Tennessee Valley Chapter
Region VII CRC
Chattanooga, Tennessee

Selecting Pumps for Ultimate Owner Satisfaction

August, 2018

Selecting Pumps for Ultimate Owner Satisfaction

(Advanced Pumping and Selection)

There is a fundamental shift in the way we design, construct, maintain and operate a building being driven by ASHRAE Standards becoming code, DOE Efficiency Mandates and Hydraulic Institute piping guidelines. The Owners are expecting us to still provide pumping systems that satisfy their demands for the Best LCC Pump Life Expectance, the best System Efficiency Operating Cost and other needs.

This presentation will examine a few of the key design decisions and their impact on the owner's true requirements.

Happy Pumps make Happy Owners

What is Important to Owner Satisfaction

Best First Cost and Life Cycle Cost

Best System Comfort and Operating Cost

Pump Station Piping and Foot Print

Third Party Guidelines Best Practice

ASHRAE HANDBOOK and 90.1

Hydraulic Institute Guide lines

DOE Department of Energy

The Pump Types Per ASHRAE & DOE

ESCC End suction close Couple Single Stage
IL Inline End suction close Couple
ESFM End suction frame mounted on Base Plate
VTS submersible turbine
DSBM Double Suction Base mounted Horizonal or Vertical Split case Single Stage
ILSCDS Inline Split Coupler Double Suction Over hung impeller single stage

ASHRAE Handbook Chapter 44 and DOE (CFR Parts 429 and 431) Energy Conservation Standards for Pumps Compliance required January 27, 2020

The Pump Types Per ASHRAE & DOE

- No one pump type is best for the owner's satisfaction in all applications. A detailed study of piping connections, installed pump piping foot print, LCC pump life, and installed pump station head loss is required.
- First cost is controlled by casing size and single or double suction style pump.

7

Pump Life Expectancy For Life Cycle cost

8

ASHRAE 2015 HANDBOOK

ASHRAE Equipment Life Expectancy chart

ASHRAE is the industry organization that sets the standards and guidelines for most all HVAC-R equipment. For additional info about ASHRAE the website is www.ashrae.org .

Equipment Item	Median Years	Equipment Item	Median Years	Equipment Item	Median Years
Air conditioners		Air terminals		Air-cooled condensers	20
Window unit	10	Diffusers, grilles, and registers	27	Evaporative condensers	20
Residential single or Split		Induction and fan coil units	20	Insulation	
Package	15	VAV and double-duct boxes	20	Molded	20
Commercial through-the wall	15	Air washers	17	Blanket	24
Water-cooled package	15	Ductwork	30	Pumps	
Heat Pumps		Dampers	20	Base-mounted	20
Residential air-to-air	15	Fans		Pipe-mounted	10
Commercial air-to-air	15			Sump and well	10
Commercial water-to-air	19				

Typical Pump Lifetimes By DOE

DOE defines "equipment lifetime" as the age when a pump is retired from service. DOE consulted with market experts to establish typical pump lifetimes by class of equipment. The average life time by equipment class as published by DOE is:

ESCC 1800 13 years
ESCC 3600 11 years
IL 1800. 16 years
IL 3600. 13 years
ESFM 1800 23 years
ESFM 3600 20 years
VTS 3600. 11 years

ESCC End suction close Couple
IL inline
ESFM End suction frame mounted
VTS submersible turbine

Allowable Vibration and Pump Life

ANSI/HI 9.6.4-2000

Hydraulic Institute 9.6.4-2000
10 hp to 100 hp

End Suction Foot Mounted Single Stage	.125 to .175 in/sec rms unfiltered
Vertical-Inline Separately Coupled	.125 to .175 in/sec rms unfiltered
Between Bearing Horizontal Split Case	.125 to .200 in/sec rms unfiltered

Between Bearings HSC Double Suction Can Tolerate More Vibration
These Vibration Values are to be used as a general owner acceptance guide.

HI 2009 Changes all to the same

11

What is Important to Owner Satisfaction

Best First Cost and Life Cycle Cost

Best System Comfort and Operating Cost

Pump Station Piping and Foot Print

12

- **Basic Pump Affinity Laws**
- Pump Head Loss Calculations
  1. ASHRAE 90.1-2010 & 90.1-2013
  2. Open Versus Close Systems
  3. Constant Fixed and Variable Head
- Pump Curve Review

13

Brake Horsepower

Brake Horsepower (Bhp) = the power required for pumps to circulate water through a hydronic system

For water:

$$Bhp = \frac{GPM \times \Delta h}{3960 \times E_p}$$

14

Pump Affinity Laws

VFD - Speed Change

$$GPM_2 = GPM_1 \times \left(\frac{N_2}{N_1}\right)$$

$$h_2 = h_1 \times \left(\frac{N_2}{N_1}\right)^2$$

$$bhp_2 = bhp_1 \times \left(\frac{N_2}{N_1}\right)^3$$

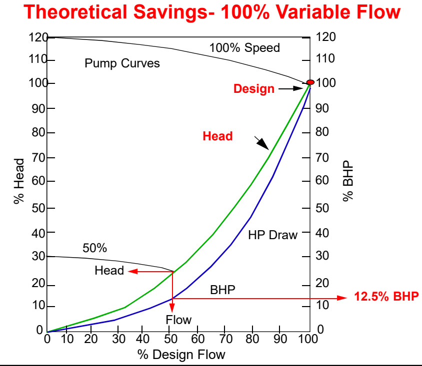
Impeller Diameter Change

$$GPM_2 = GPM_1 \times \left(\frac{D_2}{D_1}\right)$$

$$h_2 = h_1 \times \left(\frac{D_2}{D_1}\right)^2$$

$$bhp_2 = bhp_1 \times \left(\frac{D_2}{D_1}\right)^3$$

Theoretical Savings- 100% Variable Flow

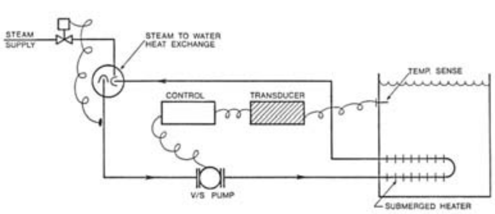


16

"100% Variable Head Loss"

