Modern Pump Selection for System Efficiency

By: Kyle DelPiano - Business Development Manager, Bell & Gossett

Our Seminar Goal!!

Be REALISTIC and Honest regarding variable speed pumping. Actual efficiency depends on the configuration of pump vs. load conditions **(rarely at full load)** and flow conditions. These conditions must be accounted for to determine expected **actual operating pump efficiency** and therefore **actual cost savings from variable speed pumping.** You must map the range of operating conditions to be accurate.

To Get **Highest System Pumping** Efficiency

Maximize your efficiency islands!!!

Outline of Presentation

- Basic Pump Affinity Laws
- Pump Head Loss Calculations
- Pump Curve Review
- System Curve Review
- Pump Selection Examples
- Summary

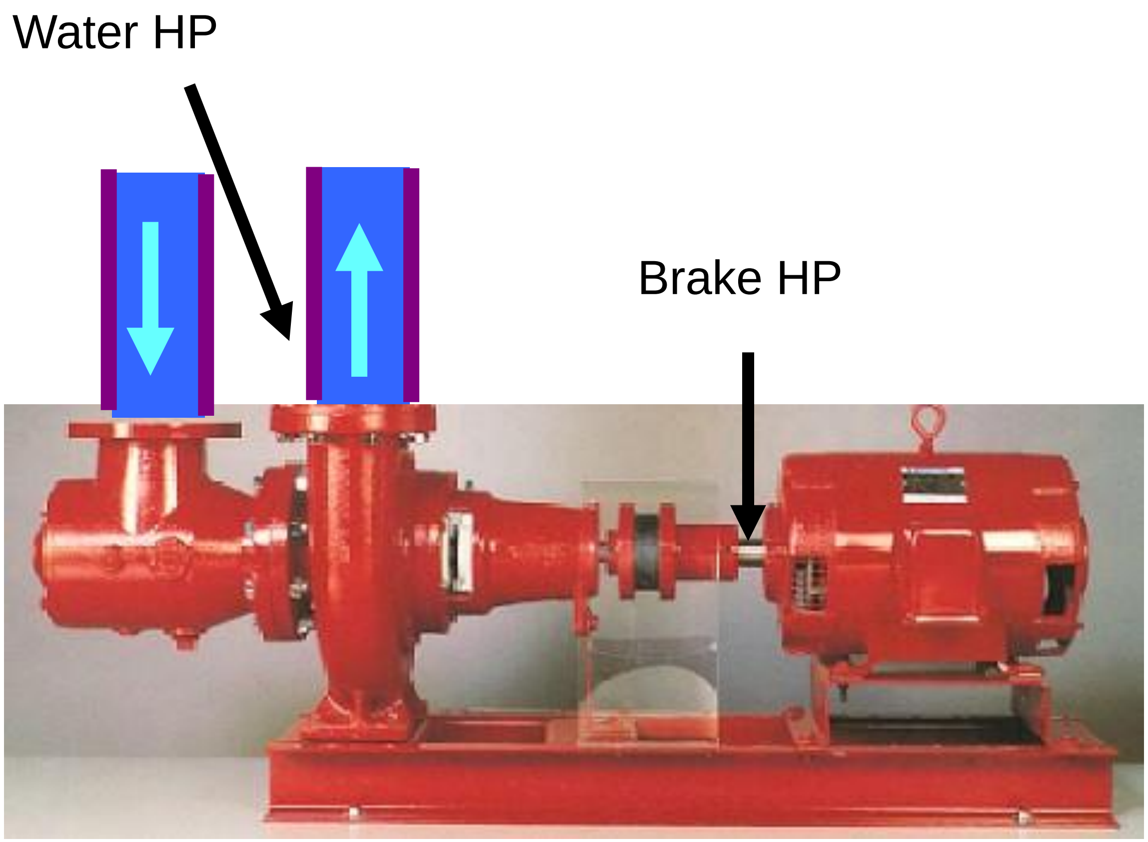
Outline of Presentation

- 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

Pump Efficiency

Pump Efficiency (E_p) = the percentage of power delivered to the pump by the motor shaft that is imparted to the water.

$$E_p = \frac{Output}{Input} \times 100\% = \frac{Whp}{Bhp} \times 100\% = \frac{25}{31} \times 100\% = 81\%$$



Brake Horsepower

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

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

For water:

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

Pump Affinity Laws

VFD - Speed Change

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

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

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

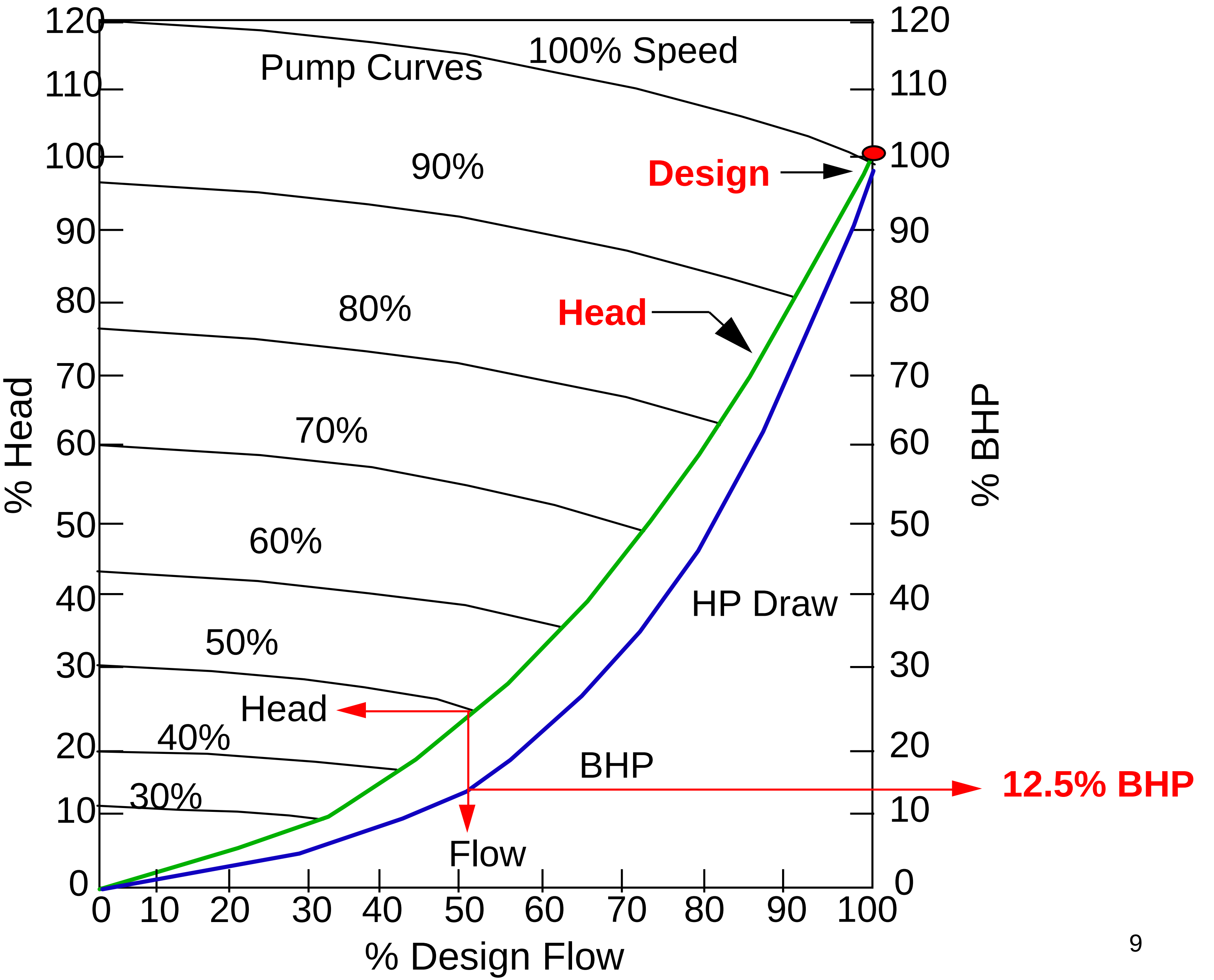
Impeller Diameter Change

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

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

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

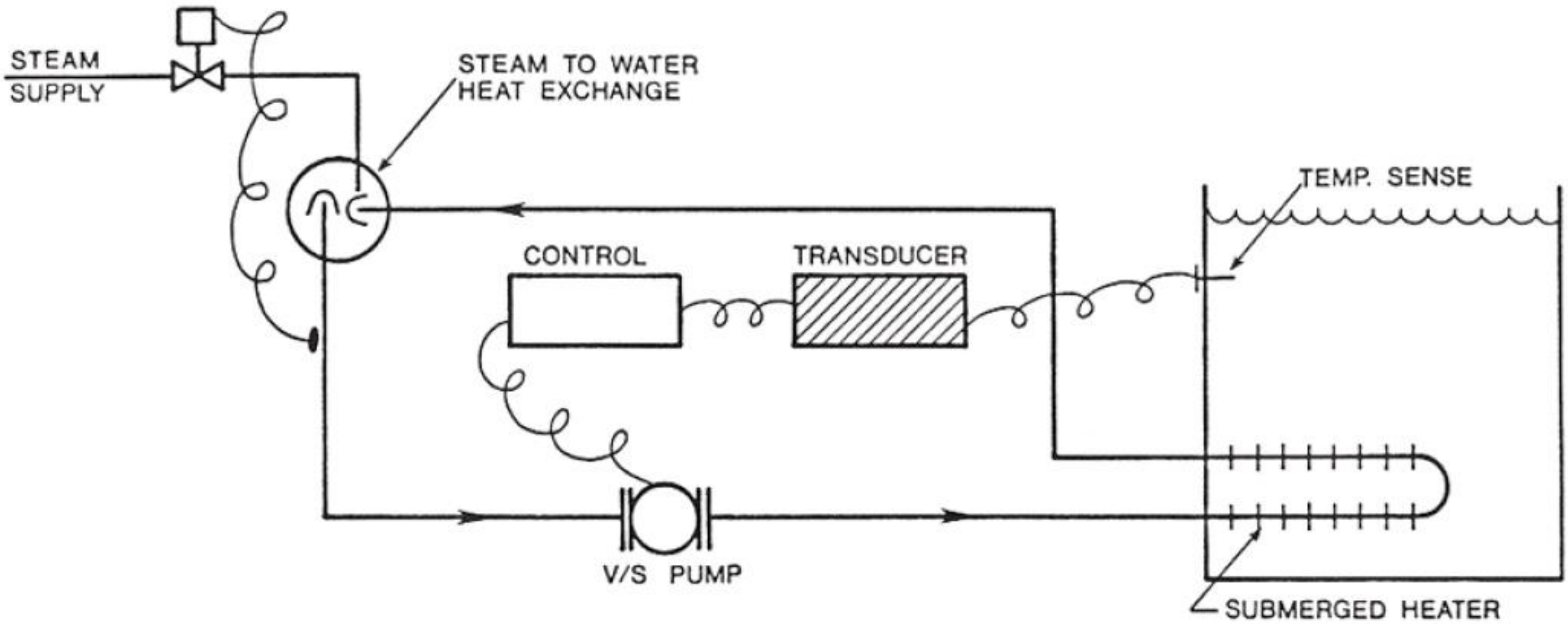
Theoretical Savings- 100% Variable Flow



“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

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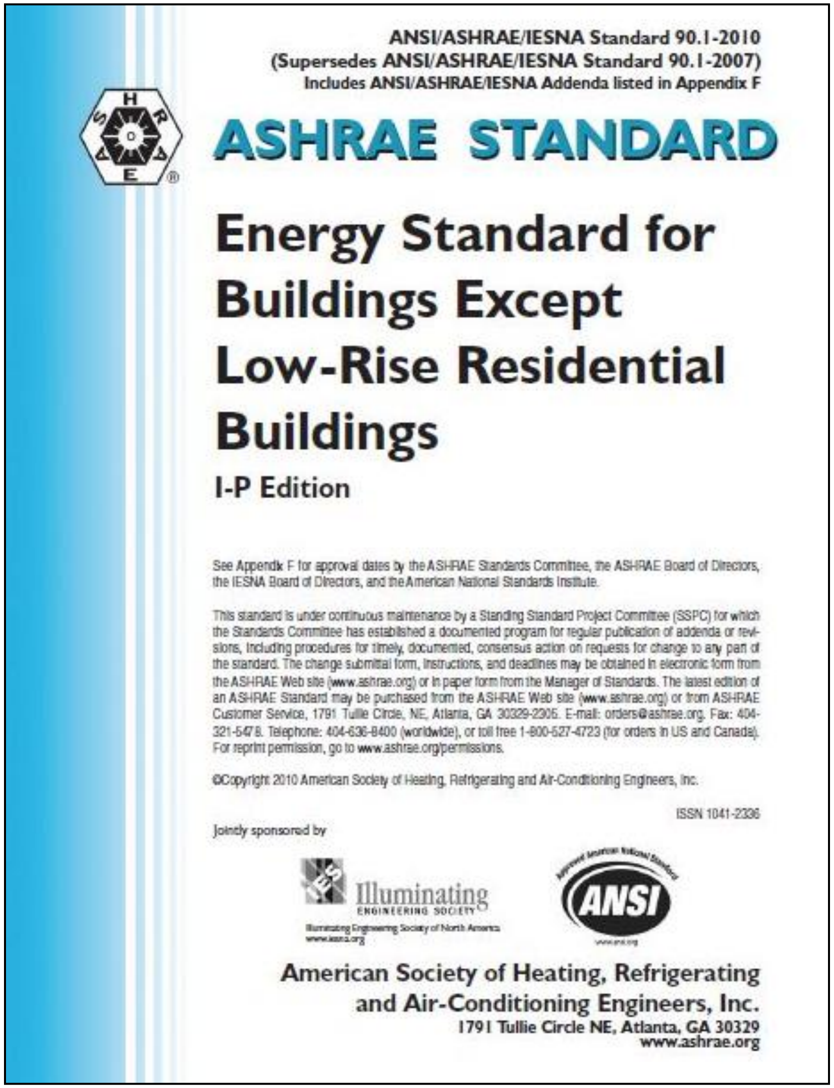
ASHRAE STANDARD

ASHRAE is dedicated to improve its Standards to facilitate the move to **NZEBs**



ANSI/ASHRAE/IESNA 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 IESNA 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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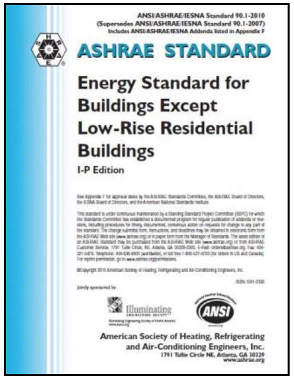
ANSI/ASHRAE/IESNA/Standard 90.1-2010 (I-P Edition)

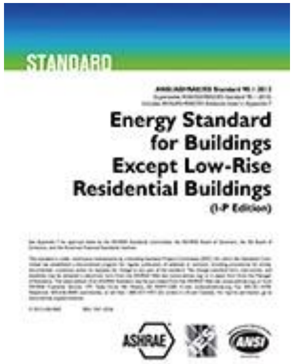
States to Use 90.1-2010 by Oct. 18, 2013



WASHINGTON—ASHRAE's Washington office is reporting that the U.S. Department of Energy (DOE) has determined that ANSI/ASHRAE/IES Standard 90.1-2010, *Energy Standard for Buildings Except Low-Rise Residential Buildings,* saves more energy than Standard 90.1-2007. Specifically, DOE found national source energy savings of approximately 18.2%, and site energy savings of approximately 18.5%, when comparing the 2010 and 2007 versions of Standard 90.1. As a result of this week's **DOE final determination, states are required to certify by Oct. 18, 2013 that have reviewed the provisions of their commercial building code regarding energy efficiency and updated their code to meet or exceed Standard 90.1-2010.**

http://www.iccsafe.org/gr/documents/stateadoptions.pdf

ANSI/ASHRAE/IES Standard 90.1-2013



On September 26, 2014, DOE issued a determination that Standard 90.1-2013 would achieve greater energy efficiency in buildings subject to the code. DOE estimates national savings in commercial buildings of approximately:

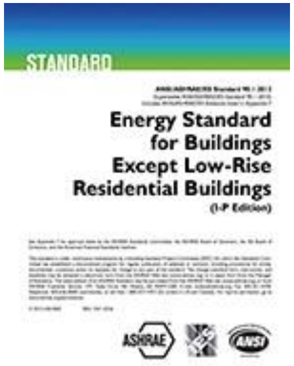
- 8.7% energy cost savings
- 8.5% source energy savings
- 7.6% site energy savings

Additional information related to this action, including the official *Federal Register* publication and docket containing public comments received, is available at Regulations.gov.

State Certification

Upon publication of an affirmative determination, States are required to certify that they have reviewed the provisions of their commercial building code regarding energy efficiency, and, as necessary, updated their codes to meet or exceed the updated edition of Standard 90.1. Additionally, DOE provides guidance to States on submitting certification statements and requests for deadline extensions. **State certifications for Standard 90.1-2013 must be submitted by September 26, 2016.**

UPDATE: ANSI/ASHRAE/IES Standard 90.1-2016



On July 25, 2017, DOE issued a preliminary determination that Standard 90.1-2016 would achieve greater energy efficiency in buildings subject to the code. DOE estimates national savings in commercial buildings of approximately:

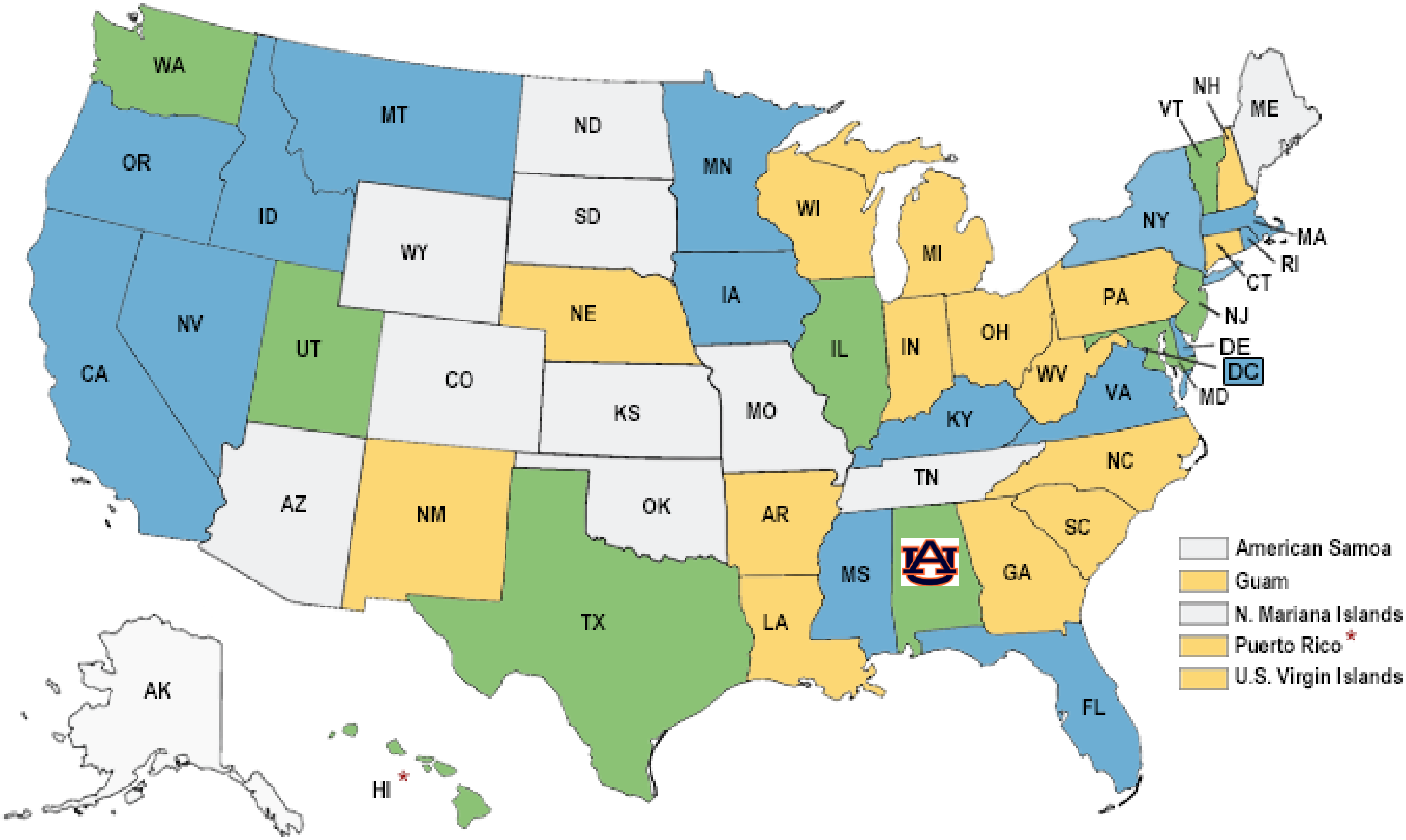
8.2% energy cost savings
7.9% source energy savings
6.7% site energy savings

Additional information related to this action, including the official Federal Register publication and docket containing public comments received, is available at Regulations.gov.

