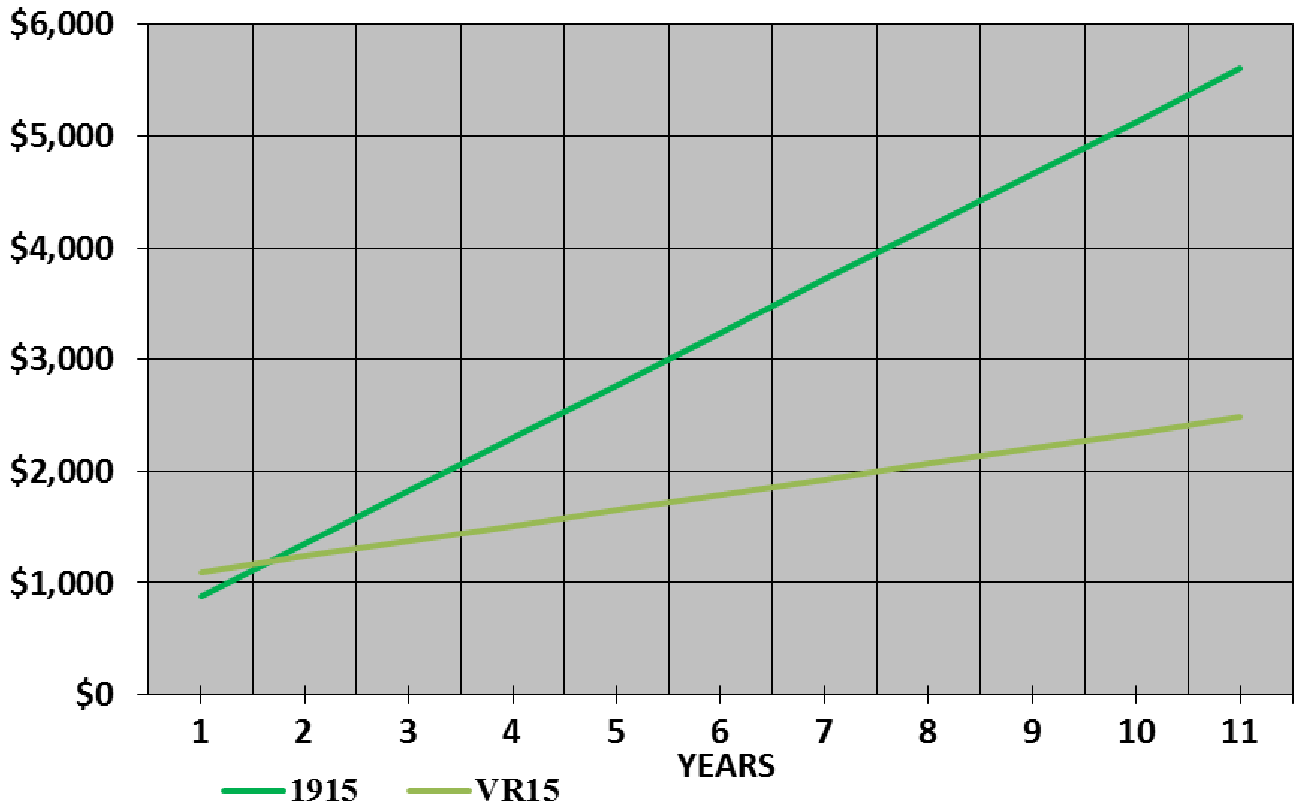


AC Part Load Analysis - ARI Standard

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

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



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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

Variable Speed Pumping

Questions???

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ECM and Self Sensing Technology

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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.