12.5% BHP in theory at 50% flow

Only when no control valves



Extremely hard to find in the real world

17

- Basic Pump Affinity Laws
- Pump Head Loss Calculations
  1. ASHRAE 90.1-2013
  2. Open Versus Close Systems
  3. Constant Fixed and Variable Head
- Pump Curve Review

18

Current ASHRAE 90.1 Code Adoptions

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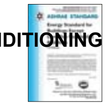
CHAPTER 6

HEATING, VENTILATING, AND AIR CONDITIONING



SECTION 6.4

Mandatory Provisions

6.4.2 Calculations.

6.4.2.1 Load Calculations. Heating and cooling system design loads for the purpose of sizing systems and equipment shall be determined in accordance with ANSI/ASHRAE/ACCA Standard 183-2007, Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings.

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.**

20

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- Basic Pump Affinity Laws
- Pump Head Loss Calculations
  1. ASHRAE 90.1-2010 & 90.1-2013
  2. **Constant Fixed** and **Variable Head**
- Pump Curve Review

21

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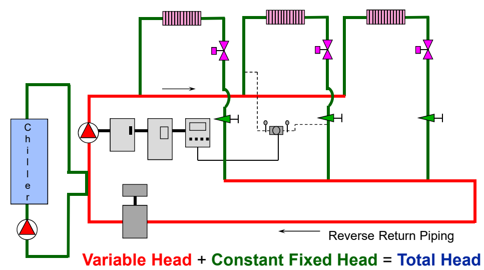
Pump Head Calculation



Variable Head + **Constant Fixed Head** = **Total Head**

52 ft + **28** ft = **80** ft

22

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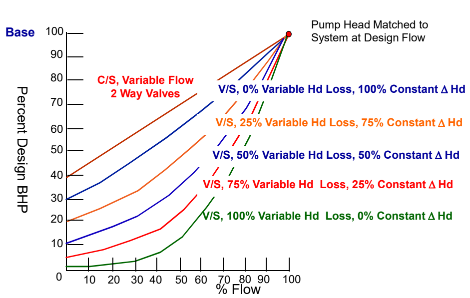
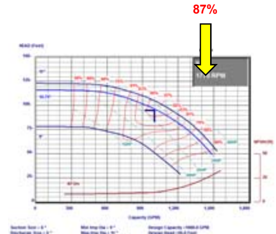
Variable Head Loss Ratio



23

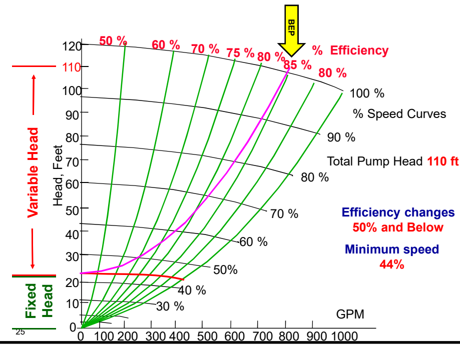
Pump Curve Review



- Plots head (feet) vs. Flow (Gallons Per Minute) for a pump.
- Should include the following information to be considered complete:
  - Pump Name, size and speed
  - Performance curve including impeller diameter
  - Efficiency curve
  - Brake Horsepower
  - NPSHr often included

BEP = **Pump Best Efficiency Point**

Real World V/S Curves



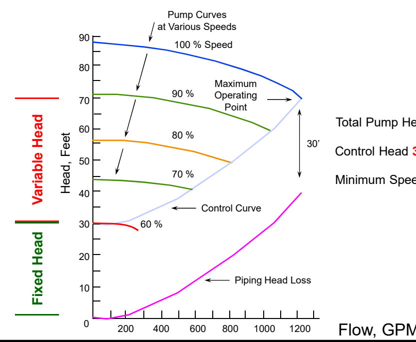
25

- System Curve Review
  1. Constant Fixed Head and Variable Head
  2. Constant Volume and Variable Volume
  3. Pump Selection Guidelines ASHRAE
  4. Efficiency Islands and Load Profiles
- Pump Selection Examples
  1. Condenser Water Pump Selection and BEP with VSD
  2. Variable Volume Pump Sections and Efficiency Islands
     - Energy Savings Old Versus New Pumps

26

What happens to **minimum pump speed** as you **increase minimum control head, fixed head, or differential pressure set point**?

