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Let's Solve Water

The Little Red Schoolhouse

Large Chilled Water System Design Seminar

Courtesy of Oslin Nation Company

Variable Speed Pumping

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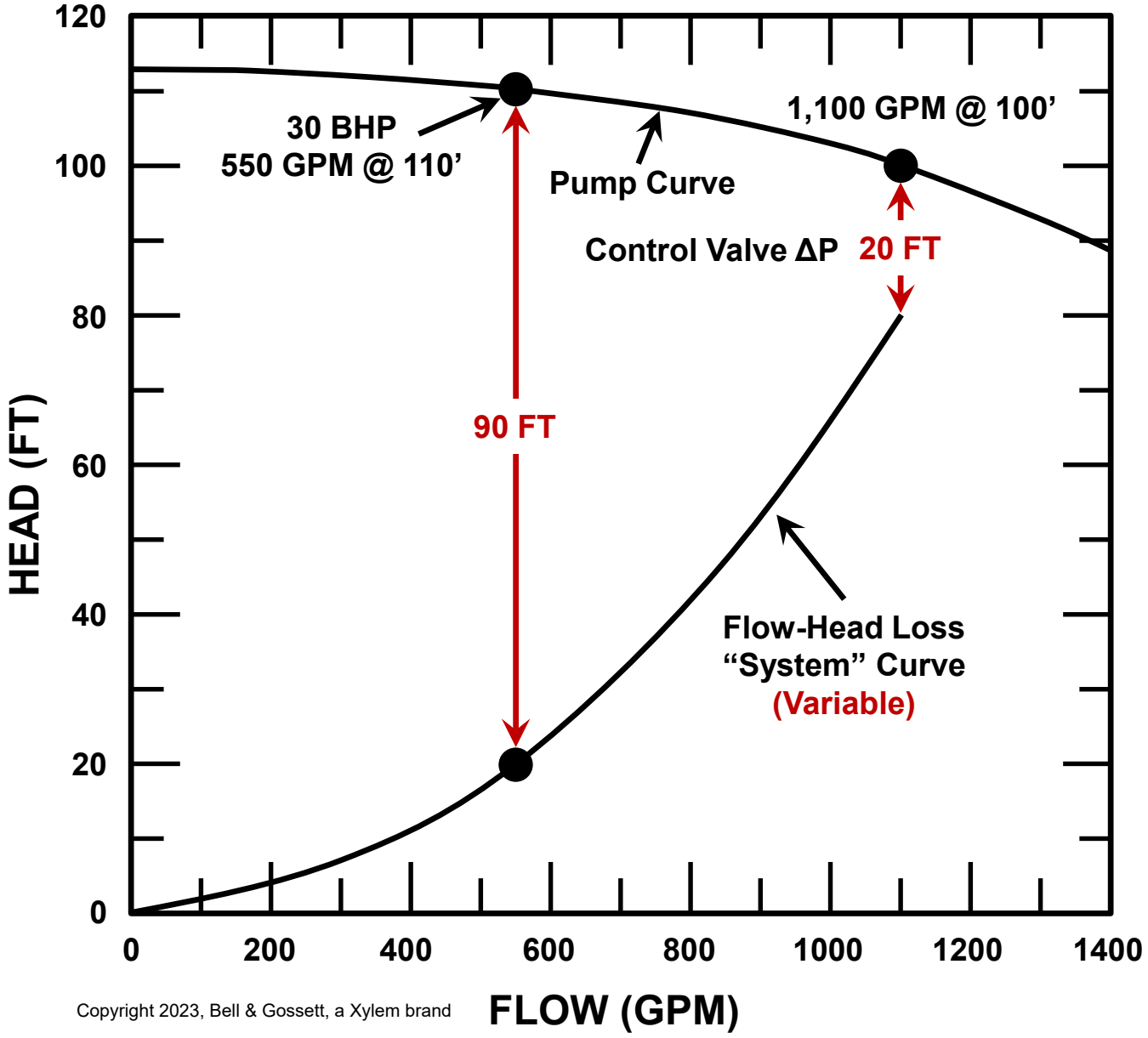
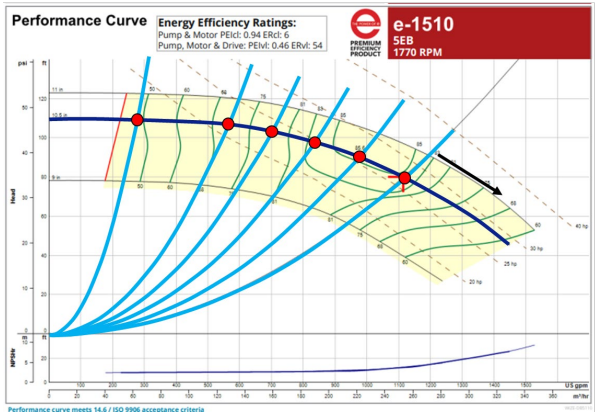
ASHRAE 90.1 Section 6.5 – Prescriptive Compliance Path

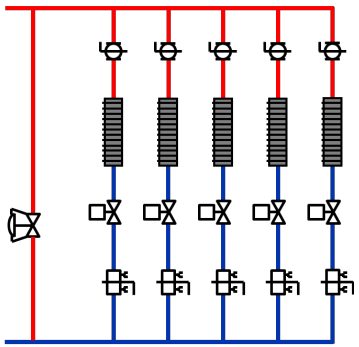
6.5.4.2 Hydronic Variable Flow Systems

Chilled- and – Hot Water *distribution systems* that include **three or more *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 and configured to **reduce pump flow rates to no more than the larger of 25% of the design flow rate or the minimum flow required by the heating/cooling *equipment manufacturer*** for the proper operation of *equipment.*

…. Individual or parallel pumps serving variable-flow heating-water or chilled-water *systems*, where the *nameplate horsepower* of the motor or combined parallel motors is at least **2 HP or greater**, shall have *controls* or devices that will result in pump motor *demand* of **no more than 30% of design wattage at 50% of the design water flow.**







- Pump Head increases with flow reduction
- Piping/Equipment head loss decreases with flow reduction

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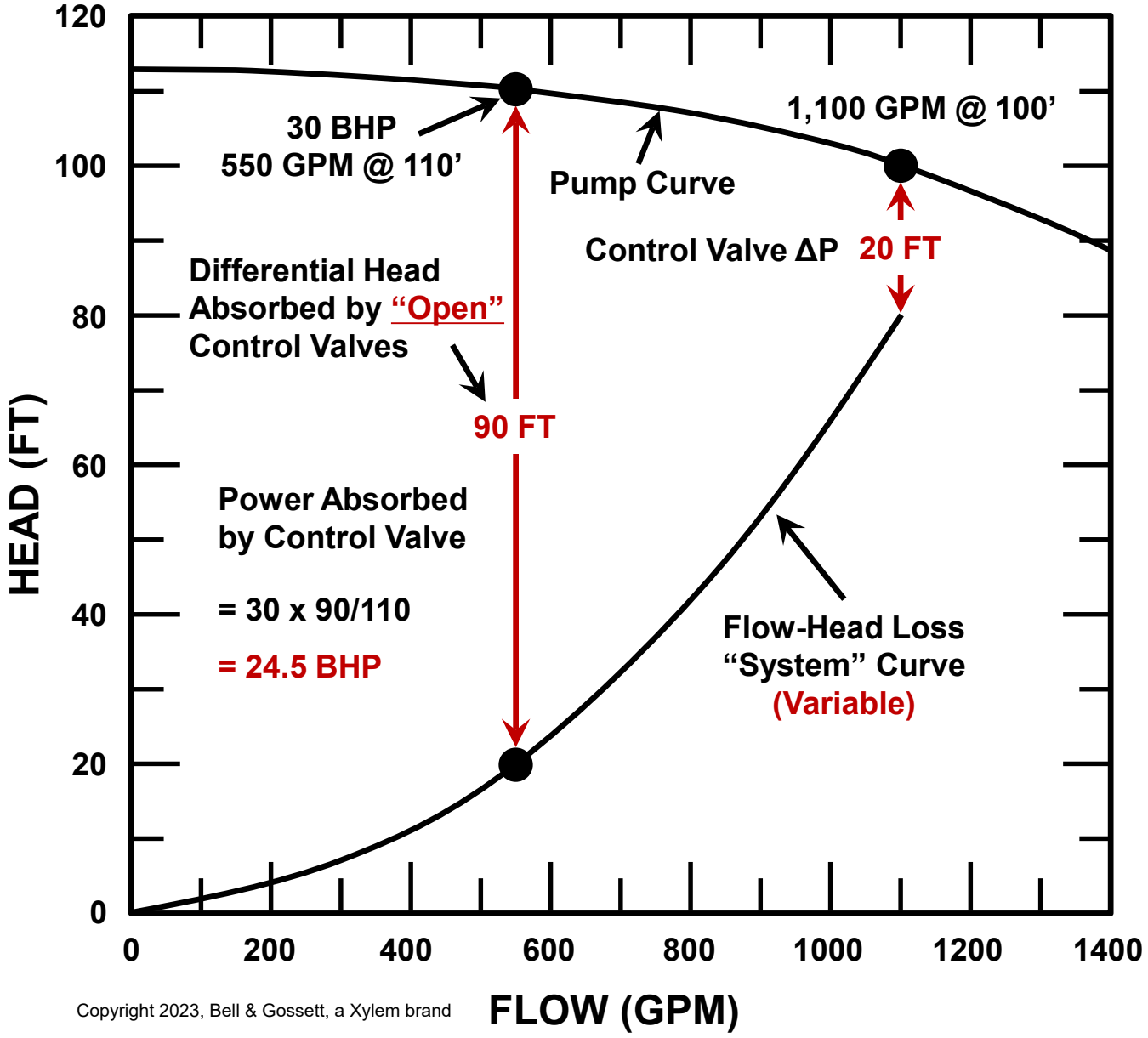

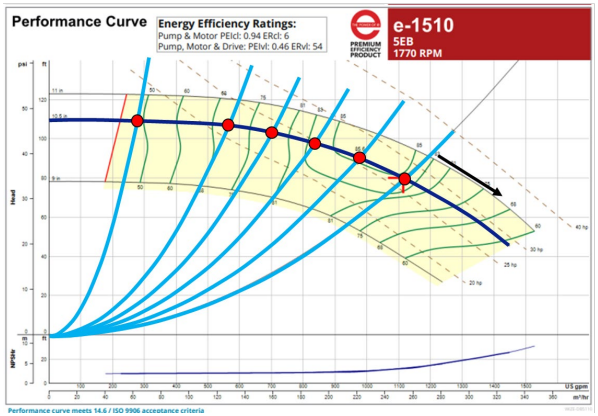

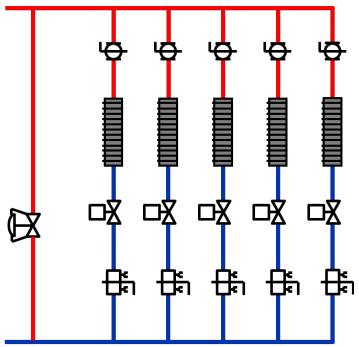

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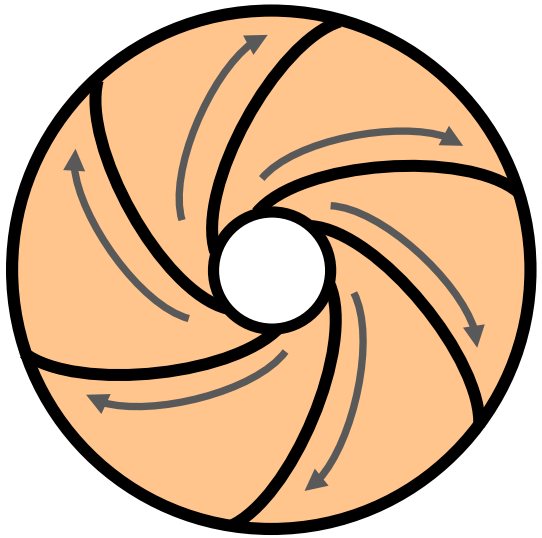
- Flow
  - $Q_2 = Q_1 (N_2/N_1)$
- Head
  - $h_2 = h_1 (N_2/N_1)^2$
- Power
  - $bhp_2 = bhp_1 (N_2/N_1)^3$

Q = Flow
N = Speed
h = head
bhp = Horsepower

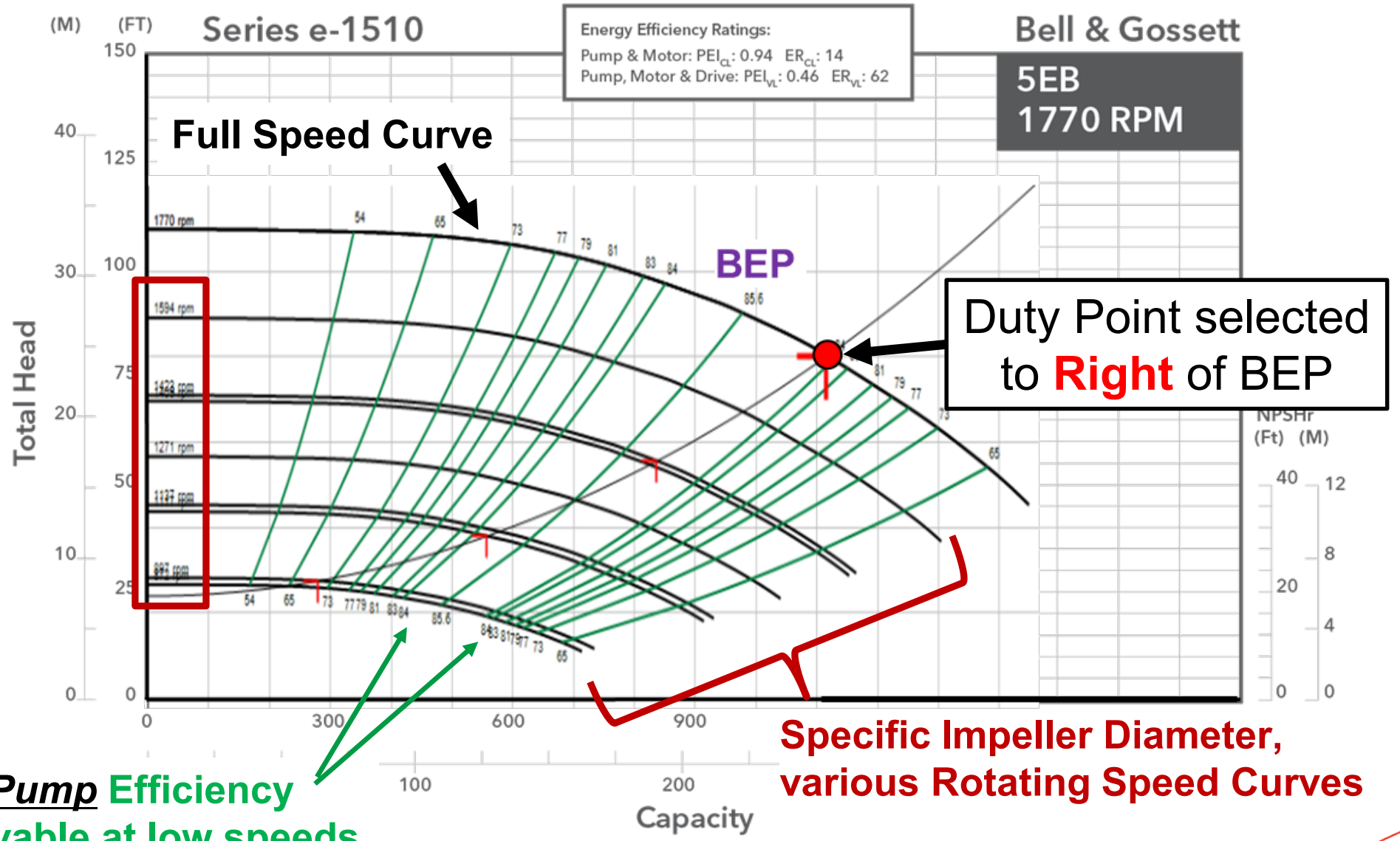
Subscript 2 indicates “new condition”

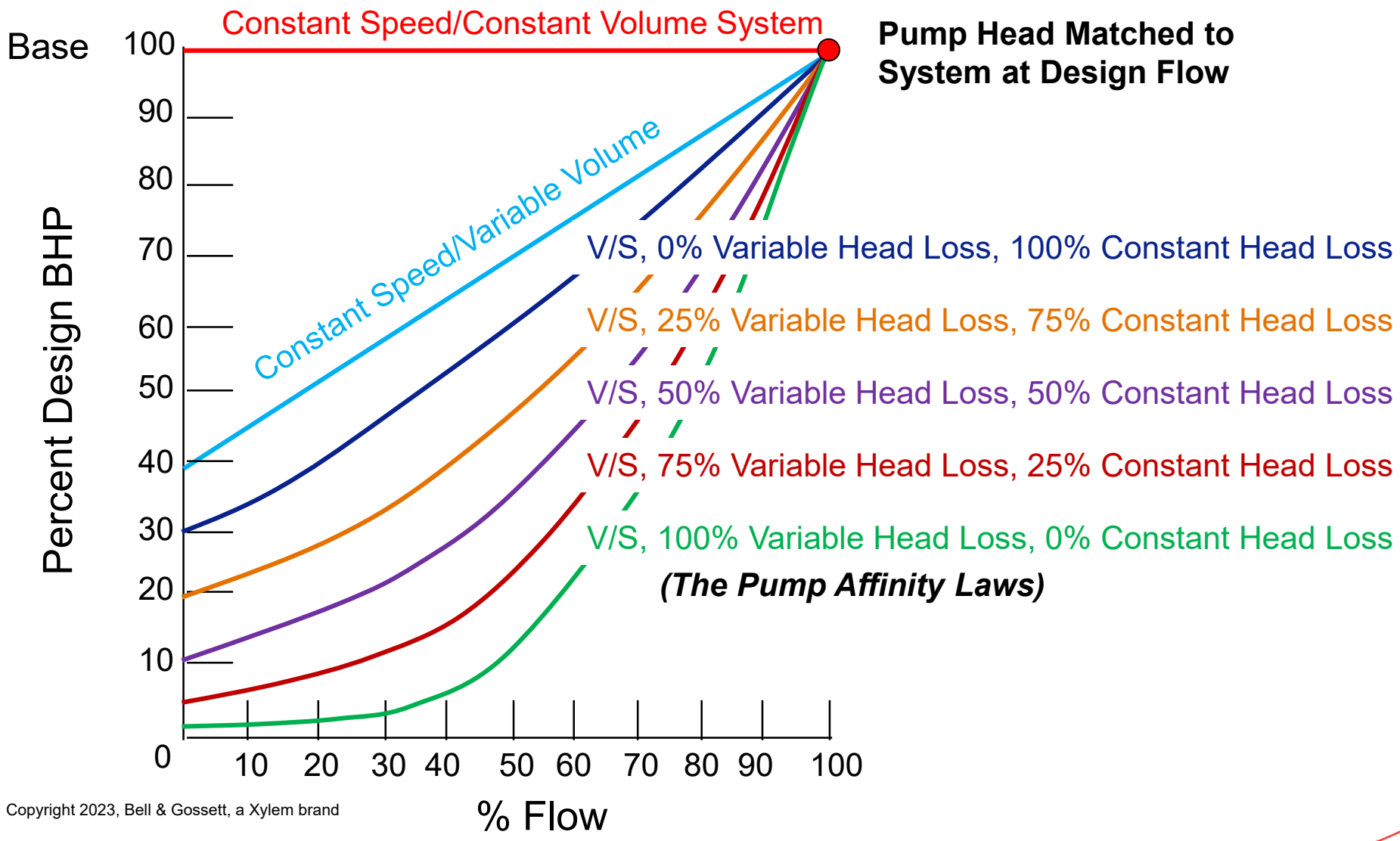
Subscript 1 indicates “old condition”



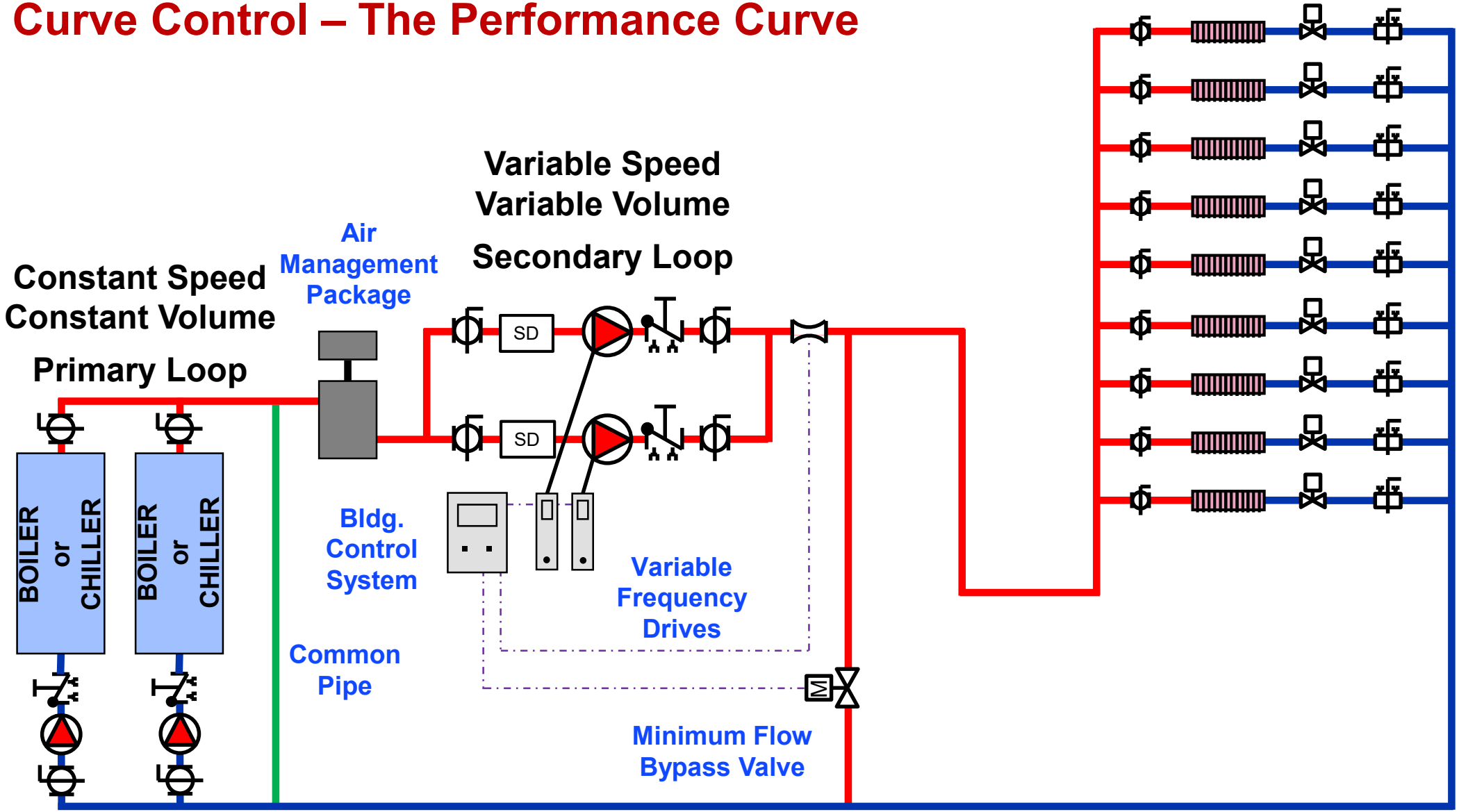
Speed	Flow/ Volume	Head	Horsepower Required
100%	100%	100%	100%
90%	90%	81%	73%
80%	80%	64%	51%
70%	70%	49%	34%
60%	60%	36%	22%
50%	50%	25%	13%
40%	40%	16%	6%
30%	30%	9%	3%
20%	20%	4%	-
10%	10%	1%	-
0%	0%	0%	-

- **Assumes all Head is “Variable”**
- **Efficiency will remain relatively constant**





Curve Control – The Performance Curve



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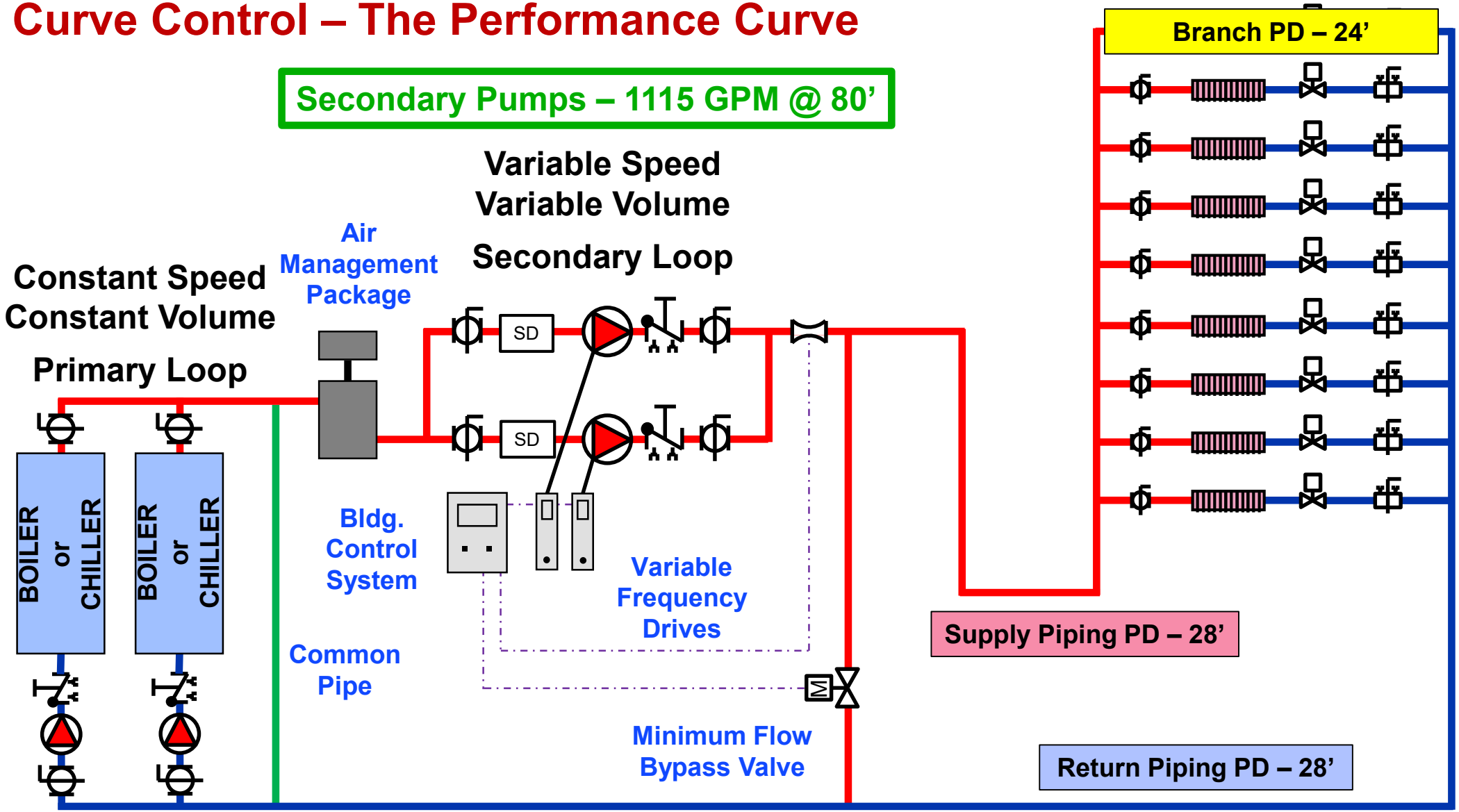

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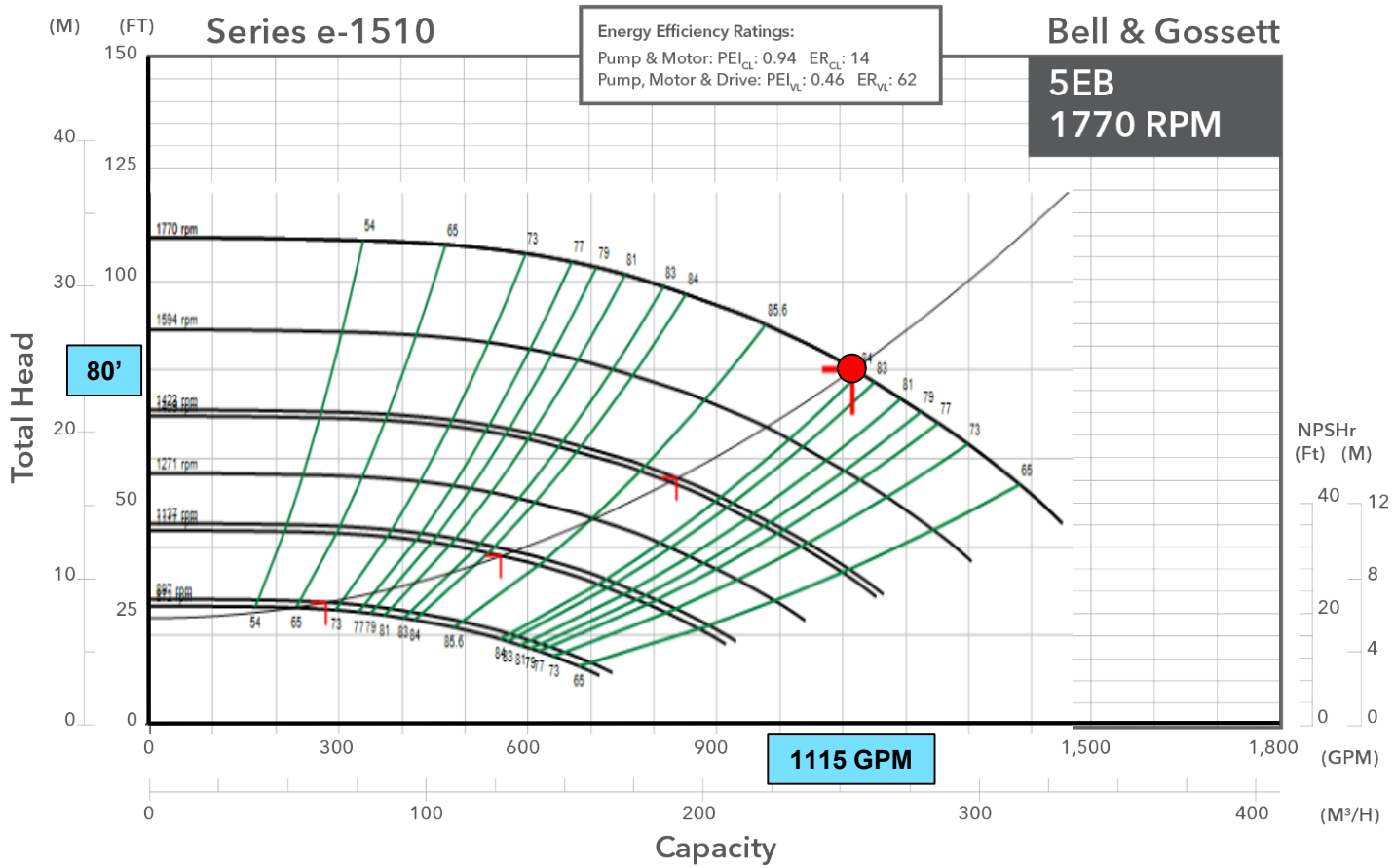