State Certification

- DOE will accept written comments and information on the Preliminary Analysis no later than **September 8, 2017**.
- No date determined….yet

Current ASHRAE 90.1 Code Adoptions

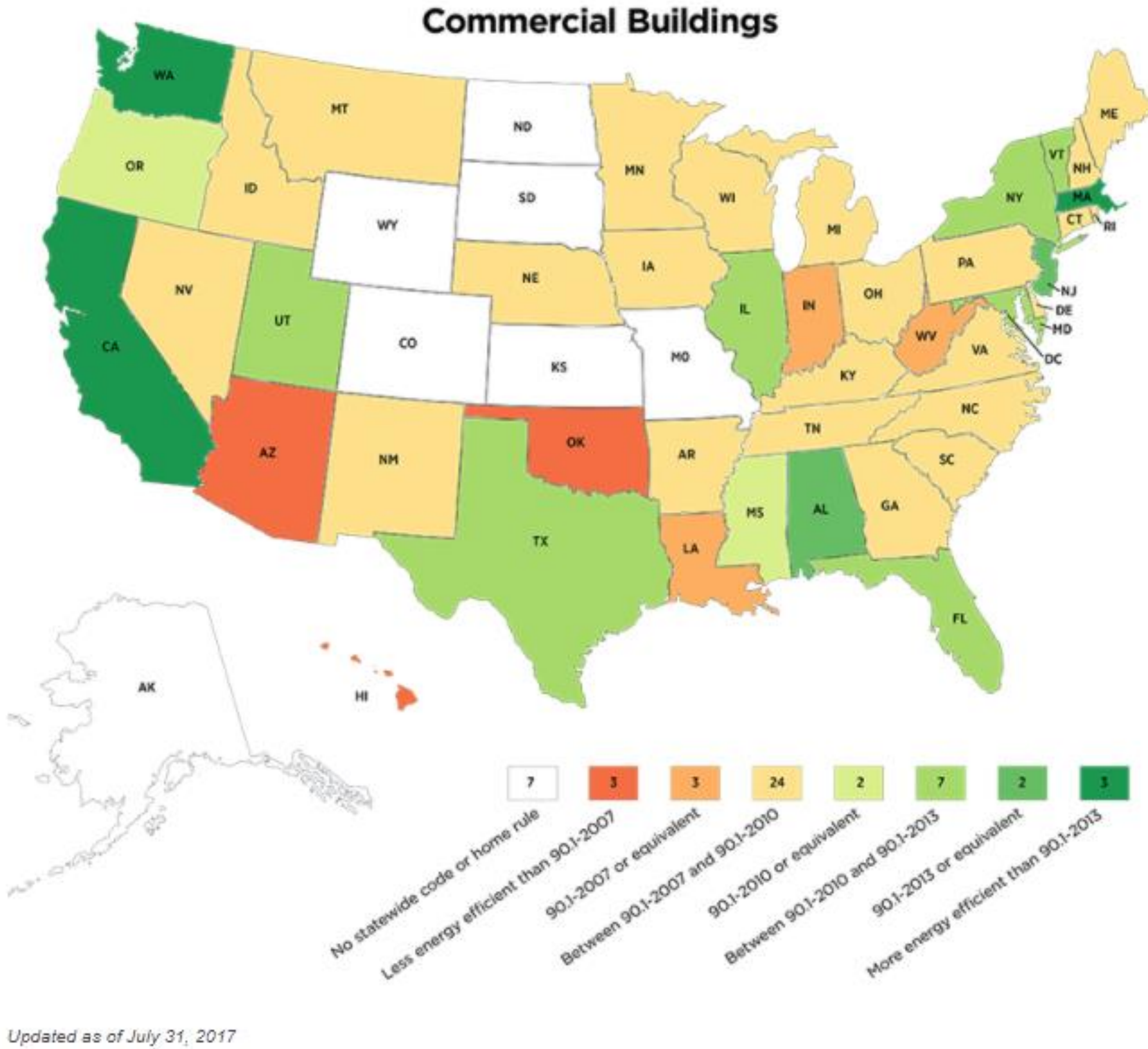


9	ASHRAE 90.1-2013/2015 IECC, equivalent, or more energy efficient
16	ASHRAE 90.1 - 2010/2012 IECC, equivalent, or more energy efficient
18	ASHRAE 90.1 - 2007/2009 IECC, equivalent, or more energy efficient
13	Older or less energy efficient than ASHRAE 90.1 - 2007/2009 IECC, or no statewide code.

* Adopted new Code to be effective at a later date

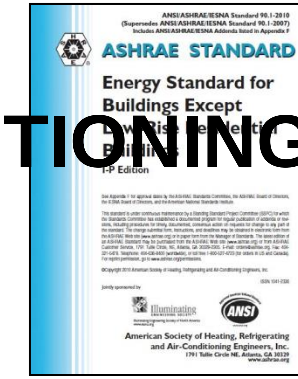
As of September 2016

Current ASHRAE 90.1 Code Adoptions



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.**

Calculator

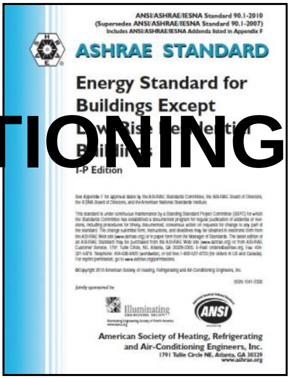
iPad & iPhone Versions

Android Version

- Available free from iTunes App Store
- All the calculators from the plastic wheel PLUS
  - Greater range of pipe sizes
  - Addition of PVC Pipe
  - Includes English & Metric Units
  - Handles fluids other than water
  - Incorporates Circuit Setter wheel

CHAPTER 6

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.

ARI 550/590 Standard
IPLV Load Profile

ARI 550/590-1998-2011 Standard
IPLV Load Profile

"IPLV" Chiller Efficiency

Intergrated part load value or "IPLV" is a single part load efficiency number for water chillers at the standard ARI rating point.

"IPLV" represents an average single chiller application

"NPLV" Chiller Efficiency

Non-standard part load value or "NPLV" is a single part load efficiency number for water chillers not intended to operate at the standard ARI rating point.

"NPLV" is used for multiple chiller plants and real world operating conditions

ARI 550/590-1998 Standard

“IPLV” Chiller Efficiency

(Integrated Part Load Value)

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

$$IPLV = \frac{1}{\frac{1\%}{A} + \frac{42\%}{B} + \frac{45\%}{C} + \frac{12\%}{D}}$$ expressed in Kw/ton

Note: Lower Condenser Water Temperature at Part Load

ARI 550/590-1998 Standard

"IPLV" Chiller Efficiency

(Integrated Part Load Value)

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

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

Efficiency %

Note: **Assume Pump Flow Rates Match % Load**

Efficiency Recommendation[a]		
Compressor Type and Capacity	Part Load Optimized Chillers	
	Recommended IPLV[b] (kW/ton)	Best Available IPLV (kW/ton)
Centrifugal 150 - 299 tons	0.52 or less	0.47
Centrifugal 300 - 2,000 tons	0.45 or less	0.38
Rotary Screw $\geq$ 150 tons	0.49 or less	0.46

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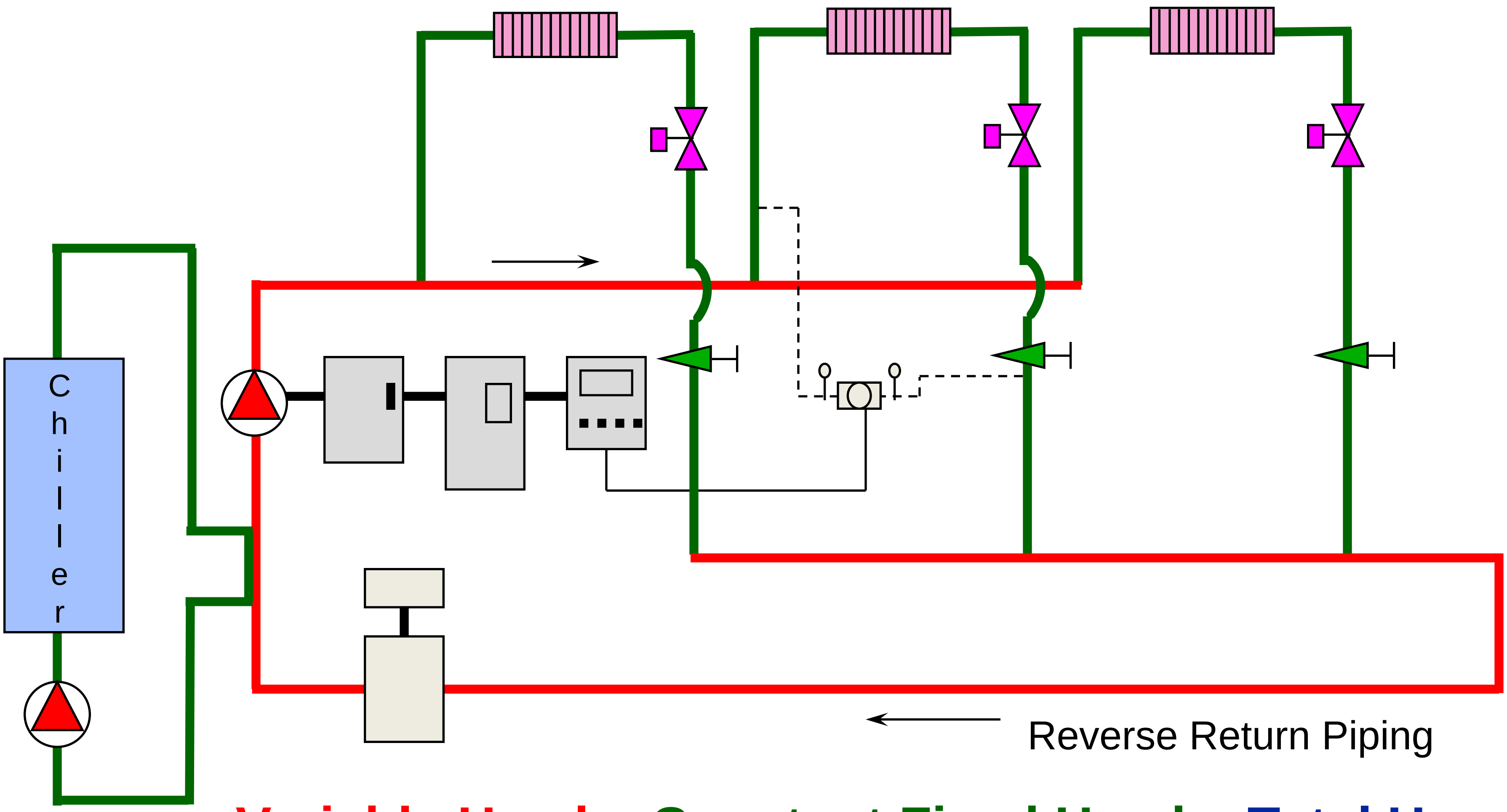
3. **Constant Fixed** and **Variable Head**

- Pump Curve Review

Pump Head Calculation



Variable Head + Constant Fixed Head = Total Head

Pump Head Calculation

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

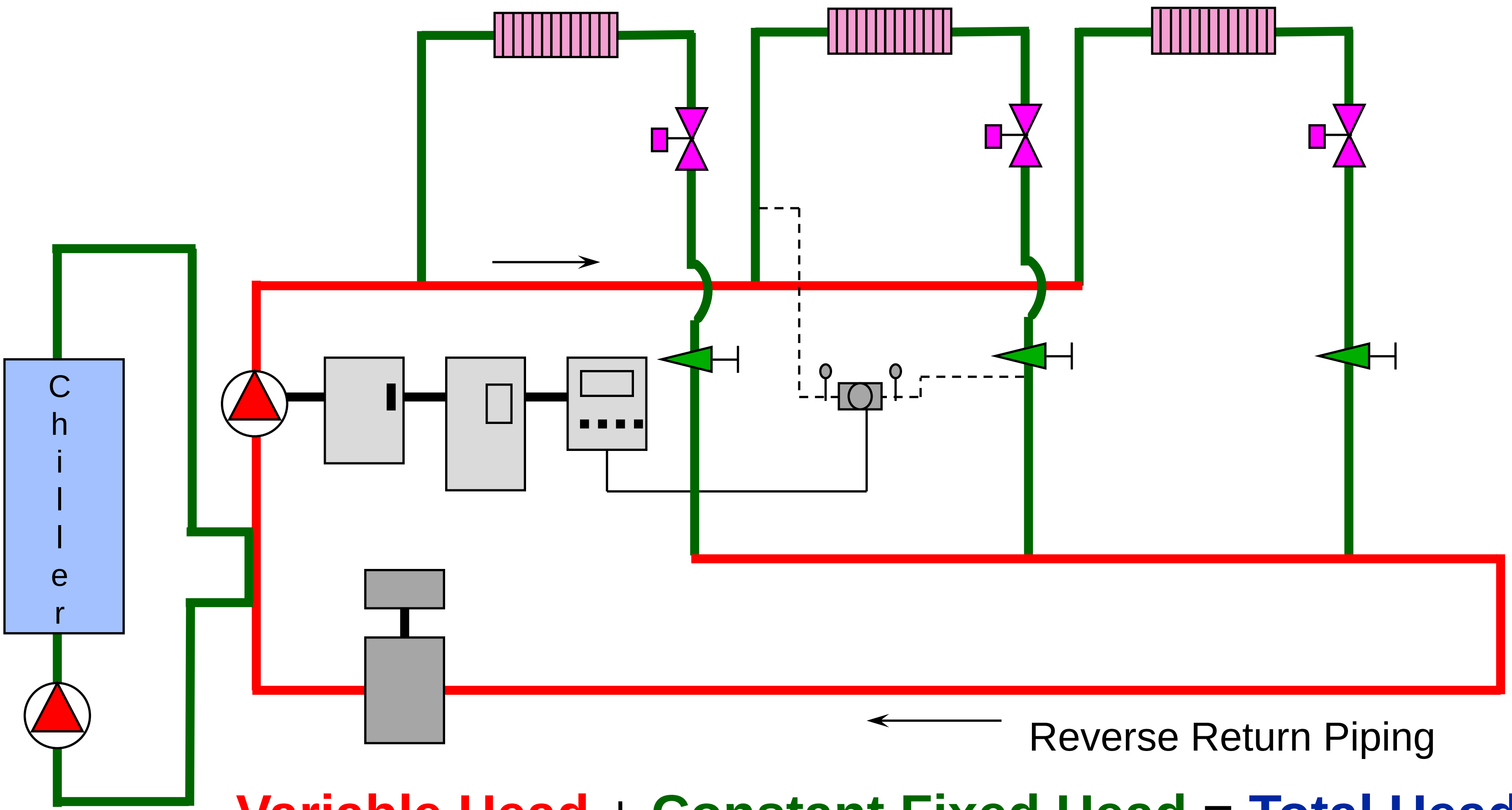
52 ft + **28** ft = **80** ft

Component	Head Loss
Pipe - 1756 ft of 10" Pipe at a Flow Rate of 2200 GPM	**40.4 Ft.**
Elbows - 15 - 10" Flanged Reg Ells Total Equivalent Feet (210) **(2.3 ft per 100 ft)**	**4.8 Ft.**
Valves - 10 - 10" Gate Valves Total Equivalent Feet (28)	**.6 Ft.**
Check Valves - 3DS-8" Triple Duty At 1100 GPM	**1.2 Ft.**
Coil Piping & Circuit Setter	**3.0 Ft.**
Control -- Two Way Control Valve On Cooling CV=292 @ 733 GPM	**15 Ft.**
Coils - Cooling Coil Pressure Drop Pressure Drop Is (Catalog Tables)	**10 Ft.**
Rolairtrol - RL-10 With 2200 GPM Flow	+ **5 Ft.**
Total System Head Loss @ 2200 GPM	**80 Ft.**