27

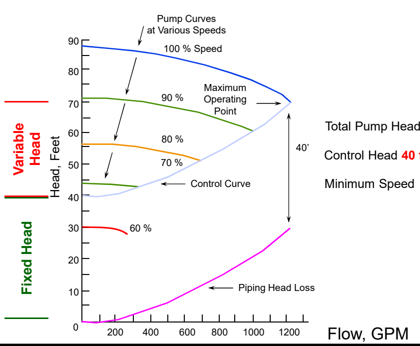


Total Pump Head 70 ft

Control Head **30 ft**

Minimum Speed **60%**

28

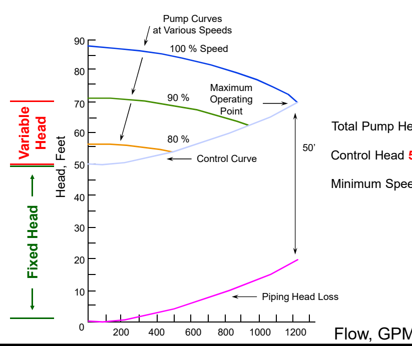


Total Pump Head 70 ft

Control Head **40 ft**

Minimum Speed **67%**

29



Total Pump Head 70 ft

Control Head **50 ft**

Minimum Speed **75%**

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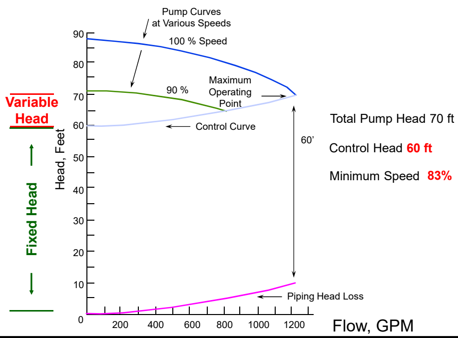
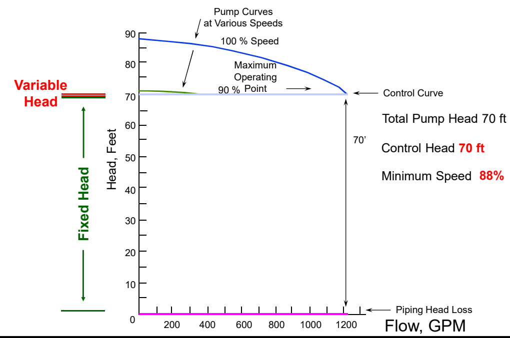


31



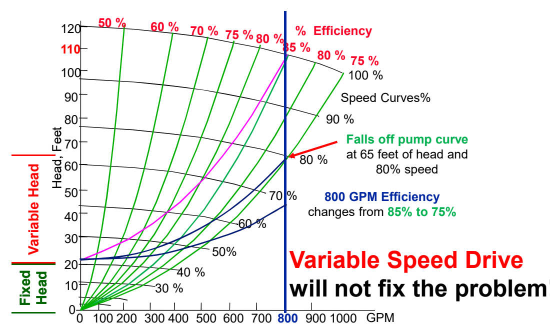
32

Possible Consequences of Oversizing Critical Circuit

What can happen to **VFD pump flow & efficiency at 100% flow** when you <u>over head</u> a pump and actual operating design point is <u>far right of BEP</u> ?

33

Real World V/S Curves



Variable Speed Drive will not fix the problem!

34

Real World V/S Curve Owner Problem

Large University Chilled Water Plant Condenser Water Pumps

Specified Right of BEP at 3,000 gpm at 100 ft head and 89% Efficient with 100 HP VFDs to allow Balancing.

Actual pump head required was 60 ft and VFD will not fix Pump Cavitating and falling Off the Pump Curve at 75 ft hd at reduced rpm.

Owner hired another Consulting Engineer to explain why the pump discharged balance valves were throttled with the VFDs ?

Minimum Wasted Energy is $16,500 per year for ever! Who pays?

The owner paid for 100 HP pumps and 100 HP VFDs. Smaller 60 HP Pumps and 60 HP VFDs will work fine! Who pays?

<u>Owners are getting Smarter</u>

35

- Control Curve Review
  1. Fixed Head and Variable Head
  2. Constant Volume and Variable Volume
  3. Pump Selection Guidelines ASHRAE
  4. Efficiency Islands and Load Profiles
- Pump Selection Examples
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36

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ASHRAE Recommendation

"selection limits of **66% to 115% of flow** at the BEP are suggested"

"Where possible, pumps should be chosen to operate to the **left of the BEP** because the pressure in the actual system may be less than design due to overstated data for pipe friction and for other equipment. Otherwise, the pump operates at a higher flow and **possibly in the turbulent region**."

-- 2016 ASHRAE Systems and Equipment Handbook, p 44.11

37

Should we consider selecting pumps at full design flow to the right of BEP to maximize variable flow system efficiency?

(**Must have accurate pump head calculations**)

(**Do Not Overhead**)

Two 50% parallel selected pumps may have a higher system efficiency and provide 75% plus standby

Pump Efficiency is the highest at the maximum size impeller Diameter and reduced rpm using VFD kw limiting. Caution if You need constant motor speed standby limit the impeller size To be non-over loading at synchronous speed. Check motor torque.

As the load changes, control valves change the system curve and the operating point moves to a new point on the pump curve

- 2016 ASHRAE Systems and Equipment Handbook, p 44.11

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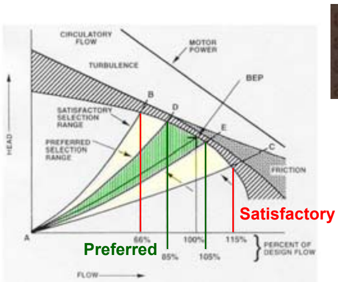

Fig. 35 Pump Selection Regions

2016 ASHRAE Systems and Equipment Handbook, p 44.11

"selection limits of **66% to 115% of flow** at the BEP are suggested"

60

AHRI Air-Conditioning, Heating, and Refrigeration Institute

AHRI 550/590 Standard
IPLV Load Profile

AHRI CERTIFIED® www.ahridirectory.org

ASHRAE

AHRI 550/590-2015 Standard

"IPLV" Chiller Efficiency

(Integrated Part Load Value)

IPLV Formula Weighting Factors & Condenser Water Temperatures				
Chiller Load	Weighting	Condenser Temp °F	kw/Ton	Run Point
100%	1%	85		A
75%	42%	75		B
50%	45%	65		C
25%	12%	65		D

$$\text{IPLV} = \frac{1}{\frac{1\%}{A}+\frac{42\%}{B}+\frac{45\%}{C}+\frac{12\%}{D}}$$

expressed in Kw/ton

Note: Lower Condenser Water Temperature at Part Load

23

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AHRI 550/590 Standard

"IPLV" Pump Efficiency - Load Profile

(Integrated Part Load Value)