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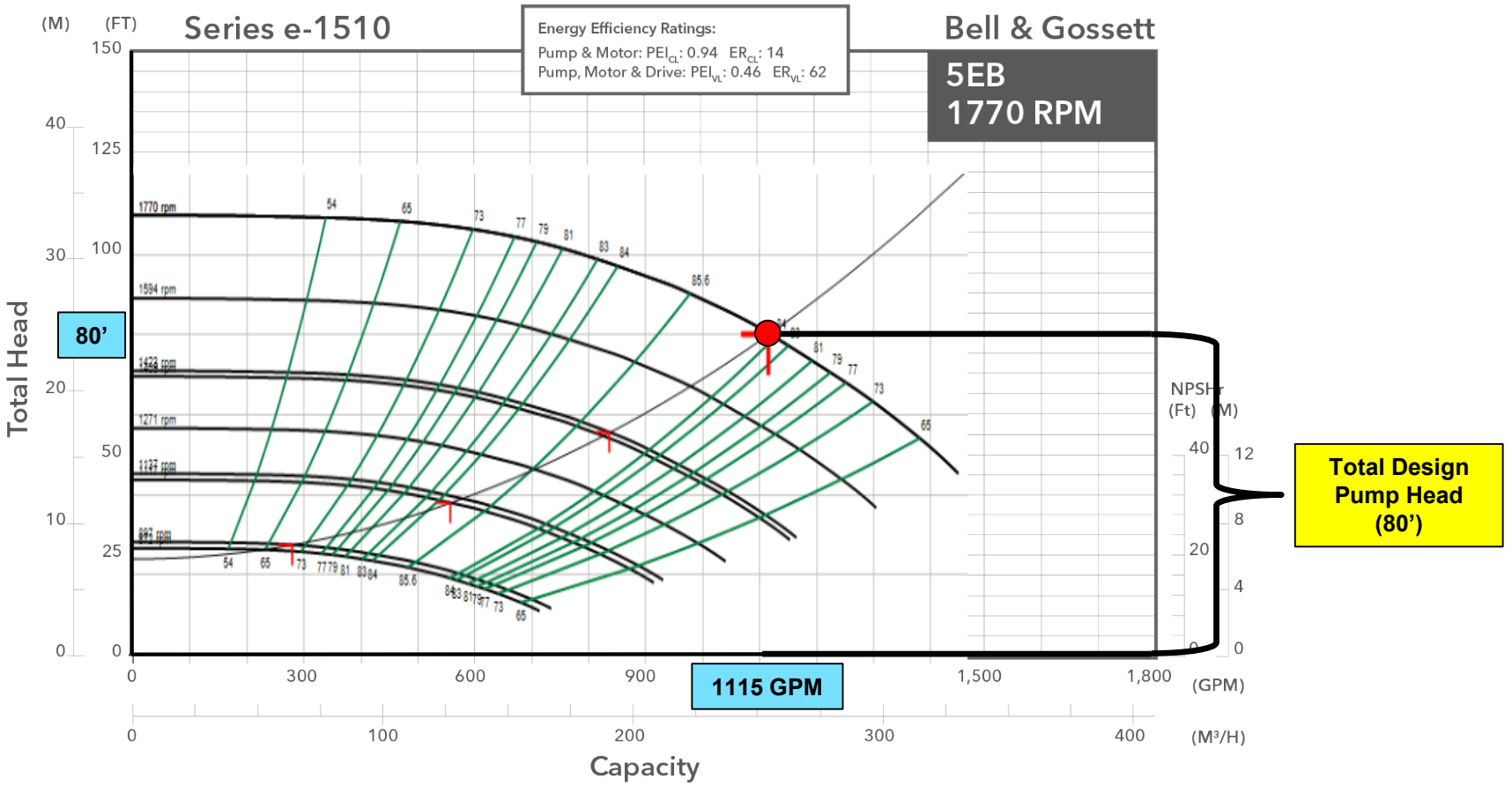

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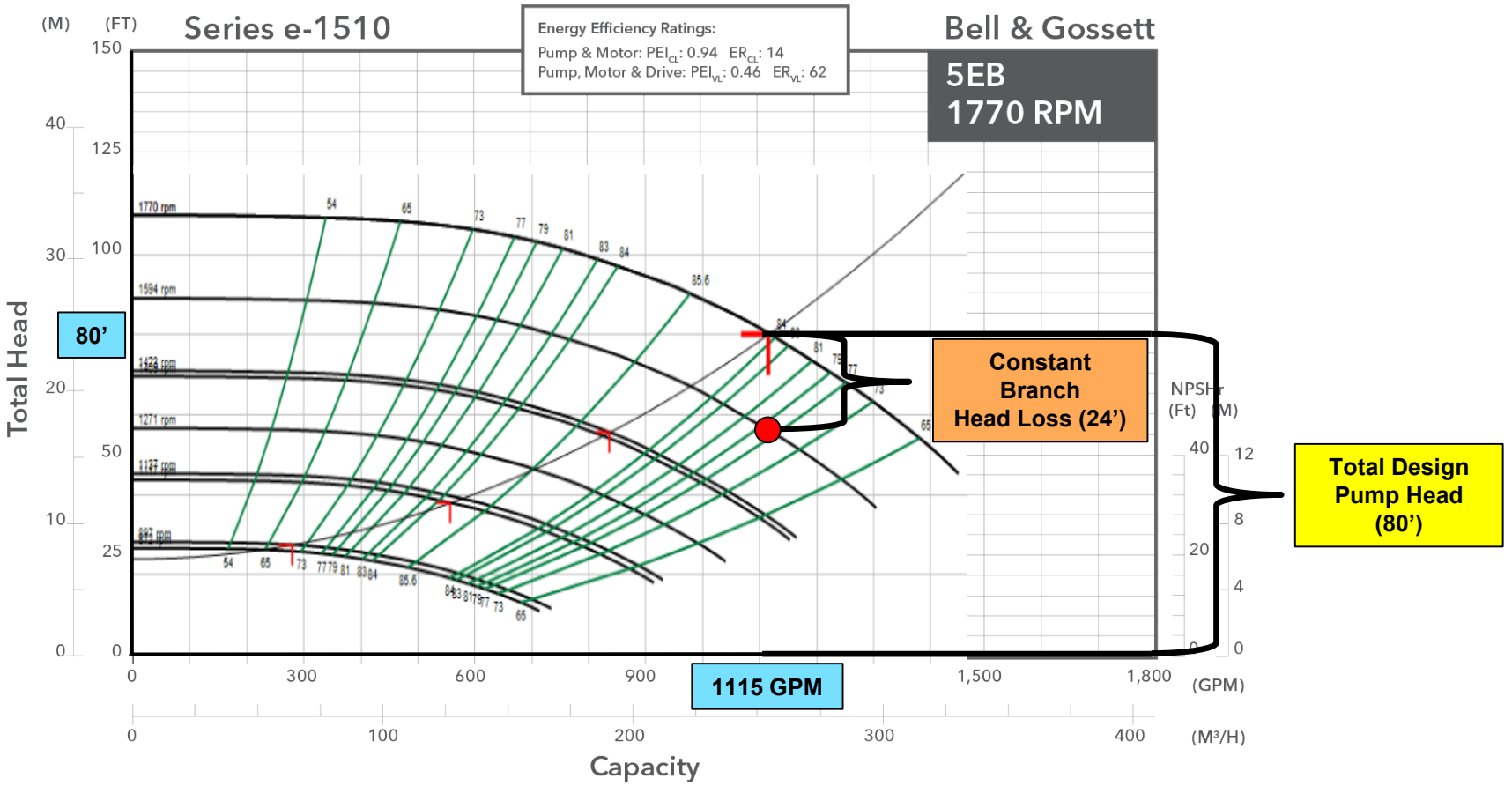

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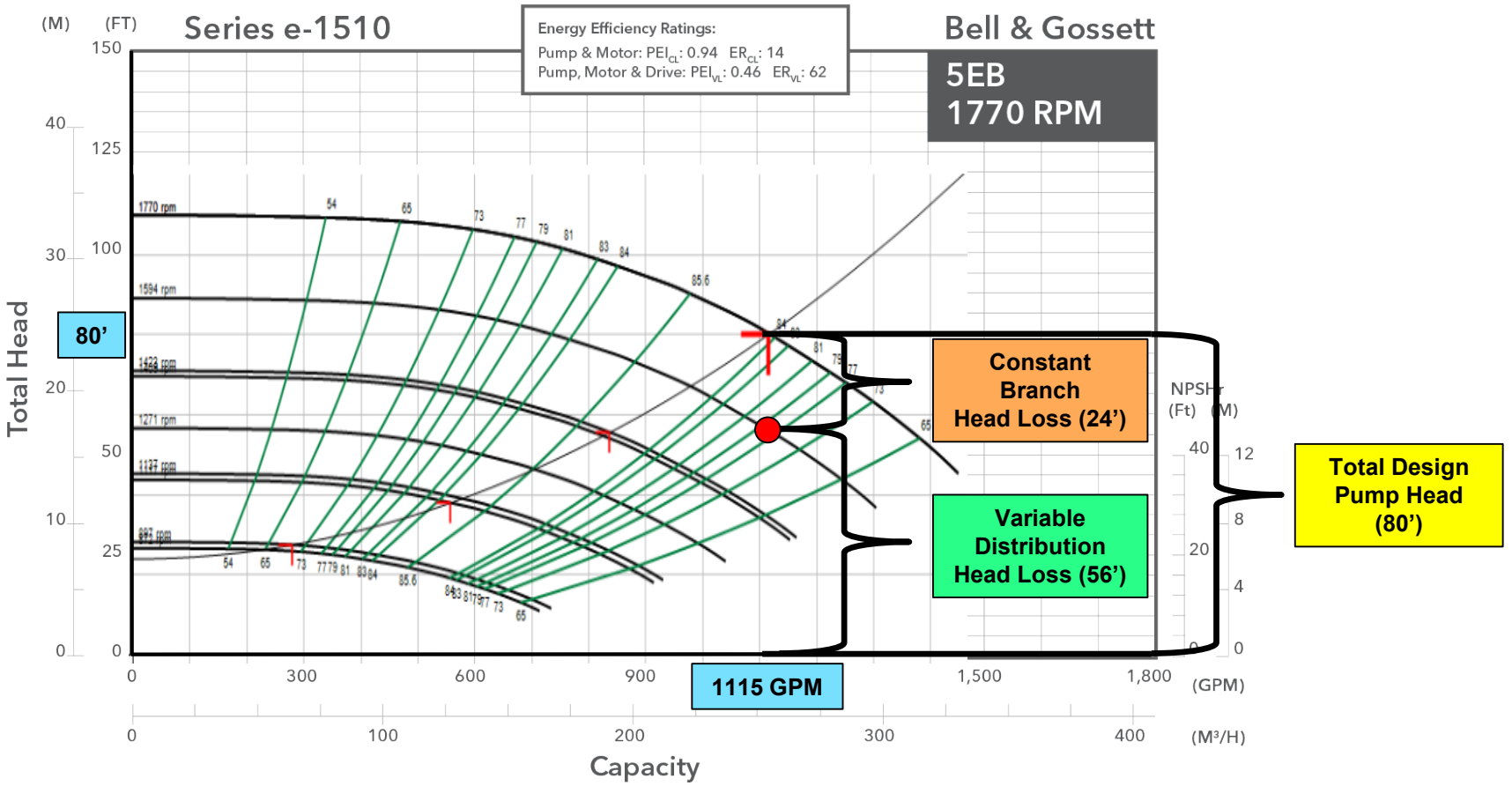

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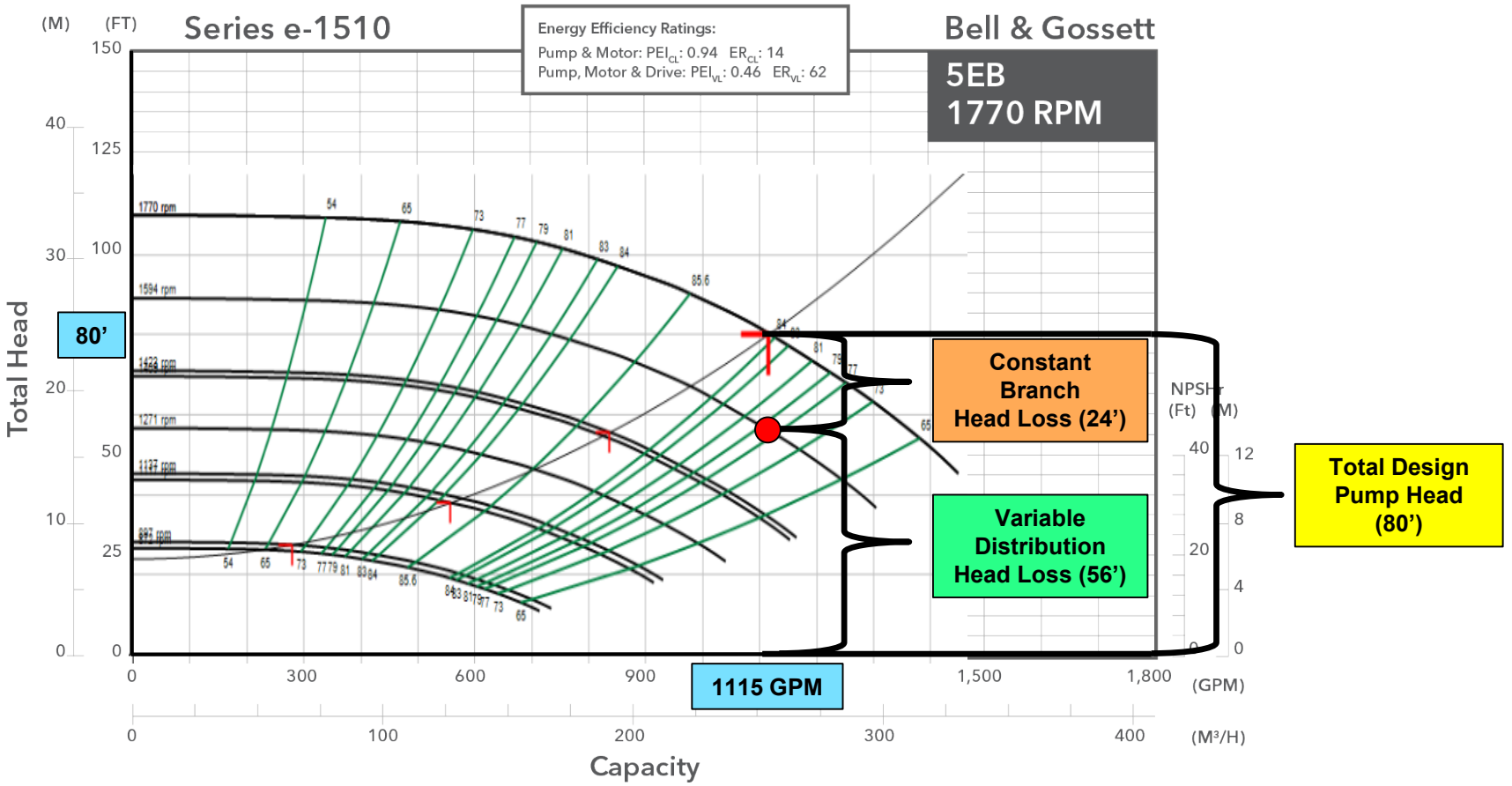
The “System Curve”

$$\left(\frac{Q_2}{Q_1}\right)^2 = \left(\frac{h_2}{h_1}\right)$$

Flow (GPM)	Head (FT)
1115	56
978	43
825	31
705	22
578	15
225	2
0	0



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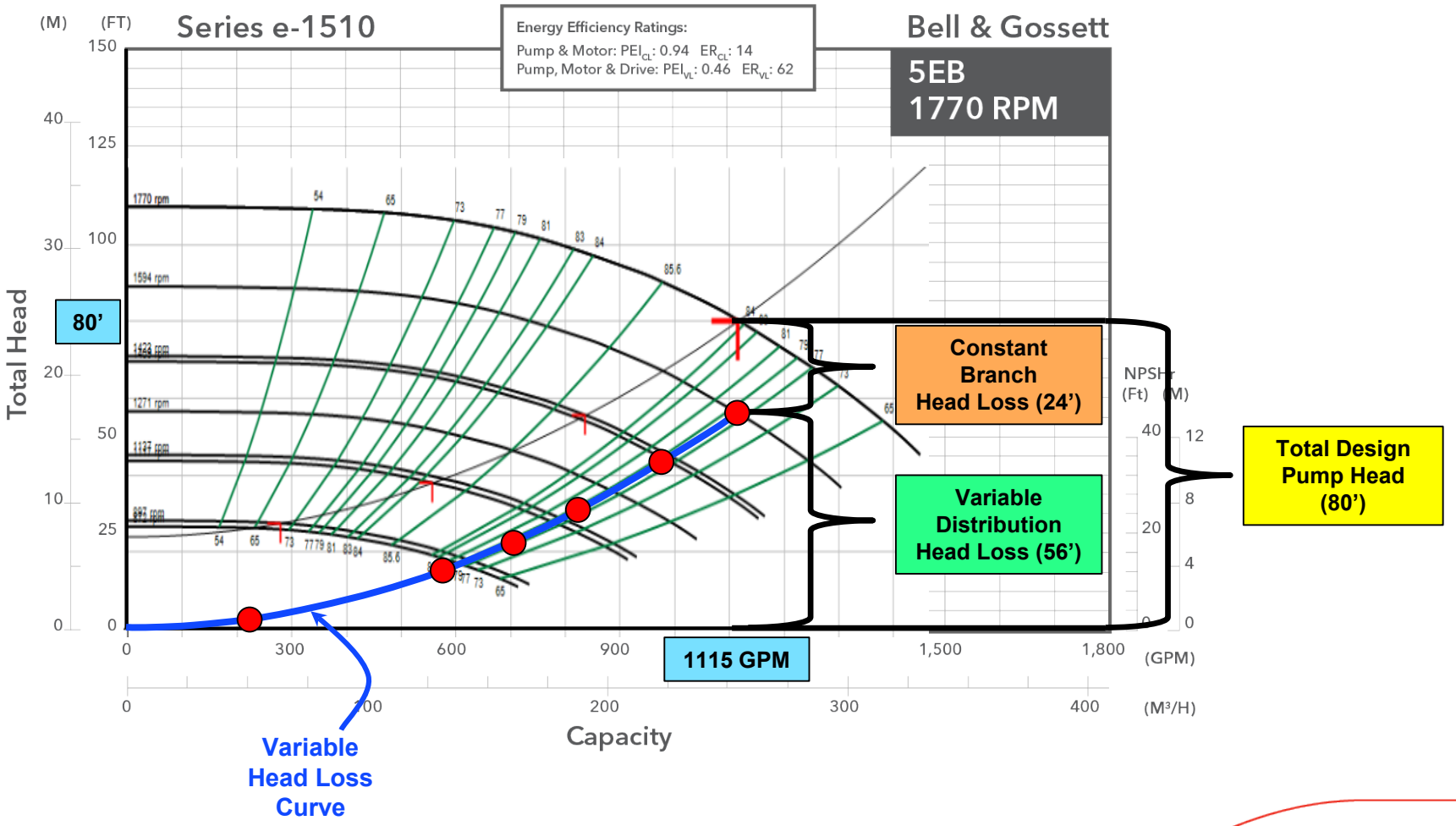

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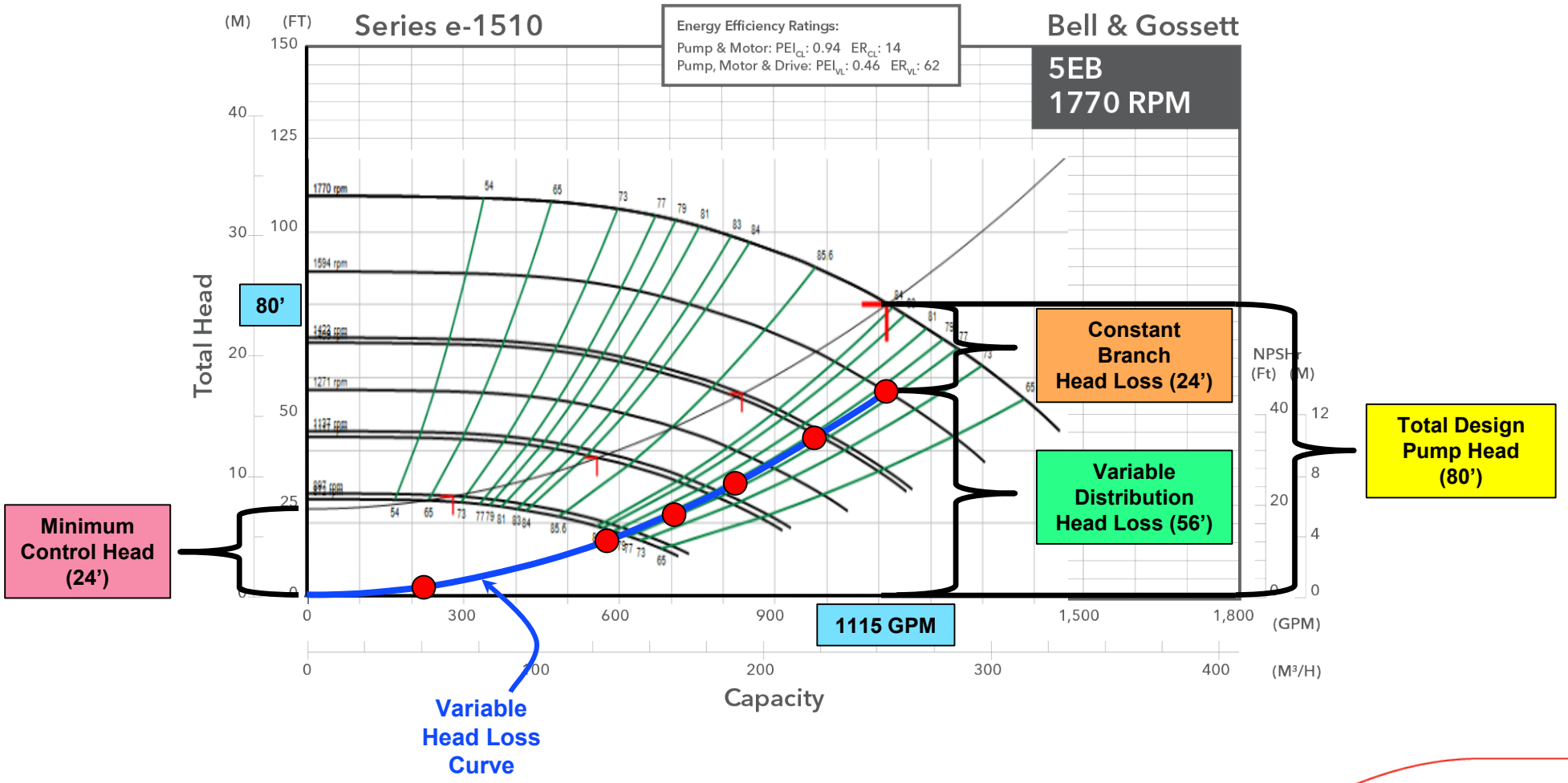

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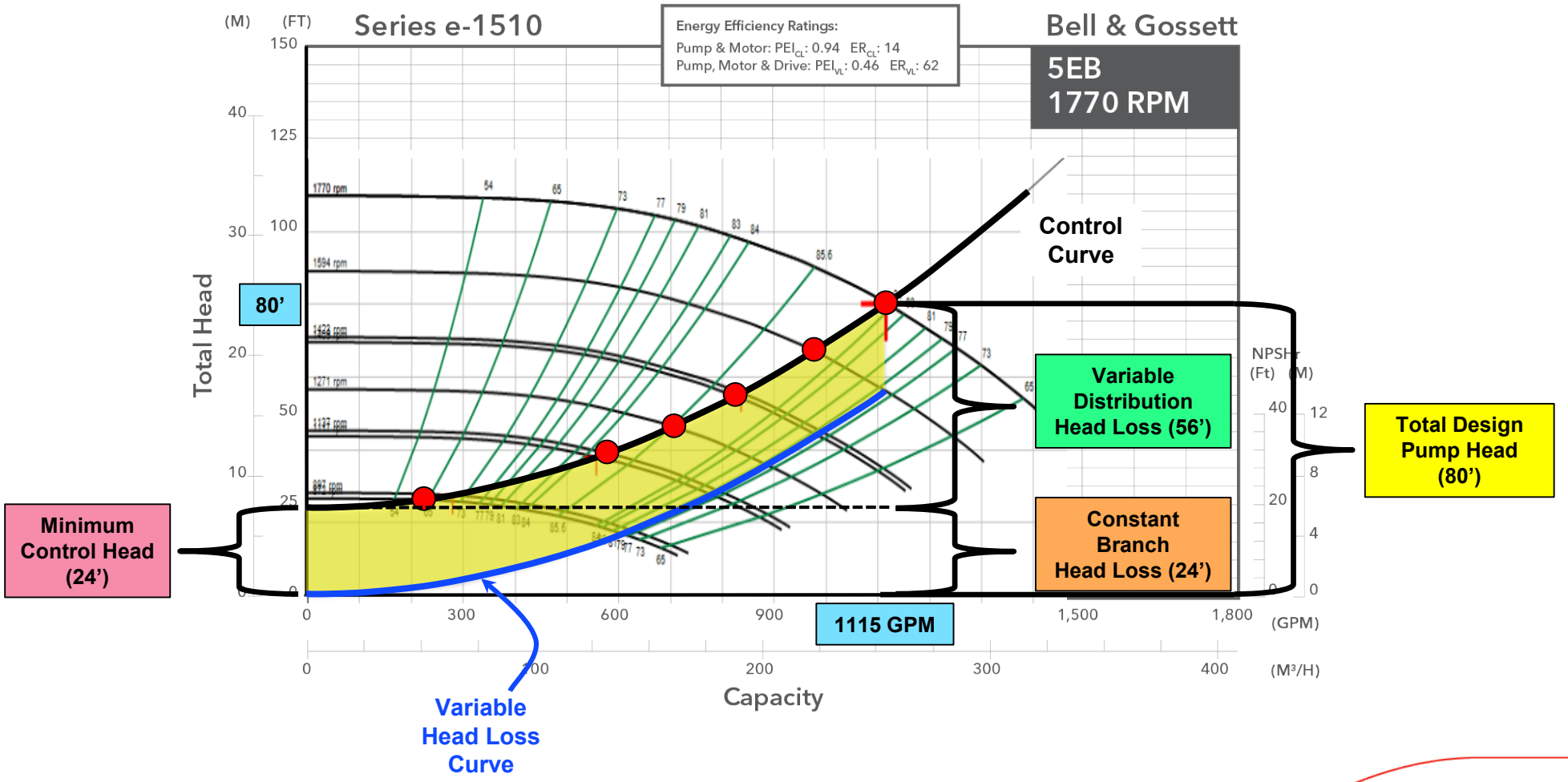

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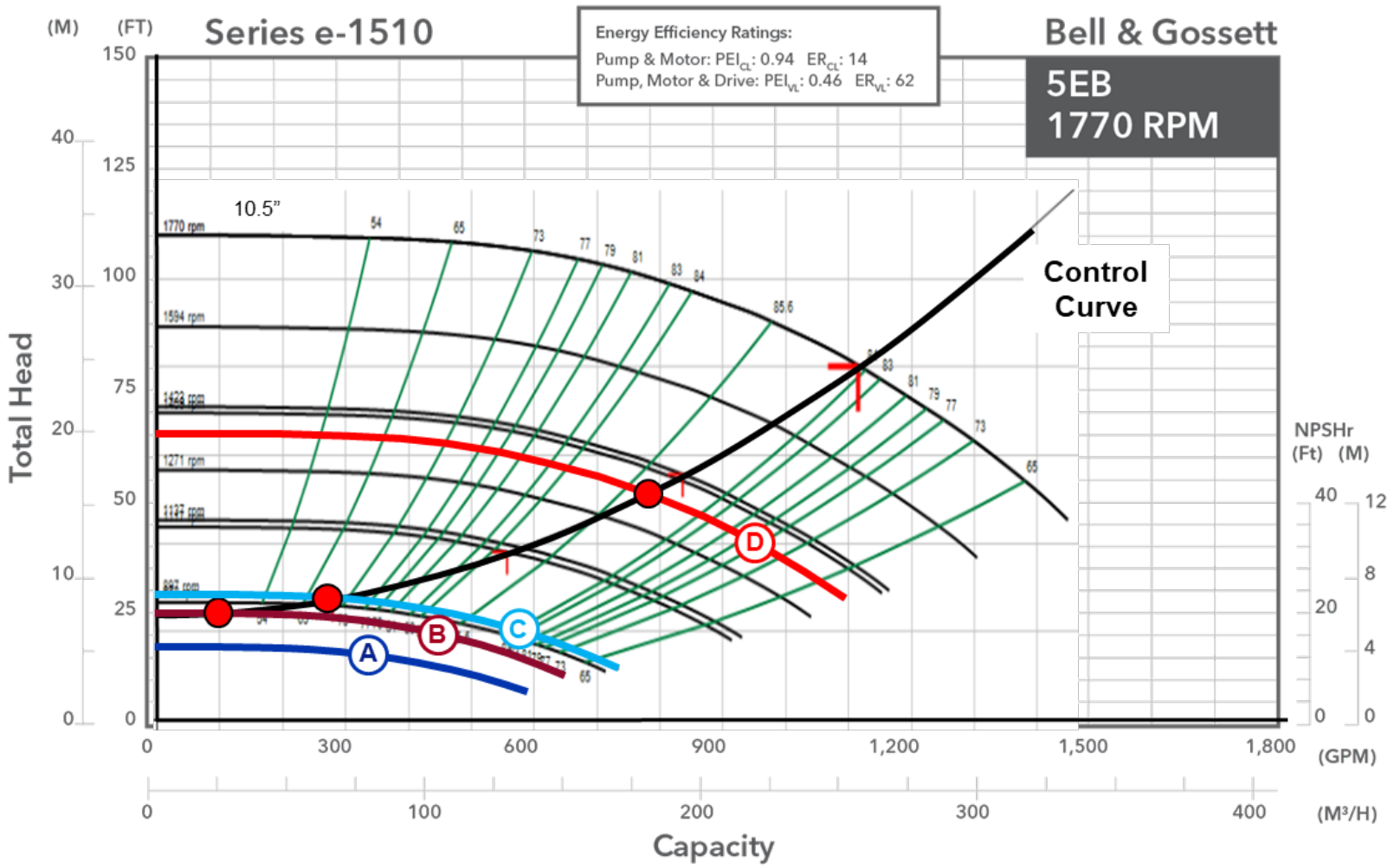

- **All Pump Applications:**

Ⓐ Minimum recommended speed by motor manufacturer. Typically 20%-30% of rated motor RPM.