52 ft

Coil & Valve 28 ft

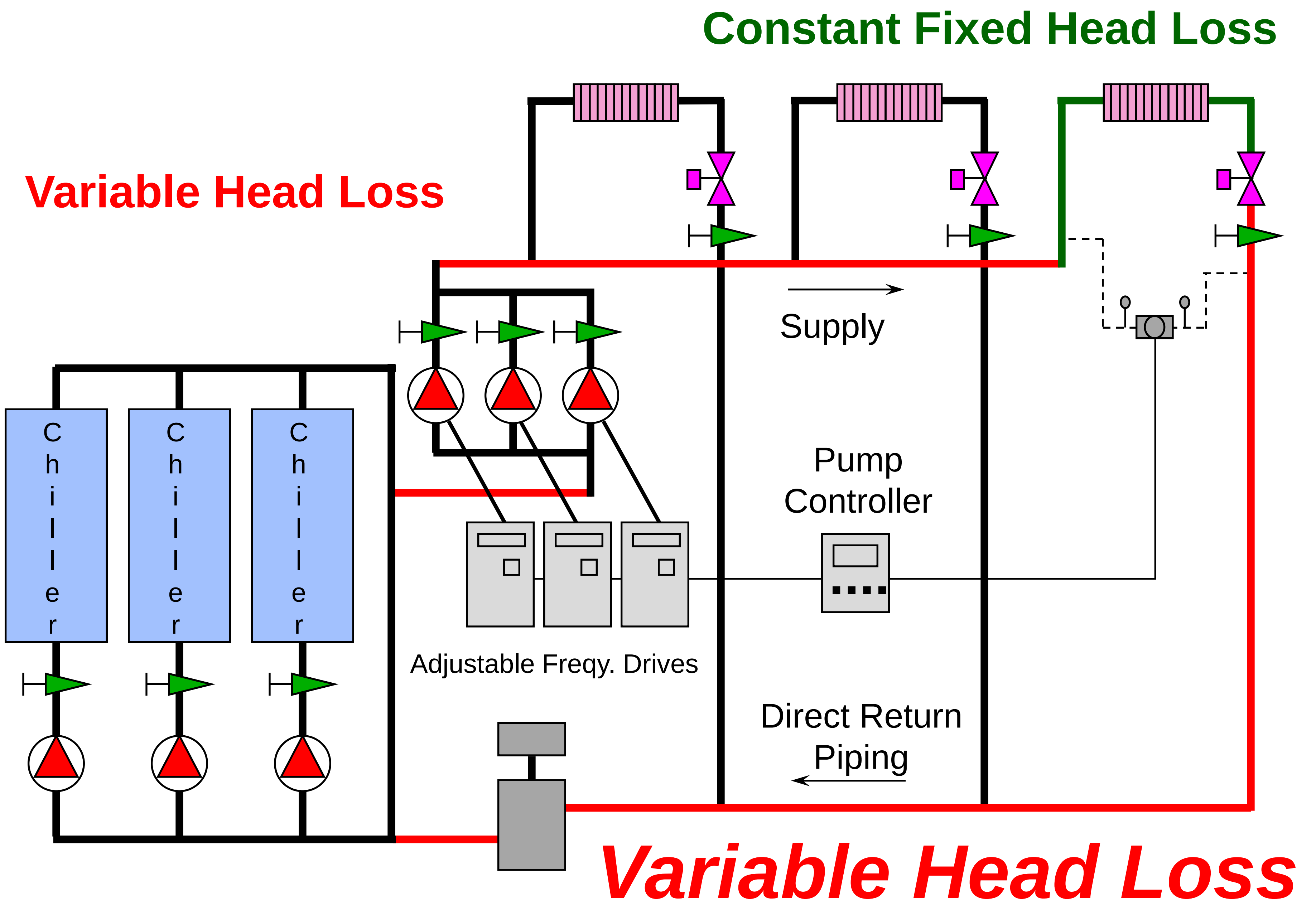
Pump Head Calculation



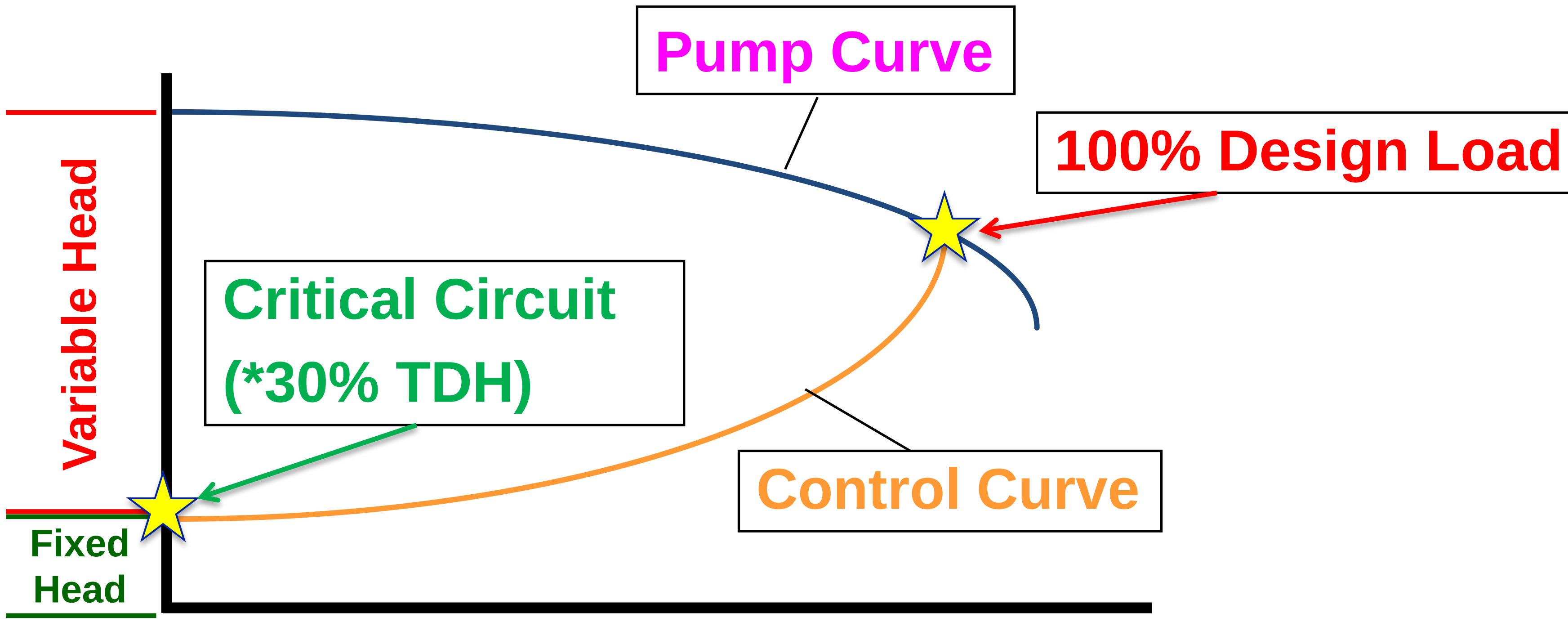
Variable Head + **Constant Fixed Head** = **Total Head**

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

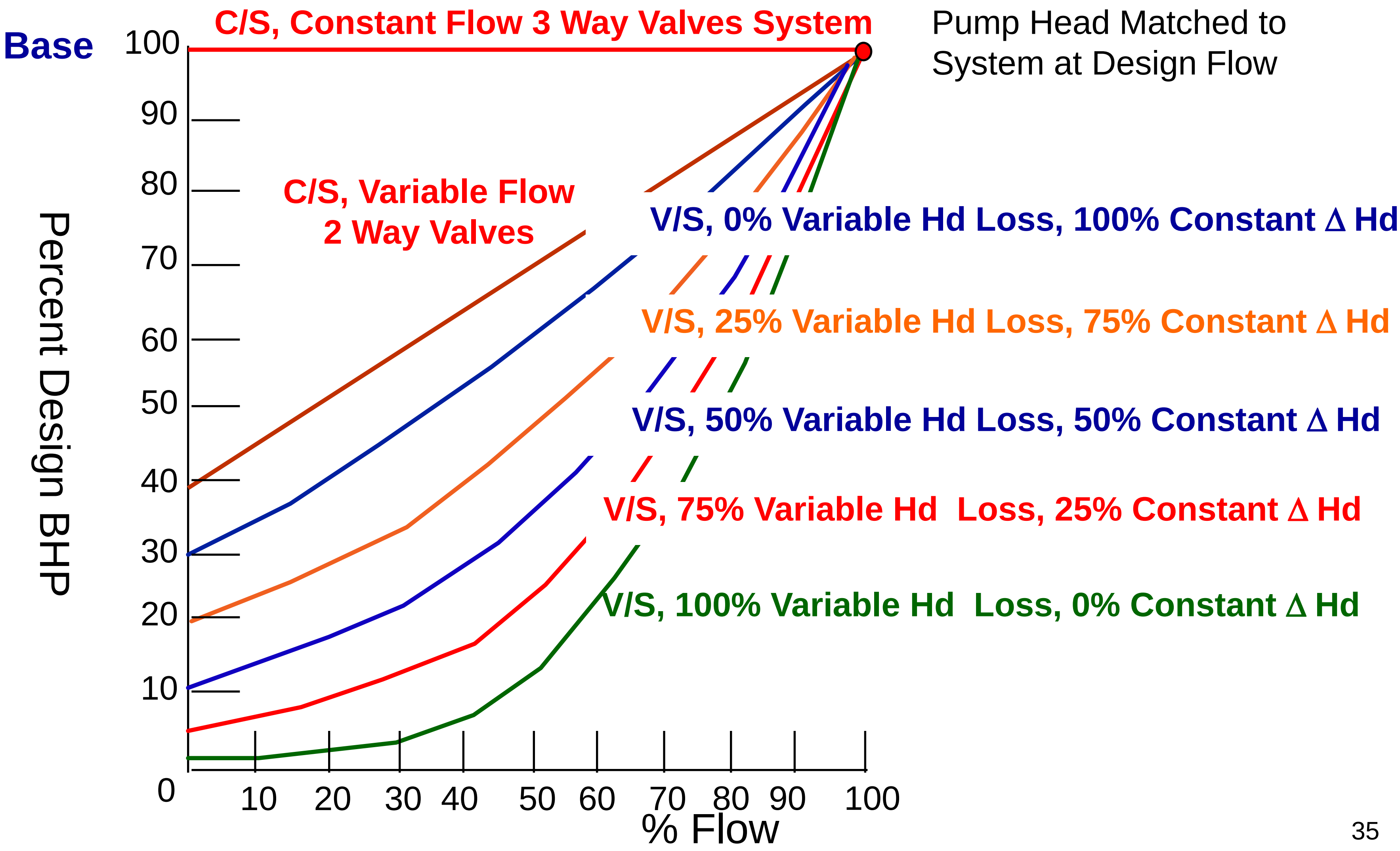
Multiple Pump Systems



Variable Head Loss



Variable Head Loss Ratio



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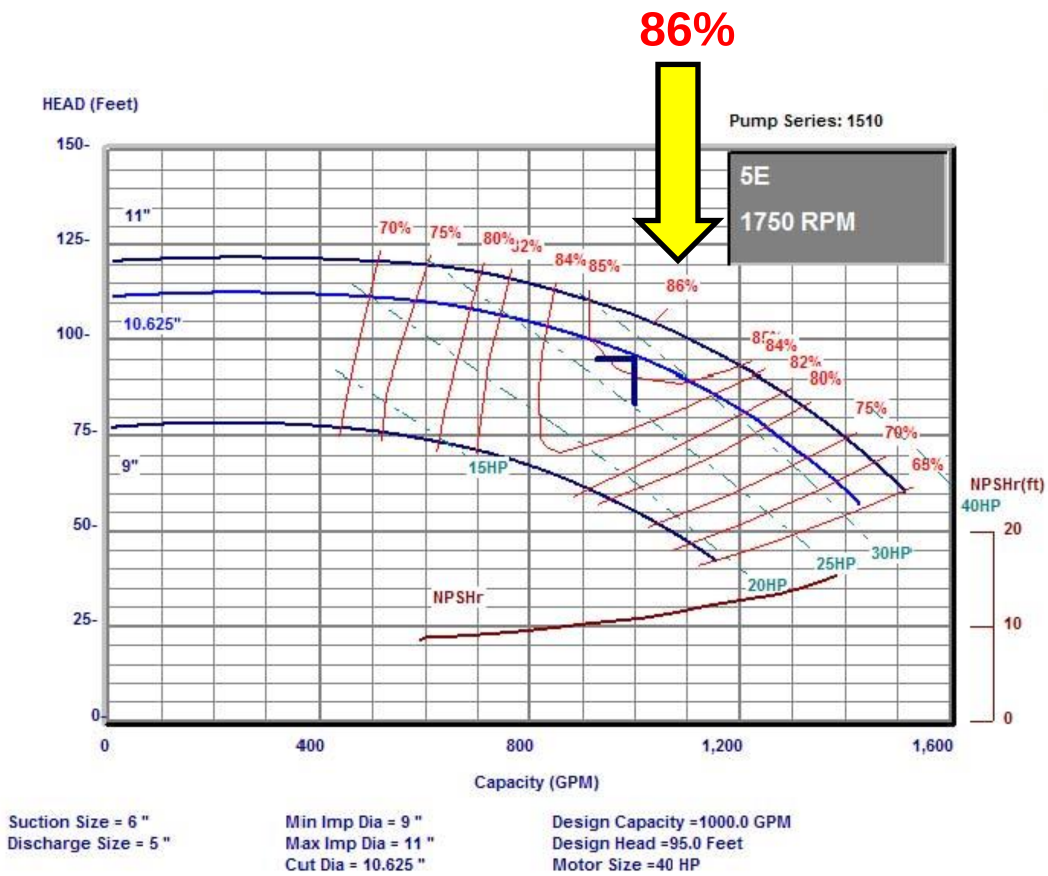
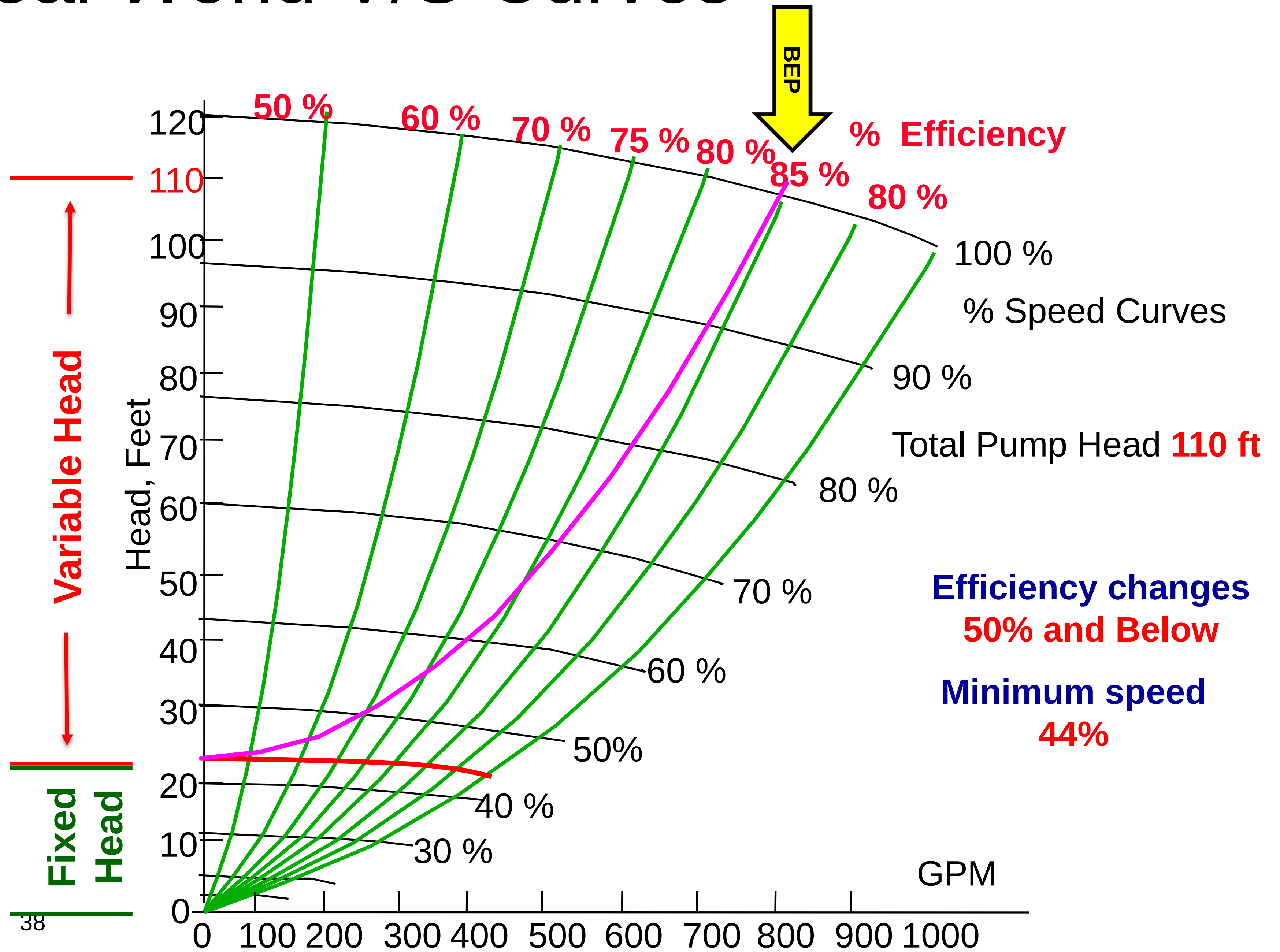
Pump Curve



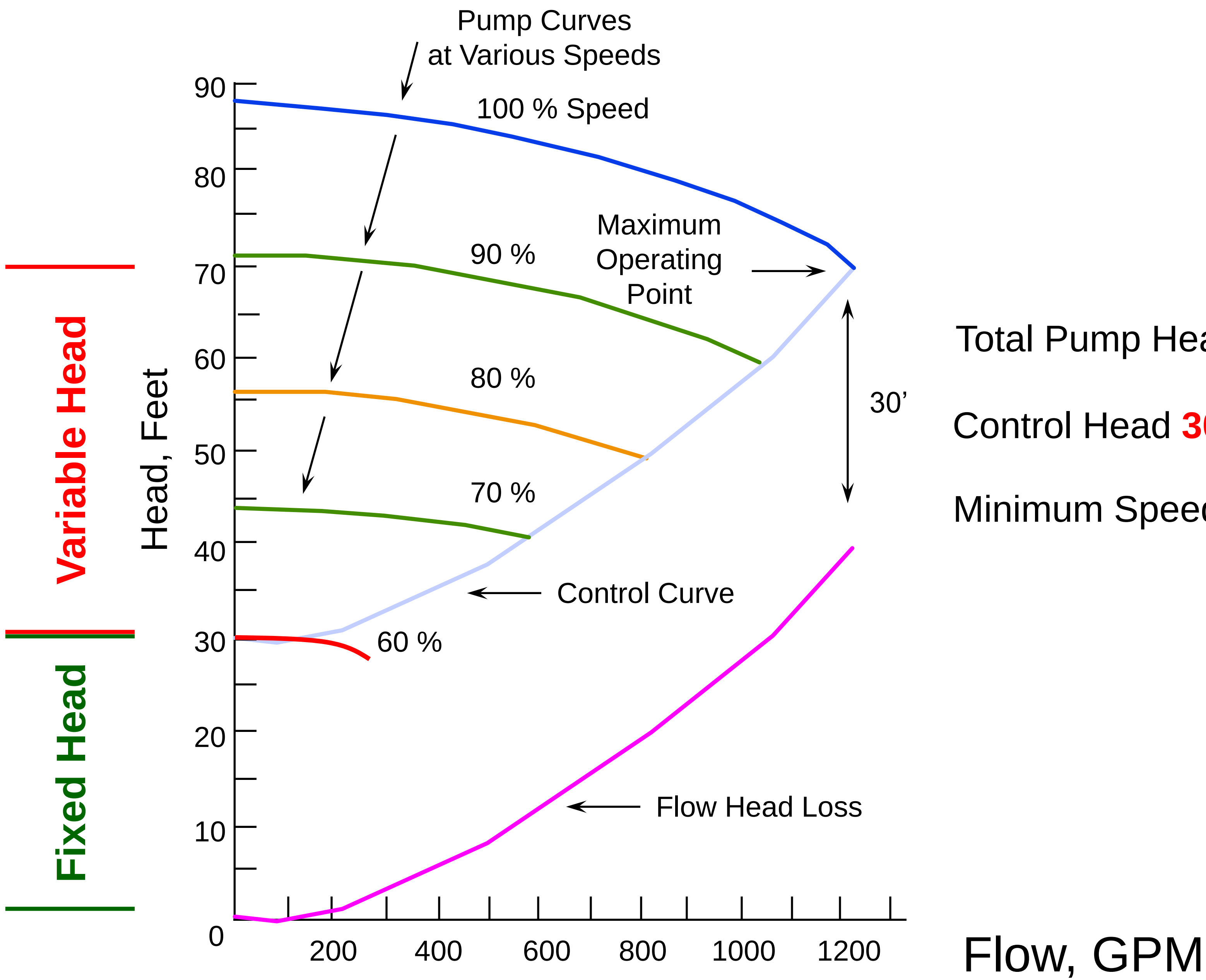
- Plots head (feet) vs. Flow (Gallons Per Minute) for a pump.
- Should include the following information to be considered complete:
  - Pump Name, size and speed
  - Performance curve including impeller diameter
  - Efficiency curve
  - Brake Horsepower
  - NPSHr often included
- Curves can be found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

BEP = pump Best Efficiency Point

Real World V/S Curves



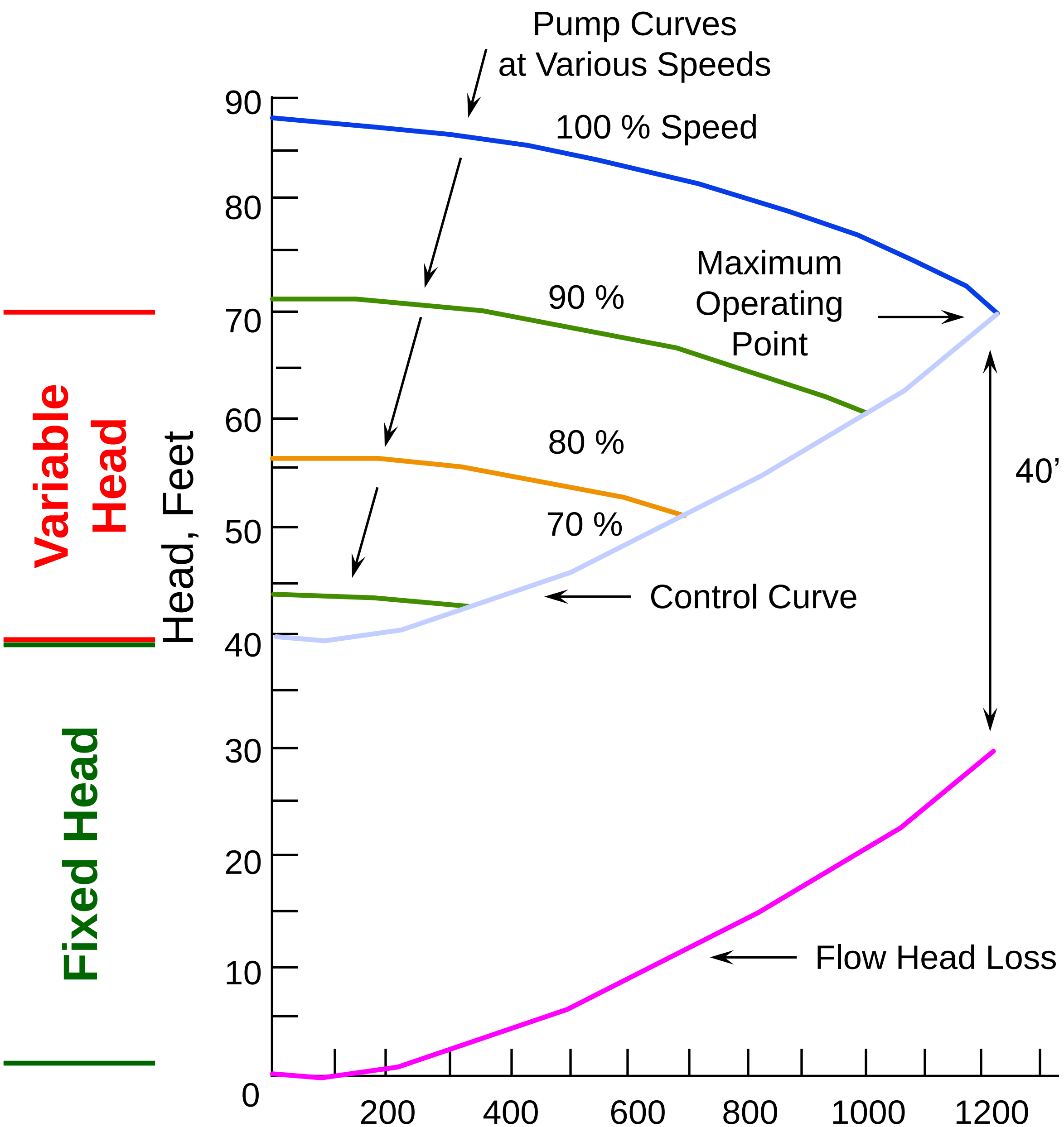
What happens to **minimum pump speed** as you **increase minimum control head** or **differential pressure set point**?