Based on **30% constant fixed head**

IPLV Formula Weighting Factors & Water Pump Flow Rates						
HVAC Load	Weighting	Pump Flow Rate	Pump kw	Run Point	Pump Efficiency	Operating Hours
100%	1%	100%		A		
75%	42%	75%		B		
50%	45%	50%		C		
25%	12%	25%		D		

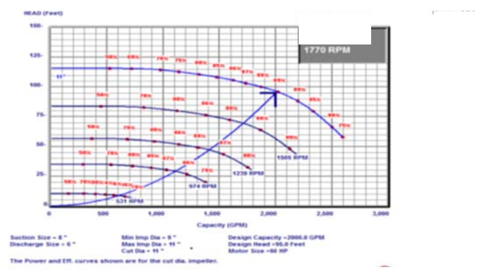
$$\textbf{Pump PLEV} = \frac{1}{\frac{1\%}{A}+\frac{42\%}{B}+\frac{45\%}{C}+\frac{12\%}{D}}$$

expressed in blended efficiency

Note: Assume pump flow rates match % load

42

- System Curve Review
  1. Fixed Head and Variable Head
  2. Constant Volume and Variable Volume
  3. Pump Selection Guidelines ASHRAE
  4. Efficiency Islands and Load Profiles
  5. Pump Annual Operating Cost



"100% Variable Head"

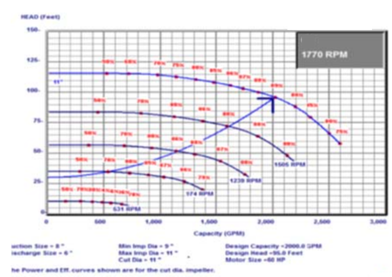
Pump Annual Operating Cost

Load	Hours	Flow GPM	Head Feet	RPM	Pump Eff.	BHP	Drive/ Motor Eff.	kWHR	Cost/day	Wire/Water Eff
25%	2.88	500.0	6.9	466	88.44	0.98	83.25	2.54	$0.25	73.6%
50%	10.80	1,000.0	24.6	891	88.56	7.00	88.51	63.74	$6.37	78.4%
75%	10.08	1,500.0	54.0	1325	88.53	23.11	87.72	198.04	$19.80	77.7%
100%	0.24	2,000.0	95.3	1761	88.52	54.35	86.61	11.23	$1.12	76.7%

Variable Speed Operating Cost	
Total Kilowatt Hours = 100,574.3	Cost per kwhr = $0.10
Total Hours per Year = 8,760	Annual Operating Cost = $10,057.43

PL 5%

"100% Variable Head"



"30 Feet Constant Head"

Pump Annual Operating Cost

Load	Hours	Flow GPM	Head Feet	RPM	Pump Eff.	BHP	Drive/ Motor Eff.	kWHR	Cost/day	Wire/Water Eff
25%	2.88	500.0	34.1	964	68.06	6.32	88.48	15.34	$1.53	60.2%
50%	10.80	1,000.0	46.3	1161	85.70	13.63	88.14	124.55	$12.46	75.5%
75%	10.08	1,500.0	66.6	1439	88.06	28.64	87.43	246.23	$24.62	77.0%
100%	0.24	2,000.0	95.0	1759	88.52	54.23	86.62	11.20	$1.12	76.7%

Variable Speed Operating Cost	
Total Kilowatt Hours = 145,022.1	Cost per kwhr = $0.10
Total Hours per Year = 8,760	Annual Operating Cost = $14,502.21

Pump PLEV = 84.6%

"30 Feet Constant Head"

Who is going to pay the difference

Owners are getting smarter

"100% Variable Head"

Variable Speed Operating Cost	
Total Kilowatt Hours = 100,574.3	Cost per kwhr = $0.10
Total Hours per Year = 8,760	Annual Operating Cost = $10,057.43

Pump PLEV = 88.5%

$ 4,444.78

"30 Feet Constant Head"

Variable Speed Operating Cost	
Total Kilowatt Hours = 145,022.1	Cost per kwhr = $0.10
Total Hours per Year = 8,760	Annual Operating Cost = $14,502.21

Pump PLEV = 84.6%

Variable-Speed Pumping Control Strategies

Outline of Presentation

ASHRAE 90.1 and Variable Speed Pumping
Control Curve and Control Area Review
Variable Speed Curve Control Strategies
- Pump Head Control
- Full System Flow Sensor
- Sensorless

Variable Speed Area Control Strategies
- Remote DP
- Remote DP with valve position reset

Summary

ANSI/ASHRAE/IES Standard 90.1-2013

HEATING, VENTILATING, AND AIR CONDITIONING

SECTION 6.5
Prescriptive Path

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.