Ⓑ Speed required to generate minimum Control Head

Ⓒ Speed required to generate minimum Pump Flow

- **Variable Primary Applications:**

Ⓓ Speed required to provide minimum Equipment Flow *(Chiller, Boiler, Heat Exchanger)*

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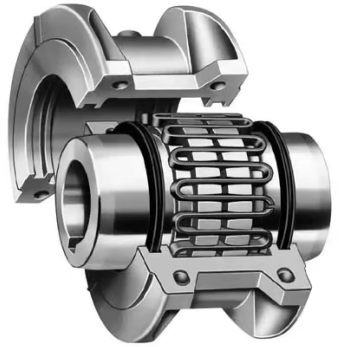
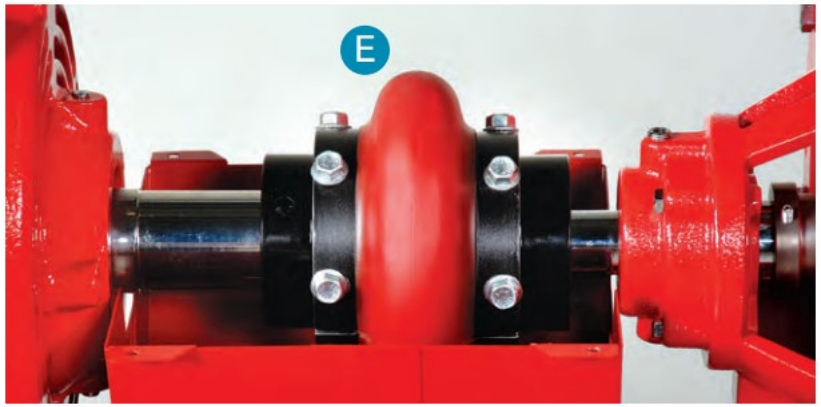
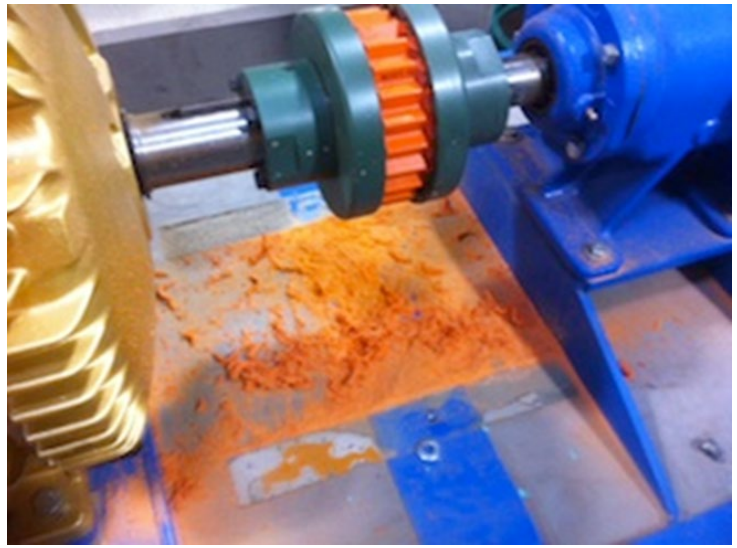
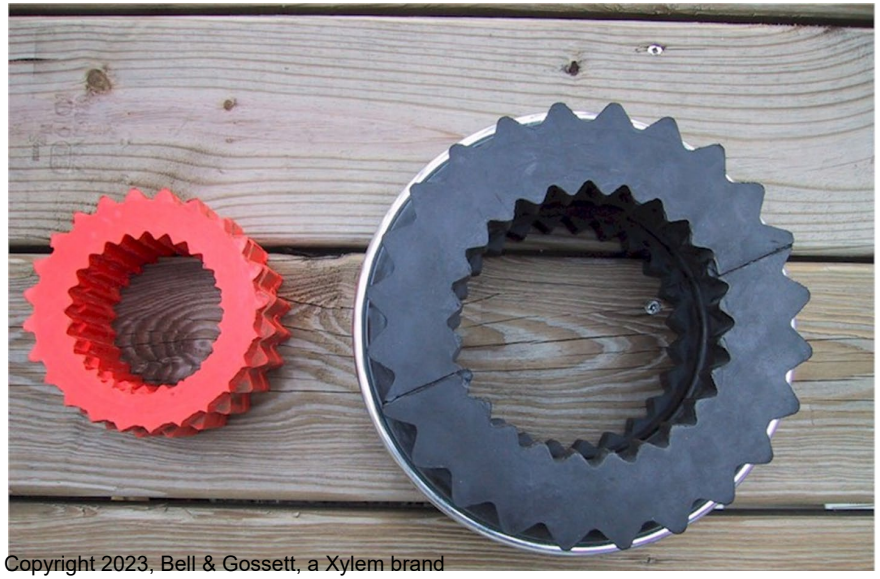
What type of coupler?





- Hytrel is a stiffer durometer
- Plastic Resin melts and shreds
- EPDM/Neoprene replacement will be larger
- Adequate space between motor and bearing frame required.
- Is motor position adjustable??





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Selecting the correct VSD Control Strategy

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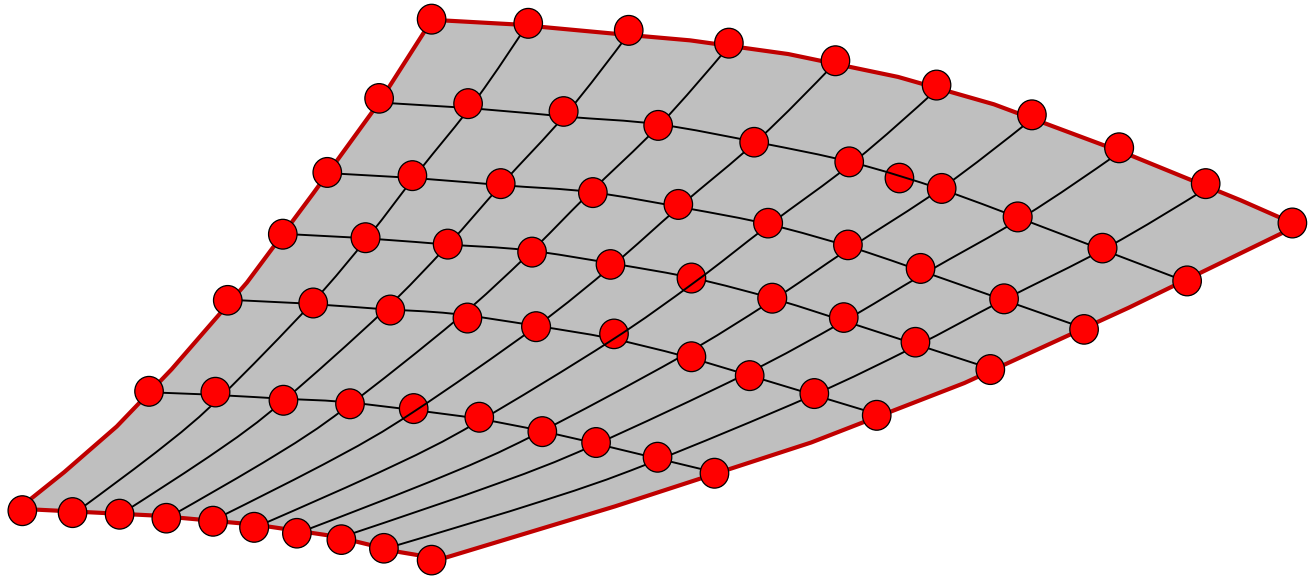
Curve Control

- Factory generated Pump Performance Map
  - Flow
  - Head
  - Power
  - Speed
  - Torque

7 Speeds
10 Data Pts. Each

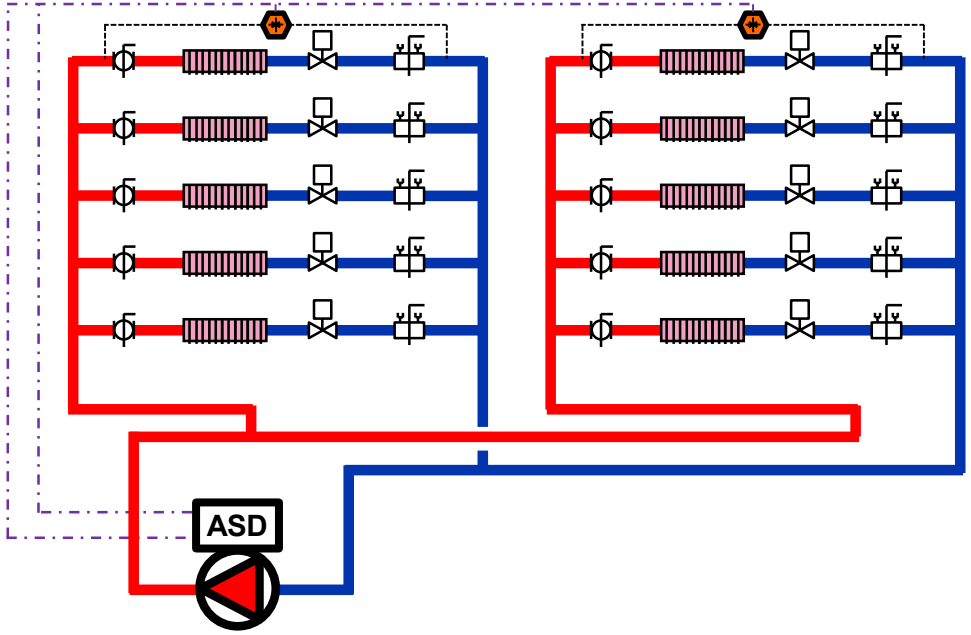


Area Control

- **Feedback Sensor(s) located in the System**
  - Wired directly to ASD
  - Wired to a BMS

Applications

- High Diversity Hot & Chilled Water Systems
- Large Control Area *(Low BRPDR)*

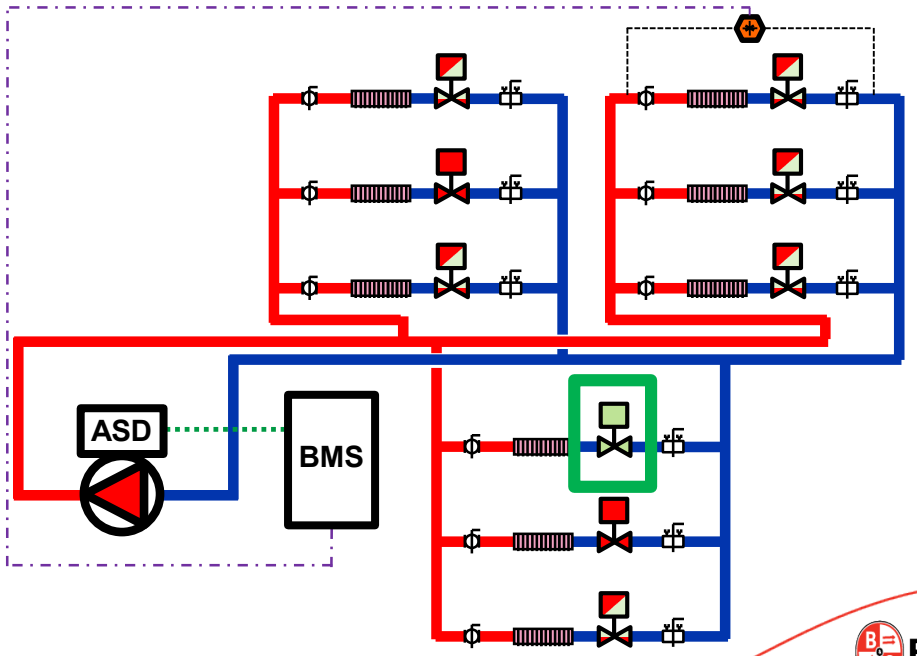


Area Control

- **Control Valve Position *(ASHRAE 90.1 "Reset")***
  - Use Valve Actuator Feedback Signal Only
  - Add Differential Pressure Sensor, modify setpoint

Applications

- Where BMS can monitor valve position
- *Not recommended when PICV's are used*



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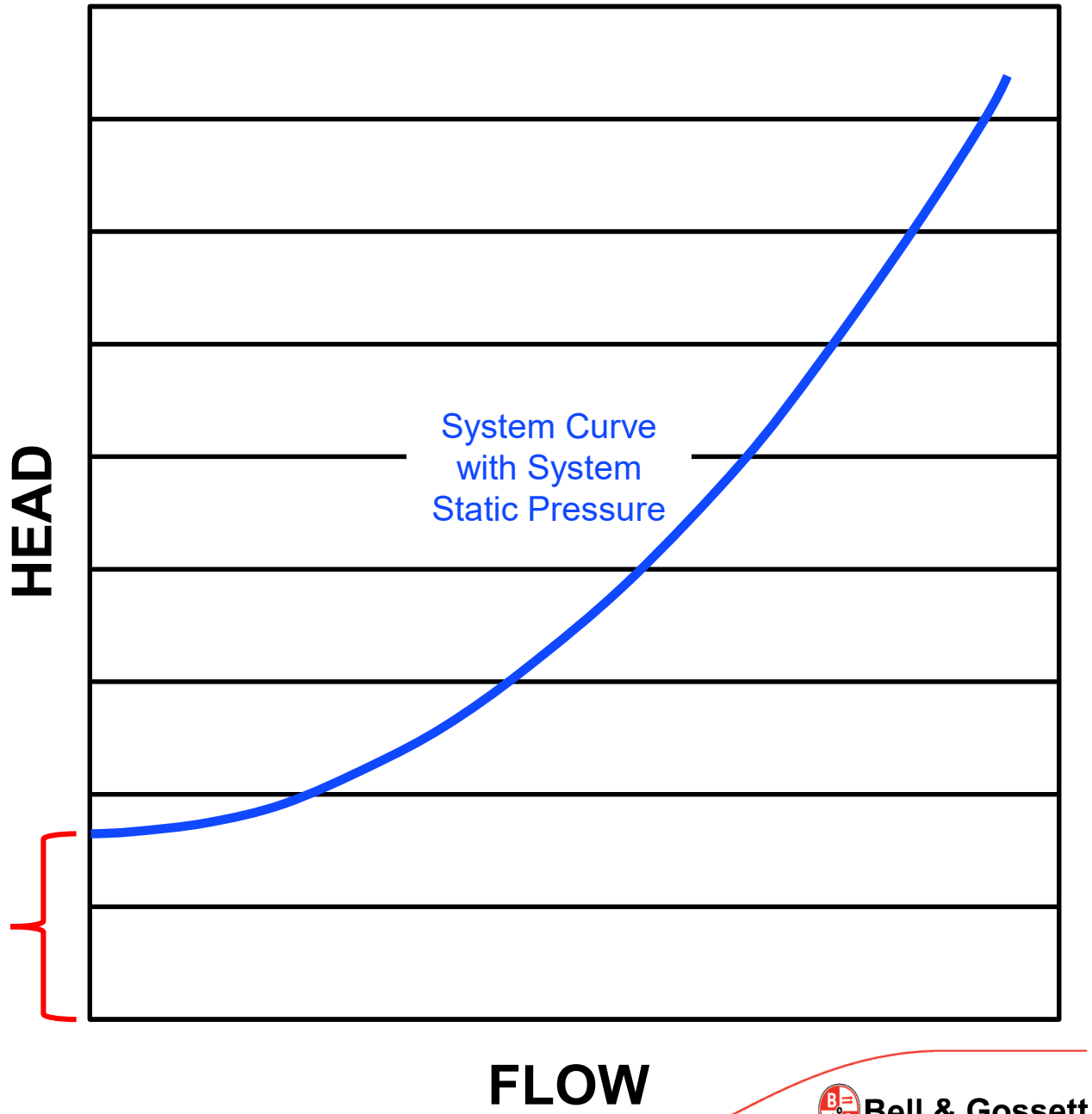
The **“Control Area”** represents all flow/head operating point possibilities for a specific piping system.

- Accounts for system resistance changes with load adjustments, dependent on where they occur in the piping network
- The size and shape is influenced by piping ***Branch to Riser Pressure Drop Ratio***
- Used for selecting applicable Variable Speed Control Strategy



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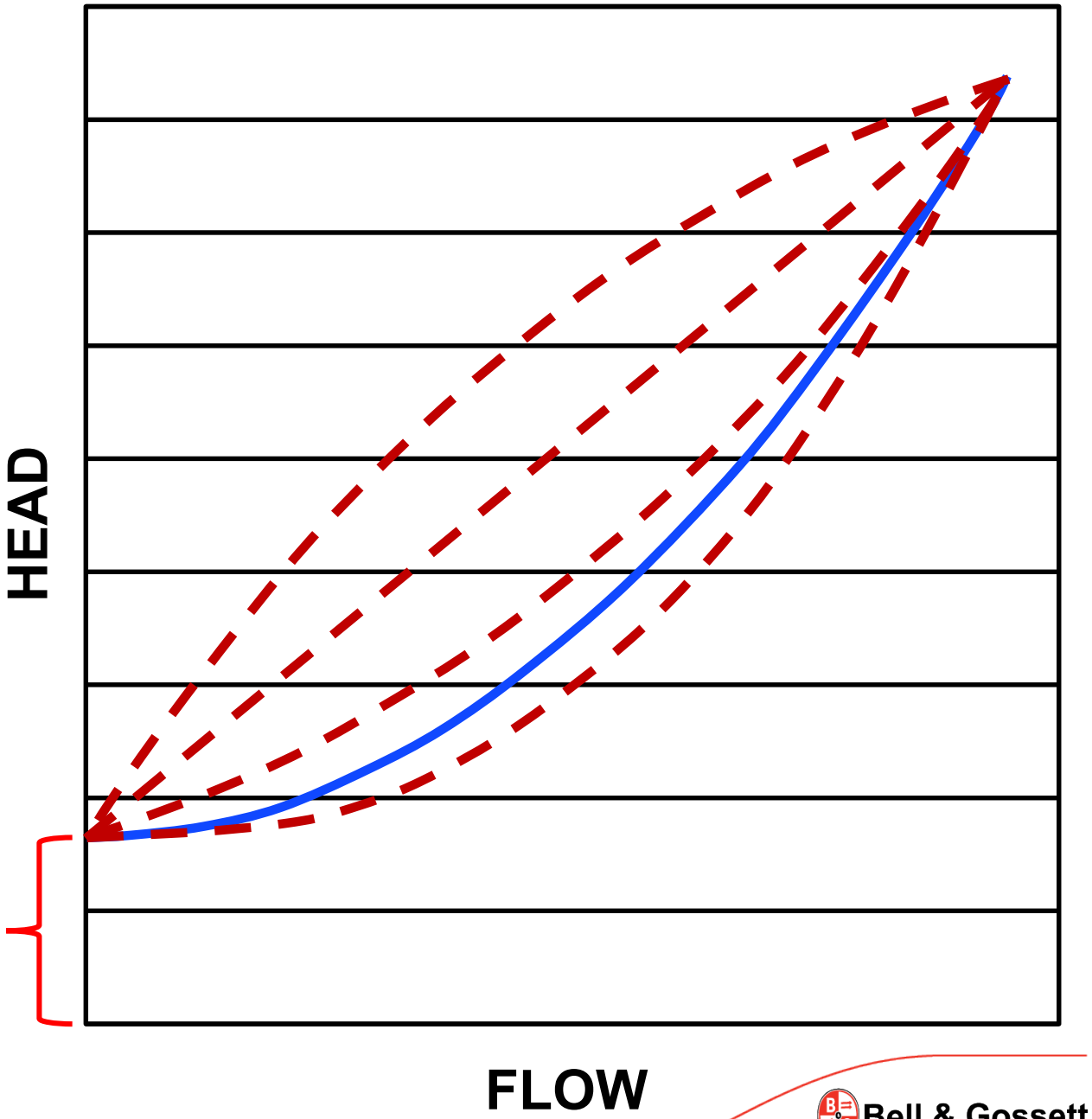

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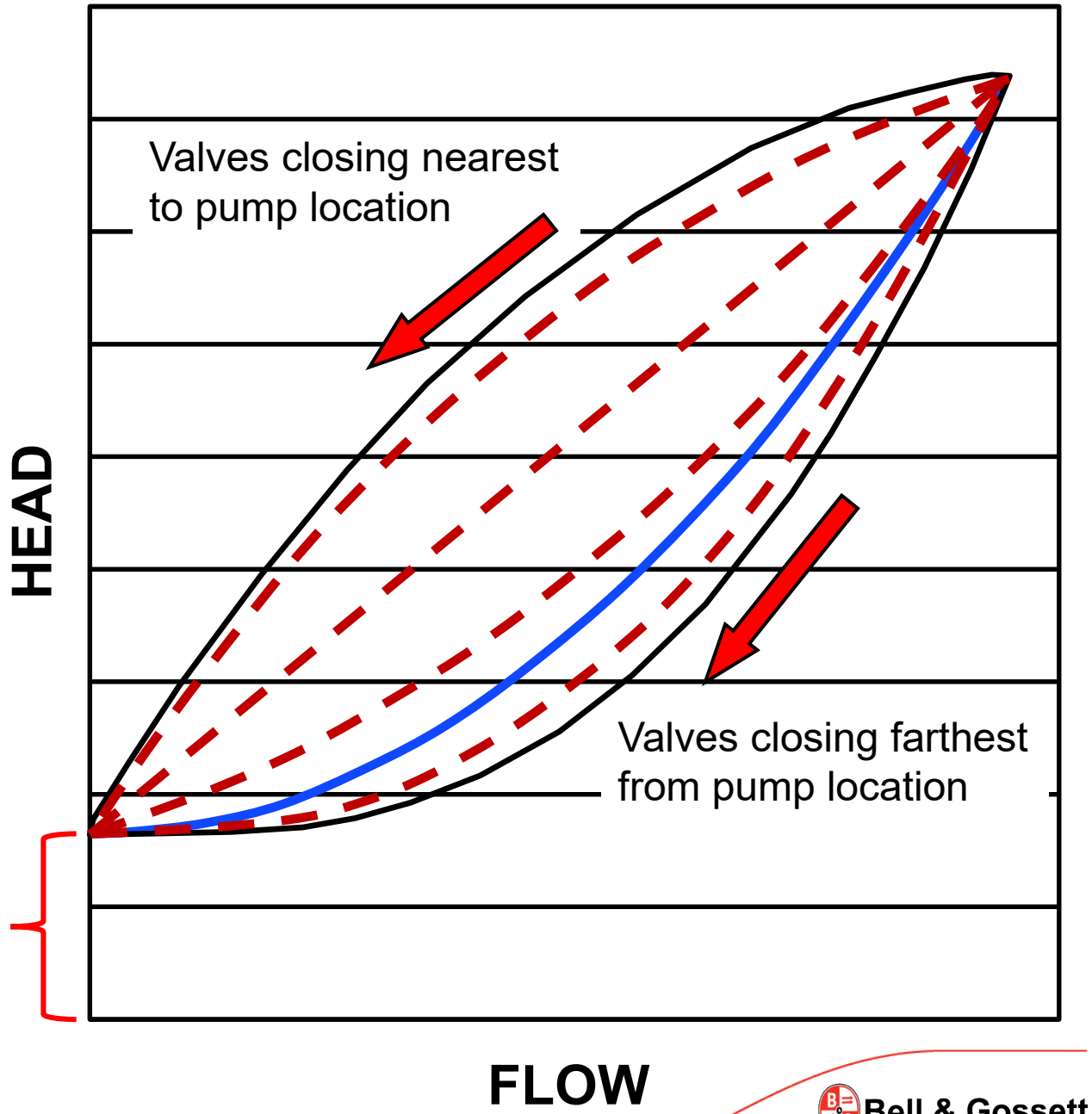

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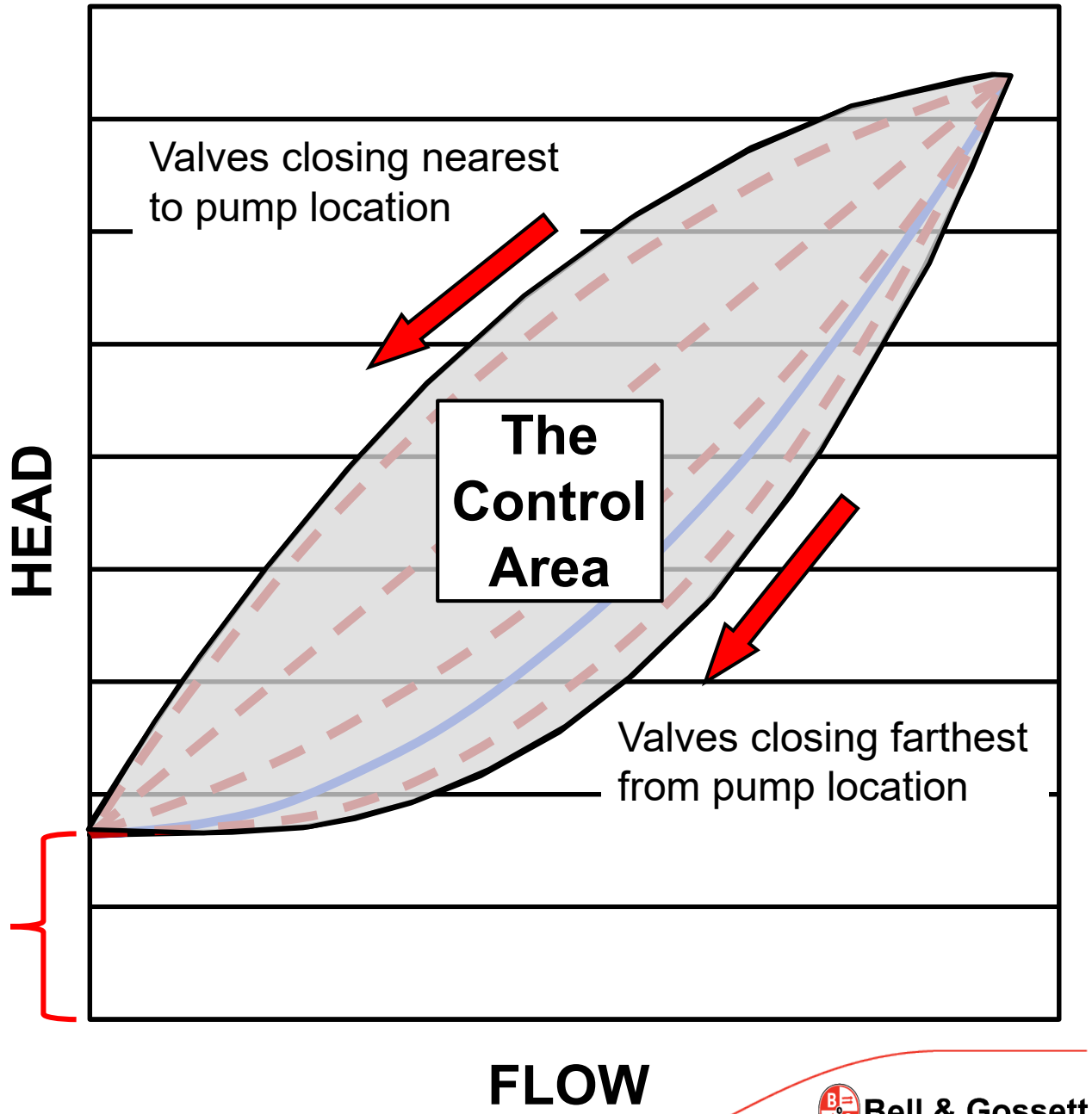
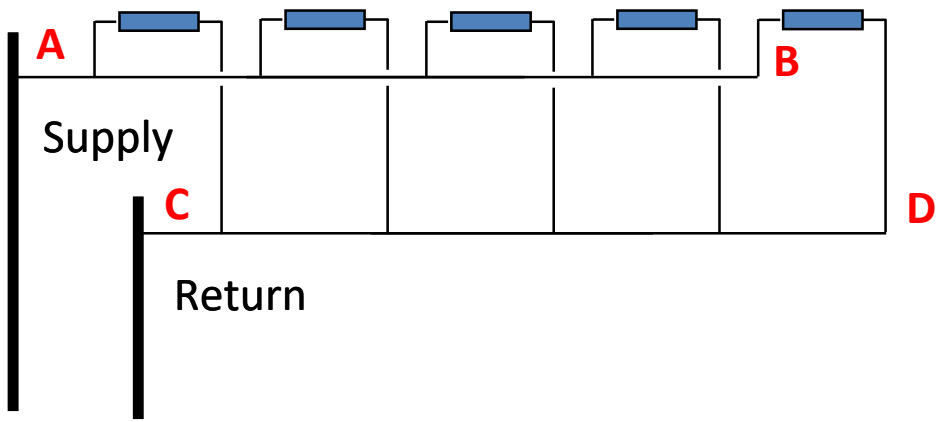