Total Pump Head 70 ft

Control Head **30 ft**

Minimum Speed **60%**

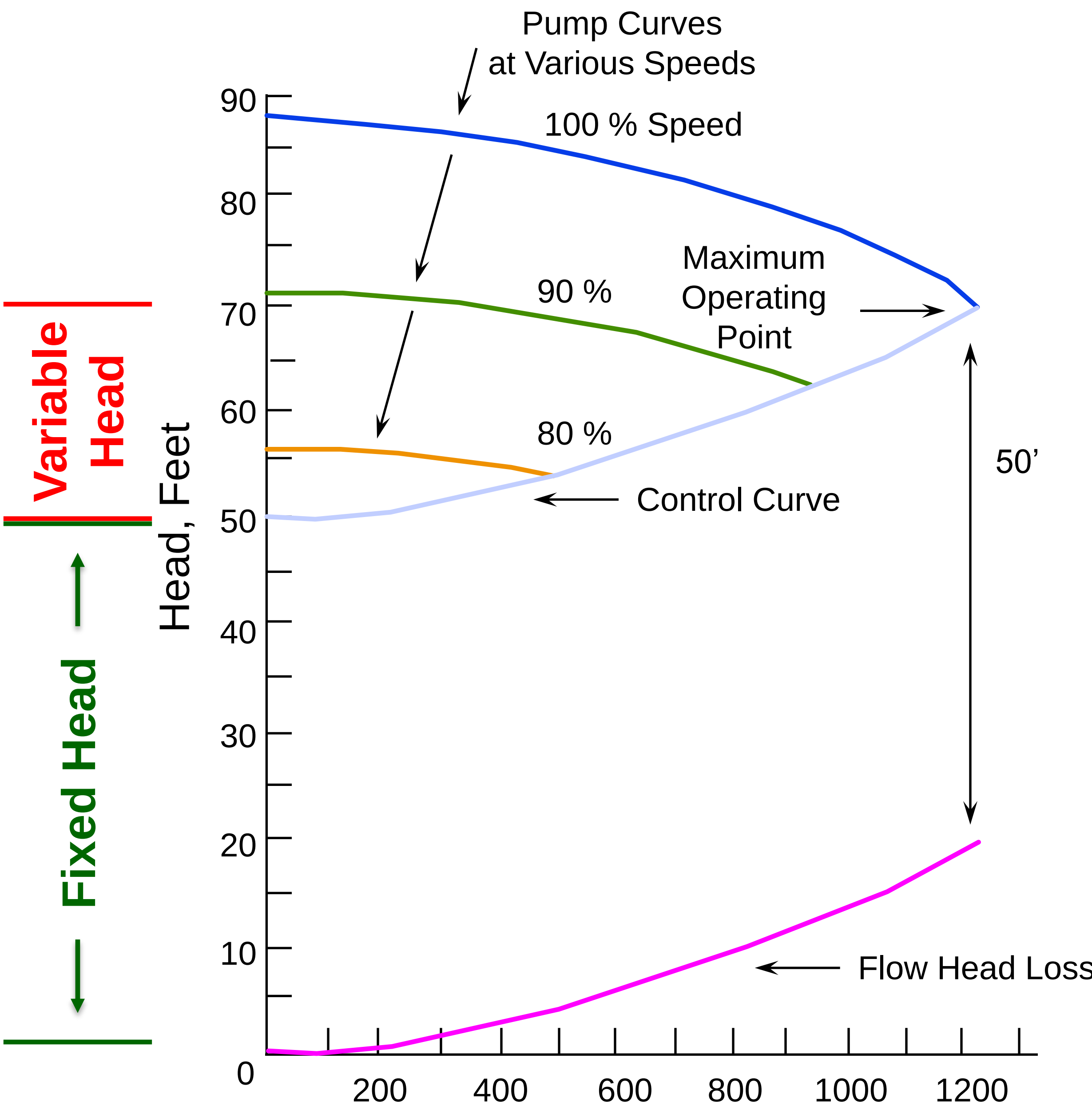


Total Pump Head 70 ft

Control Head **40 ft**

Minimum Speed **67%**

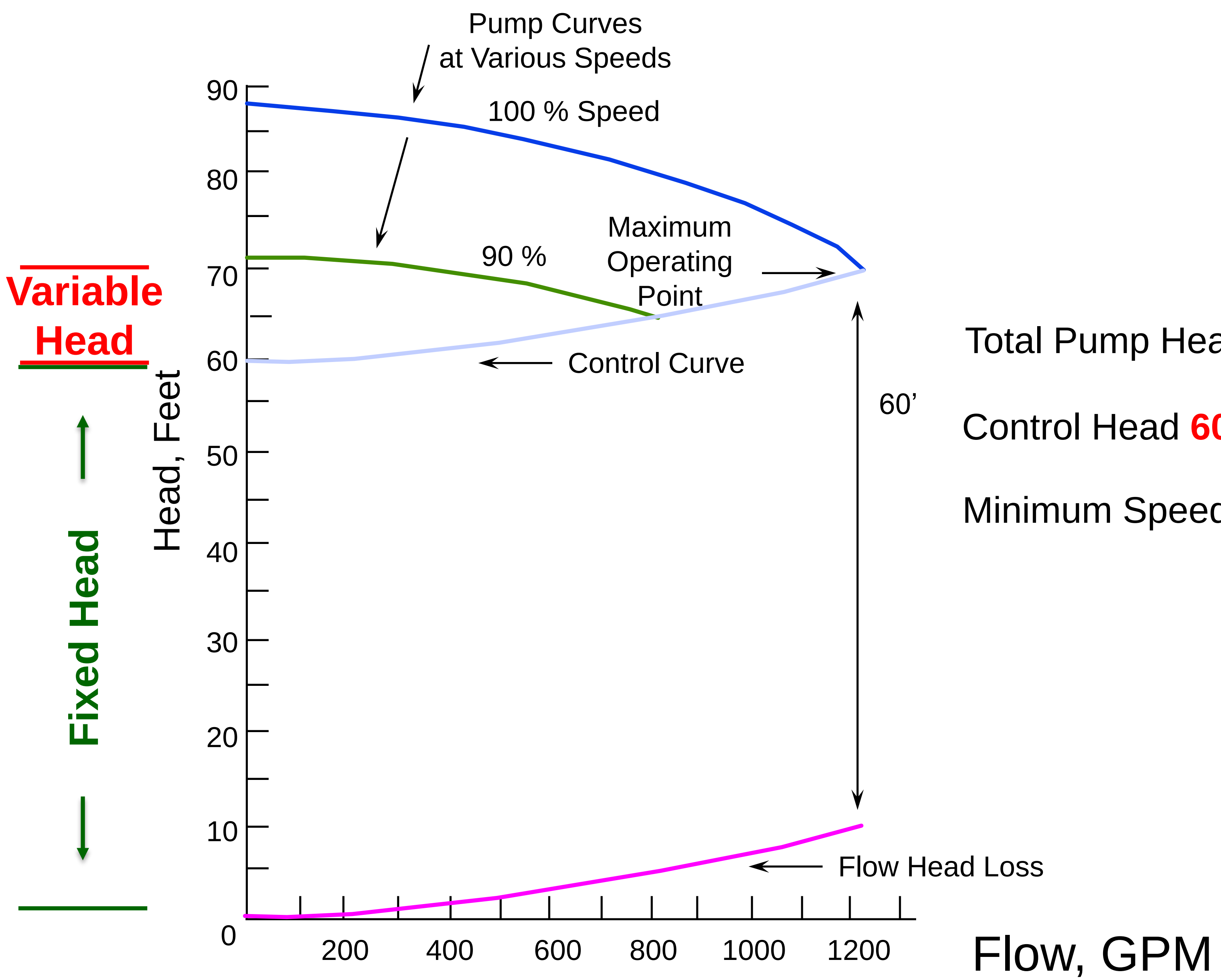
Flow, GPM



Total Pump Head 70 ft

Control Head **50 ft**

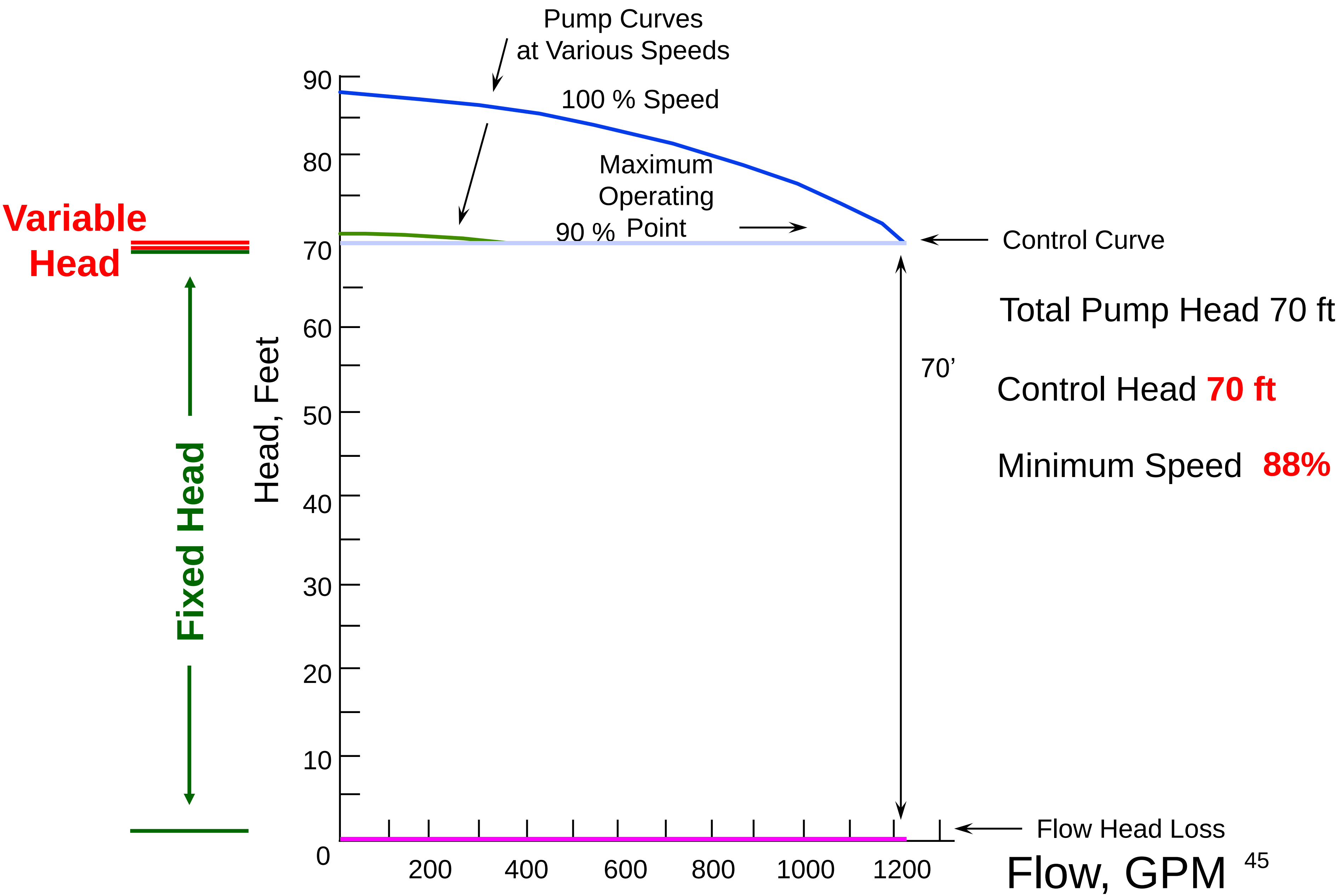
Minimum Speed **75%**



Total Pump Head 70 ft

Control Head **60 ft**

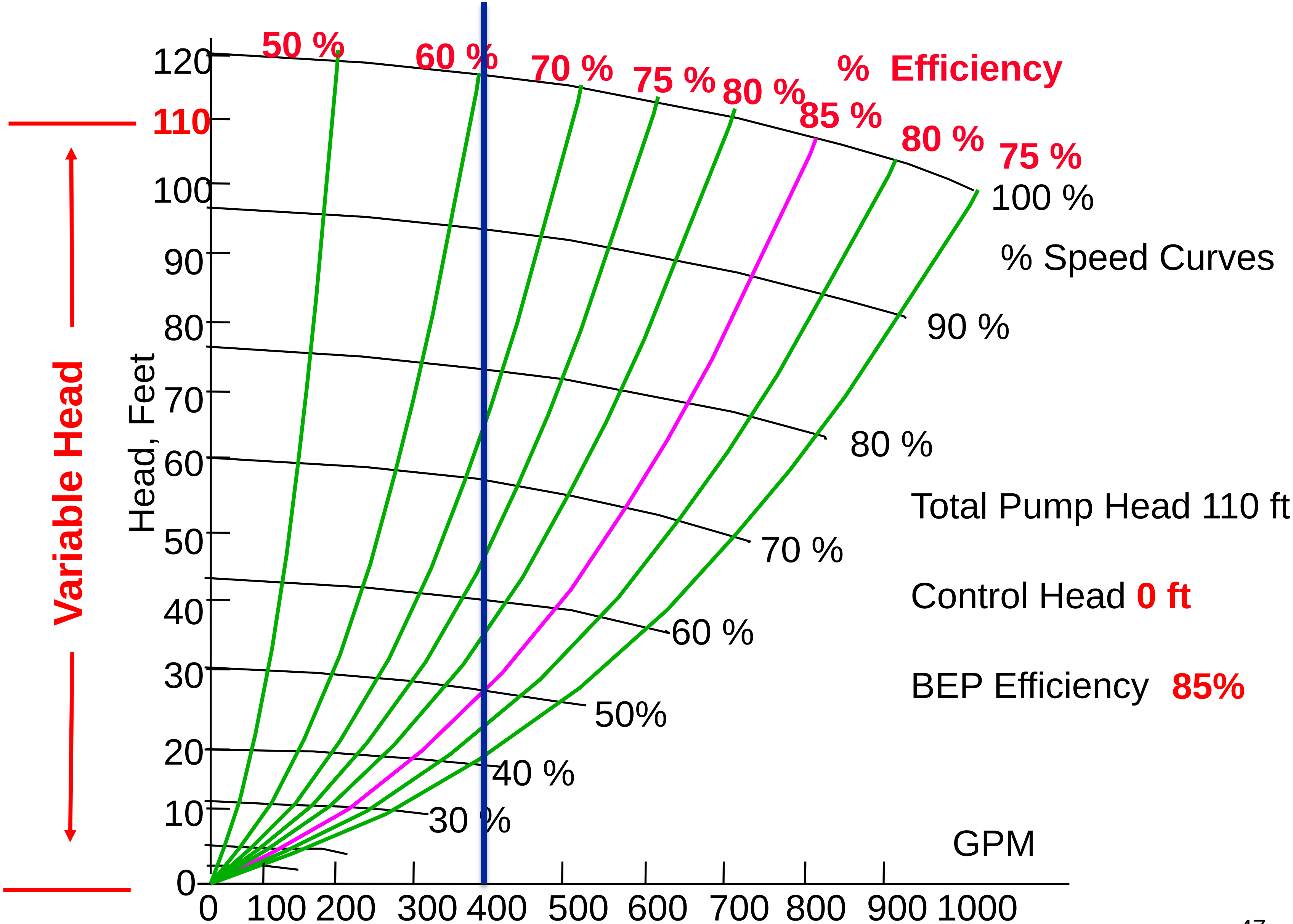
Minimum Speed **83%**



Pump Curves
at Various Speeds
100 % Speed
Maximum
Operating
Point
90 %
Control Curve
Variable
Head
Fixed Head
Head, Feet
90
80
70
60
50
40
30
20
10
0
Total Pump Head 70 ft
70'
Control Head 70 ft
Minimum Speed 88%
Flow Head Loss
200
400
600
800
1000
1200
Flow, GPM

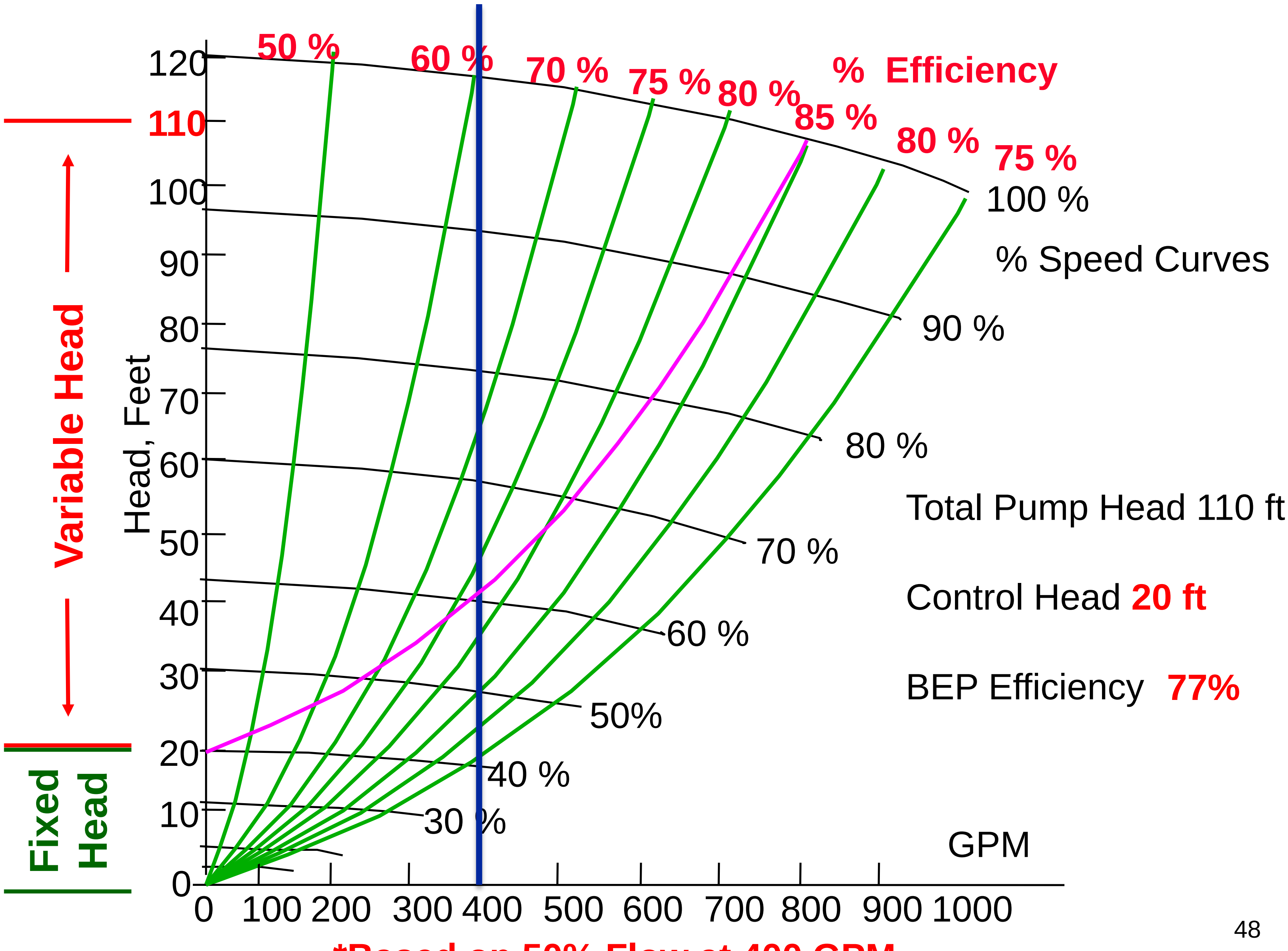
What happens to **BEP pump efficiency (at 50% flow)** as you **increase minimum control head** or **differential pressure set point**?