51

Outline of Presentation

ASHRAE 90.1 and Variable Speed Pumping
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Variable Speed Area Control Strategies
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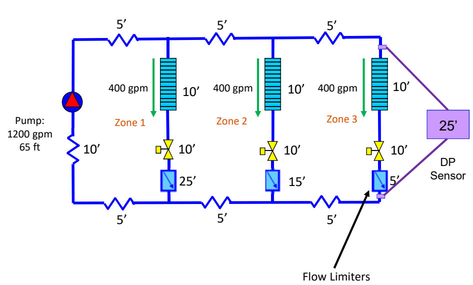
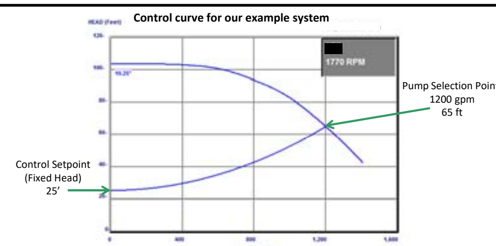
Summary

Our Example System



Control curve for our example system

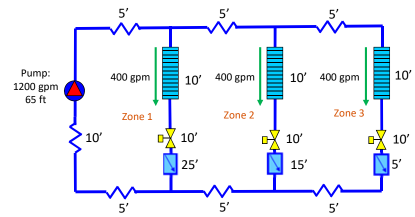


Variable Speed Curve Control **adjusts pump speed to keep the pump operating on the control curve. To do this, the controller must know where the pump is operating on the pump curve. This can be achieved by sensing RPM along with pump flow, pump head, or pump kW.**

*Curve control is based on the **design flow and head** which has a safety factor. ? (which means higher operating costs than necessary if not corrected during commissioning)*

Variable Speed Pumping System Control Area Review

How much pump head does our example system need at 400 gpm?



Answer: It depends on where the load is!

The sun rises in the east and sets in the west. Zone loads will shift with the sun

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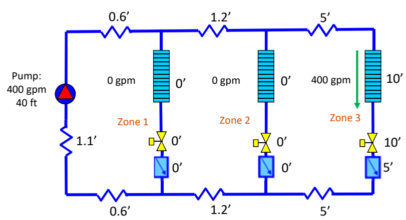

If all 400 gpm is through Zone 3, required pump head is 40 feet

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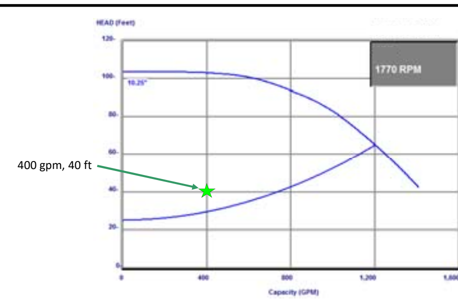
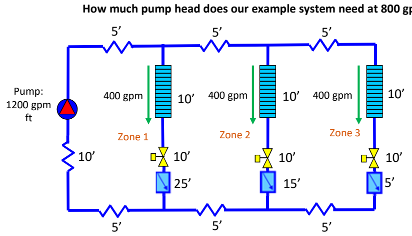


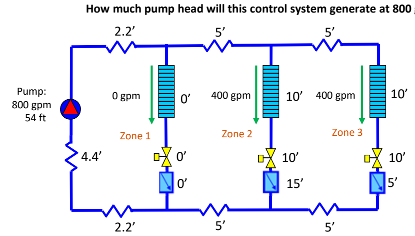
Note that this point is above the control curve. Hydronic systems will need to operate above and below the control curve if exact flow demands are delivered.

How much pump head does our example system need at 800 gpm?

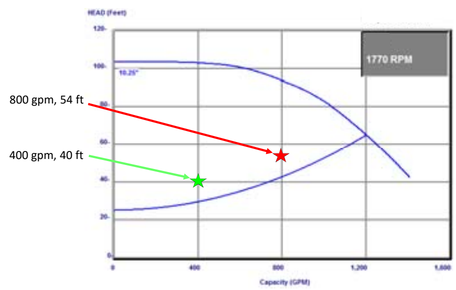


Answer: It depends on where the load is!

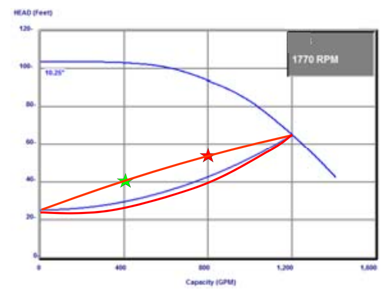
How much pump head will this control system generate at 800 gpm?



With Zones 2 and 3 fully loaded, pump head is 54 feet.

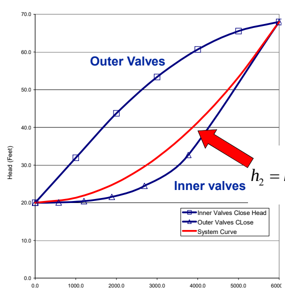


Once again, we are operating above the control curve



We can plot all of these possible operating points and end up with the ***control area***.

The Control Area



2016 ASHRAE Systems and Equipment Handbook, p 13.10

Using typical load profiles we only run at full load and flow one percent of the time.

$$h_2 = h_1\left(\frac{Q_2}{Q_1}\right)^2 + \text{Min Control Head}$$

The single line Quadratic equation used for Sensorless Control

63

Outline of Presentation

ASHRAE 90.1 and Variable Speed Pumping

Control Curve and Control Area Review

Variable Speed Curve Control Strategies

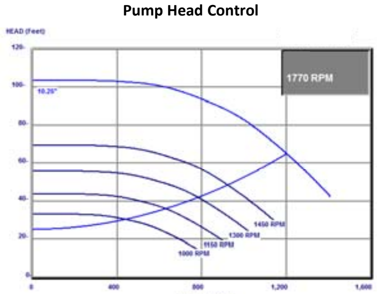
- Pump Head Control
- Full System Flow Sensor
- Sensorless

Variable Speed Area Control Strategies

- Remote DP
- Remote DP with valve position reset

Summary

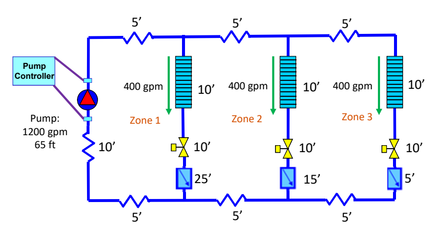
Pump Head Control



There is a unique speed (rpm) for each pump (head) point on the control curve

Variable Speed Curve Control will operate on the fixed control curve

Pump Head Control



- **Works with any drive manufacturer**
- **Works with any pump (as we will see, some pumps are not suitable for sensorless pump control)**