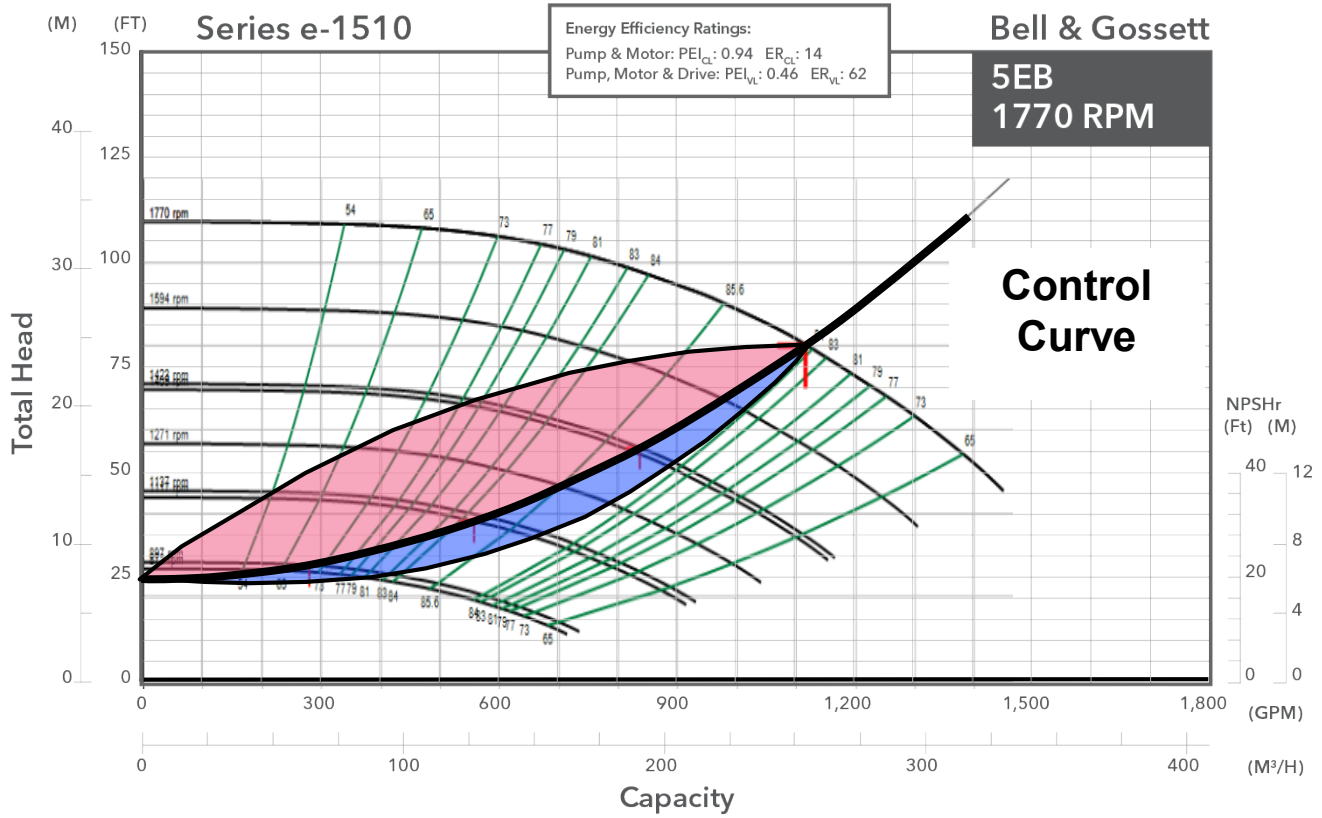


$$BRPDR = \frac{BD}{AB + CD}$$

BD – The “Branch”

AB – Supply Riser

CD – Return Riser



- **The higher the Ratio, the smaller the Control Area**

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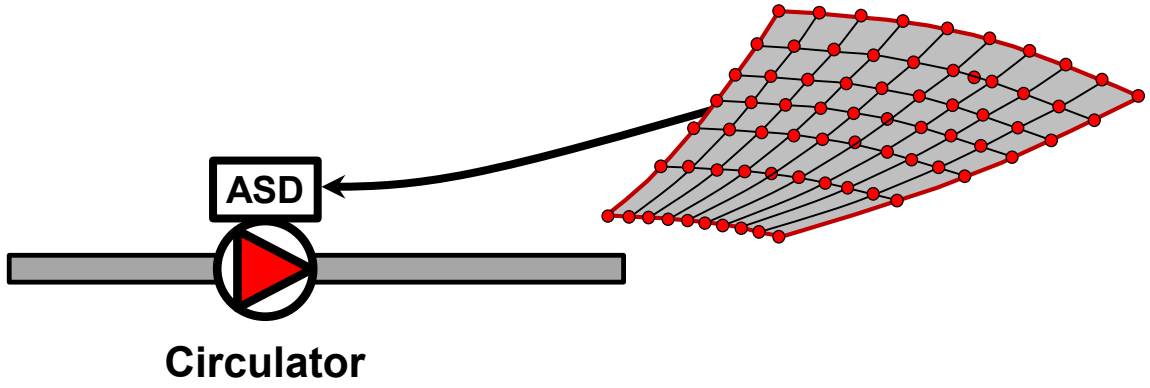
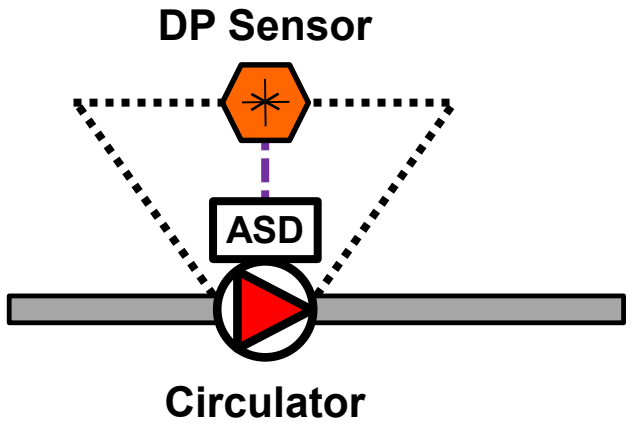
Curve Control

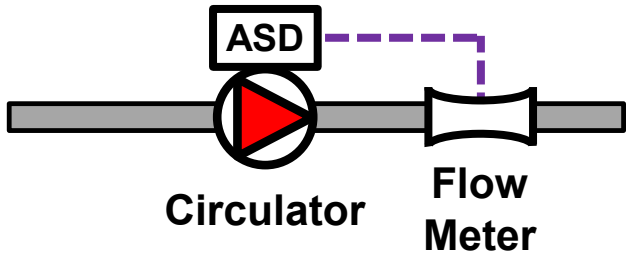
- Uses Factory generated Pump Performance Map
  - Monitor Motor Power & Torque change
  - Measure Differential Pressure across Pump
  - Measure Flow at Pump Outlet



Applications

- Small Control Area *(High BRPDR)*
- Where Zones may be equally loaded
- Hot Water Systems where DDC not present
- Retrofit Systems





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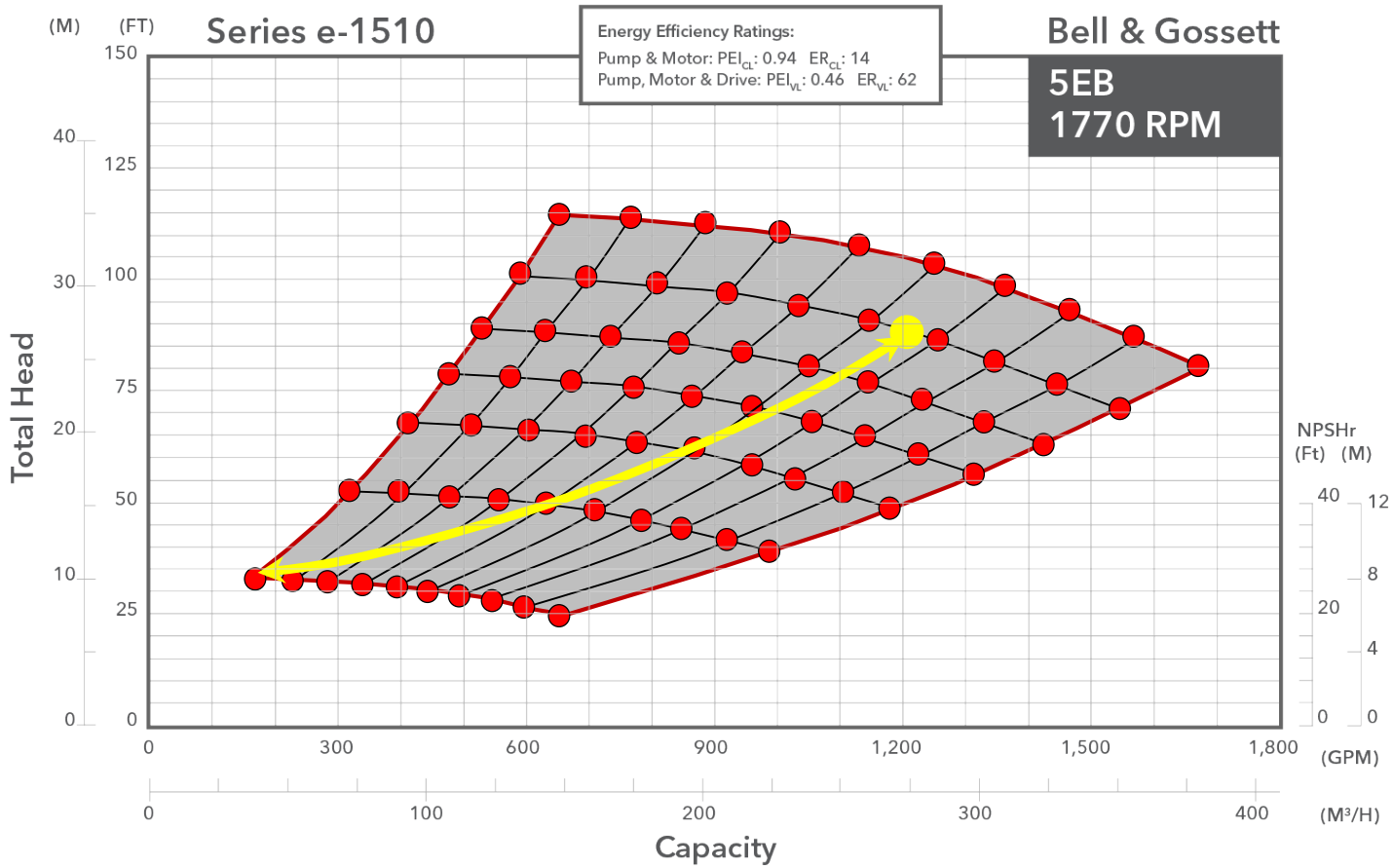
- **Design Flow**
- **Design Head**
- **Minimum Control Head**

Factory Default is 40% of Pump Design Head



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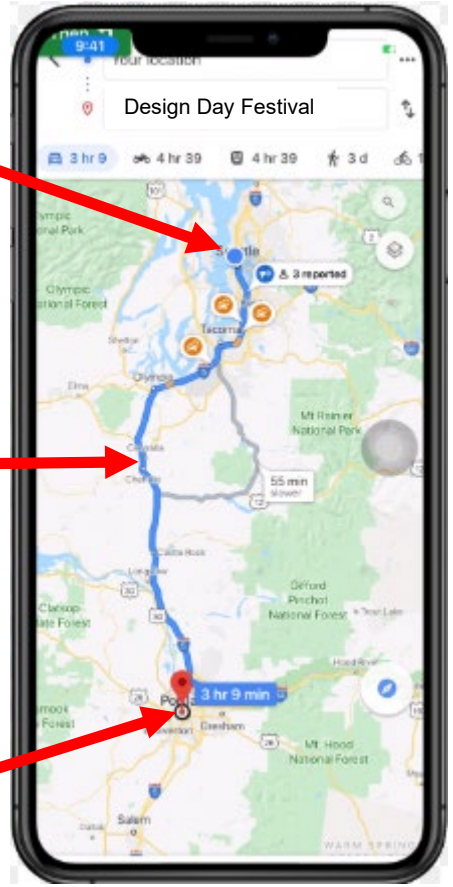
Your House
“Control Head” @ No Flow

Your Planned Route
“The Control Curve”

Your Destination
“Design Flow & Head”



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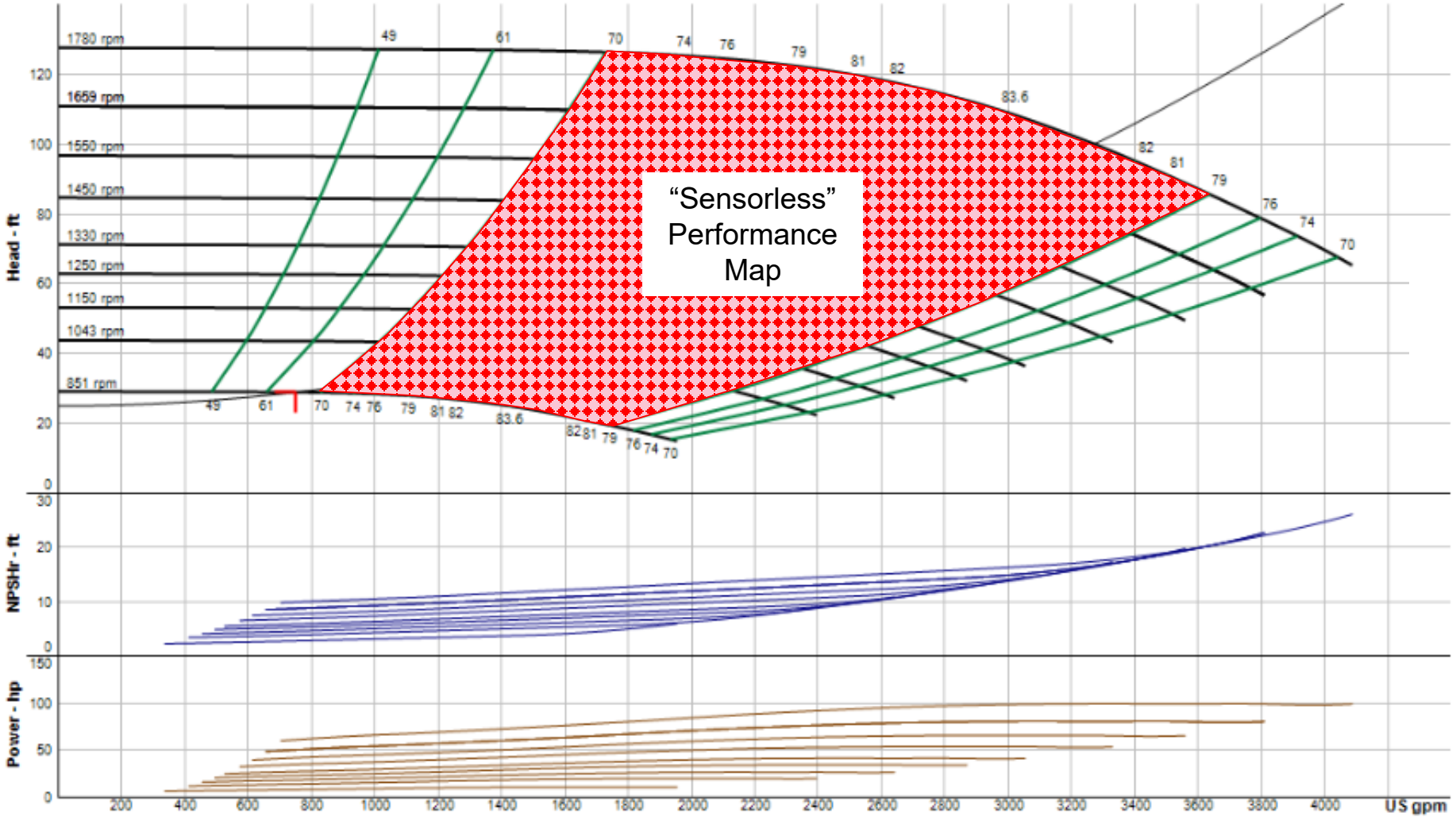

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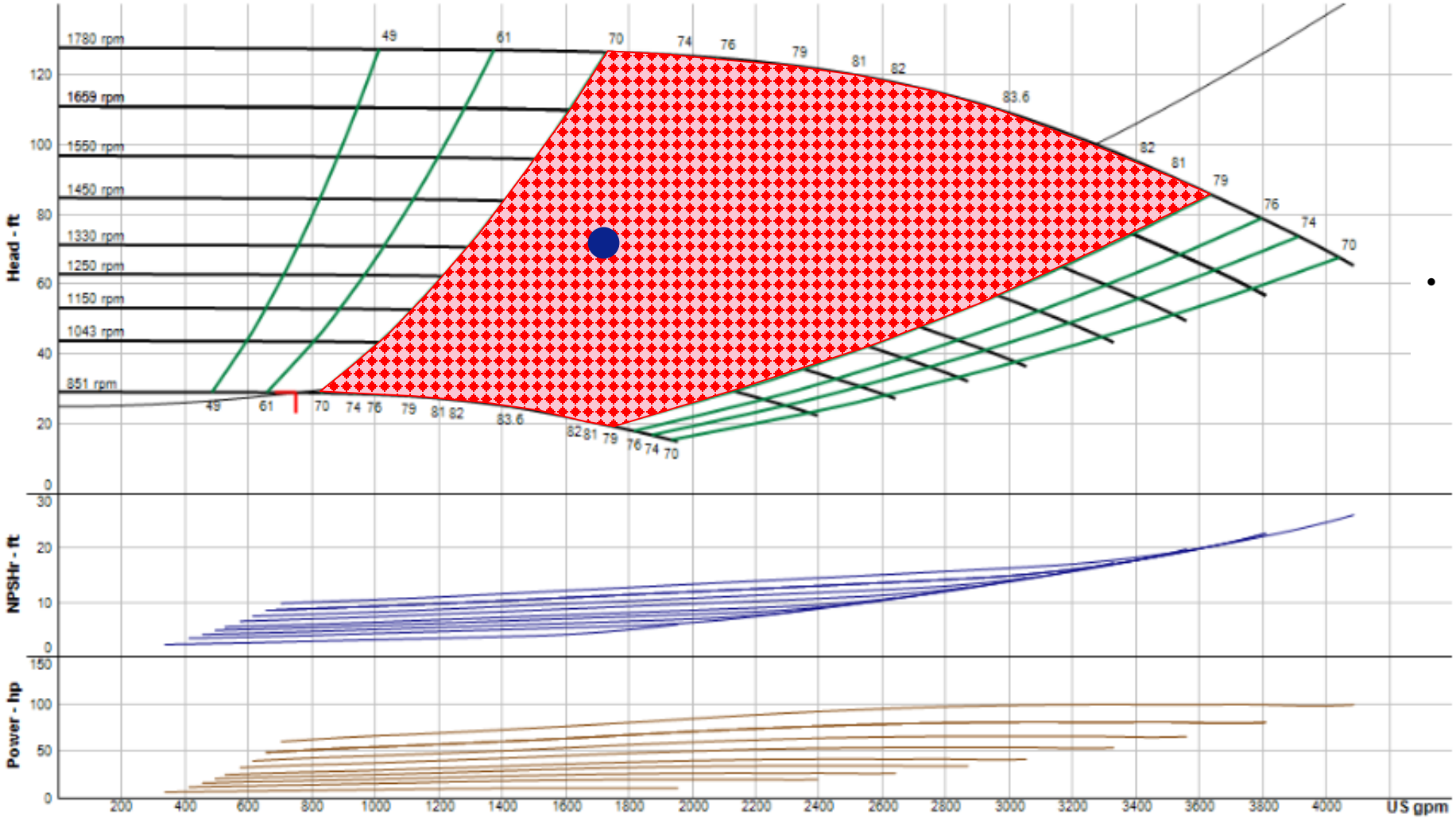

- Design Flow, Head, and Minimum Head can be adjusted in the field without impeller or motor modifications.

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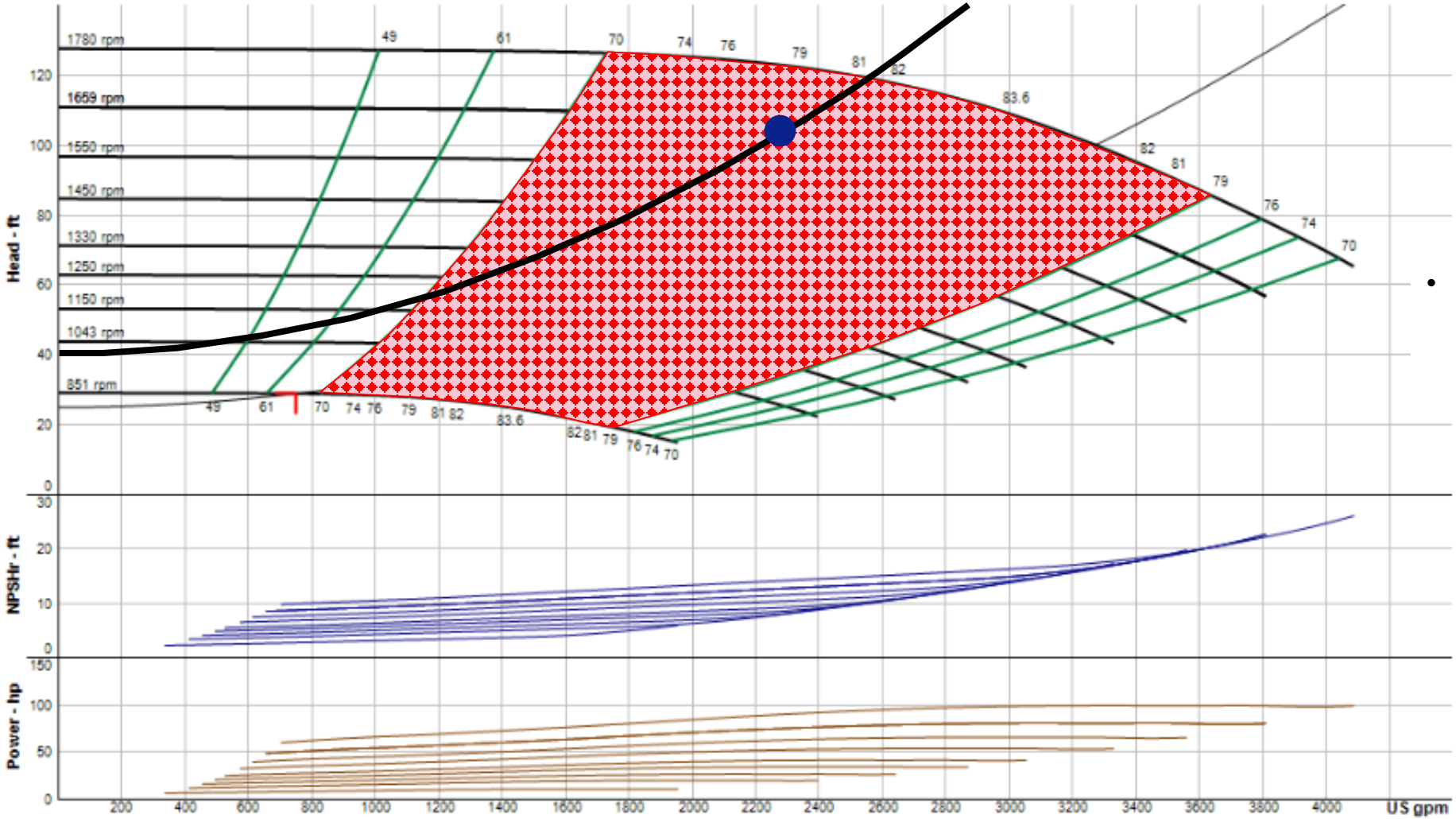

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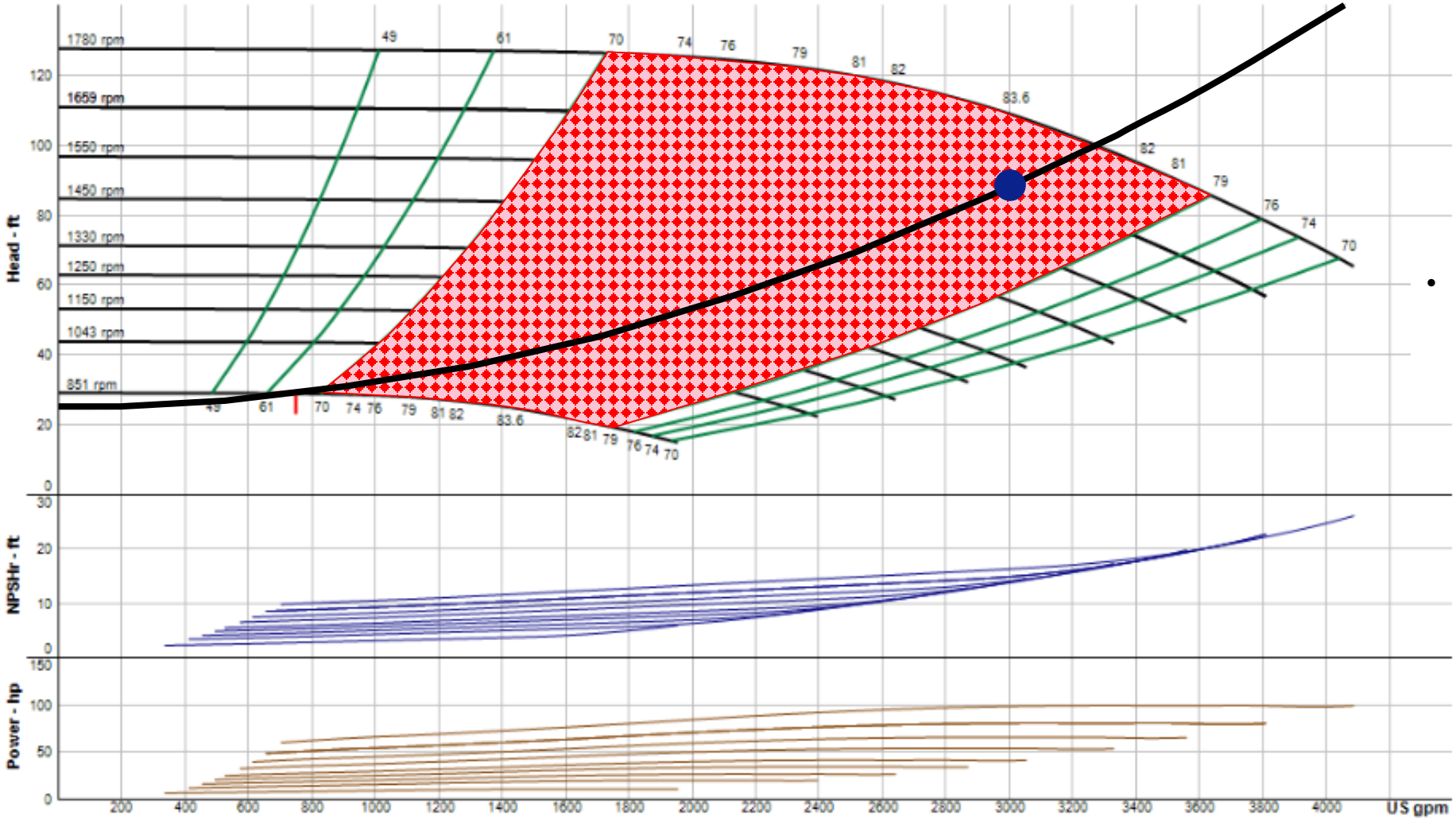

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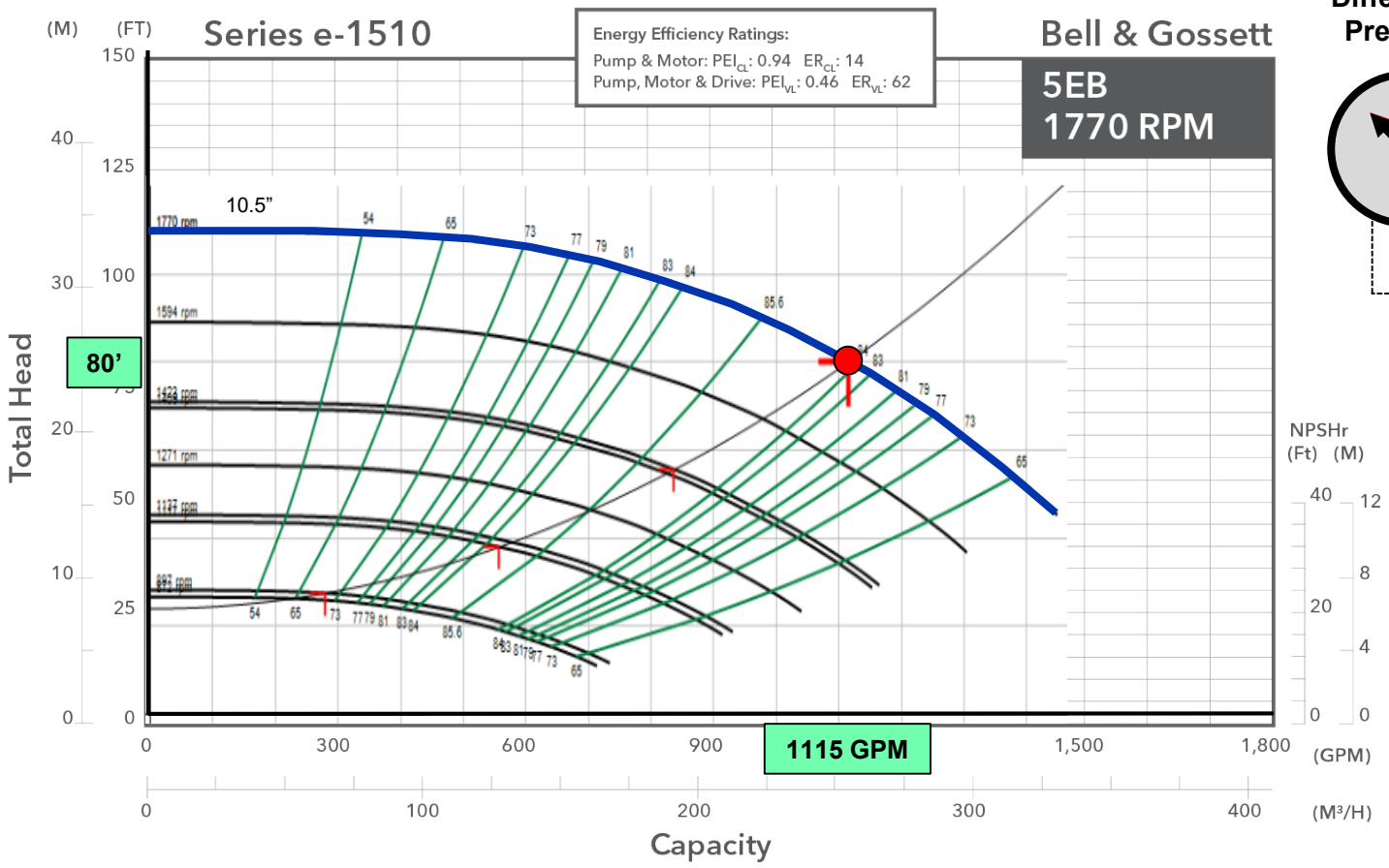