Real World V/S Curves



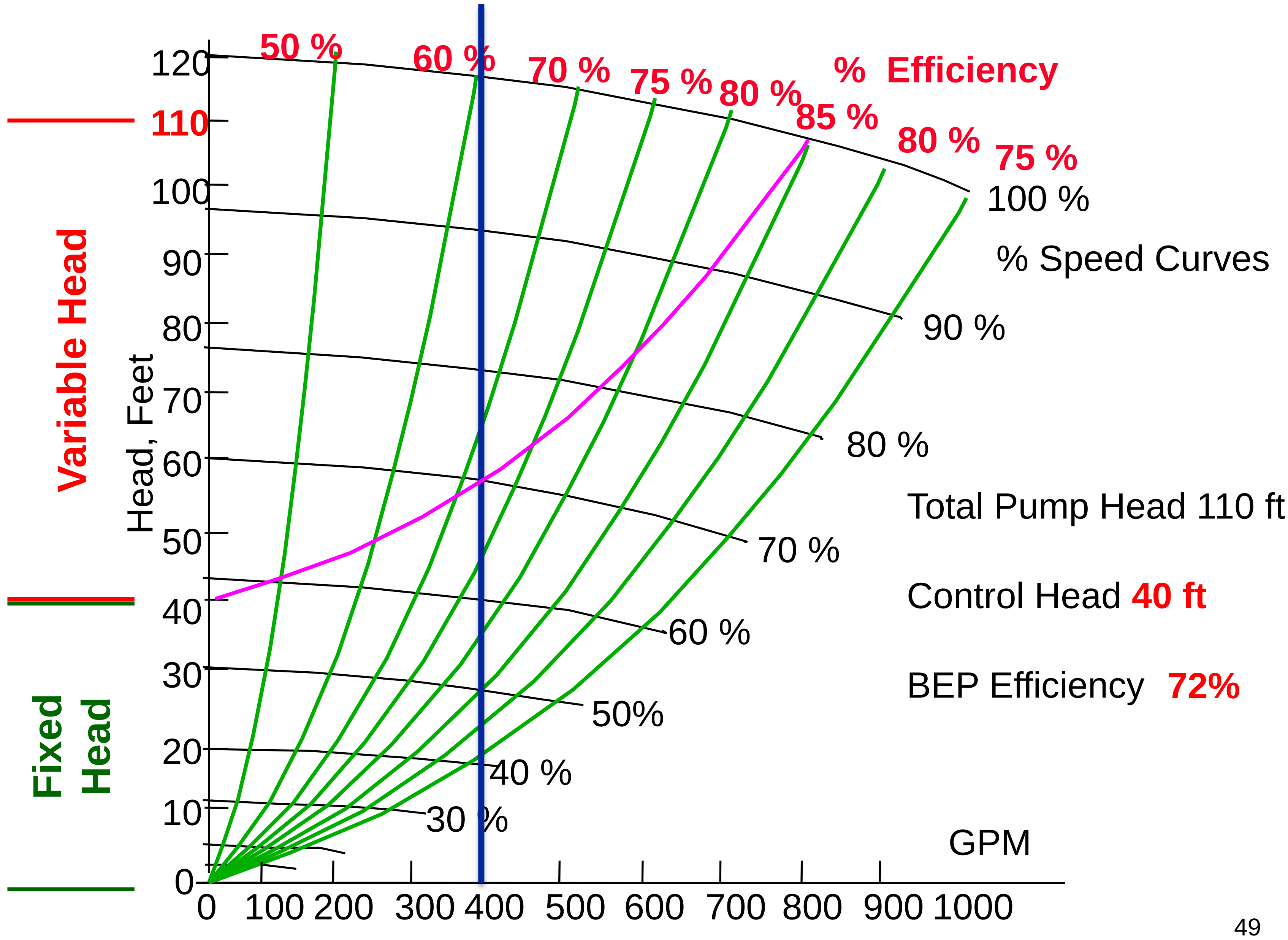
*Based on 50% Flow at 400 GPM

Real World V/S Curves



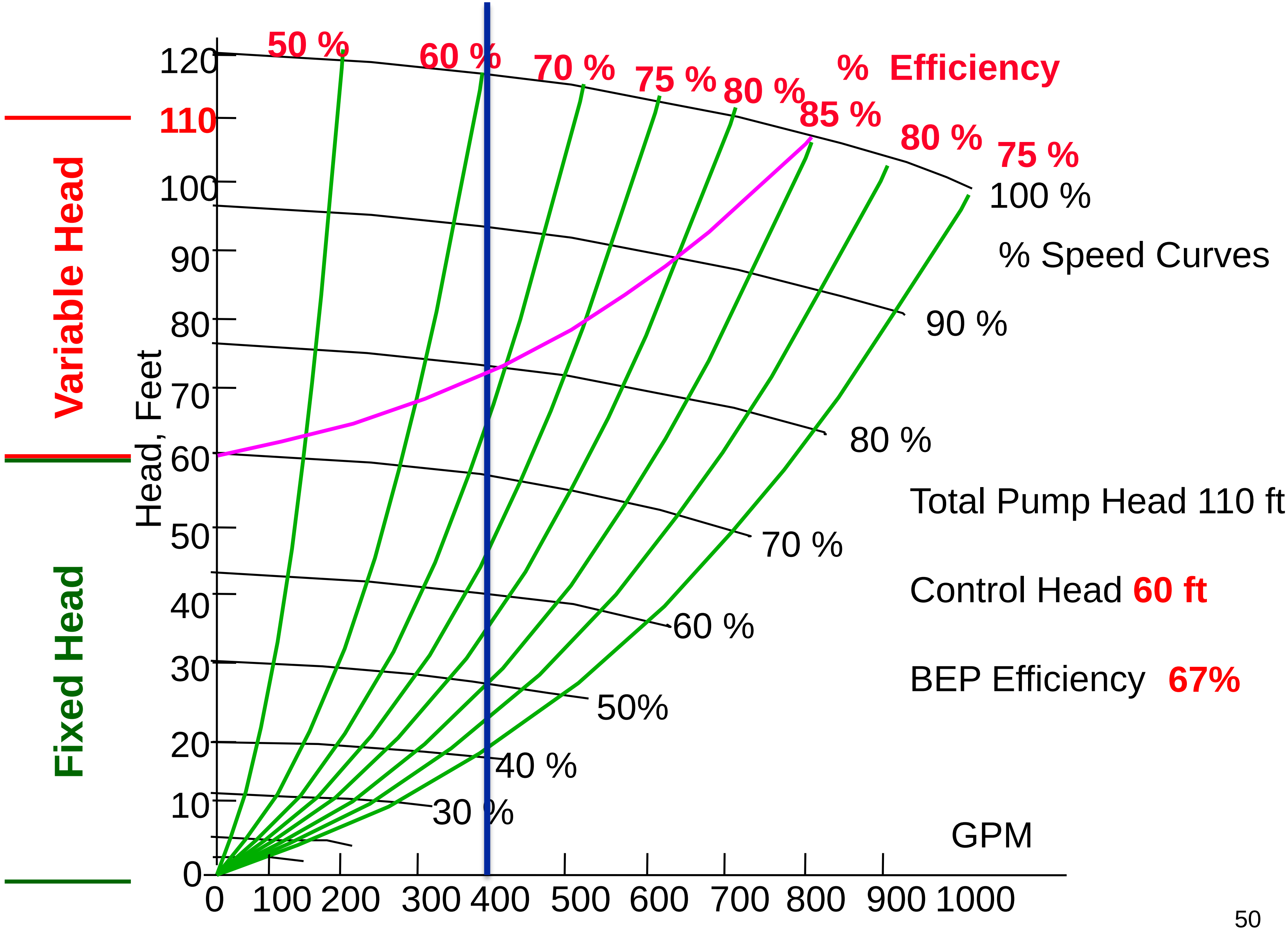
*Based on 50% Flow at 400 GPM

Real World V/S Curves



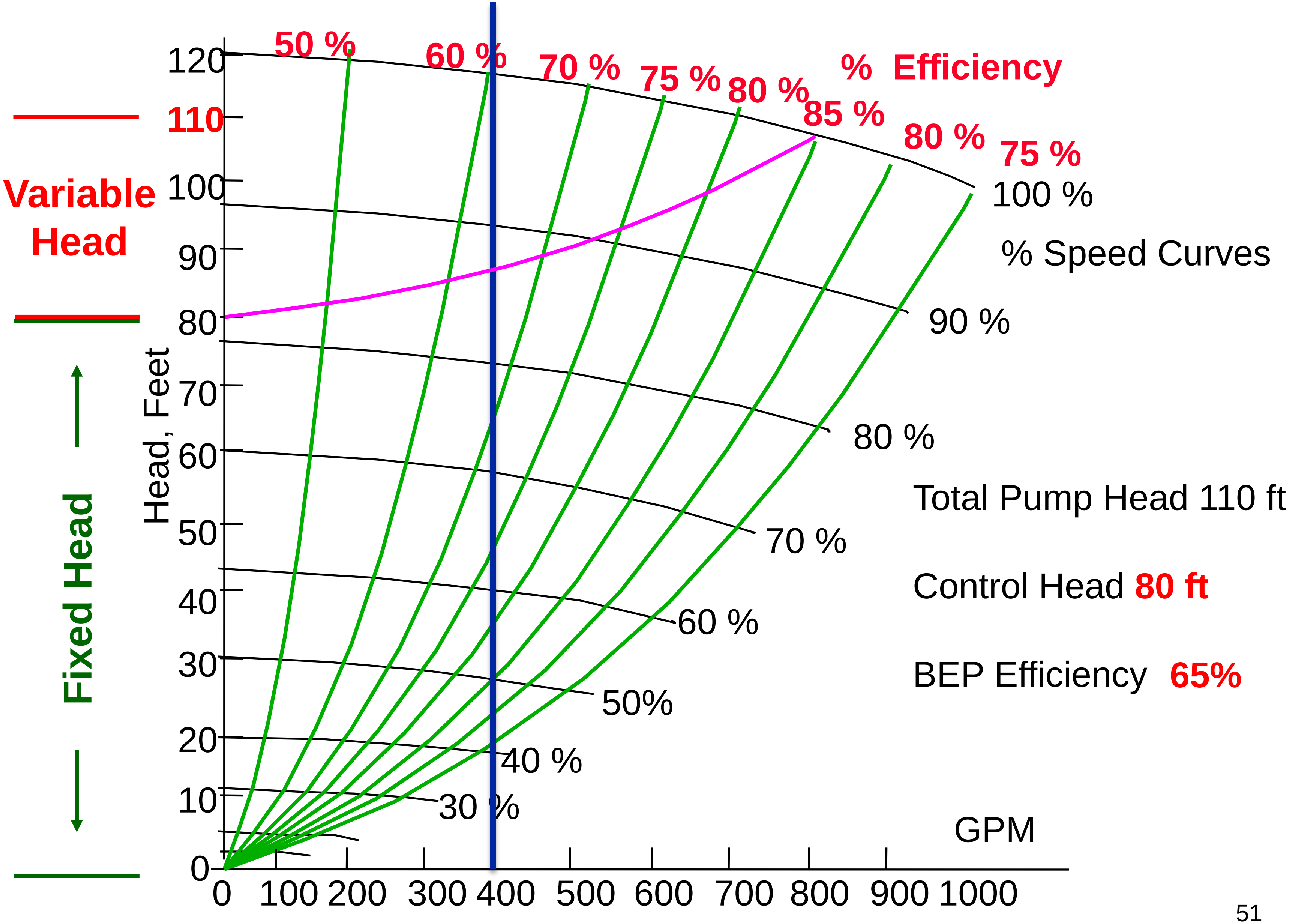
*Based on 50% Flow at 400 GPM

Real World V/S Curves



*Based on 50% Flow at 400 GPM

Real World V/S Curves



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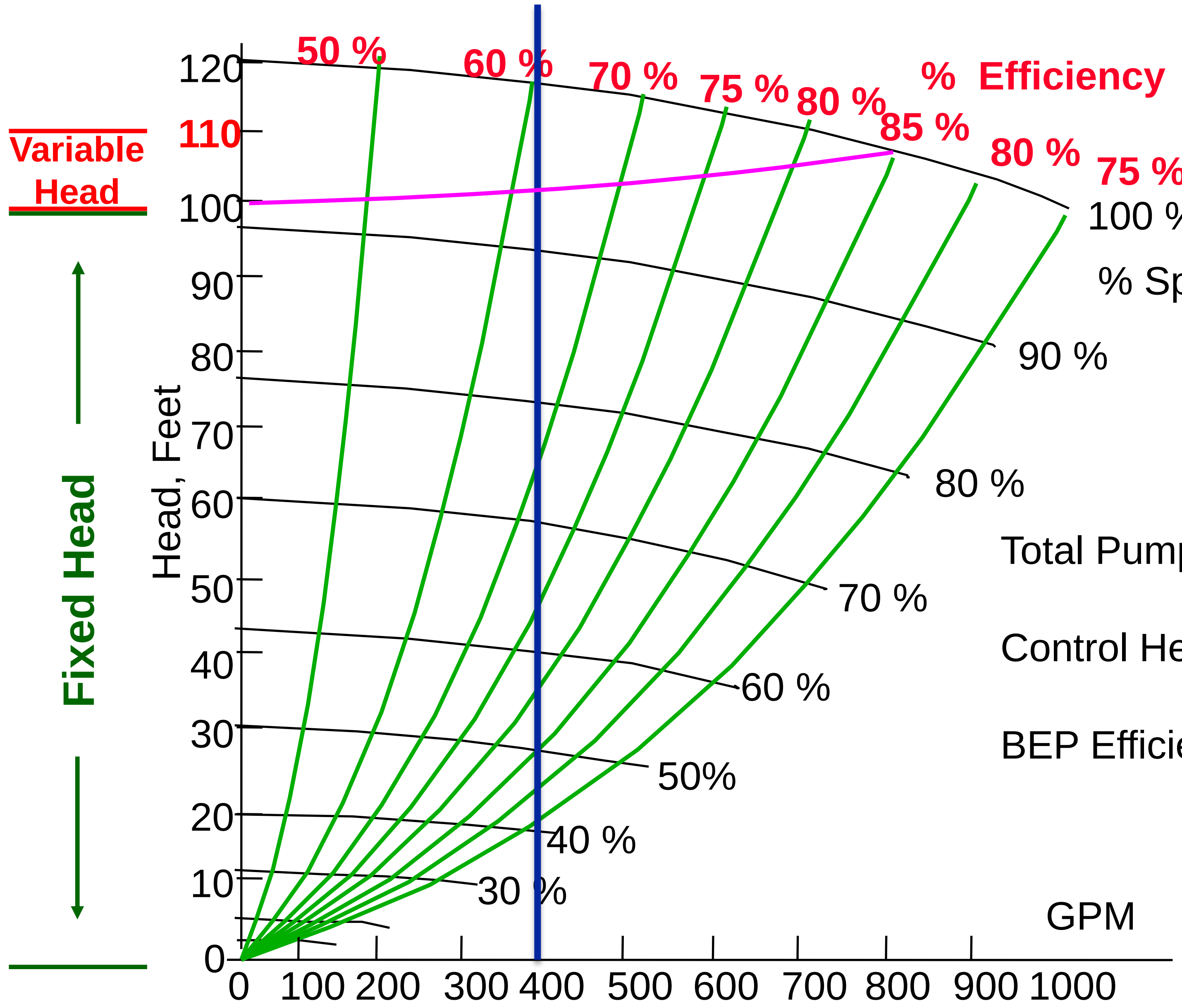
Real World V/S Curves



Total Pump Head 110 ft

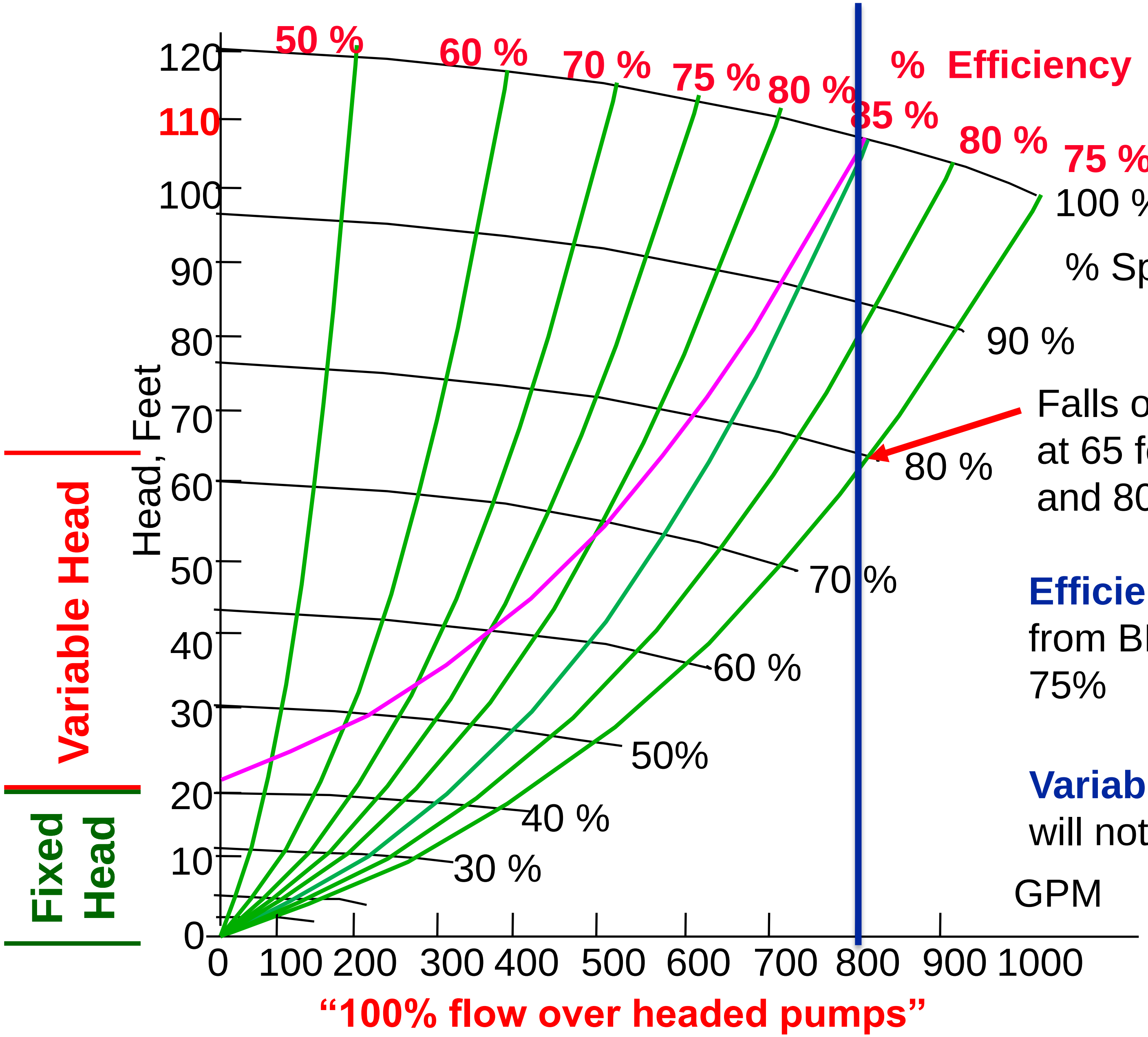
Control Head **100 ft**

BEP Efficiency **62%**

***Based on 50% Flow at 400 GPM**

What happens to **BEP pump efficiency at 100% flow** when you **over head** a pump?