Curve Control Pump Control will operate on the fixed control curve

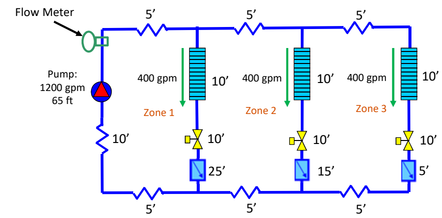
Outline of Presentation

ASHRAE 90.1 and Variable Speed Pumping
Control Curve and Control Area Review
Variable Speed Curve Control Strategies
- Pump Head Control
- Full System Flow Sensor
- Sensorless

Variable Speed Area Control Strategies
- Remote DP
- Remote DP with valve position reset

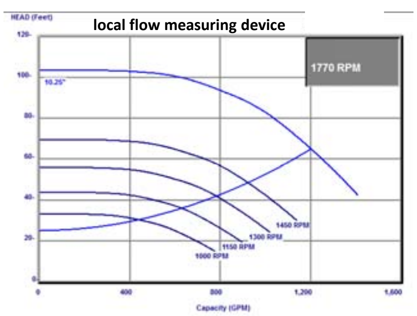
Summary

Variable Speed Curve Control (with local flow measuring device)



- Works with any drive manufacturer
- Works with any pump (as we will see, some pumps are not suitable for sensorless pump control)

local flow measuring device



There is a unique (rpm) speed for each pump (flow) point on the control curve

Outline of Presentation

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Variable Speed Area Control Strategies
- Remote DP
- Remote DP with valve position reset

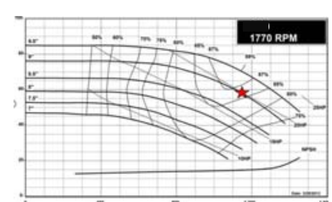
Summary

Sensorless Pumping
(Curve Control)



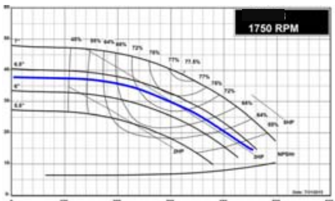
Sensorless pumping continuously does the following:
1. Flow calculation **(from RPM and HP)**
2. Uses this calculated flow to set the new RPM based on the control curve


Sensorless Flow Calculations



With 9" impeller, at 1770 RPM and 20 HP (both read from the VFD), what is our flow?

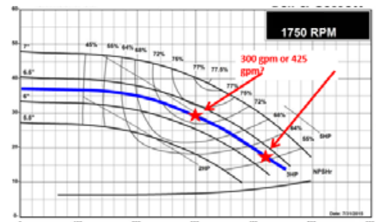
Sensorless Flow Calculations



With 6.25" impeller, at 1750 RPM and 3 HP (both read from the VFD), what is our flow?

This pump isn't suitable for sensorless pumping in certain flow ranges

Sensorless Flow Calculations

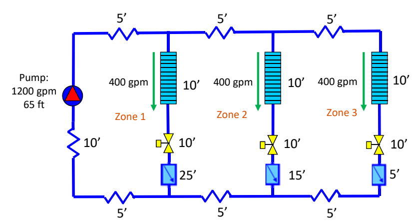


With 6.25" impeller, at 1750 RPM and 3 HP (both read from the VFD), what is our flow?

This pump isn't suitable for sensorless pumping in certain flow ranges

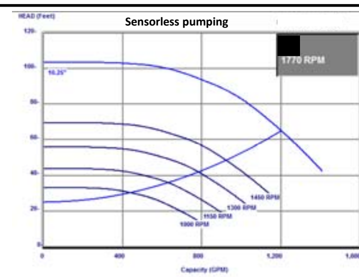
Variable Speed Curve Control (Sensorless)

- **Sensorless control head = 25 ft**
- **No external sensors or wires are needed**
- **Flow limiters are used**



ASHRAE

Sensorless pumping



There is a unique speed for each flow point on the control curve

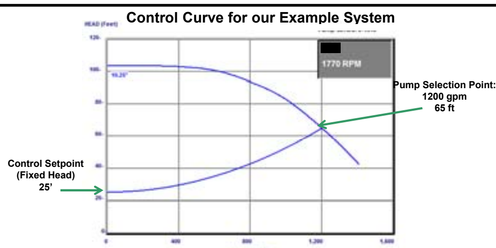
Sensorless pumping continuously does the following:

1. Flow calculation (from RPM and HP)
2. Uses this calculated flow to set the new RPM based on the control curve

A sensorless pump operates on the fixed control curve

ASHRAE

Control Curve for our Example System

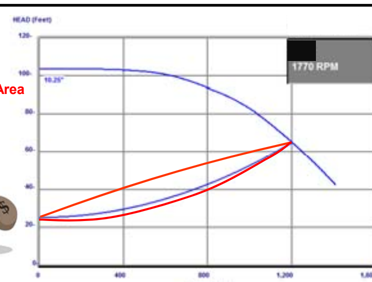


Variable Speed Curve Control adjusts pump speed to keep the _pump operating on the estimated fixed control curve_. To do this, the controller must know where the pump is operating on the pump curve. This can be achieved by sensing RPM along with pump flow, pump head, or pump kW.