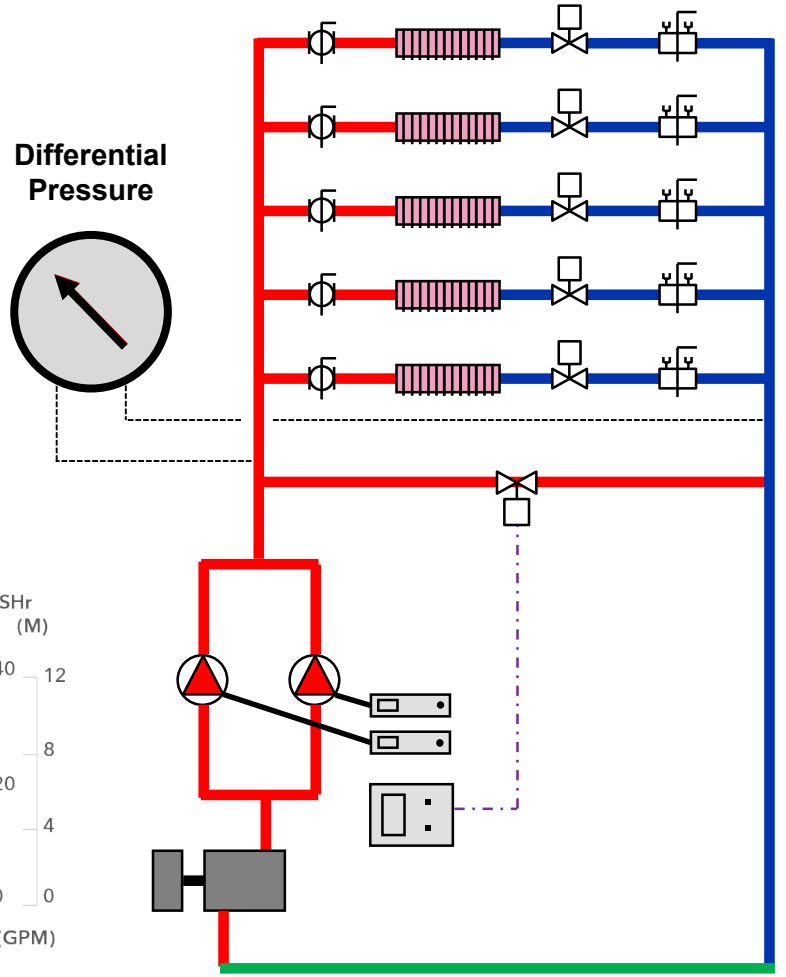

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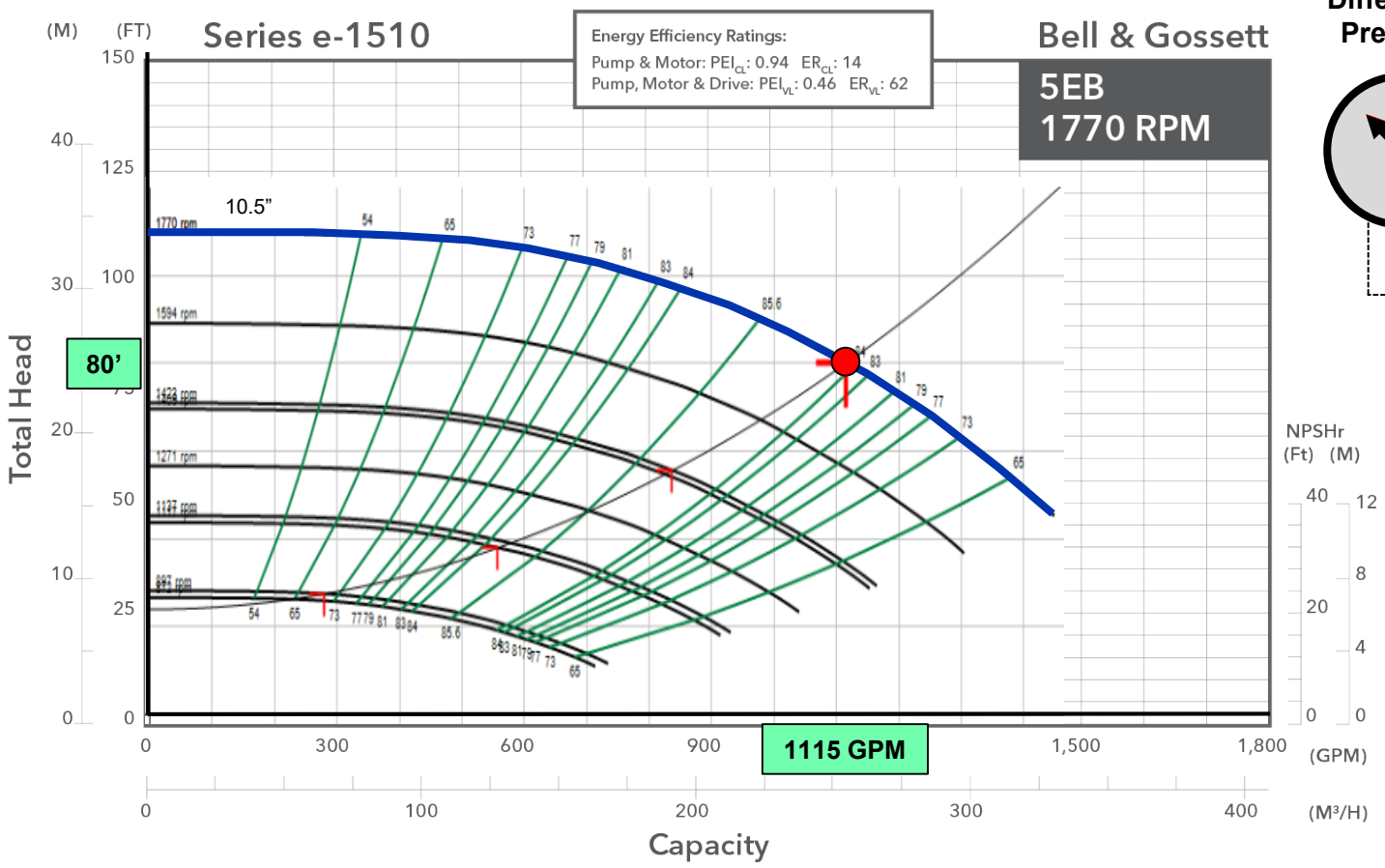
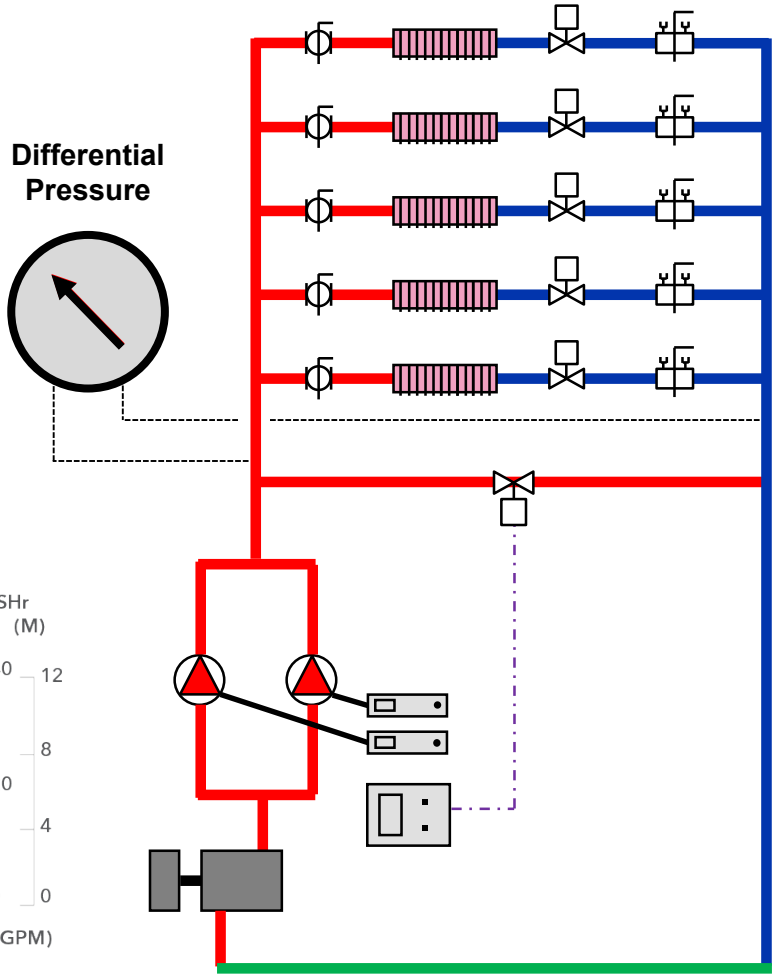
70% Variable Head Loss, 30% Constant Head Loss





Bell & Gossett
a xylem brand

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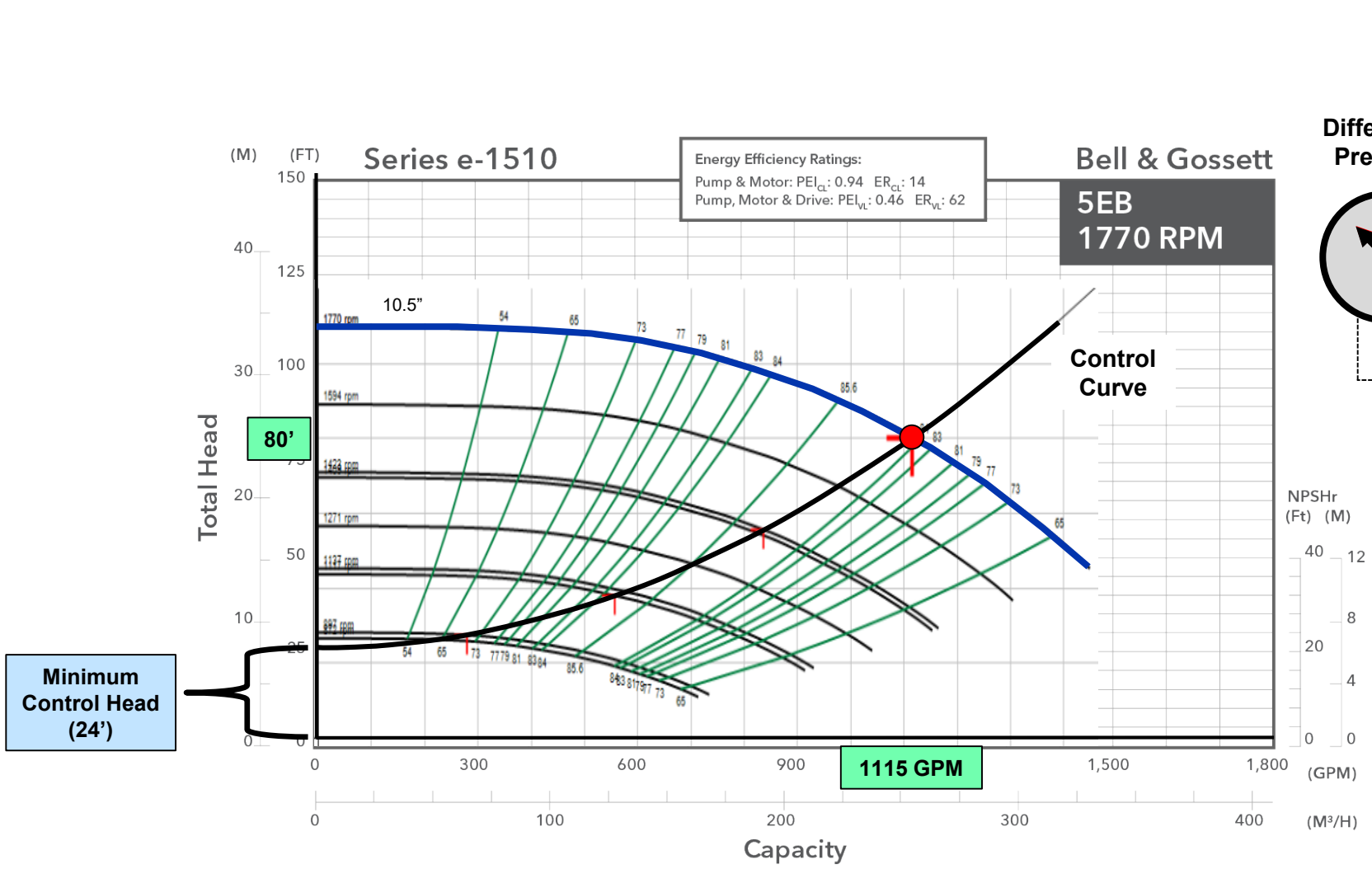

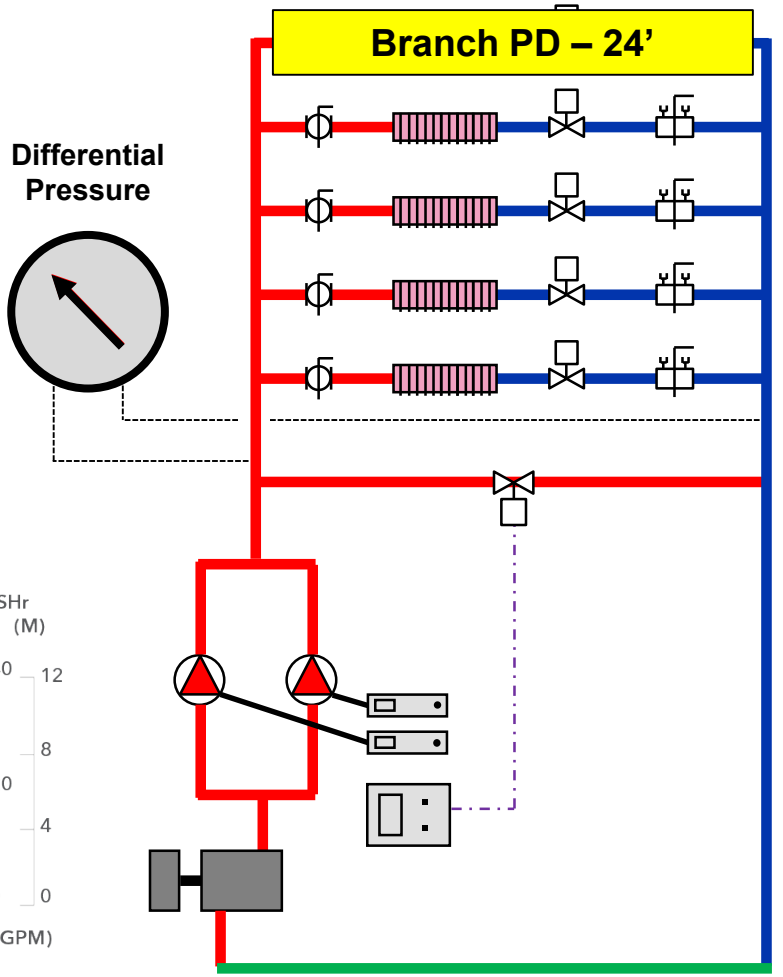

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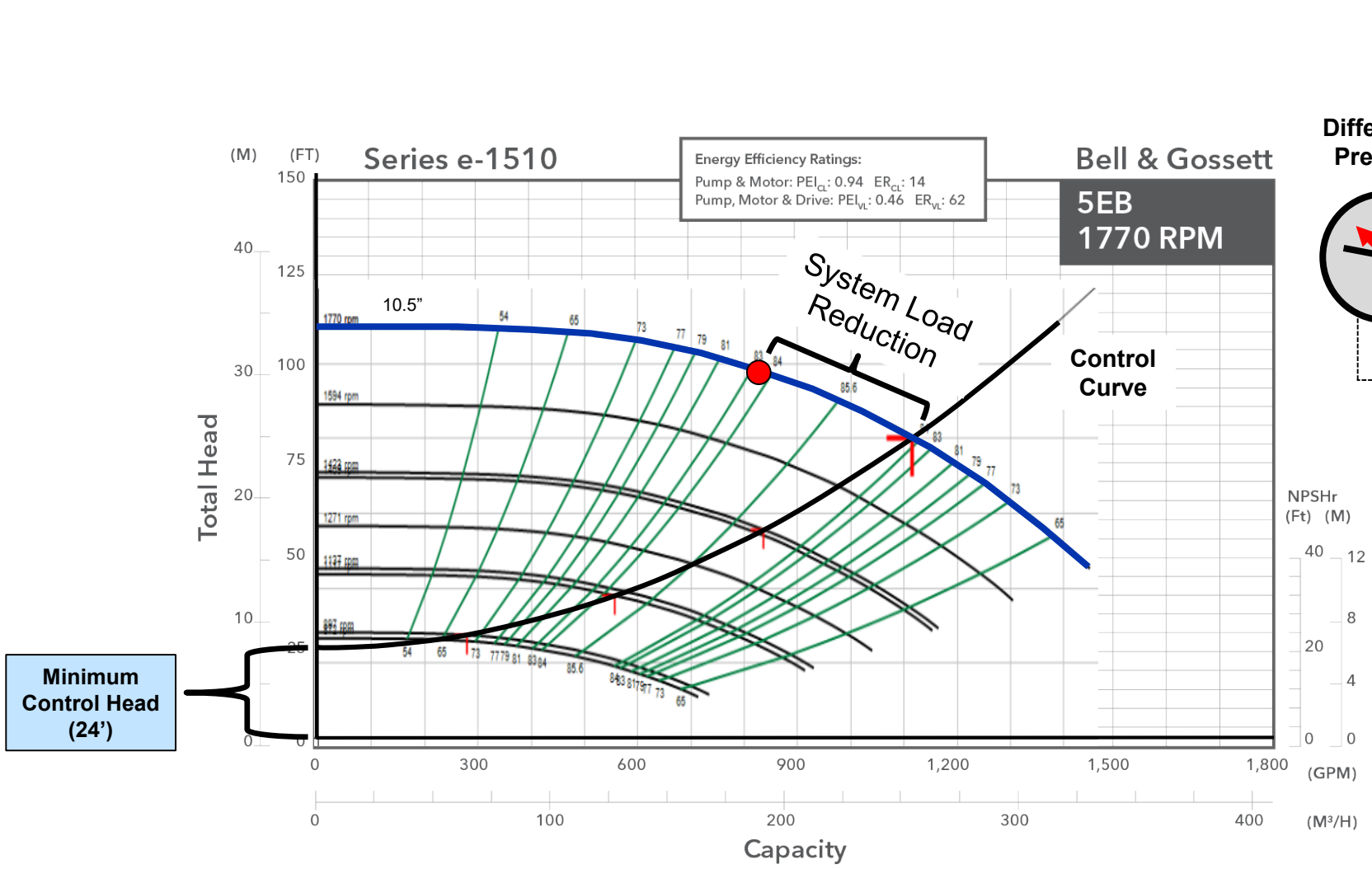

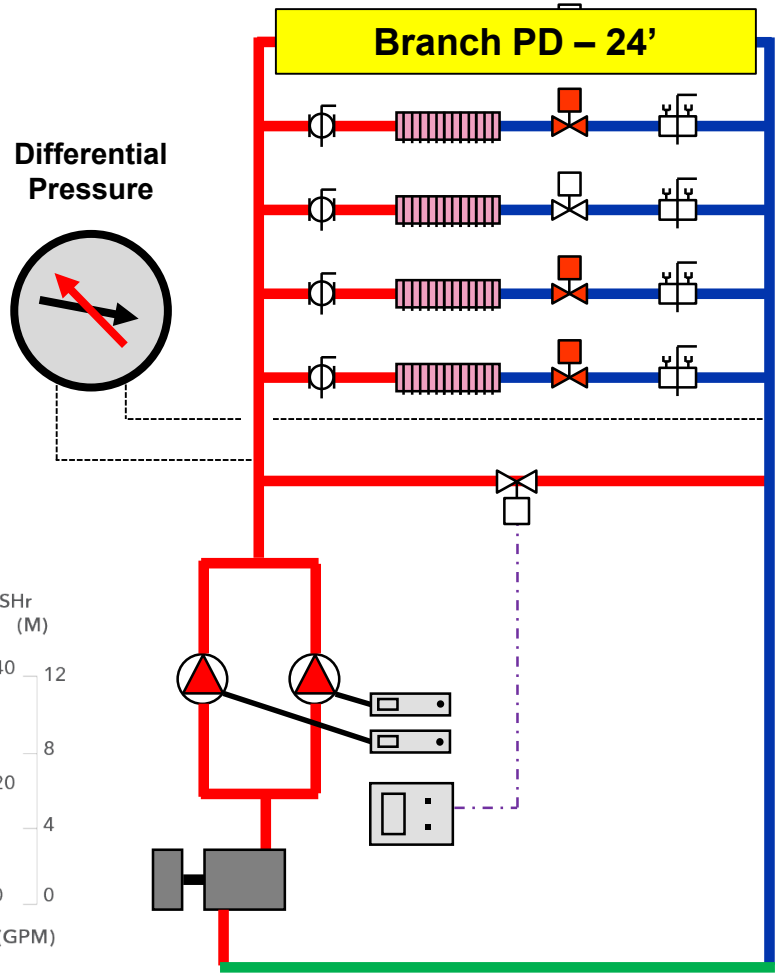

Bell & Gossett
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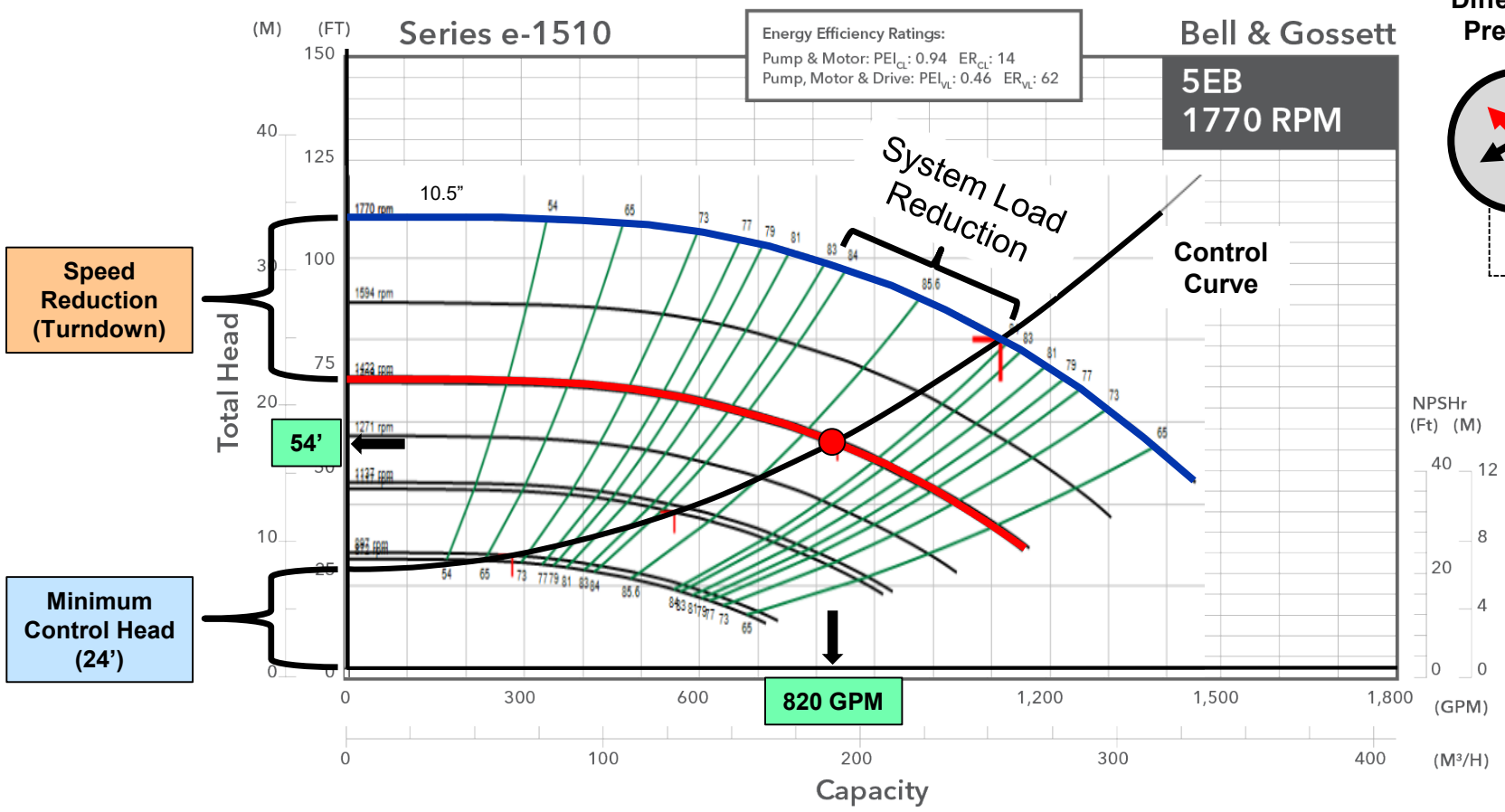
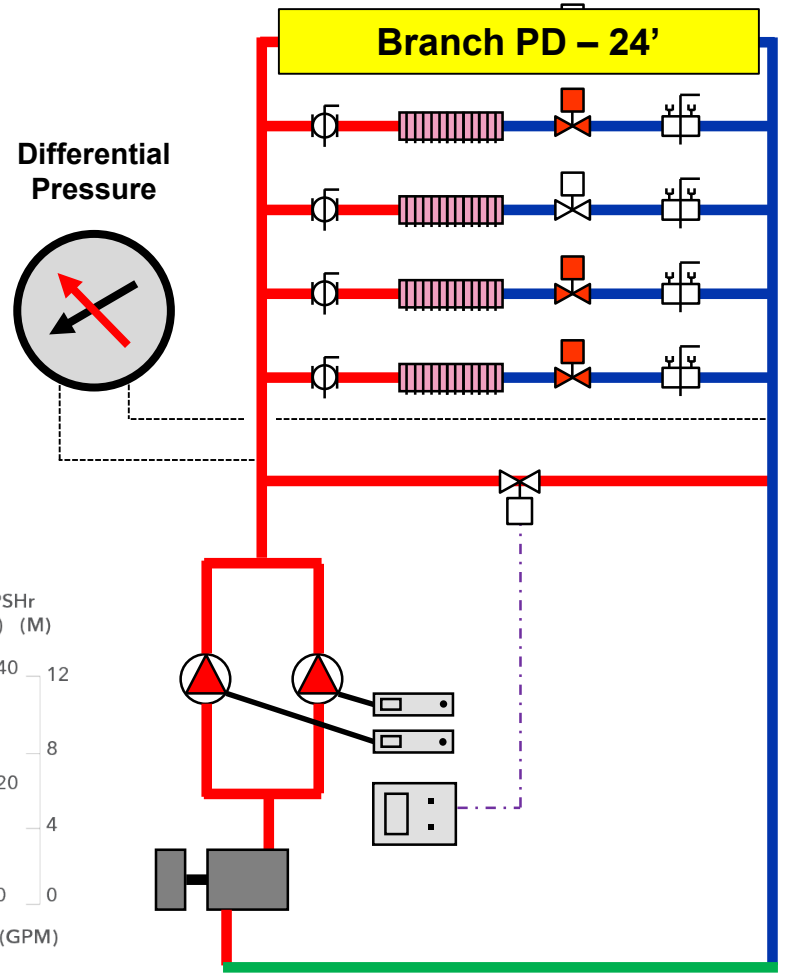
70% Variable Head Loss, 30% Constant Head Loss

(1) e-1510 5EB with 10.5" Impeller
820 GPM @ 54' [1404 RPM]

- 13.1 BHP (30HP Mtr. NOL)





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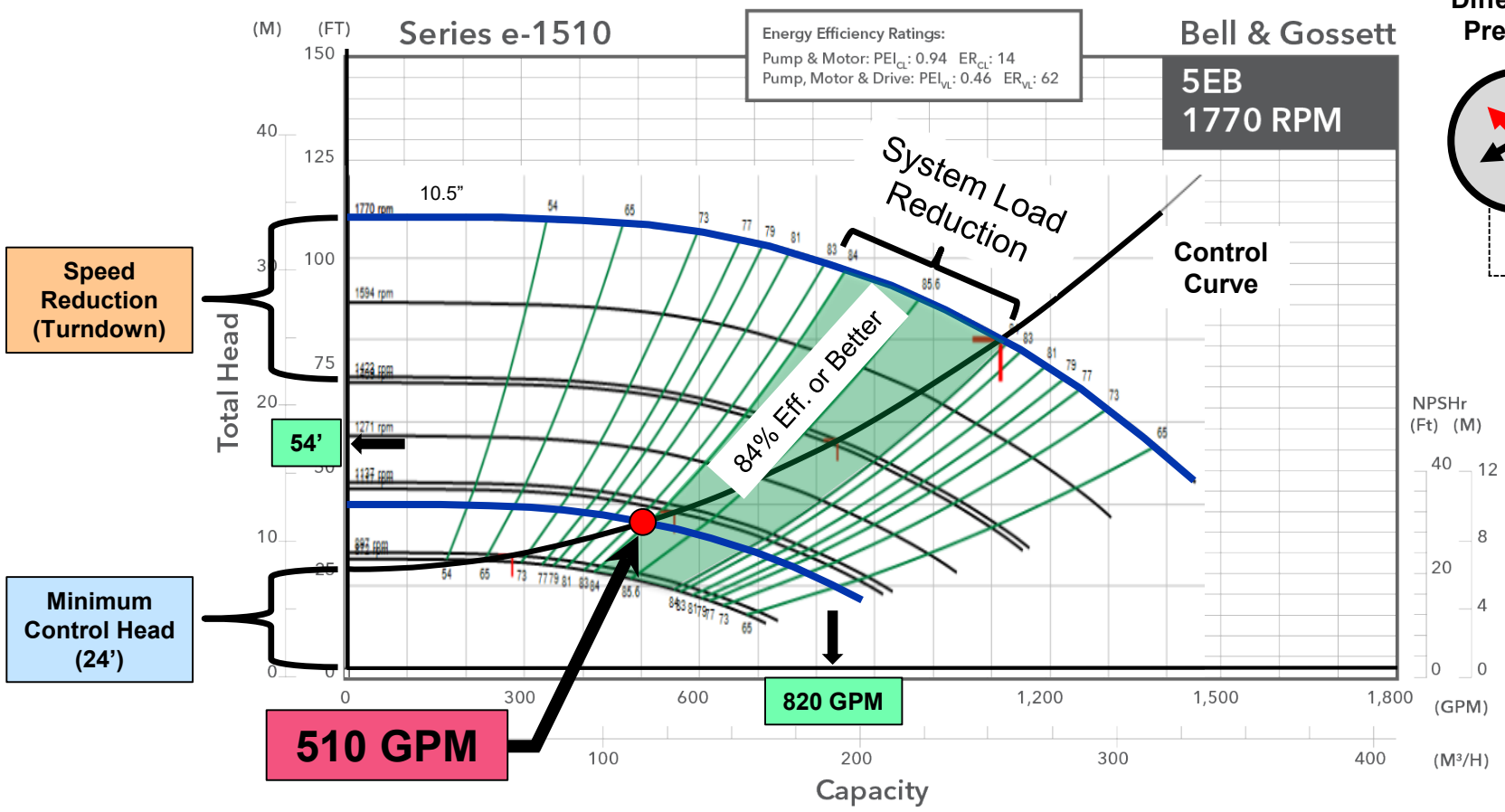