Real World V/S Curves



Falls off pump curve at 65 feet of head and 80% speed

Efficiency changes from BEP of 85% to 75%

Variable speed drives will not fix the problem

- System Curve Review
  1. Fixed Head and Variable Head
  2. Constant Volume and Variable Volume
  3. Pump Selection Guidelines ASHRAE & HI
  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

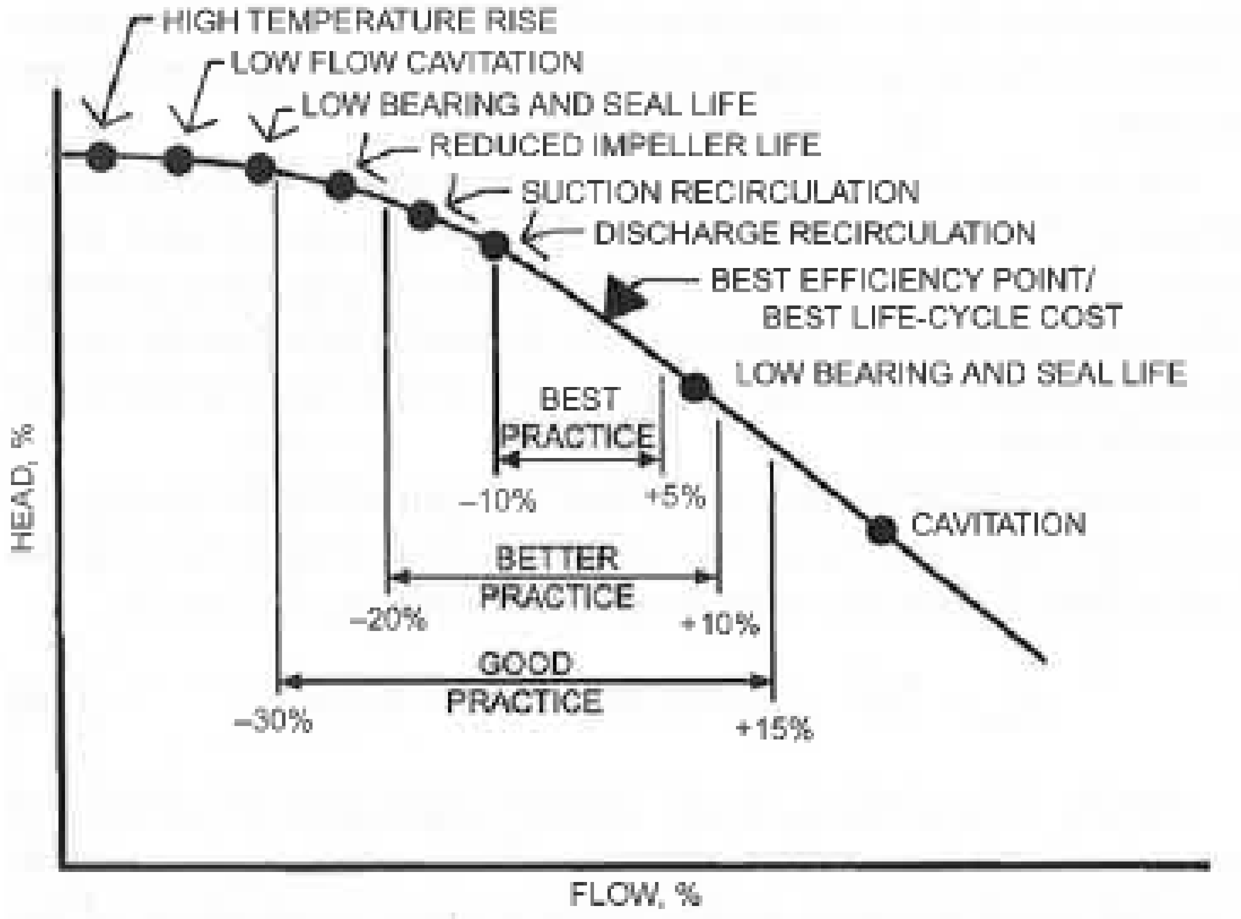
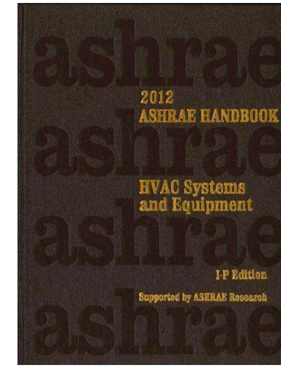


Fig. 7 General Pump Operating Condition Effects

(Hydraulic Institute)

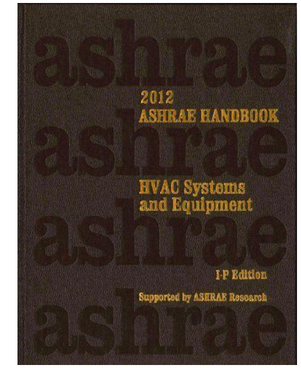
ASHRAE Recommendation



“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



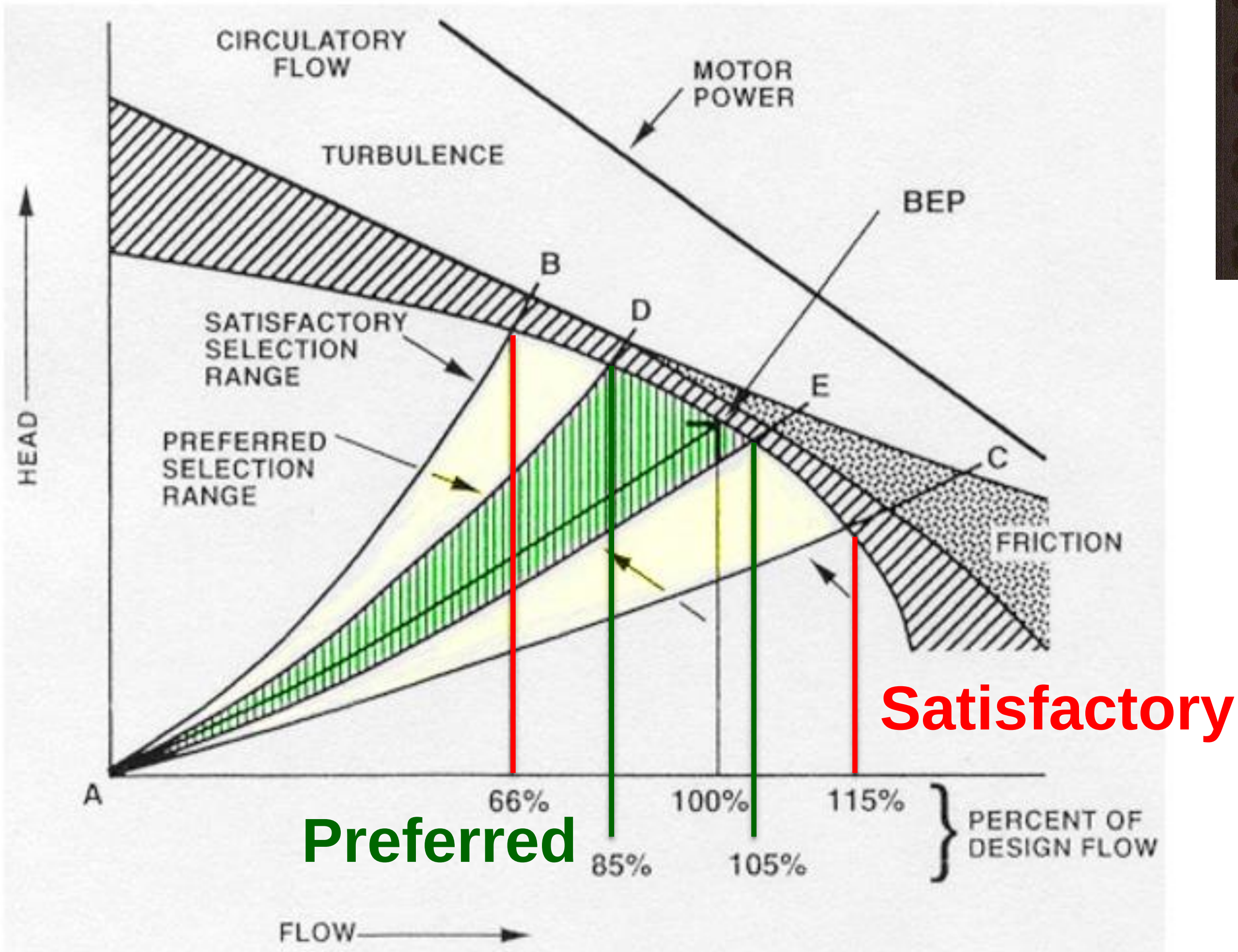


Fig. 33 Pump Selection Regions

2012 ASHRAE Systems and Equipment Handbook, p 44.11

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

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

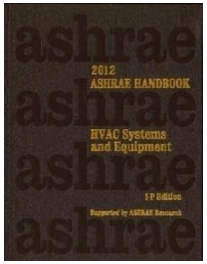
(**Must have accurate pump head calculations**)

(**Do Not Overhead**)

Two 50% parallel selected pumps will have a higher system efficiency and provide 70% plus standby

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

2012 ASHRAE Systems and Equipment Handbook, p 44.11



- 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
- 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

Efficiency Island Importance!

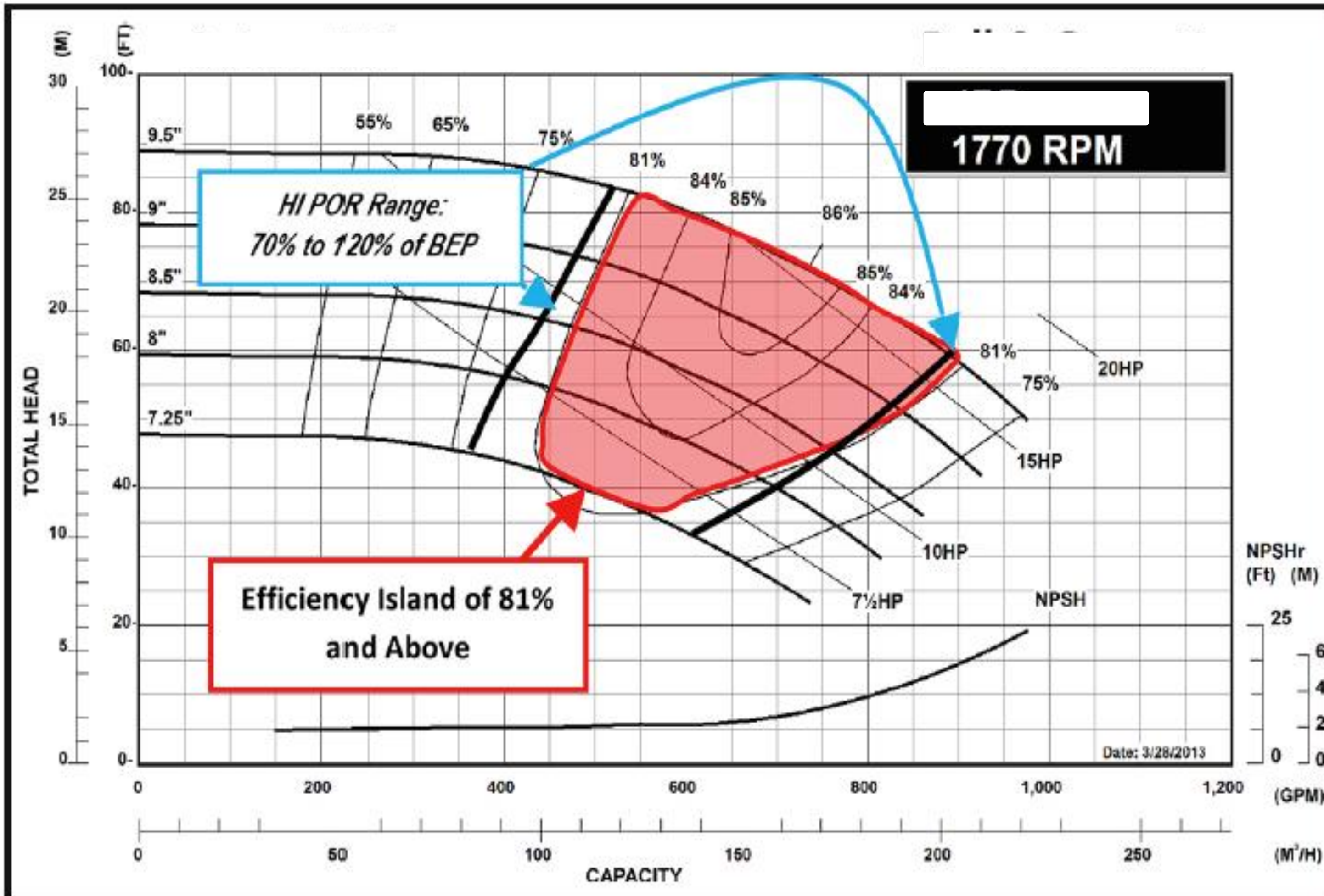
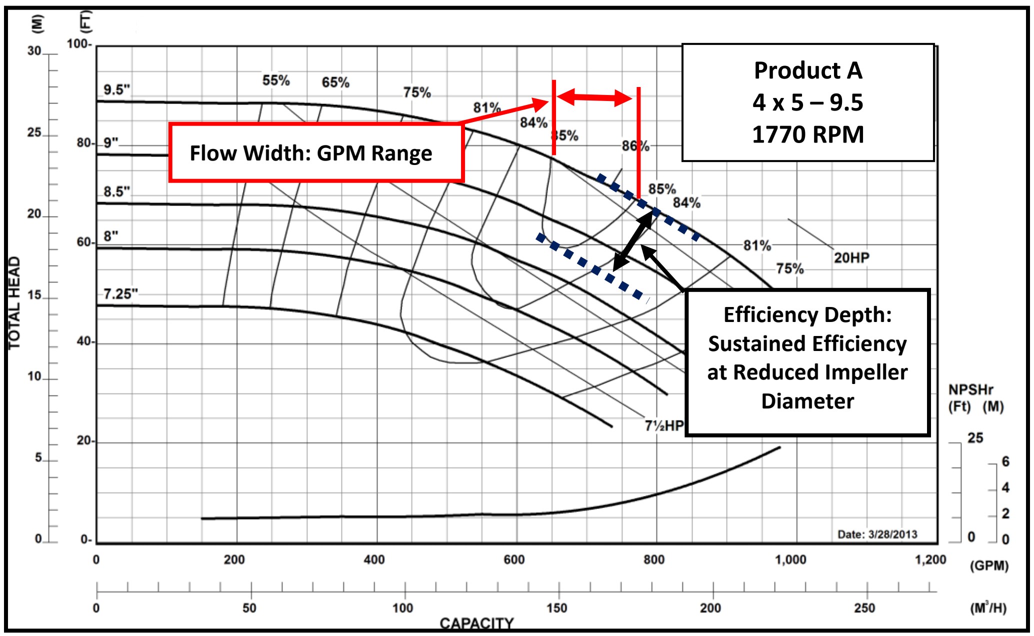


Figure 1

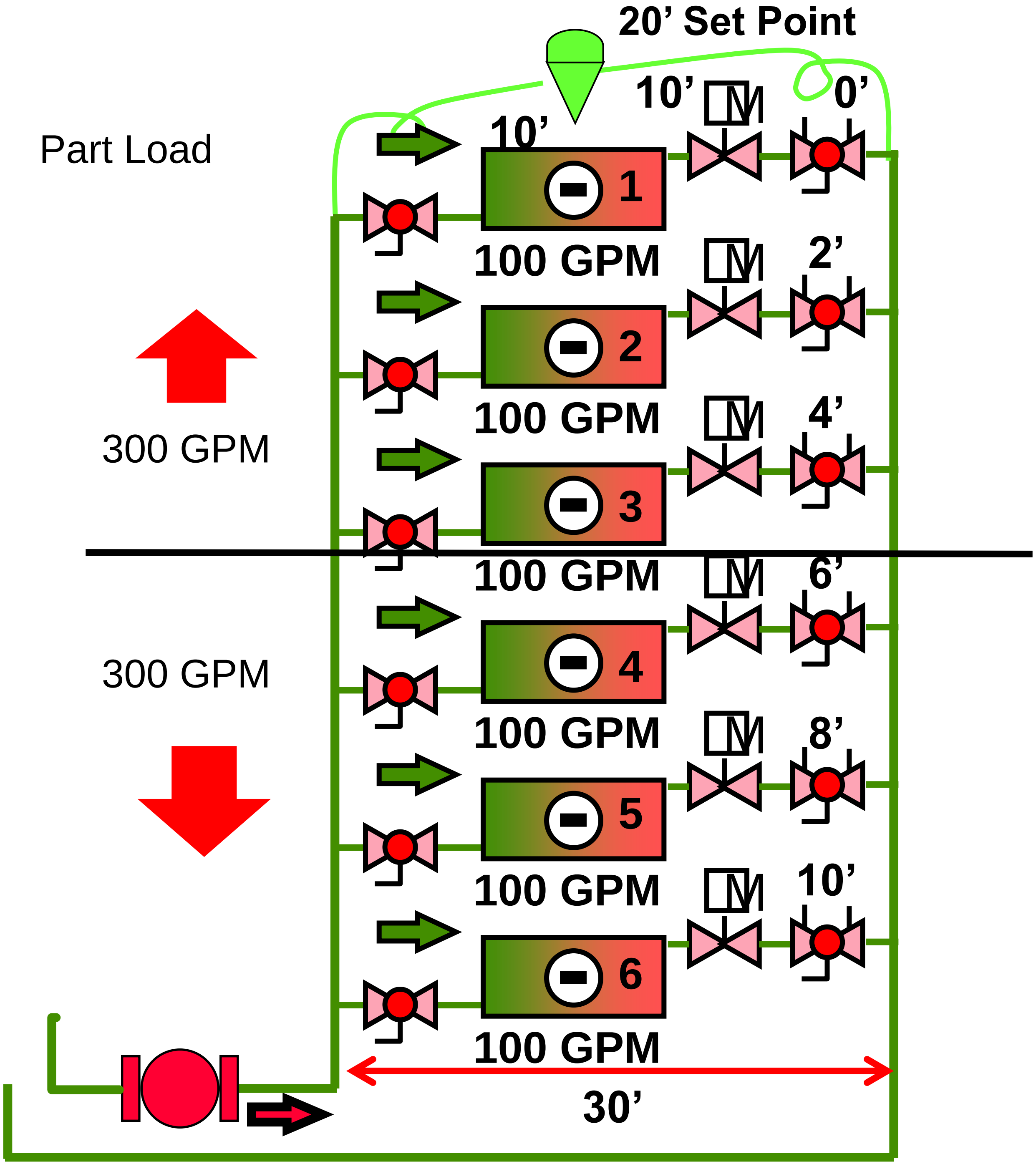
Efficiency Islands: A Technical Review

What are "Efficiency Islands"?