*Curve control is based on the **design flow and head** which has a safety factor. ? (which means higher operating costs than necessary if not corrected during commissioning)*

ASHRAE

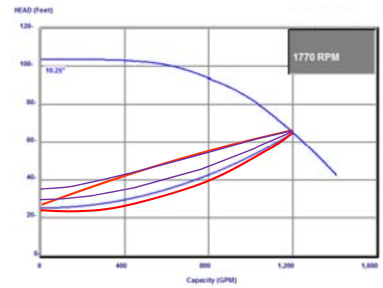
The Control Curve and Area



The control area of our system is shown in red.
Since Curve Control Pump Control operates on the control curve, there will be times when a coil is short of flow. We call this a "miss".

Control Head Creep: The phenomenon of control head increasing in value over months and years in an installed variable-speed pumping system. This can occur when the pump control system underflows coils, causing coil flow "misses".

Someone increases the control head value to fix problems



The control area of our system is shown in red.
Since Curve Control Pump Control operates on the control curve, there will be times when a coil is short of flow. We call this a "miss".

Outline of Presentation

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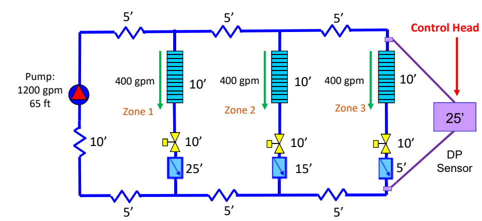
- Sensorless

Variable Speed Area Control Strategies
- Remote DP
- Remote DP with valve position reset

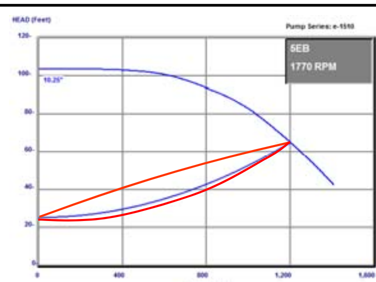
Summary

Sensor with fixed DP setpoint and DP Reset

- *Control head* is 25 ft (*pressure drop of coil, control valve and flow limiter*)
- Pump control maintains the control head across DP sensor at all times



Area Control



Remote DP sensor and DP reset operate within the control area and do not have "misses"

Area Control

ASHRAE'S DEFINITION OF A BALANCED SYSTEM

TERMINOLOGY

Balanced System. A system designed to deliver heat transfer required for occupant comfort or process load at design conditions. A minimum heat transfer of 97% should be provided to the space or load served at design flow. The flow required for minimum heat transfer establishes the system's flow tolerance. The fluid distribution system should be designed to allow flow to maintain the required tolerance and verify its performance.

2015 ASHRAE Handbook, HVAC Applications

ASHRAE RECOMMENDS
10% FLOW TOLERANCE
FOR 140 HOT WATER
FOR 45 CHILLED WATER

SENSORLESS FIXED CURVE CONTROL WILL HAVE MISSES

MR. CREEP IS THE ONLY WAY TO FIX AND ROBS YOUR ENERGY SAVINGS

AREA CONTROL REDUCES MISSES AND SAVES ENERGY

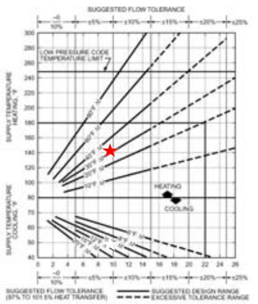


Fig. 34 Recommendations for Coil Flow Tolerance to Maintain 97% Design Heat Transfer (Carlson 1981)

2016 ASHRAE Handbook -- Systems and Equipment

Suggested Coil Flow Tolerance to maintain
97% Design Heat Transfer

Heating
140 degree supply 30 degree delta T flow tolerance is 10%

Cooling
45 degree supply 12 degree delta T flow tolerance is 10%

ASHRAE HANDBOOK 2016 – Systems and Equipment

page 44.14 Statements on Sensorless
(Predefined Curve Control)

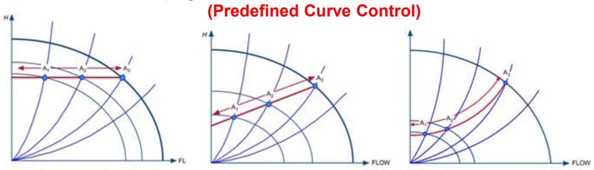


Figure 46. Constant-Pressure Control Figure 47. Variable- (Proportional-) Pressure Control Figure 48. Variable- (Quadratic-) Pressure Control

Constant-pressure control is recommended if pressure losses in the distribution and supply systems (pipe, boiler, heat exchanger, etc.) are low.

Proportional pressure control compensates for pressure loss in the distribution and supply systems with a linear approximation, with the result that differential pressure across the control valves is nearly constant, and good control performance is obtained at both full- and part-load operation

Variable- (quadratic-) pressure control is also recommended if pressure losses in the distribution and/or supply system **are well known** and it is ensured that the **system is correctly balanced (Sensorless Fixed Curve Control)**

Variable differential pressure control *can also be achieved by remote feedback from critical locations; if the critical locations can be identified and remote control is an option, this* ***can offer the best potential pump energy savings. (Area Control)***

What is Important to Owner Satisfaction

Best First Cost and Life Cycle Cost

Best System Comfort and Operating Cost

Pump Station Piping and Foot Print

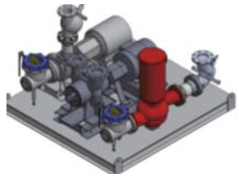
88

The Pump Station

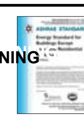
The Pump Station Piping Installed Foot Print

The Pump Station Head Loss

The Actual Required Pumping System Head Loss



89



HEATING, VENTILATING, AND AIR CONDITIONING

SECTION 6.5
Prescriptive Path

.4 Hydronic (Water Loop) Heat Pumps and Water-Cooled Unitary Air-Conditioners.