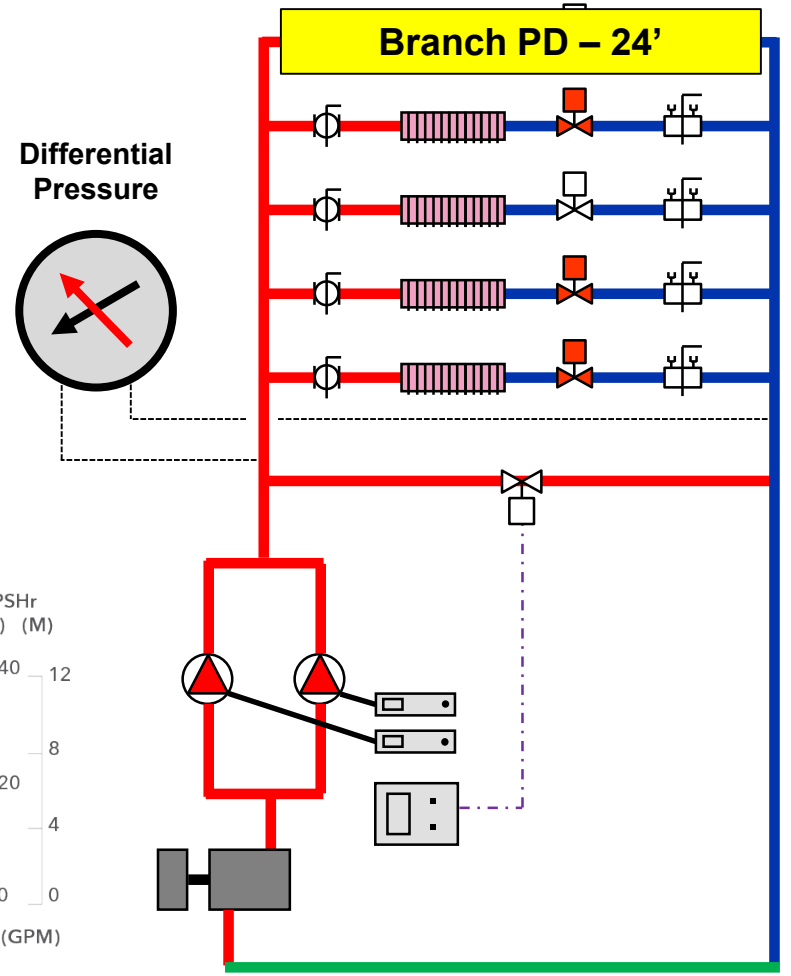

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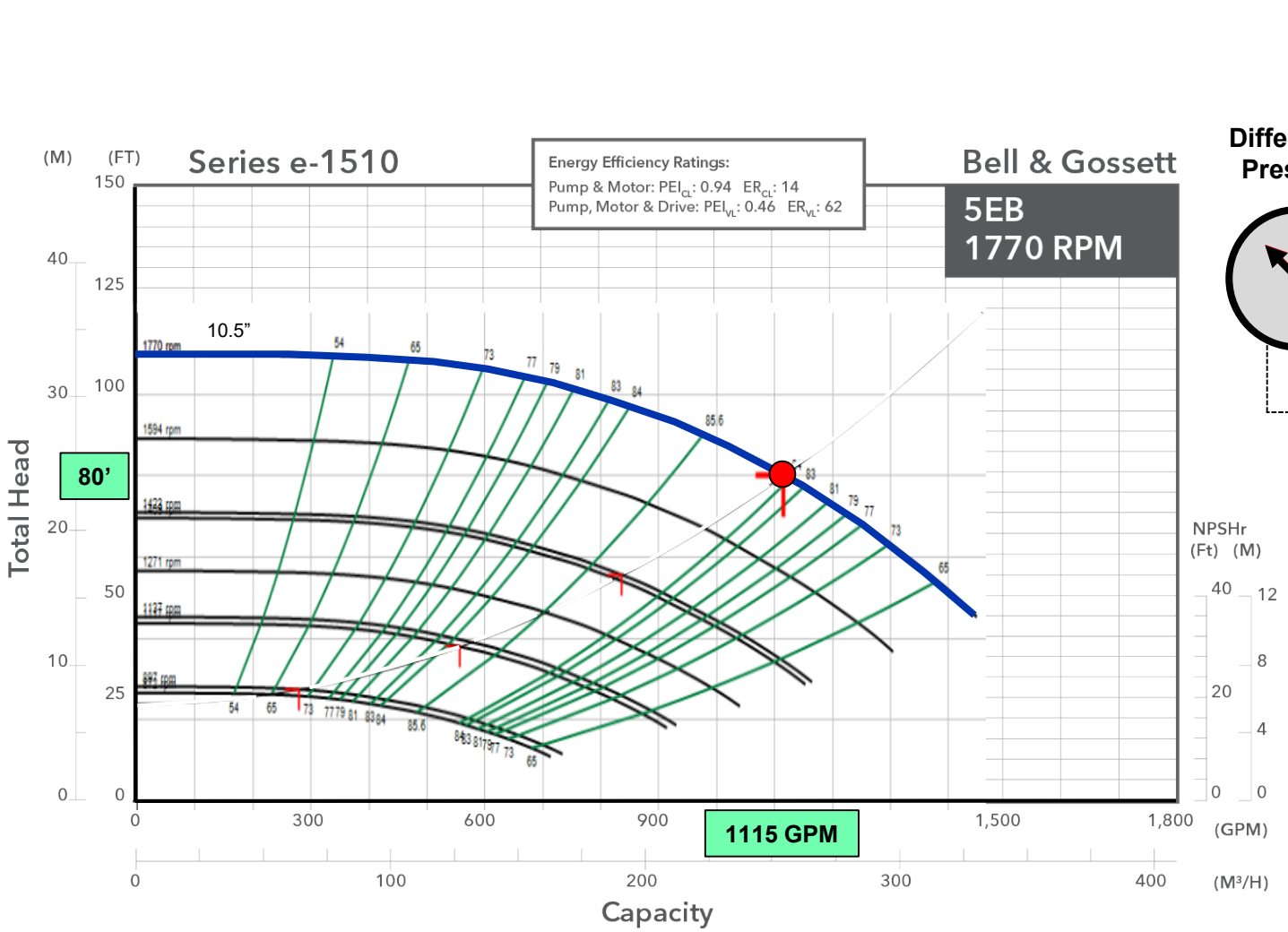

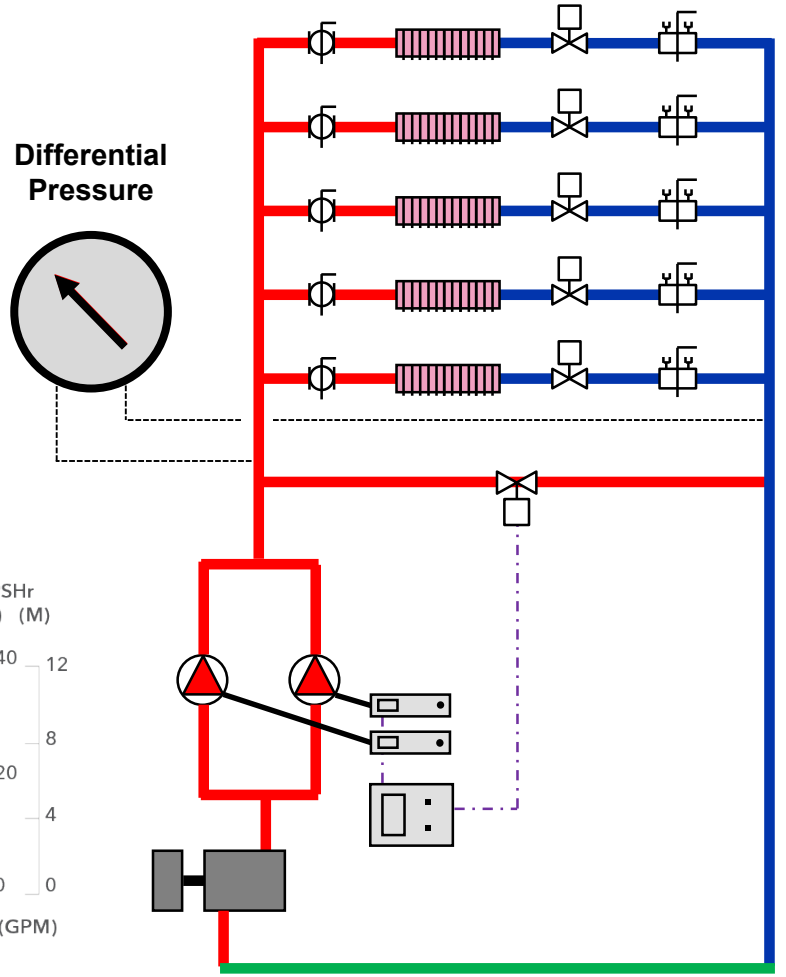

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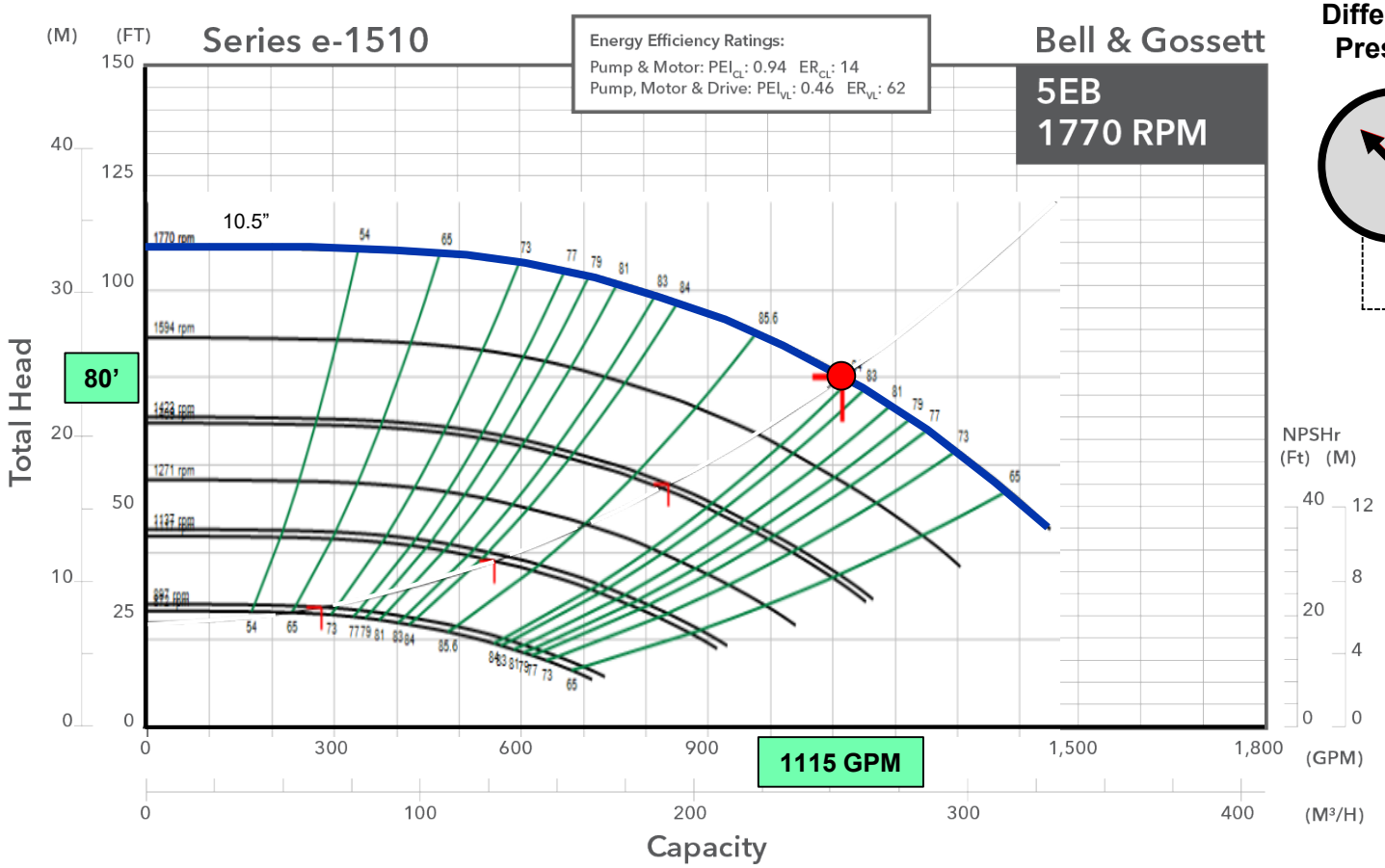
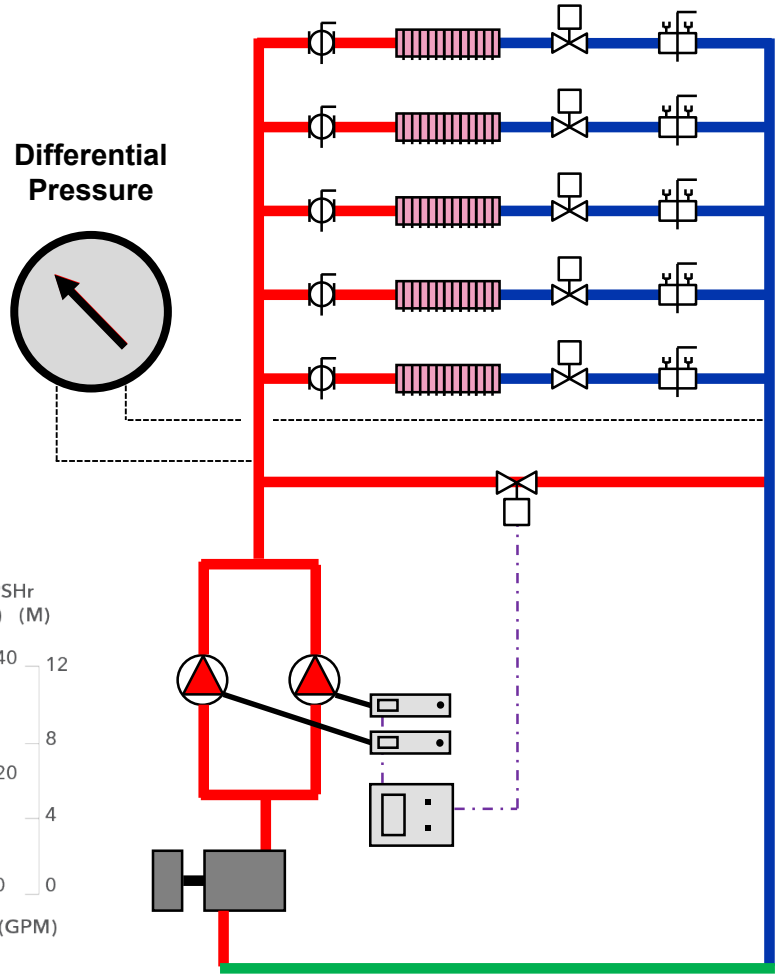
10% Variable Head Loss, 90% Constant Head Loss





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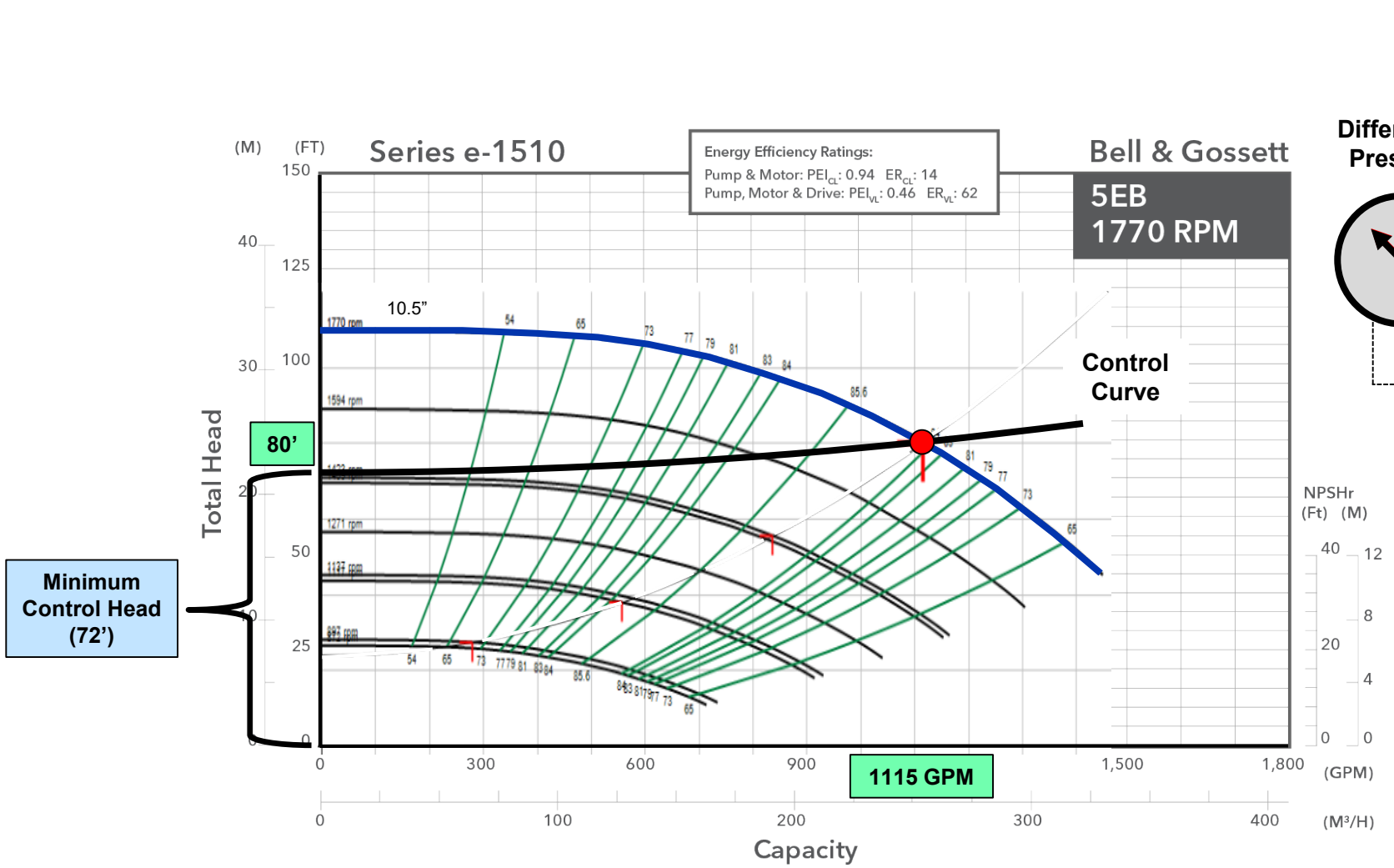

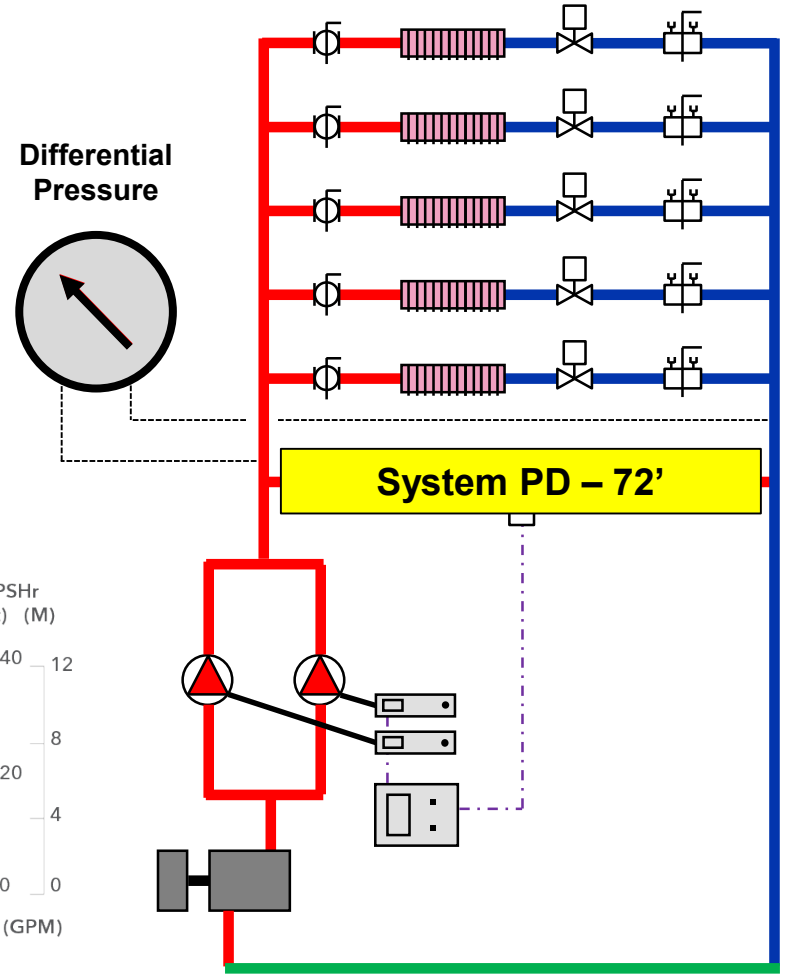

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a xylem brand

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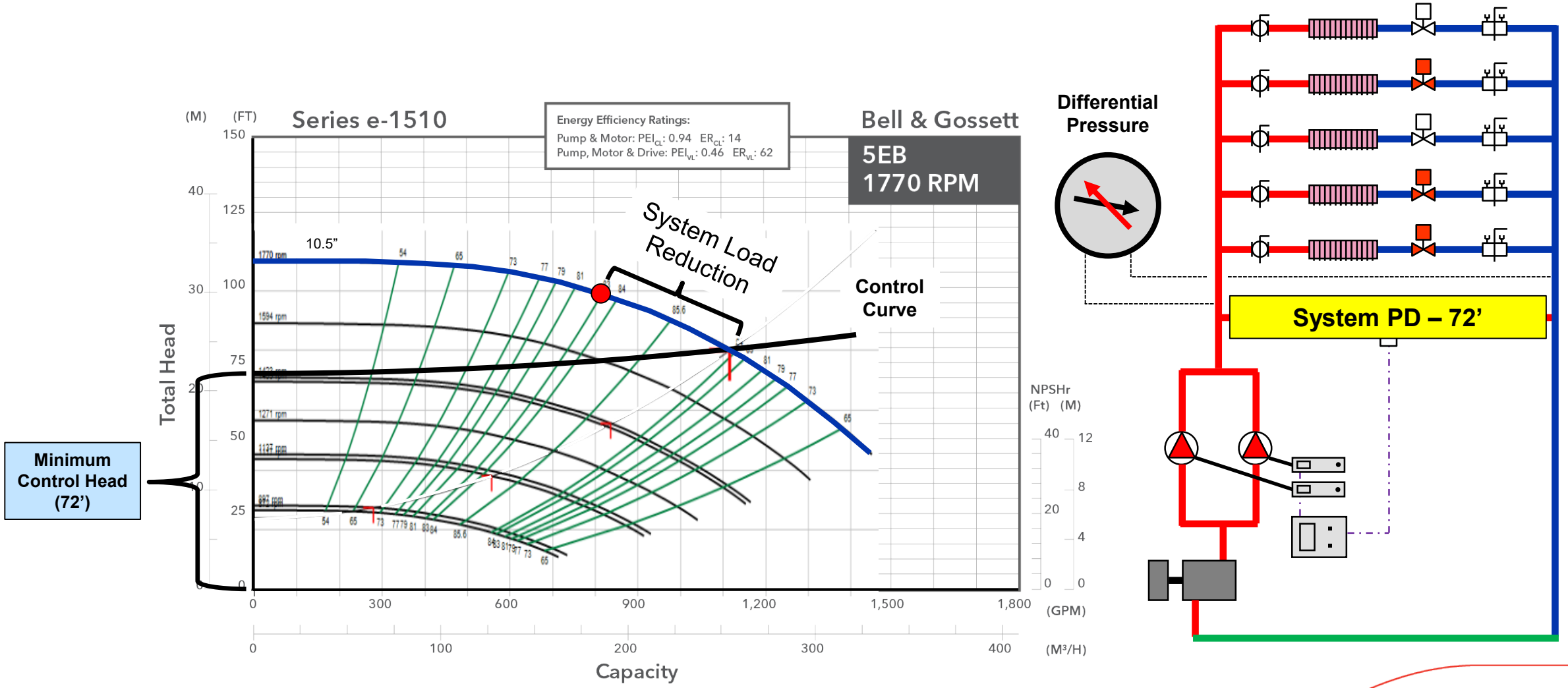

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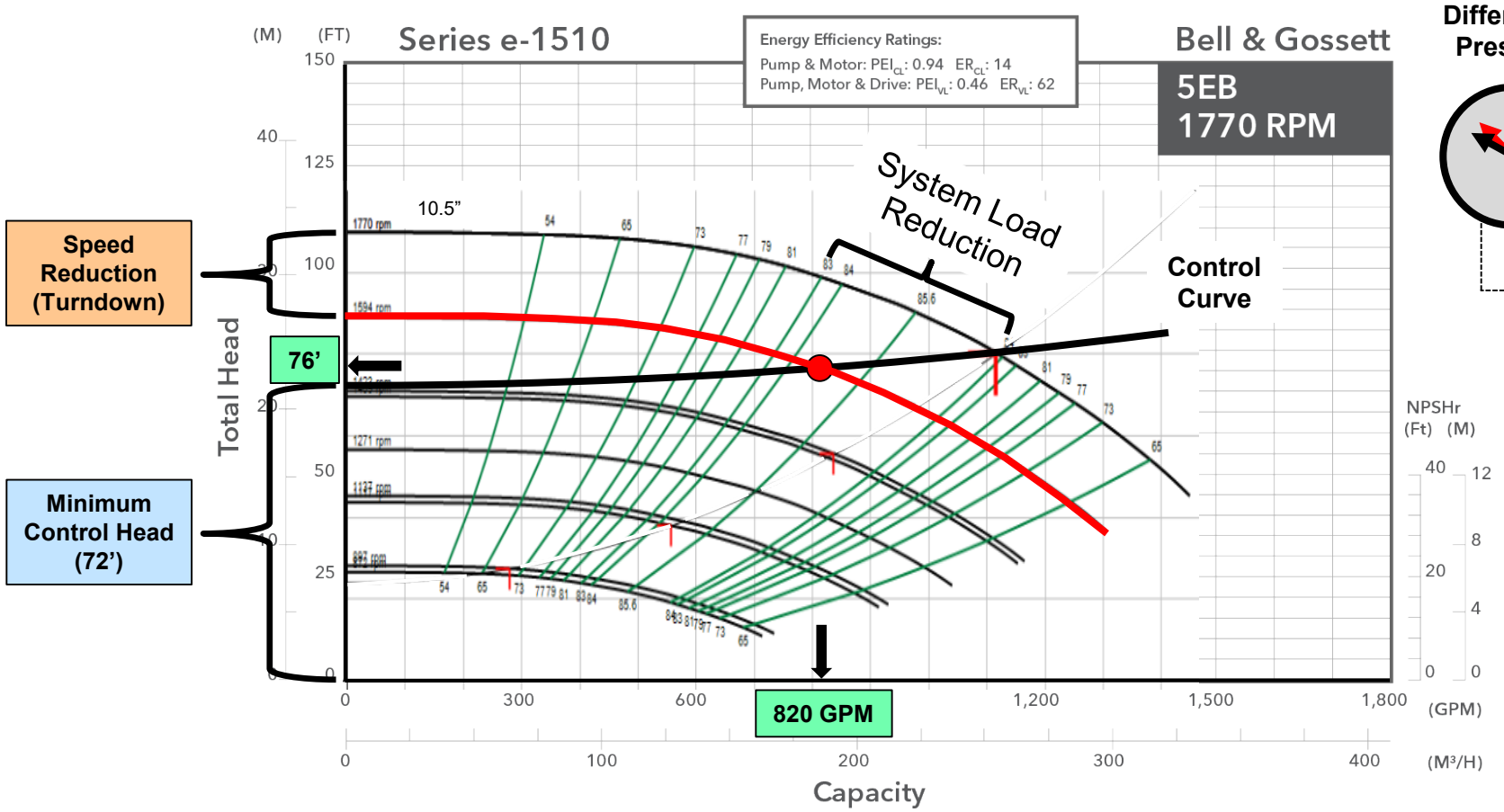
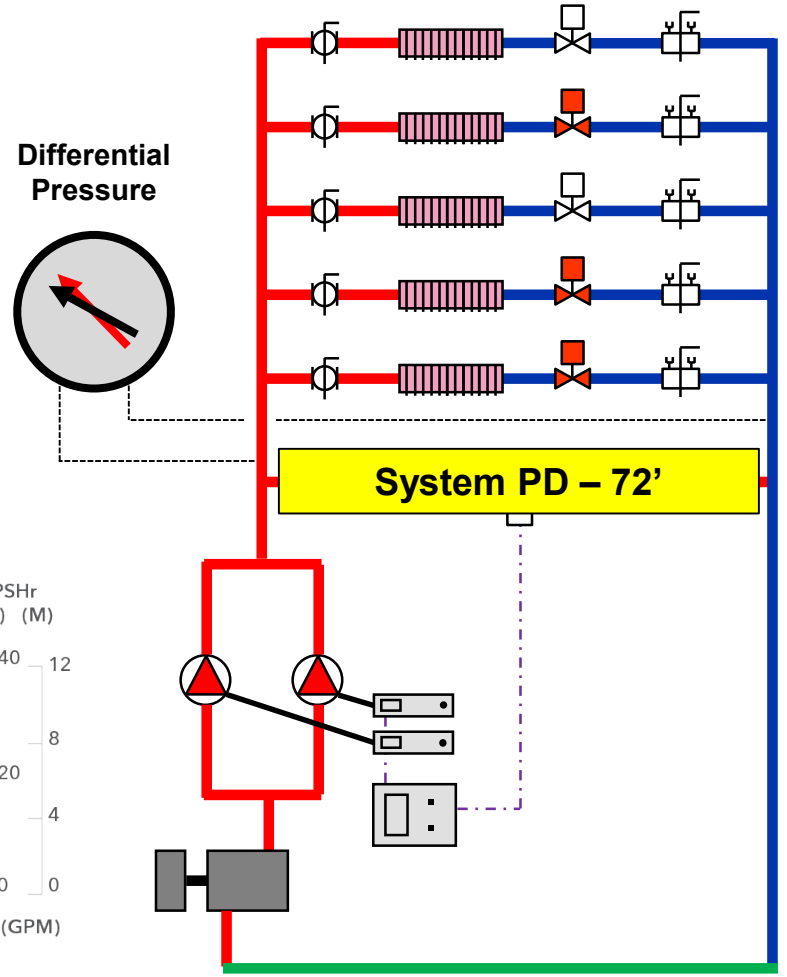
a xylem brand

10% Variable Head Loss, 90% Constant Head Loss

(1) e-1510 5EB with 10.5" Impeller
820 GPM @ 76' [1594 RPM]

- 18.5 BHP (30HP Mtr. NOL)