- The "Efficiency Island" should be as **wide and deep** as possible
- This illustration shows how the **width** is defined – in terms of flow rate for a given island
- The **depth** is also defined in terms of sustained efficiency as the impeller diameter is reduced

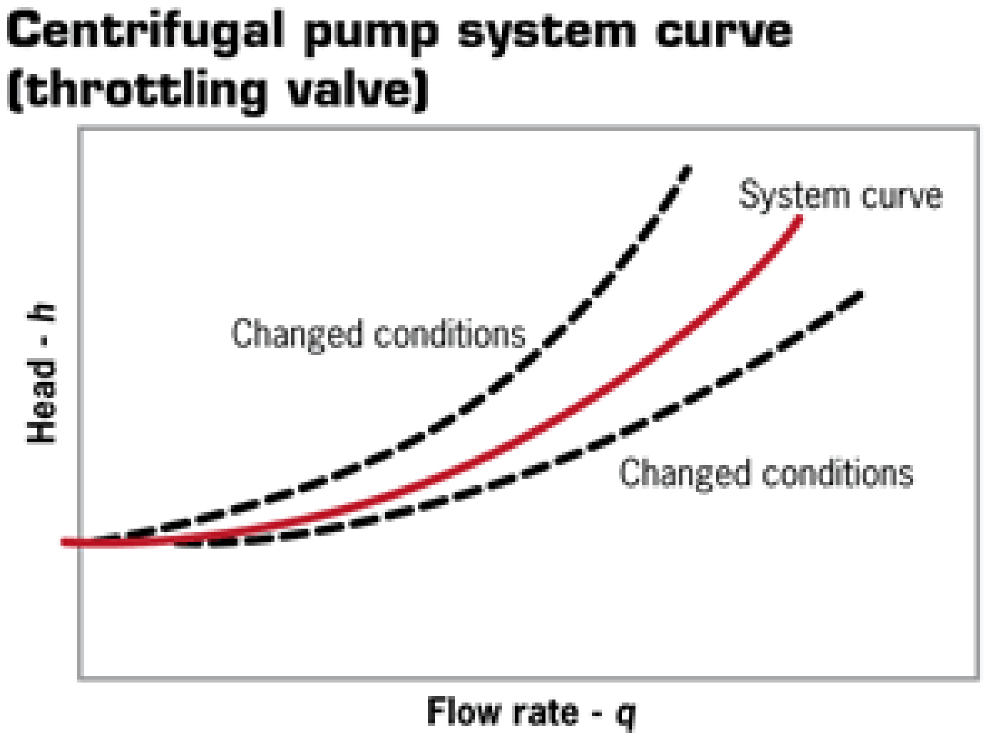
Bell & Gossett
a xylem brand



System Curve Area

As two way valves open and close we may have different flow paths and the system curve shifts. We define this as the **System Curve Area**.

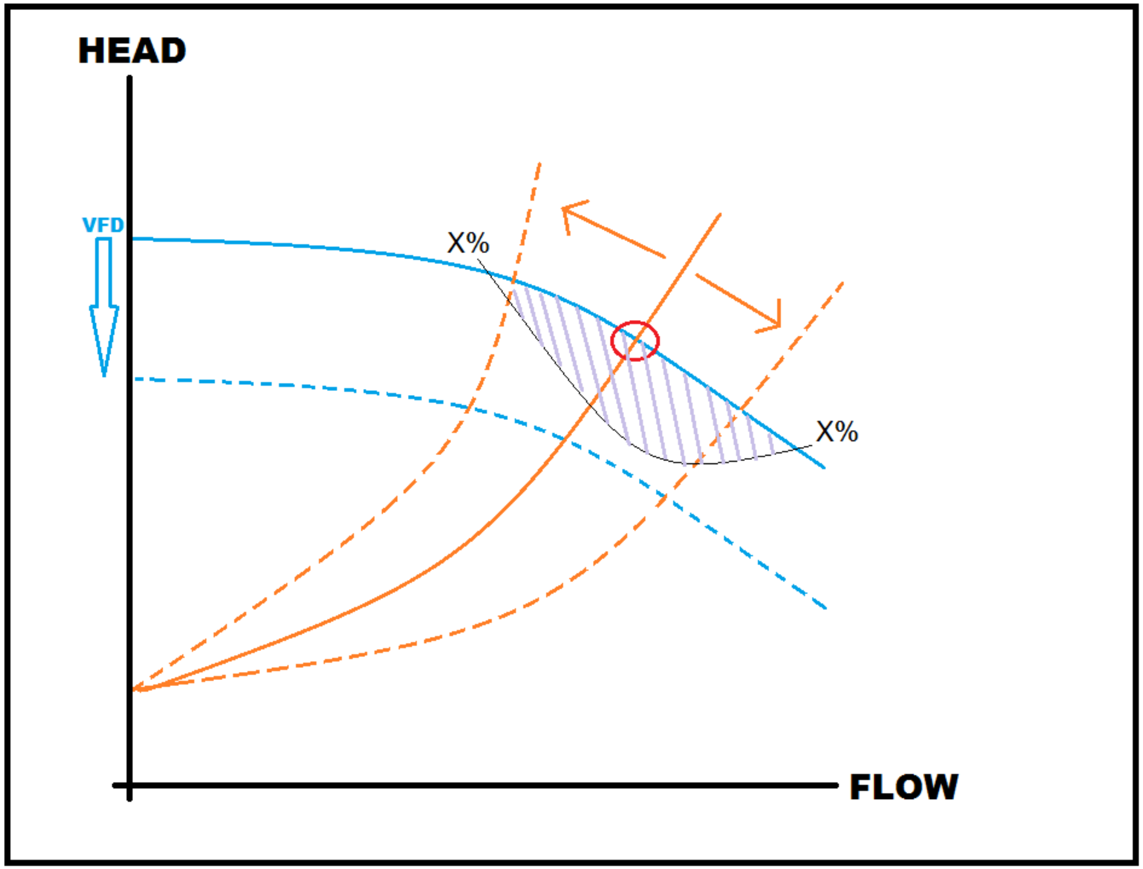
System Curve – Curve Movements & Shift



http://powerelectronics.com/site-files/powerelectronics.com/files/archive/eetweb.com/motors-drives/1211-Siemens-centrifugal-pump.gif

- **Open Valve**
  - Pivots curve to the **right**, higher flow at the same head
- **Closed Valve**
  - Pivots curve to the **left**, lower flow at the same head

Variable Frequency Drives & ASHRAE 90.1-2010

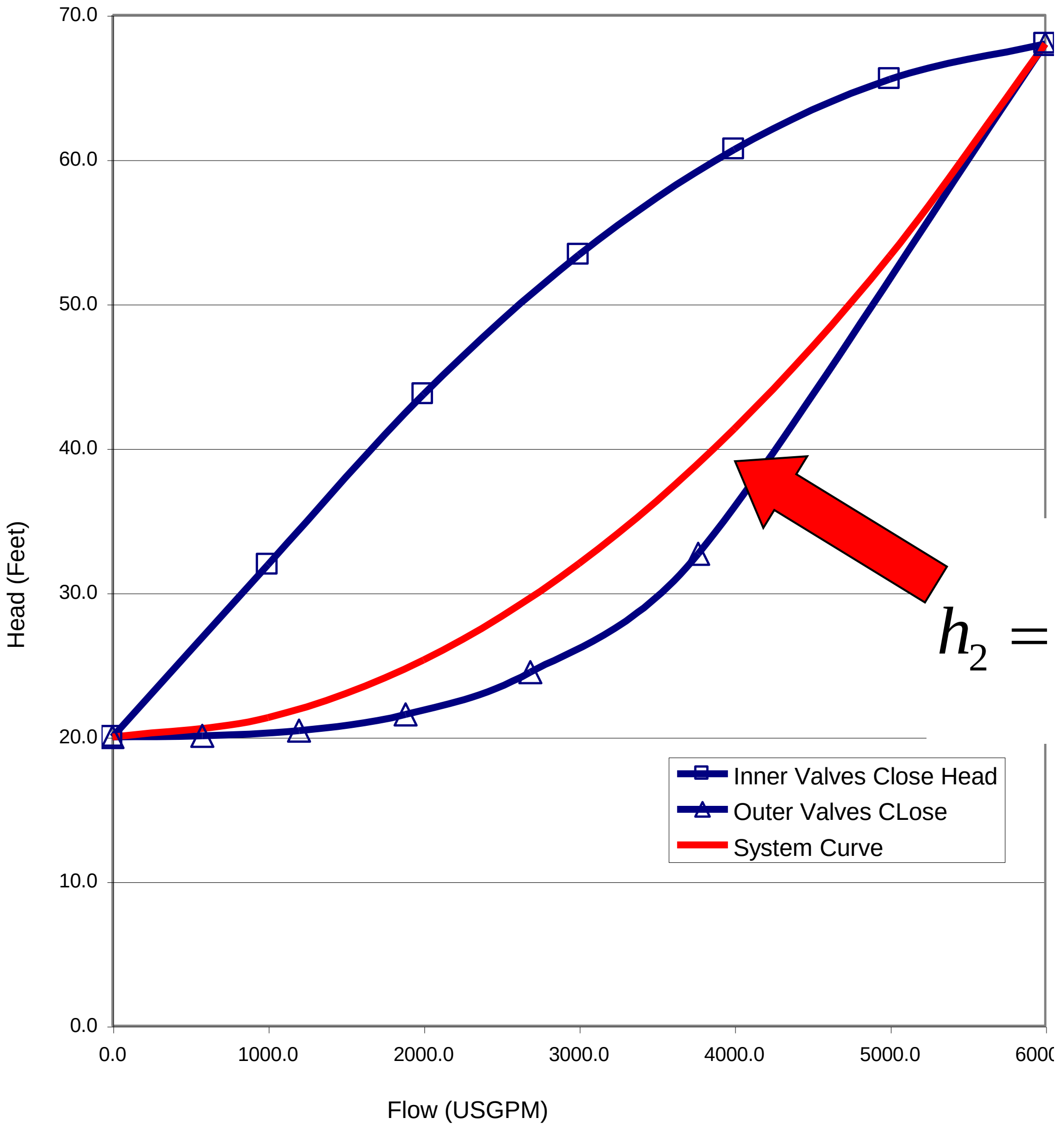


System Curve Area

As two way valves open and close we may have different flow paths and the system curve shifts. We define this as the **System Curve Area**.

- Deep and wide **efficiency islands** give the pump system more combinations to exist within the same efficiency.
- The use of a VFD can further the opportunities to maintain efficiency while maintaining target system condition.

The Control Curve



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

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

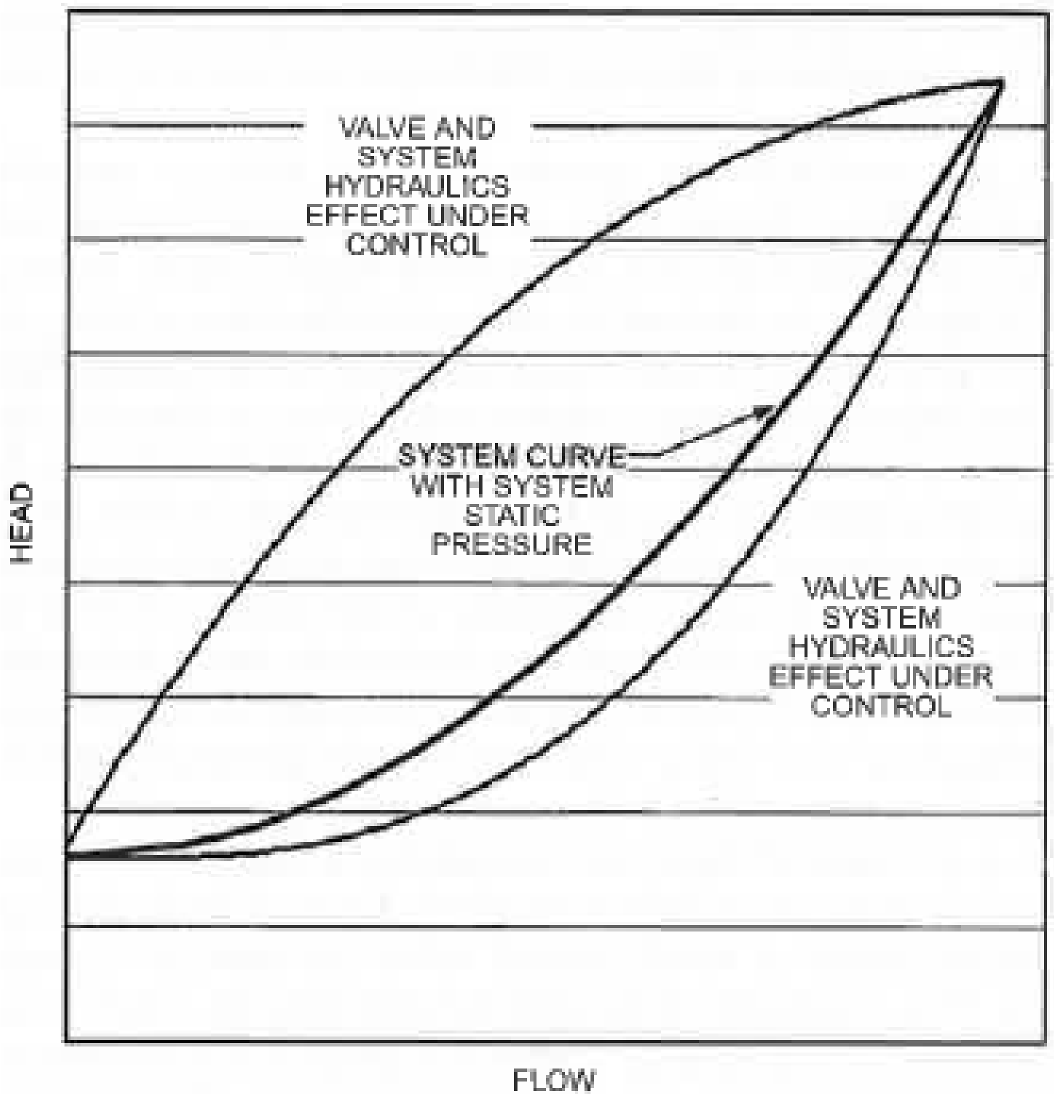


Fig. 13 System Curve with System Static Pressure

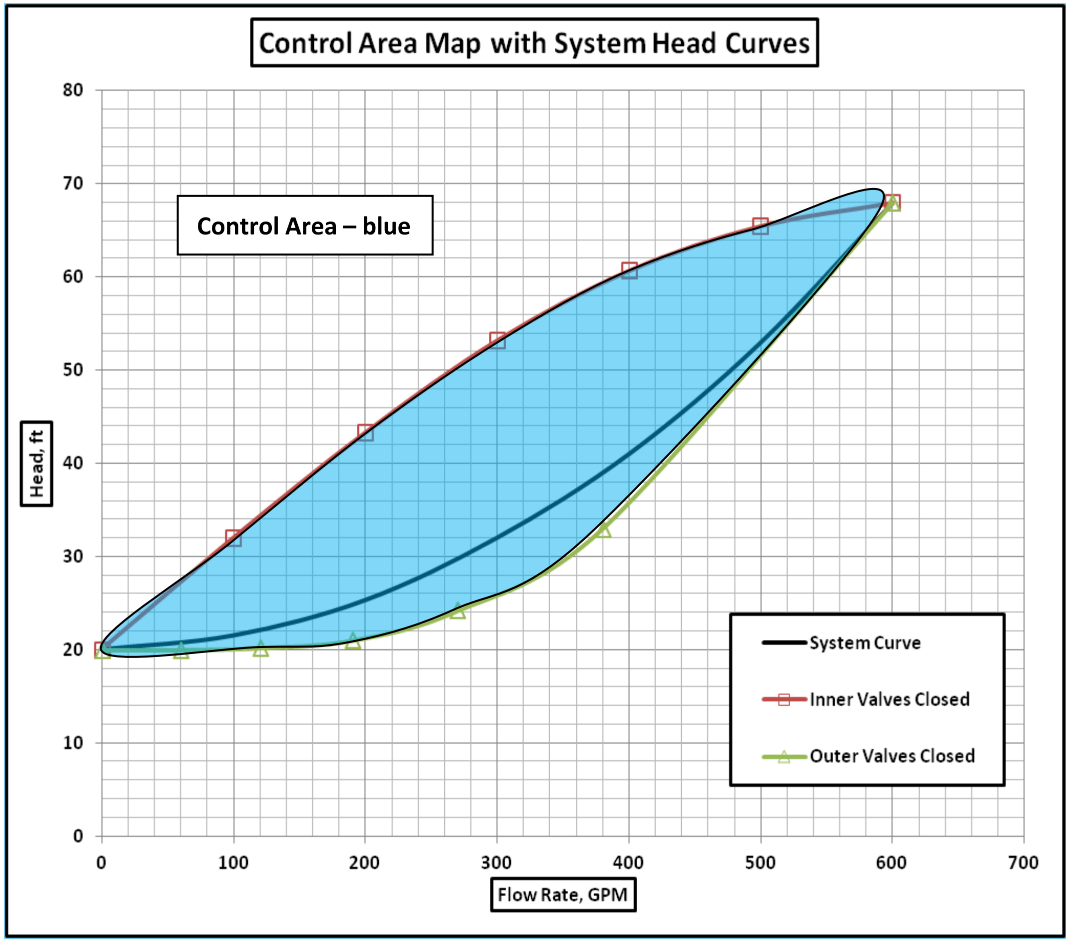
Flow will be at 50% are less the majority of the time with typical load profiles

2012 ASHRAE Systems and Equipment Handbook, p 13.9

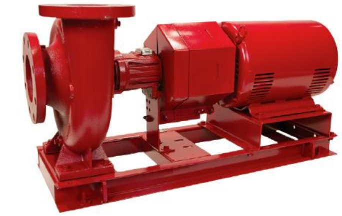
Control Area

Efficiency Islands: A Technical Review

Control Area and System Head Curves



- The **control area (blue region)** is the area between the upper and lower system head curves
- Pump operation can occur within this zone, not just at the upper and lower boundaries or on a single system curve
- Operation in a narrow band of flow rate and pressure simply doesn't happen
- To provide efficient systems, "**Efficiency Islands**" need to be wide, deep and with high efficiency levels
- **Narrow flow width** for iso-efficiencies and **rapid drop** in efficiency with impeller trim are **undesirable pump characteristics**