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.

CHAPTER 6

HEATING, VENTILATING, AND AIR CONDITIONING

SECTION 6.5
Prescriptive Path

TABLE 6.5.4.5 Piping System Design Maximum Flow Rate in GPM

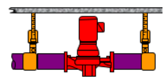
Operating Hours/Year	≤2000 Hours/Year		<2000 and ≤4400 Hours/Year		>4400 Hours/Year	
Nominal Pipe Size, in.	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed
2½	120	180	85	130	68	110
3	180	270	140	210	110	170
4	350	530	260	400	210	320
5	410	620	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

May **exceed flow** if branch **not critical circuit** over 30% of hours

91

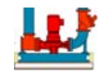
ENERGY EFFICIENT PUMP STATION DESIGNS FOR YOUR PUMPS

SIDE PUMP STATION PIPING CONNECTIONS



SIZE PIPE AND CALCULATE FITTING PRESSURE DROPS PER ASHRAE 90.1-2010 & 2013 THE CRITICAL CIRCUIT

OVER HEAD PUMP STATION PIPING CONNECTIONS



WHAT IS YOUR CHOICE?

Calculate the Required Pump Station Head

When comparing Over Head Pump Station Piping Connections based upon system flow/head there are big consequences without reassessing the system, recalculating pressure drop, additional piping costs, additional footprint, additional operating cost, and the potential for insufficient pump flow.

Note: ASHRAE 90.1-2010 Requires you to do a detailed pump head loss Calculation and to use minimum pipe sizes based on flow.

Over Head Pump Station Piping Connections

BASIS OF DESIGN

2250 GPM AT 60 FEET HEAD TOP SUCTION AND DISCHARGE SUCTION AND DISCHARGE ELBOWS BUILT IN
8.7 FEET OF PUMP HEAD REDUCTION OVER INLINE WITH 10 INCH STRAINER AND COMBINATION VALVE PER ASHRAE 90.1 PIPE SIZE

V E OFFERED CHANGE FOR A LOWER FIRST COST SMALLER PUMP AND PIPE

2250 GPM AT 60 FEET HEAD SMALLER CASING SIZE FAR RIGHT OF BEP SUCTION DIFFUSER 5.2 FEET COMBINATION VALVE 8.1 FEET
YOU ADDED 13.3 FEET OF PUMP HEAD 8 INCH PIPE SIZE and SMALLER PUMP

OWNER OPERATING COST PENALTY $4,307 TO $6,584 ANNUALLY FOR EVER

Hydraulic INSTITUTE
6 Campus Drive - 1st Floor, North
Parsippany, NJ 07054
Pumps.org

1.4.2.5.1 Pipe supports/anchors

Suction and discharge piping must be anchored, supported and restrained near the pump to avoid application of forces and moments to the pump.

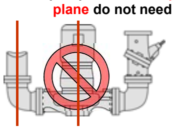
Hydraulic INSTITUTE
6 Campus Drive - 1st Floor, North
Parsippany, NJ 07054
Pumps.org

9.6.6.2 Introduction

Two of the most common detrimental effects from pump piping are the excessive nozzle loads that the piping can place on a pump and the excessive nozzle loads that unsupported equipment such as valves or vertical in-line pumps can place on the piping.

Hydraulic Institute Standards

Double suction pumps centerline plane perpendicular to pump shaft plane do not need suction diffusers



HI 1.4.2.6.6 Elbow at pump suction

"For a double suction pump, an elbow whose plane is parallel to the pump shaft should not be used."

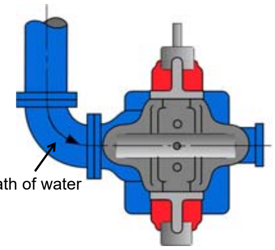
"When liquid flows through an elbow, the exit velocity is severely non-uniform. This causes fluctuating higher pressure and capacity on one side of the impeller inlet, while tending to starve the other side. It upsets the axial balance of the rotor and may cause cavitation on the starved side of the impeller. The result is high axial fluctuating loads, noisy operation and possible cavitation damage"
From ANSI/HI 1.1-1.5 1994

4) For vertical in-line pumps, elbows may be located in an orientation parallel to the pump shaft within two diameters for long-radius and three diameters for short-radius elbows.

HI 2016

97

Suction Piping



Incorrect

Pumps and Flex connectors

- **ASHRAE talks about flexible connectors and their purpose in *APPLICATIONS SECTION 48.50*.**
- ***Flexible pipe connectors (1) provide piping the flexibility to permit isolators to function properly"***
- ***Protect equipment from strain caused by misalignment and expansion and contraction of the piping***
- ***Attenuate noise and vibration transmission along the piping***

99

Happy Pumps make Happy Owners

SUMMARY

- Third Party Pump Guidelines Best Practice are ASHRAE, Hydraulic Institute & DOE
- When Calculating Owner Pump LCC use Third Party Pump Life Guidelines
- Default to IPLV or use Actual Load profile & Control head for Owner Operating Cost
- The two Control Strategies are Curve Control and Area Control
- Maximum Control head to meet ASHRAE 90.1 pump energy savings is about 40%
- Sensorless Pump Vendors default to 40% of design submitted head, commissioning critical
- Sensorless better than constant speed with simple loads where flow misses or not critical
- Area Control Strategies can reduce or eliminate misses and save more energy
- Selections of Design Flow right of BEP over headed may fall off the pump curve
- Calculate The Pump Station Piping Head loss, No one Pump Type is Best
- The Pump Station is the Critical circuit use 90.1 Minimum Pipe Size (No Owner Penalty)
- Avoid Excessive Pump Nozzle Loads Cause by Pipe Growth and Pipe Support.

Owners are getting Smarter