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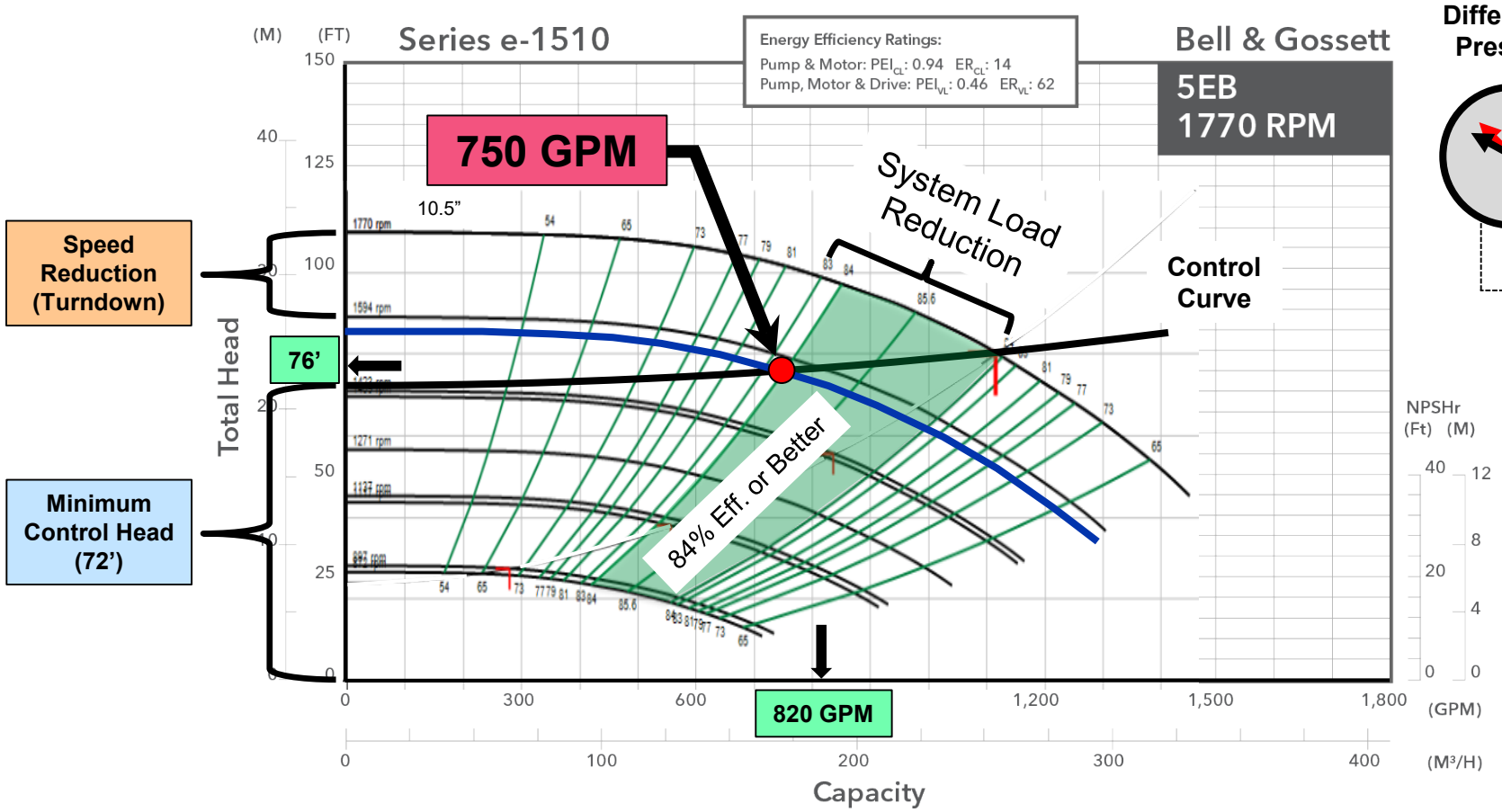

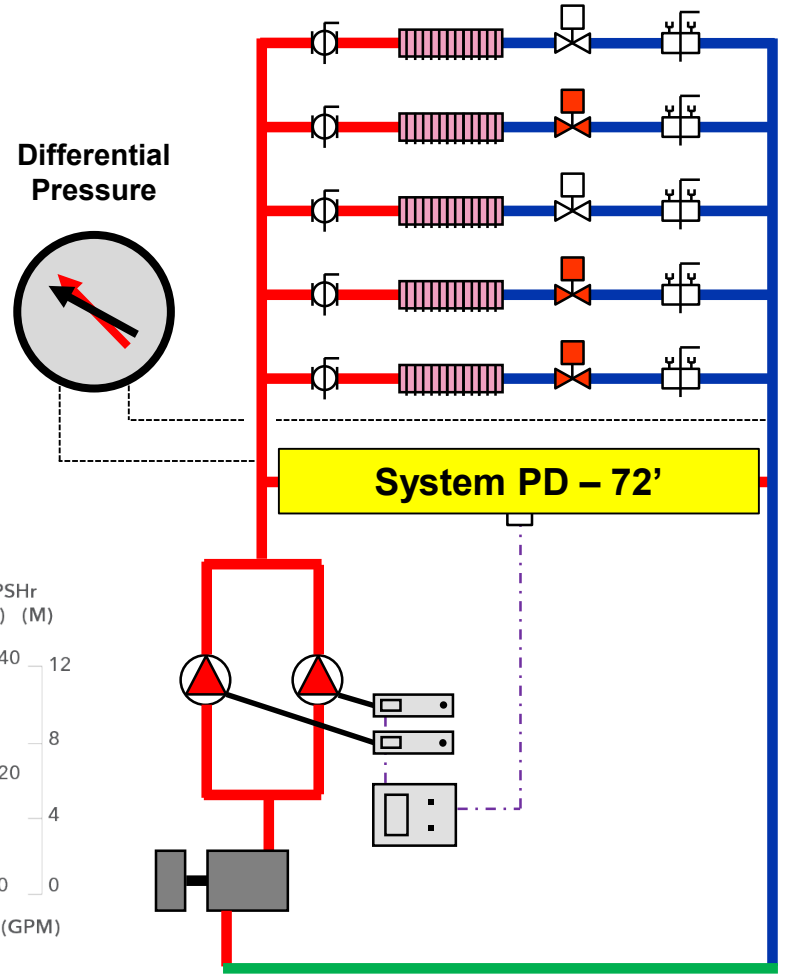

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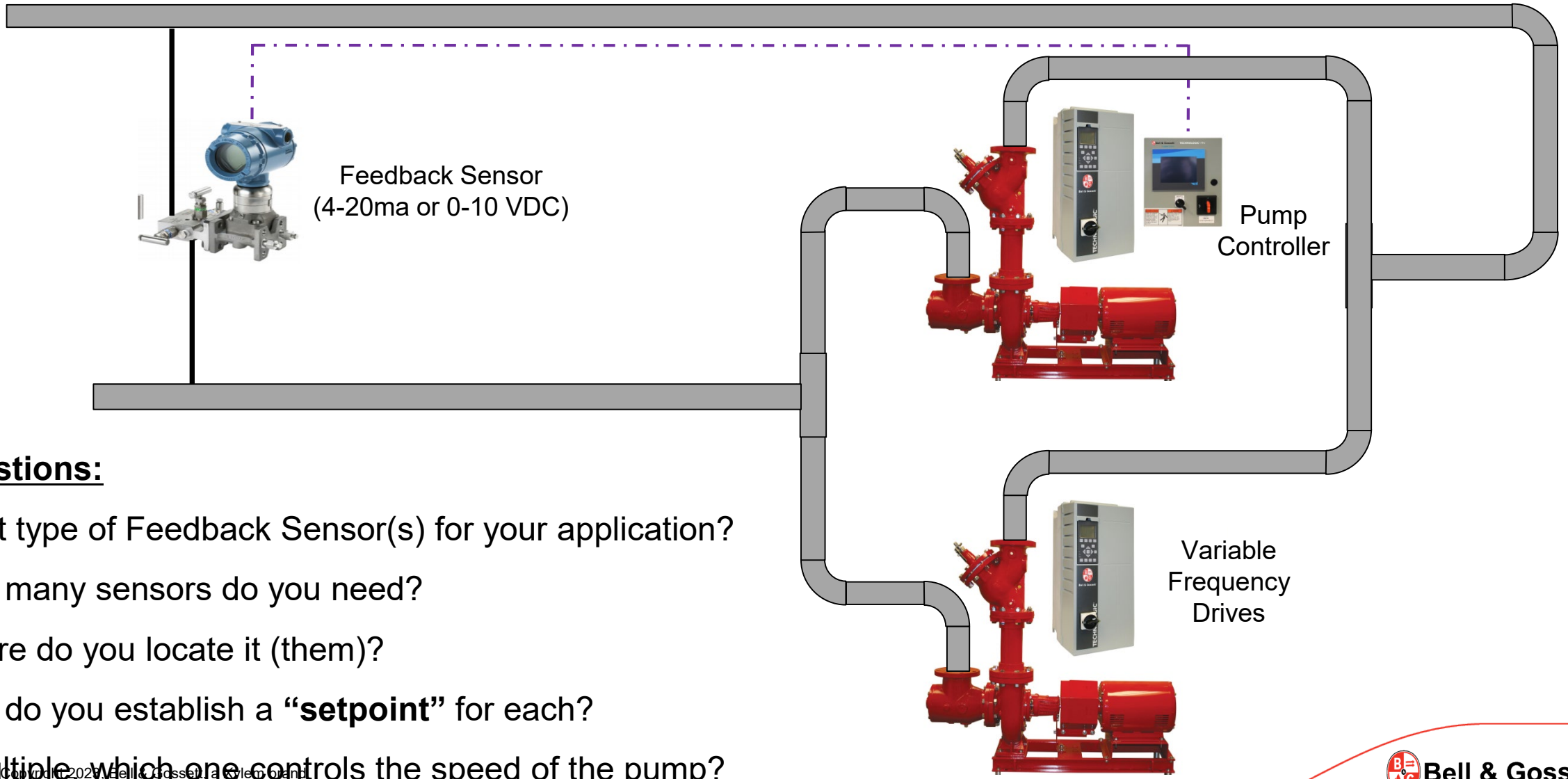
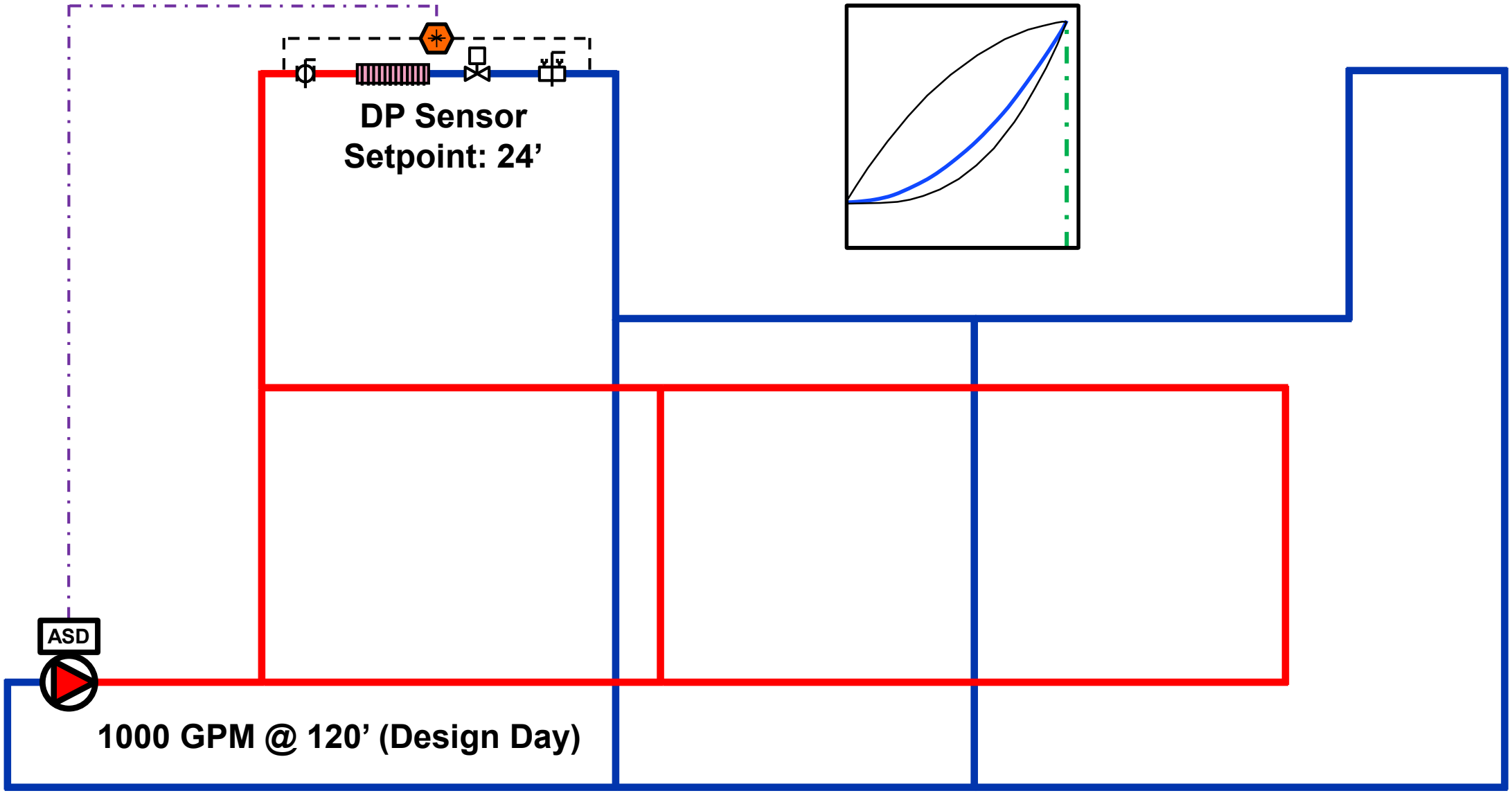
a xylem brand



- **Questions:**
- What type of Feedback Sensor(s) for your application?
- How many sensors do you need?
- Where do you locate it (them)?
- How do you establish a **"setpoint"** for each?
- If multiple, which one controls the speed of the pump?



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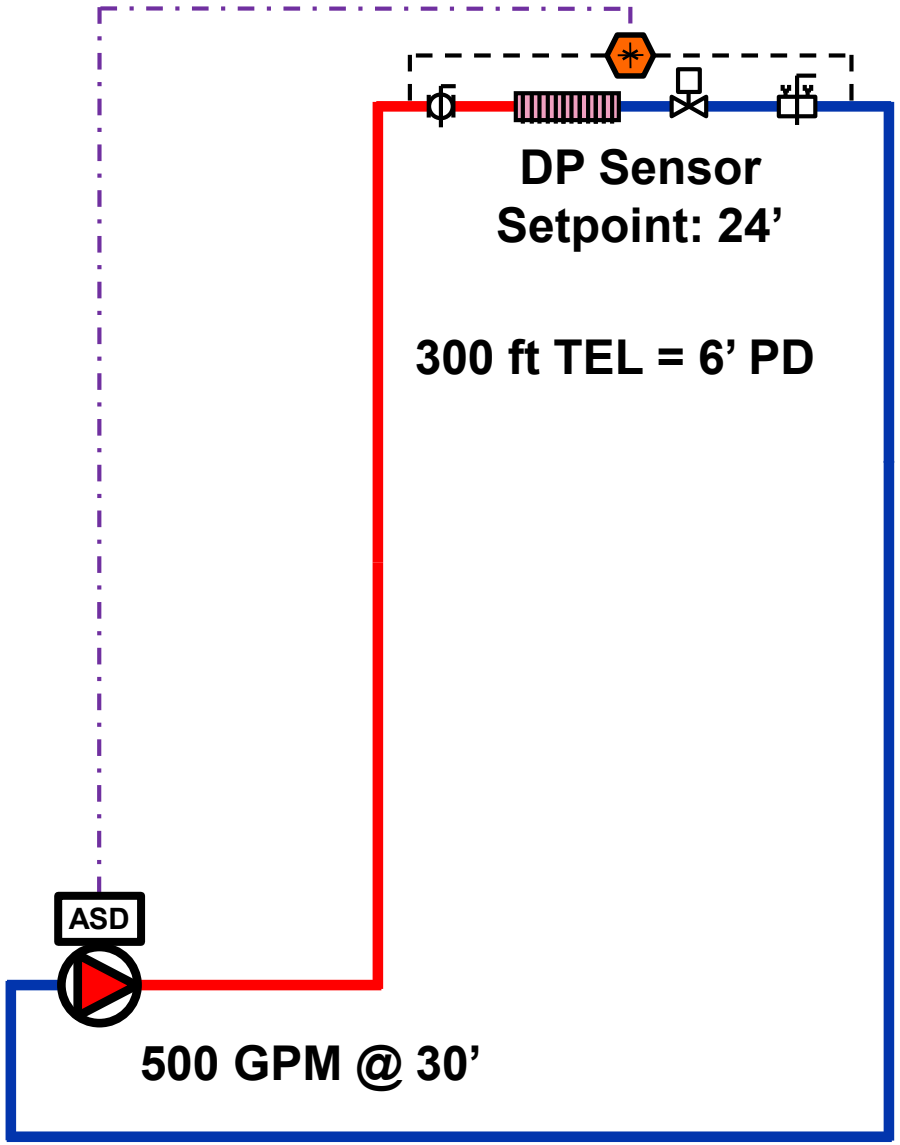
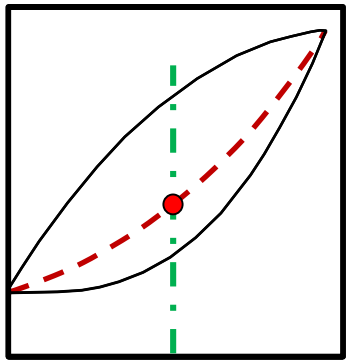
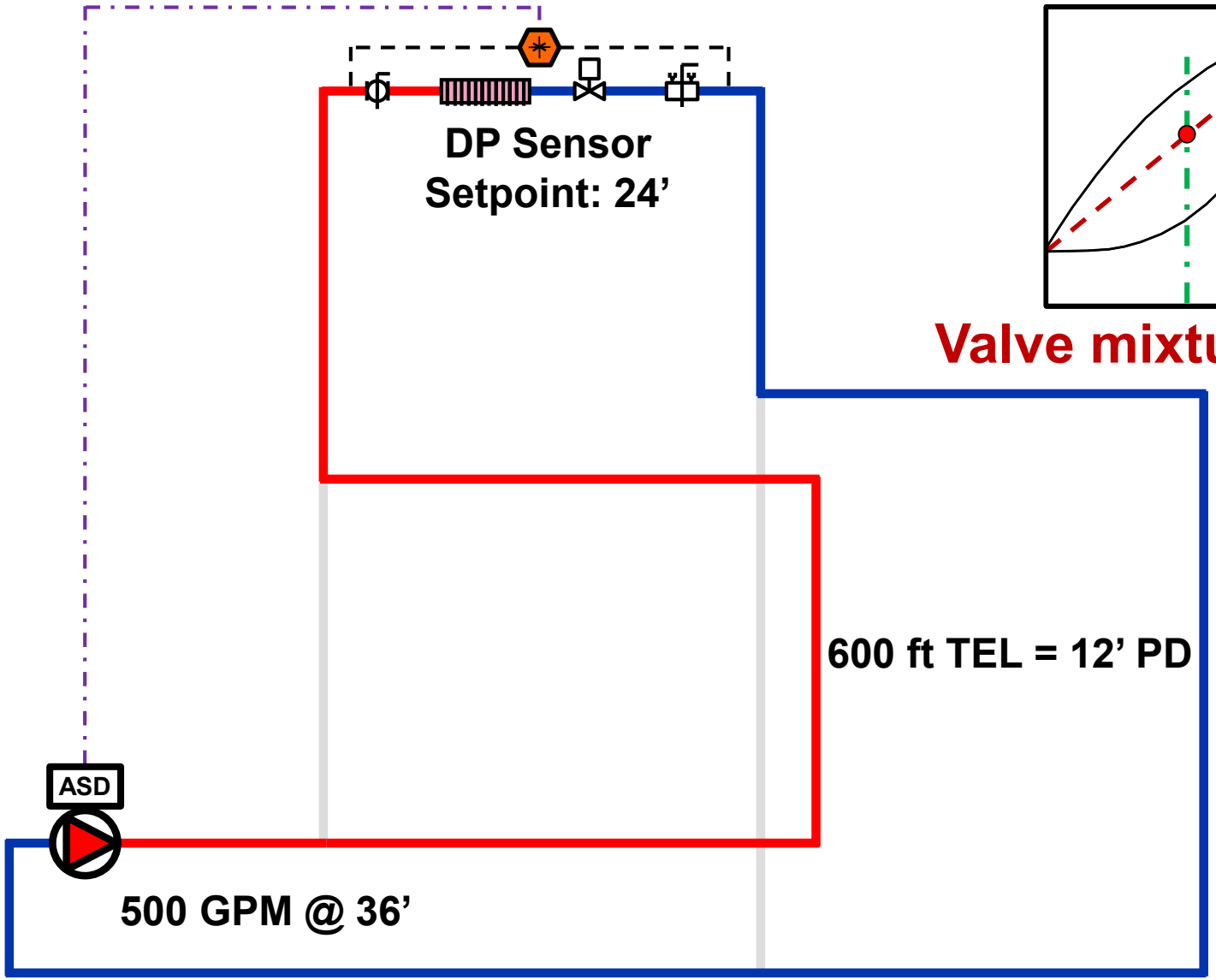
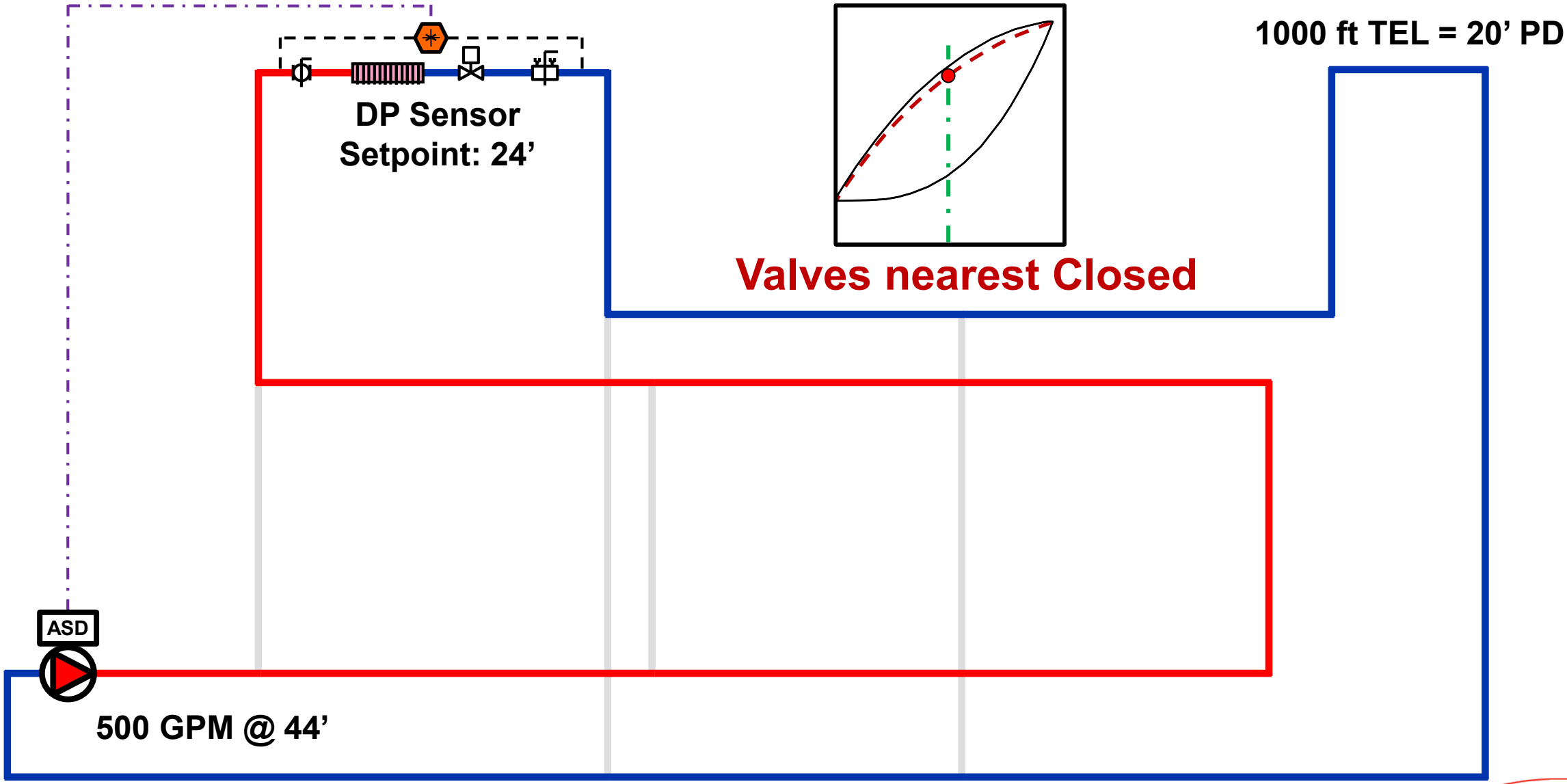




Valves farthest Closed



Valve mixture Closed



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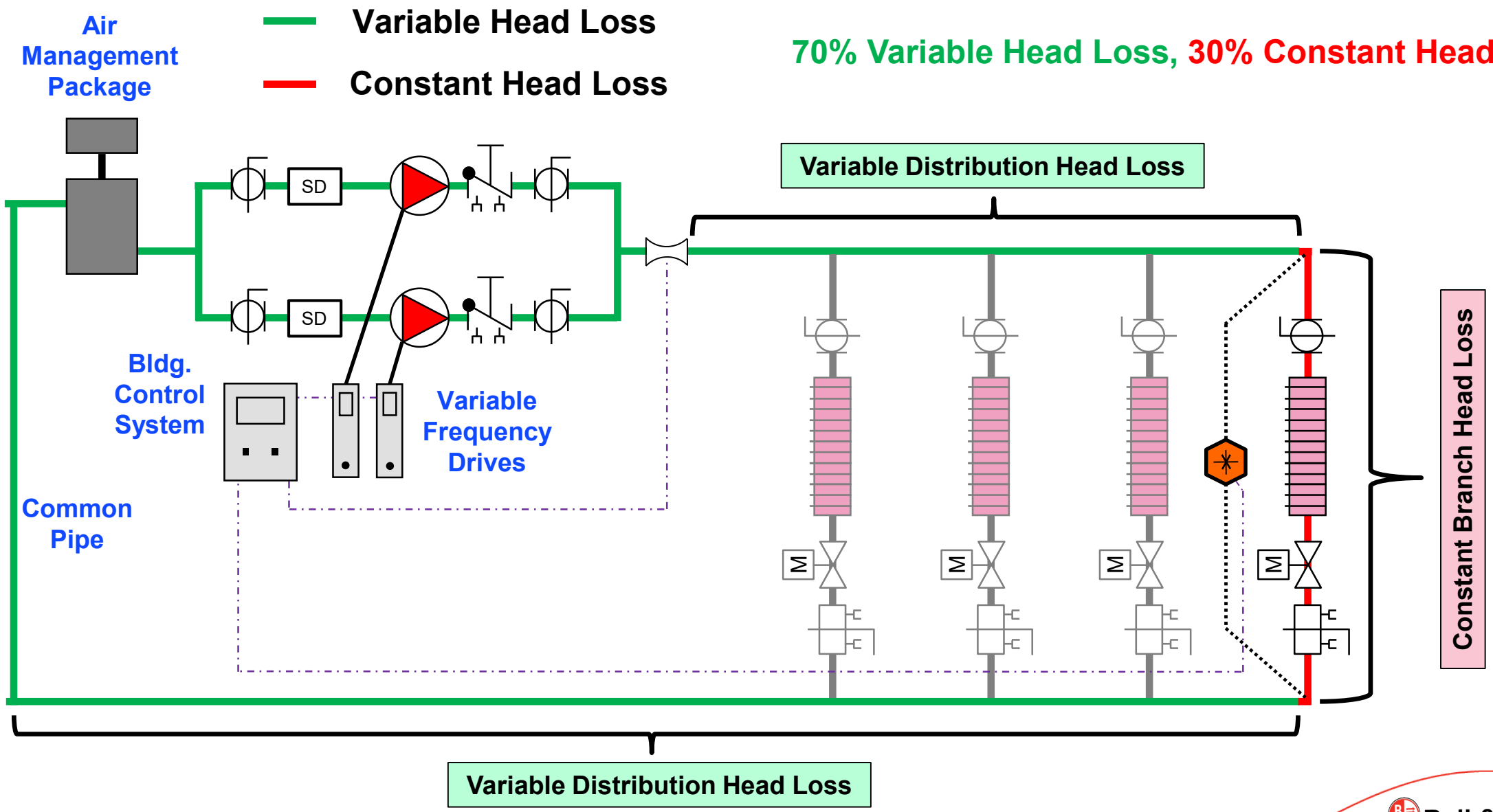
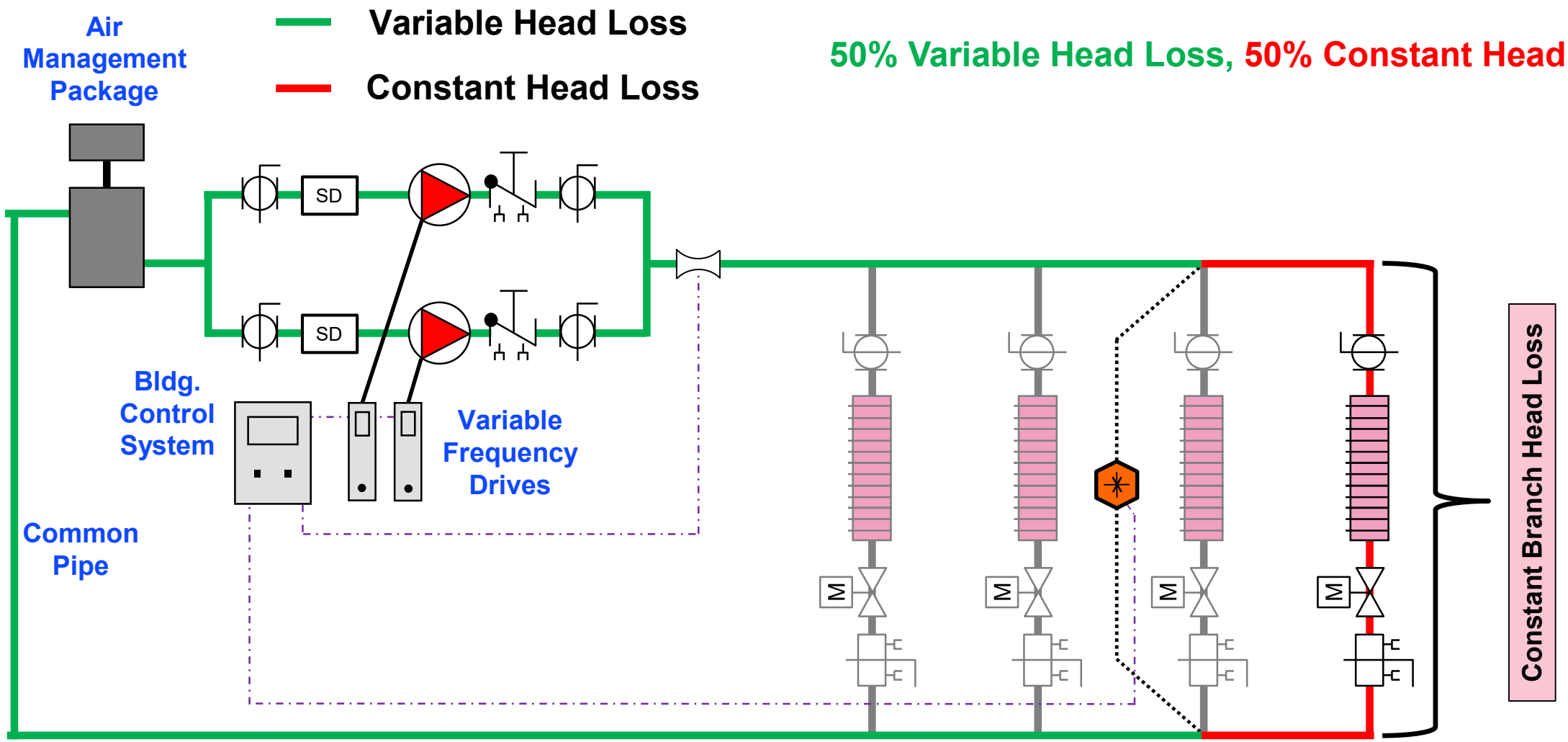
- **Common Feedback Sensor Options:**
- **Pressure** – Change in pressure at single point *(Potable Water Pressure Boosting)*
- **Differential Pressure** – Change in pressure between two points *(HVAC Heating and Cooling)*
- **Temperature** – Change in temperature at single point *(Batch Process Tank)*
- **Differential Temperature** – Change in temperature between two points *(Air or Water side of HVAC Coils)*
- **Flow Meter** – Change in flowrate in pipe or equipment *(Pump Staging, Backup to other Feedback Sensors)*
- **Discharge Air Temperature** – Air Temperature on discharge side of a water coil *(VFD Zone Pumping)*