End Suction Base Mounted Pump

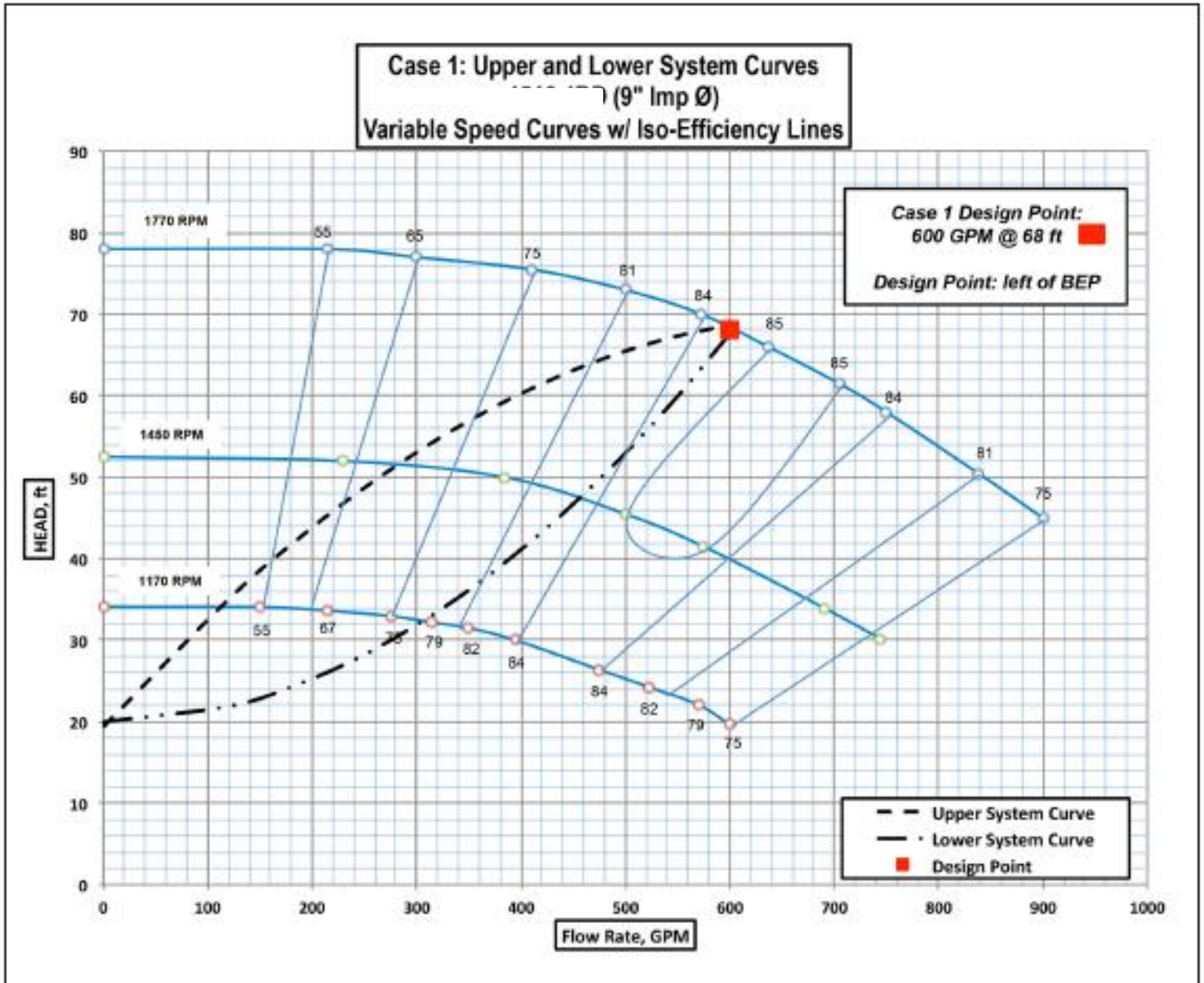
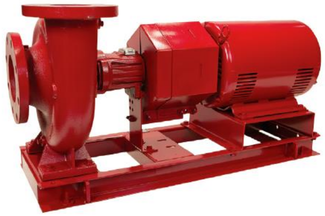


Figure 13


End Suction Base Mounted
Pump

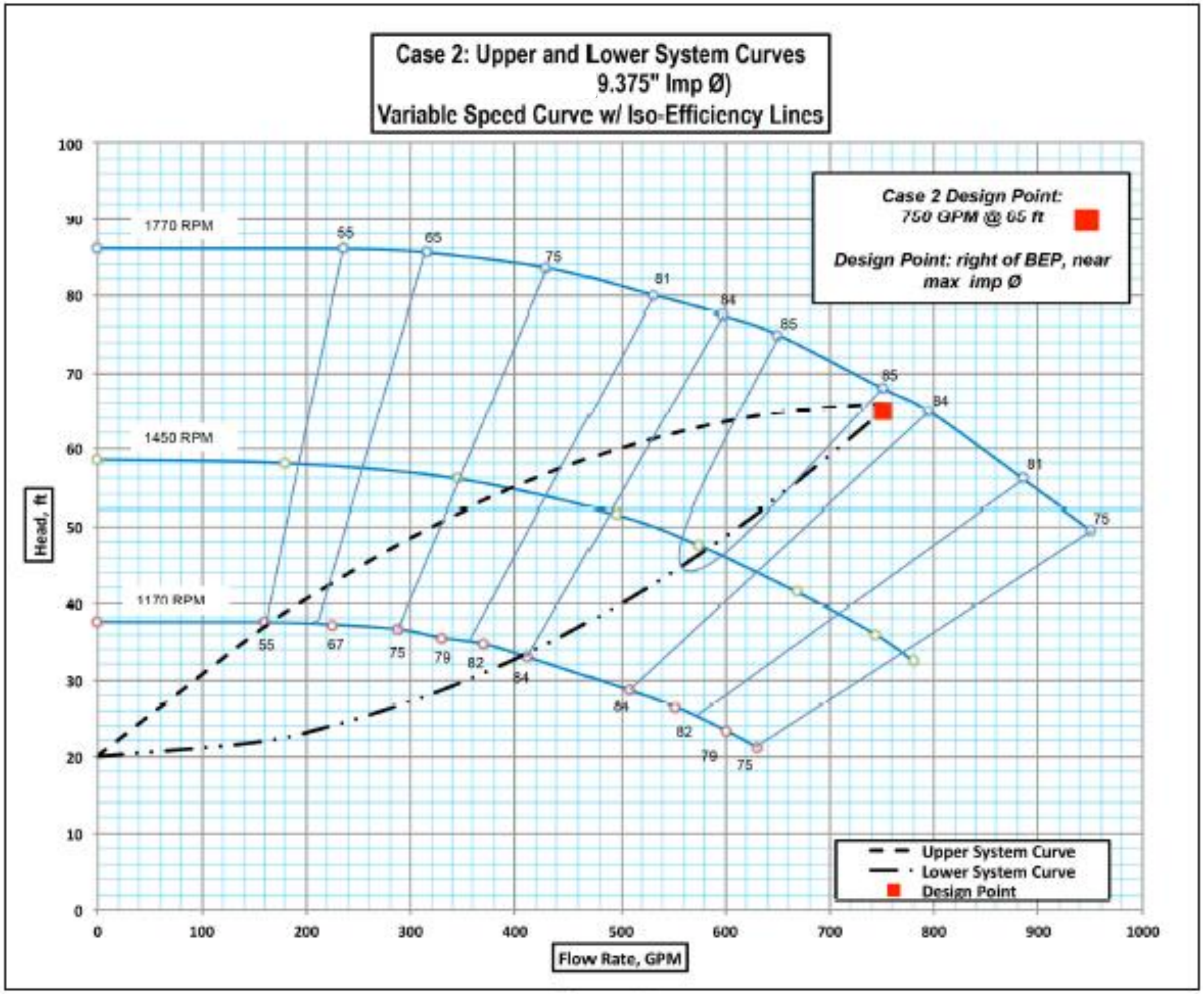

Case 2: Upper and Lower System Curves
9.375" Imp Ø)
Variable Speed Curve w/ Iso-Efficiency Lines
Case 2 Design Point:
750 GPM @ 65 ft
Design Point: right of BEP, near max imp Ø
1770 RPM
1450 RPM
1170 RPM
Head, ft
Flow Rate, GPM
Upper System Curve
Lower System Curve
Design Point

Figure 14

Suggested **Pump PLEV** Efficiency Specification

The **Pump PLEV** efficiency based on ARI Standard 550/590 “**IPLV**” load profile, **30% fixed head or calculated minimum control head**, shall not be less than that of the pump specified. A detailed pump efficiency report at each load point based on that load profile shall be submitted with the pump. A, B, C and D is the pump efficiency at 100%, 75%, 50% and 25% of flow rate.

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

Suggested Pump PLEV Efficiency Specification

PUMP SCHEDULE															
TAG / ID	MANUFACTURER	MODEL NUMBER	LOCATION	TYPE	PUMPING SYSTEM				MOTOR						REMARKS
					FLOW	HEAD	CONTROL SETPOINT	PLEV EFFICIENCY	NOMINAL POWER	PHASE	VOLT	MONINAL RPM	SPEED CONTROL		
					GPM	FT	FT		HP						
P-1	XXXX	XXXX	CHW SECONDARY SYS	END SUCTION	1000	110	33	80.16	40	3	460	1750	VFD		1,2,3
P-2	XXXX	XXXX	CHW TERCHARY SYS	END SUCTION	600	69	20	82.96	15	3	460	1750	VFD		1,2,3

NOTE 1: PUMPING SYSTEM PLEV TO BE CALCULATED PER ARI STANDARD 550/590 LOAD PROFILE AND WEIGHTING; MOTOR EFFICIENCY AT 93% AND VFD EFFICIENCY AT 97% UNLESS SPECIFIED OTHERWISE

NOTE 2: PUMPING SYTEM PLEV TO BE CALCULATED WITH CONTROL CURVE PER SPECIFIED CONTROL SETPOINT WITH CONTROL CURVE CONVERGING AT DESIGN FLOW AND HEAD

NOTE 3 A detailed pump efficiency report at each load point based on PLEVv (Equation provided below) load profile shall be submitted with each of the pump or pumps listed within this schedule. A, B, C and D are the pump efficiency values at 100%, 75%, 50% and 25% of flow rate. Based on the above equation, during any given year the Pump will operate at 100% flow (Duty Point) -only 1% of the year, 75% flow - 42% of the year. 50% flow - 45% of the year and 25% flow -only 12% of the entire year.

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

Suggested Pump PLEV Efficiency Spec Tool

Inputs are in Yellow

Design flow (GPM):	1000
Design pump head (feet):	110
Control head (feet):	10

	Pump Flow	Pump Head	Pump Efficiency (%)	
100%	1000	110	83.0%	A
75%	750	66	82.8%	B
50%	500	35	82.9%	C
25%	250	16	76.8%	D

↓

PLEV Formula (ARI 550/590 Standard):

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

Pump PLEV Efficiency = 82.1%

PLEV Specification: Click Here for Specifications

Part Load: IPLV =

ARI

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

= Part Flow: PLEV

HVAC Pumps

Heating and Cooling Flow Rates

ARI 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		

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

expressed in blended efficiency

Note: Assume pump flow rates match % load

To Get **Highest System** Pumping Efficiency

- Goal is to **maximize efficiency island**:
  Greatest range of flow and greatest span of total head

- By having a **larger island**, **shifts in the system curve** or movements along the pump curve can happen within the **same efficiency range**

To Get **Highest System Pumping** Efficiency

Maximize your efficiency islands!!!

- System Curve Review
  1. Fixed Head and Variable Head
  2. Constant Volume and Variable Volume
  3. Pump Selection Guidelines ASHRAE
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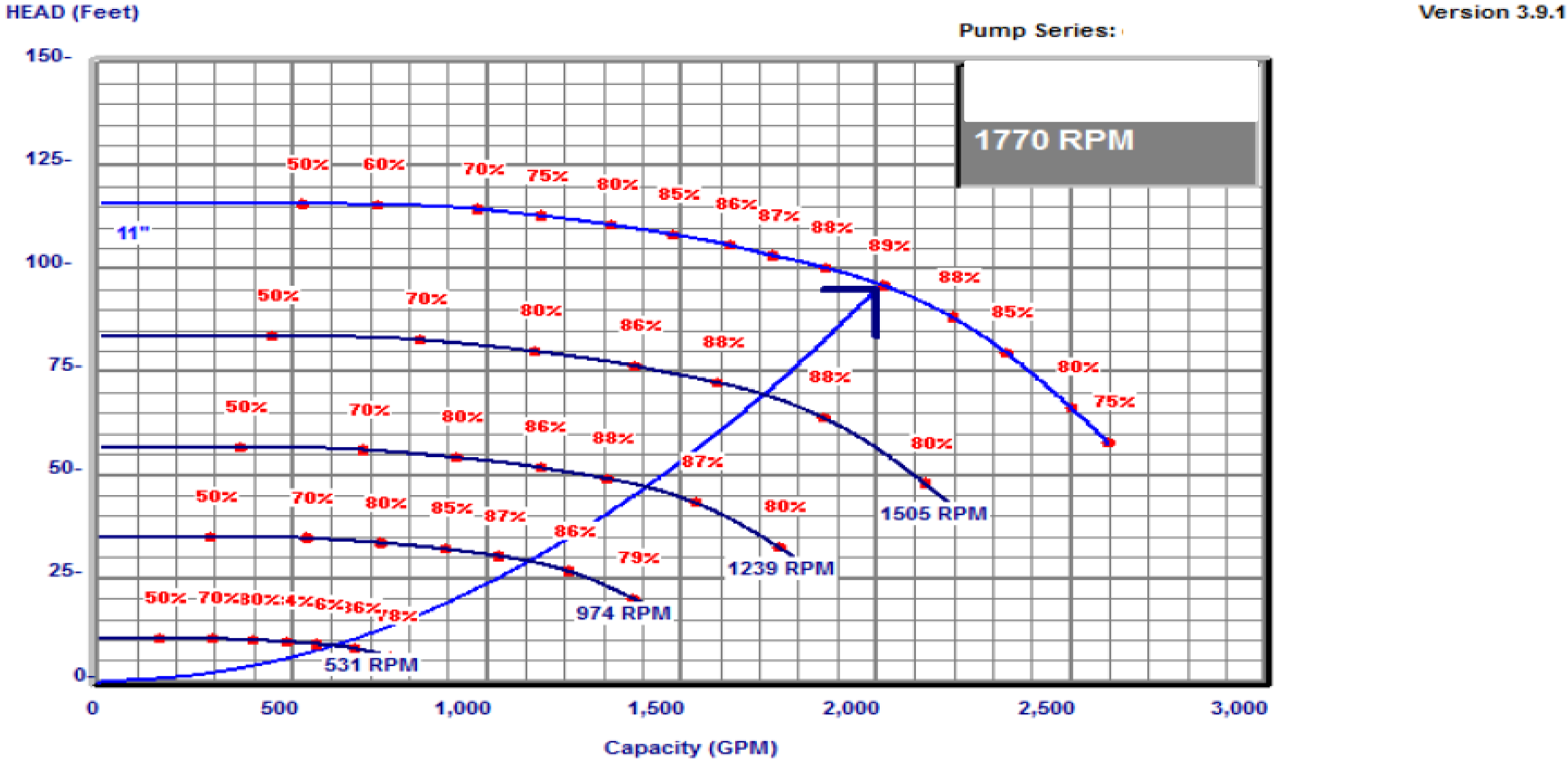
  1. Variable Volume Pump Sections and Efficiency Islands
     - Energy Savings Old Versus New Pumps



Suction Size = 8 "
Discharge Size = 6 "

Min Imp Dia = 9 "
Max Imp Dia = 11 "
Cut Dia = 11 "

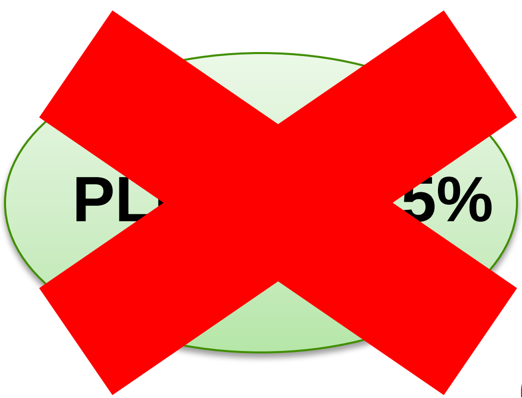
Design Capacity =2000.0 GPM
Design Head =95.0 Feet
Motor Size =60 HP

The Power and Eff. curves shown are for the cut dia. impeller.

“100% Variable Head”

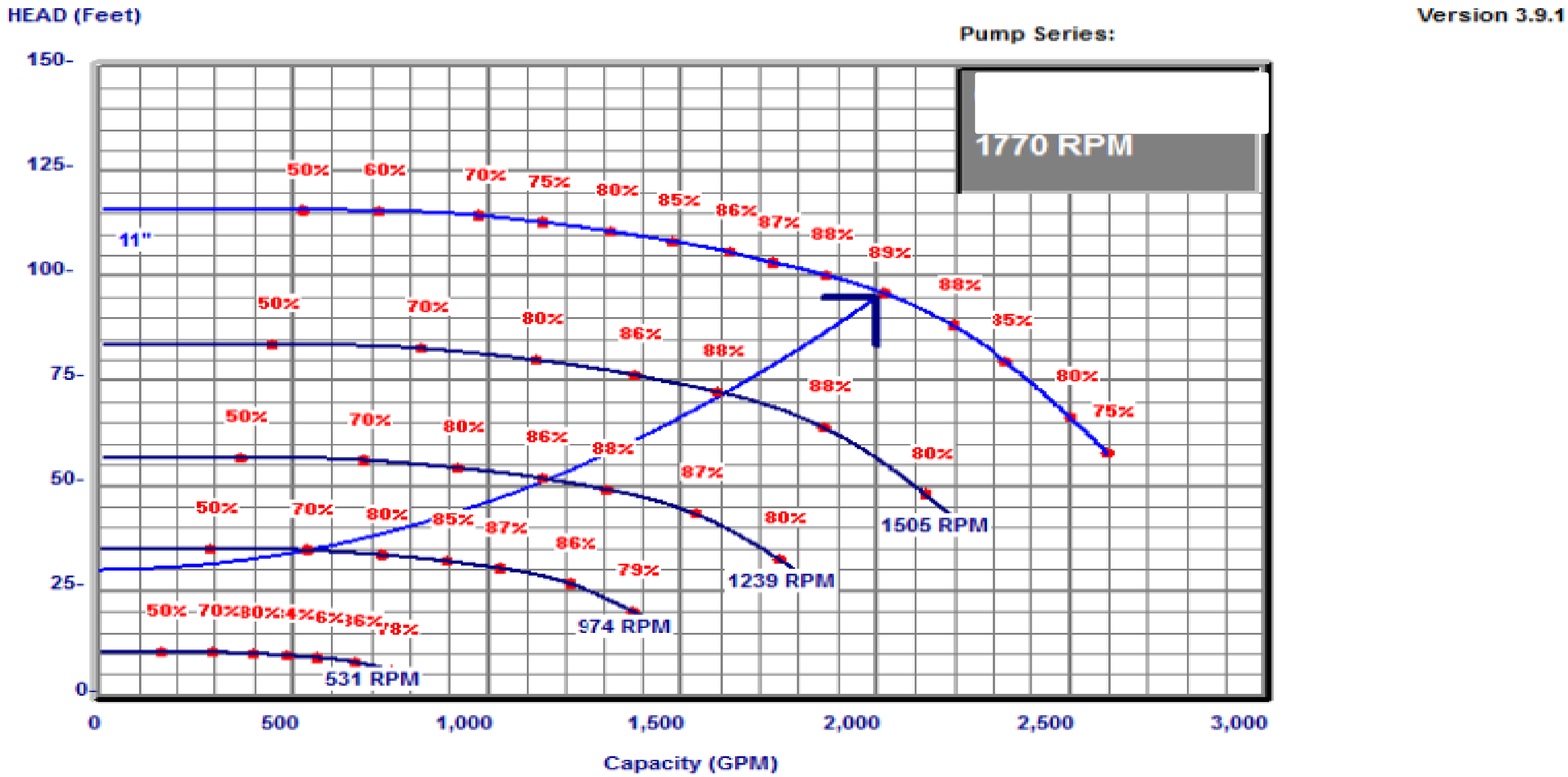
Life Cycle Costing

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

"100% Variable Head"



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Min Imp Dia = 9 "
Max Imp Dia = 11 "
Cut Dia = 11 "

Design Capacity =2000.0 GPM
Design Head =95.0 Feet
Motor Size =60 HP

he Power and Eff. curves shown are for the cut dia. impeller.

"30 Feet Constant Head"

Life Cycle Costing

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%

PLEV = 84.5%

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

"30 Feet Constant Head"

Who is going to pay the difference?

"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%

91

Which Island would you pick?

The End!

Thank you for coming!