- **Differential Pressure** – Change in pressure between two points *(HVAC Heating and Cooling)*

- **<u>Differential Pressure Feedback Sensor Locations:</u>**
- Mechanical Room
- 2/3 the system piping distance from the Mechanical Room
- Most remote hydraulic head loss circuit pump will serve ***(The "Critical Circuit")***
- **It doesn't matter (???)**





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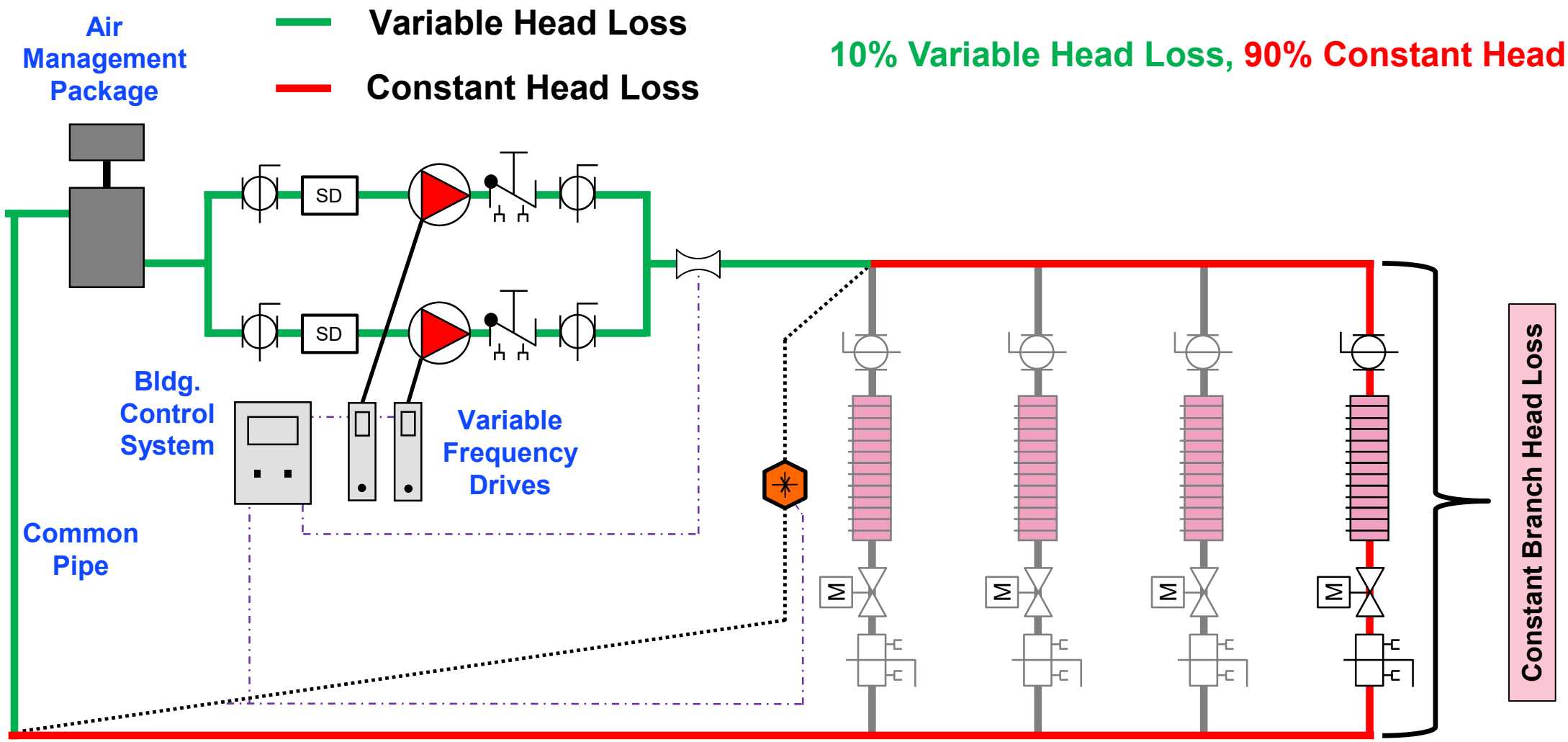

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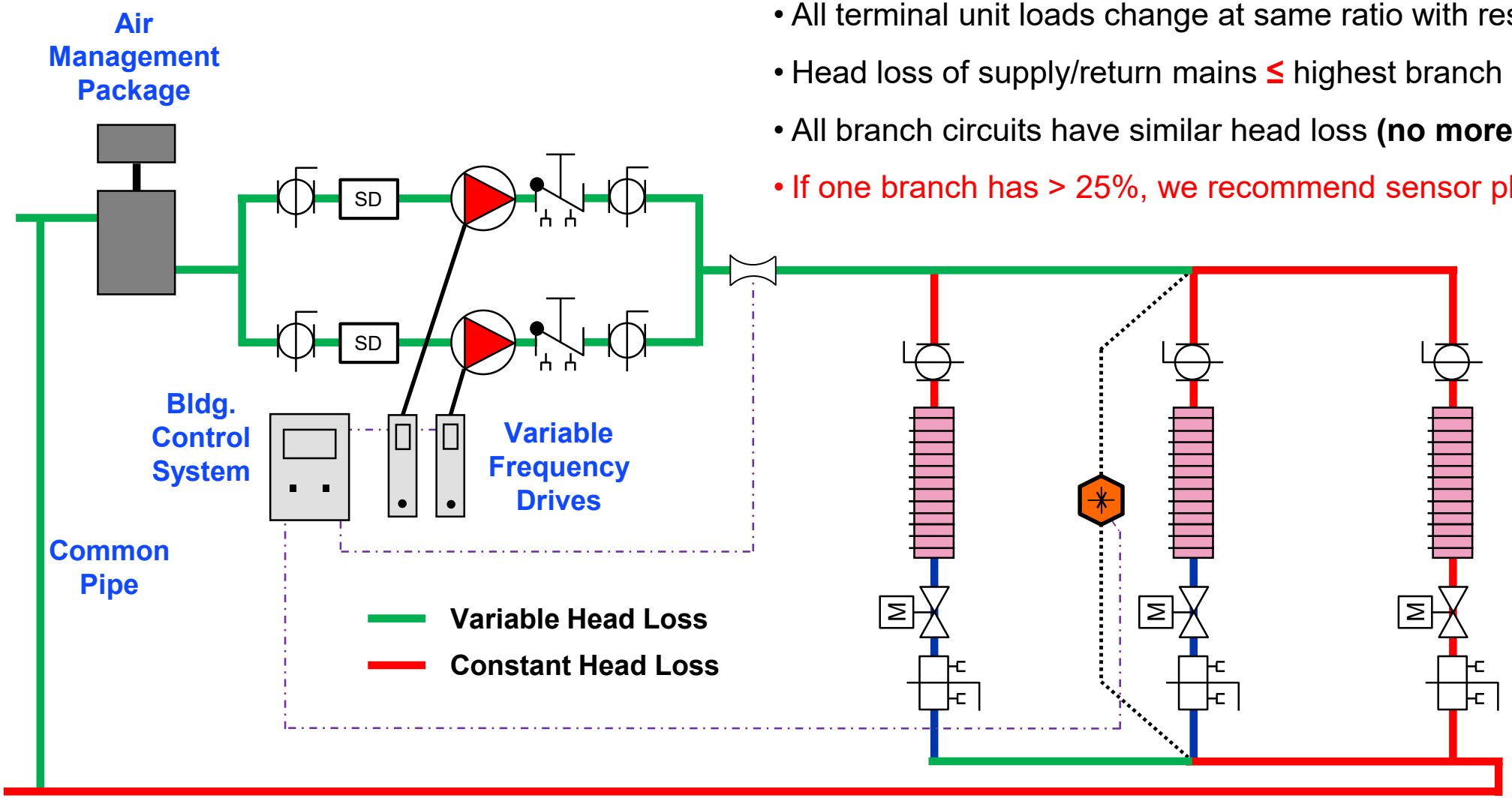
Suggested Sensor Location Assumptions:

- All terminal unit loads change at same ratio with respect to time
- Head loss of supply/return mains ≤ highest branch circuit head loss
- All branch circuits have similar head loss **(no more than 25% difference)**
- If one branch has > 25%, we recommend sensor placement at that location.



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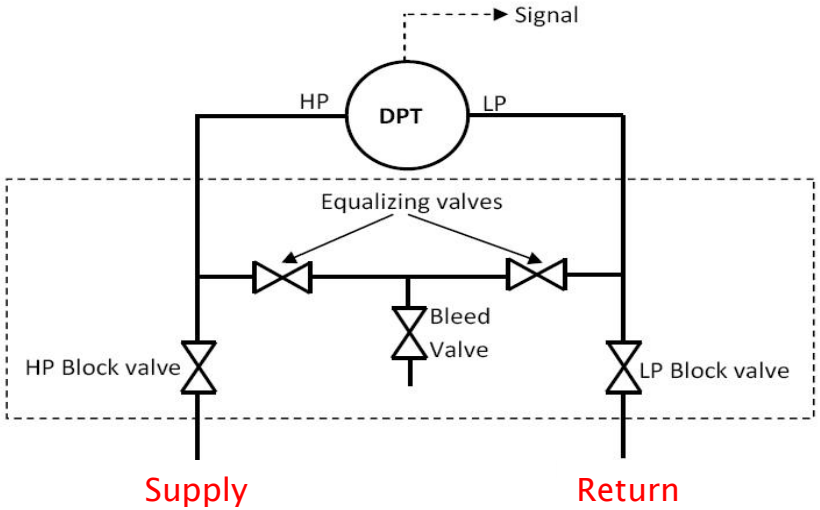
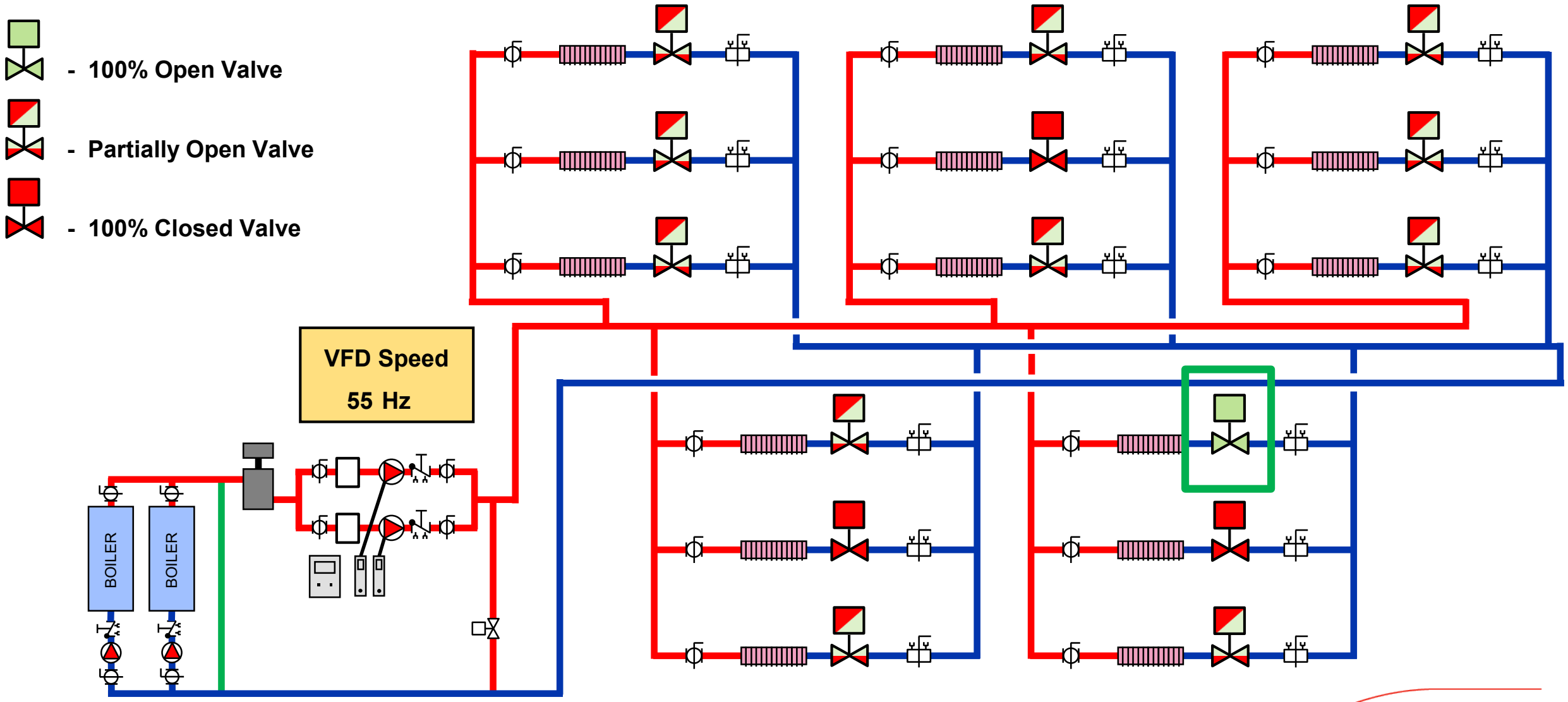


- Measure Pressures at Supply and Return to obtain differential
- Must be done under “Design Day” simulation **after final hydronic system balance has been completed**
- Data must be recorded independently for **each** sensor’s location
- Establish sensor signal range values in pump controller ***(i.e. 4ma = 18Hz., 20ma = 60Hz.)***

ASHRAE 90.1 Section 6.5 – Prescriptive Compliance Path

6.5.4.2 Hydronic Variable Flow Systems

…. 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 requiring the greatest differential pressure. **…. Where differential pressure control is used to comply with this section and *DDC systems* are used, the *set point* shall be *reset* downward based on valve positions until one valve is nearly wide open.**



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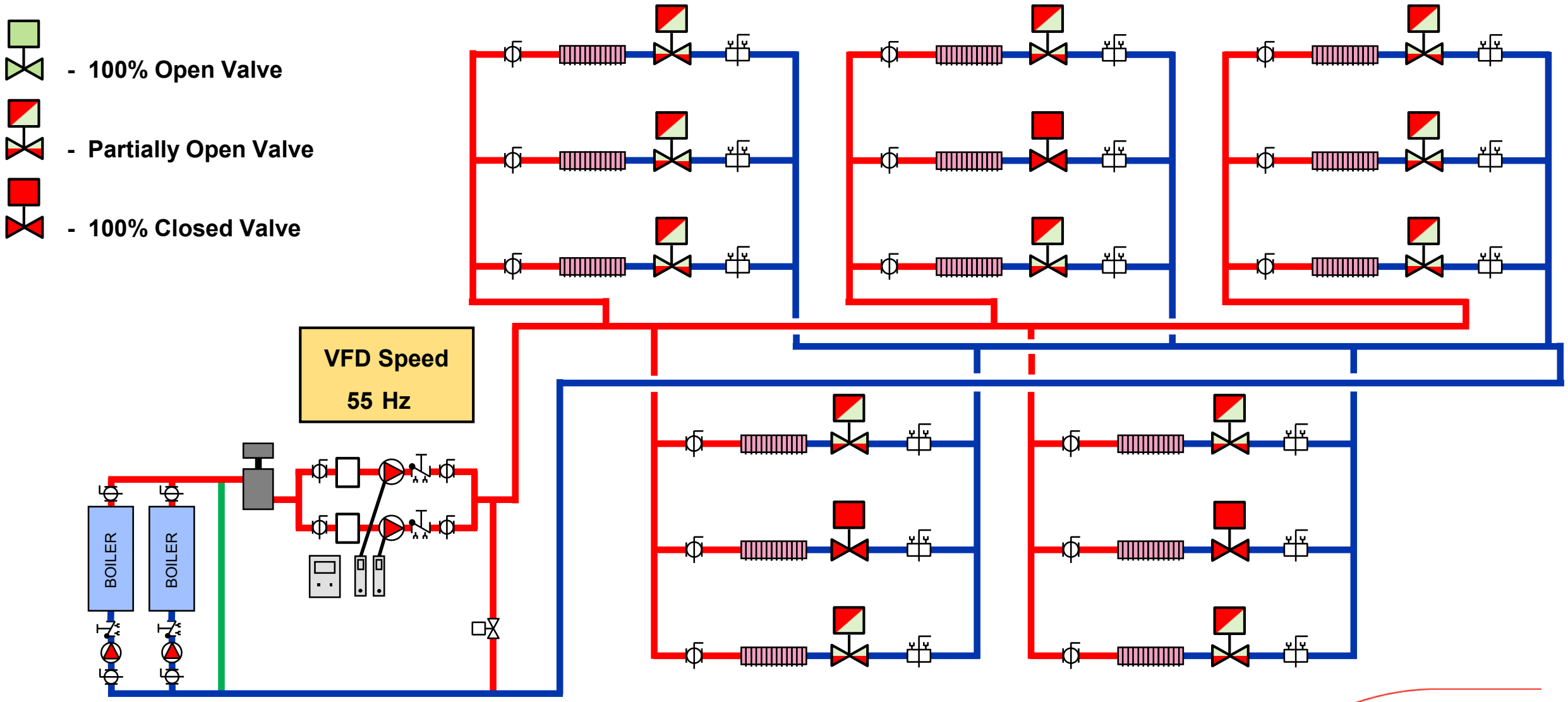

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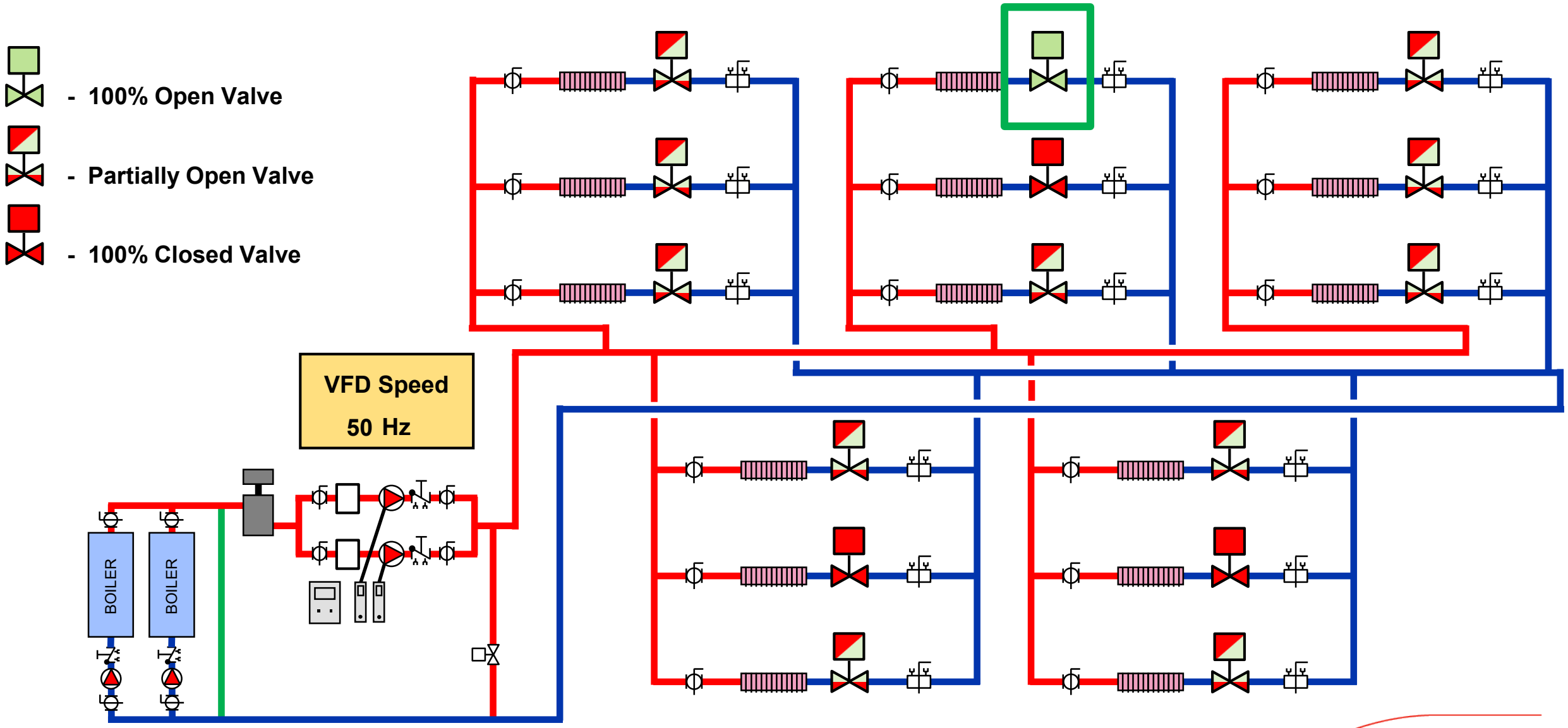

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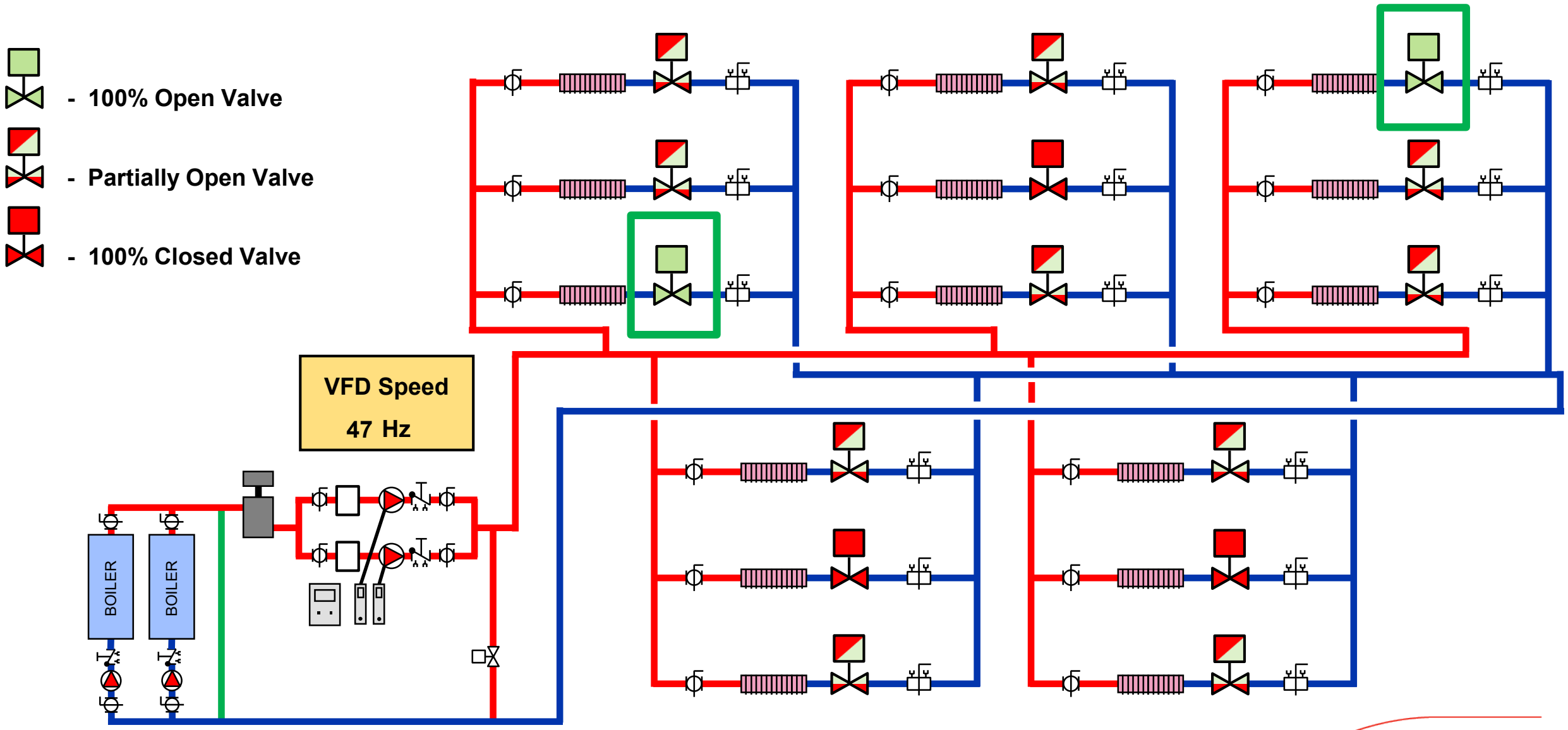

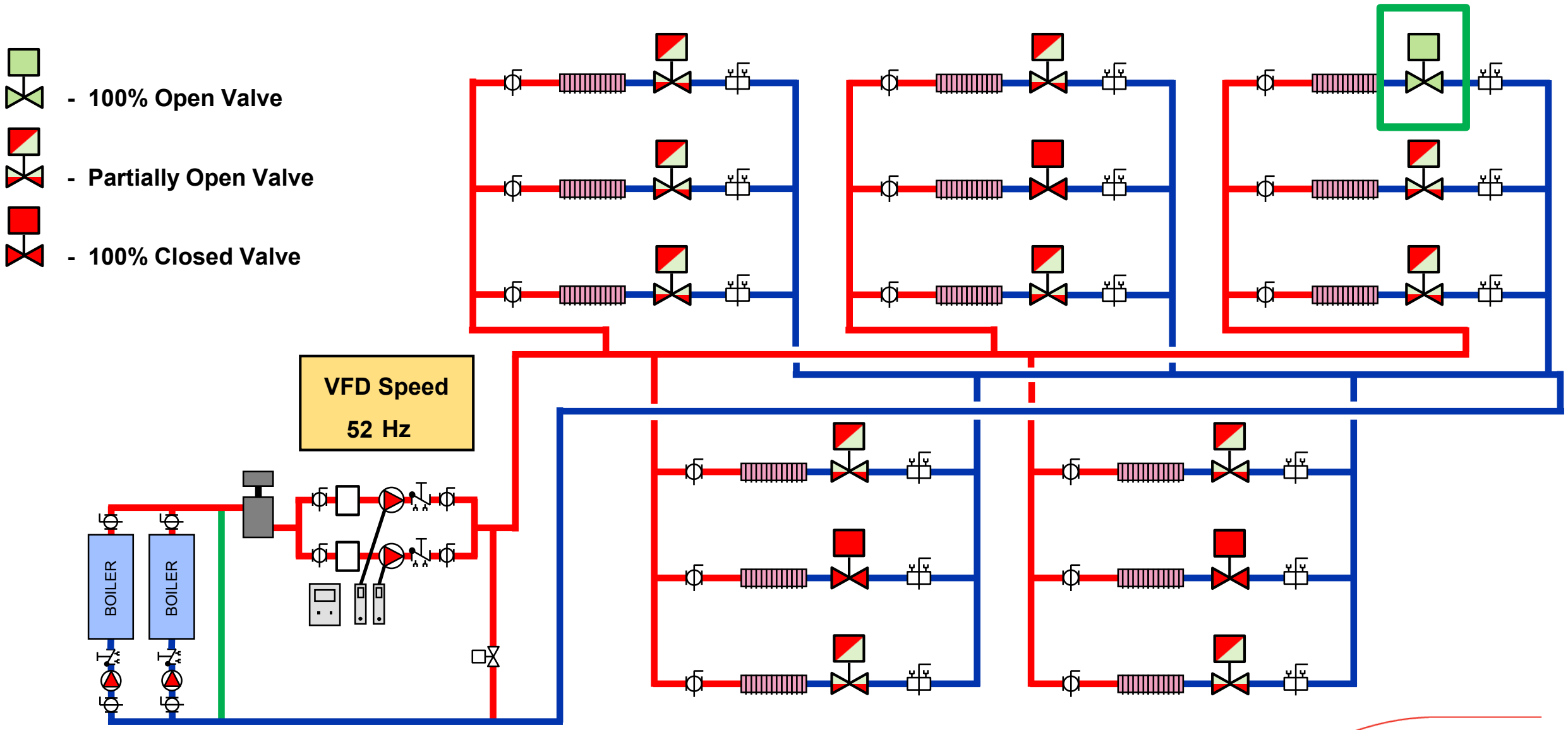

Pumps w/VFD

Cooling Towers

Feedback Sensors

Building Management System

Chillers

Actuators

Indoor/Outdoor Temperature, Air Relative Humidity

Boilers

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Let's Solve Water

Parallel Pumping with Variable Speed Drives

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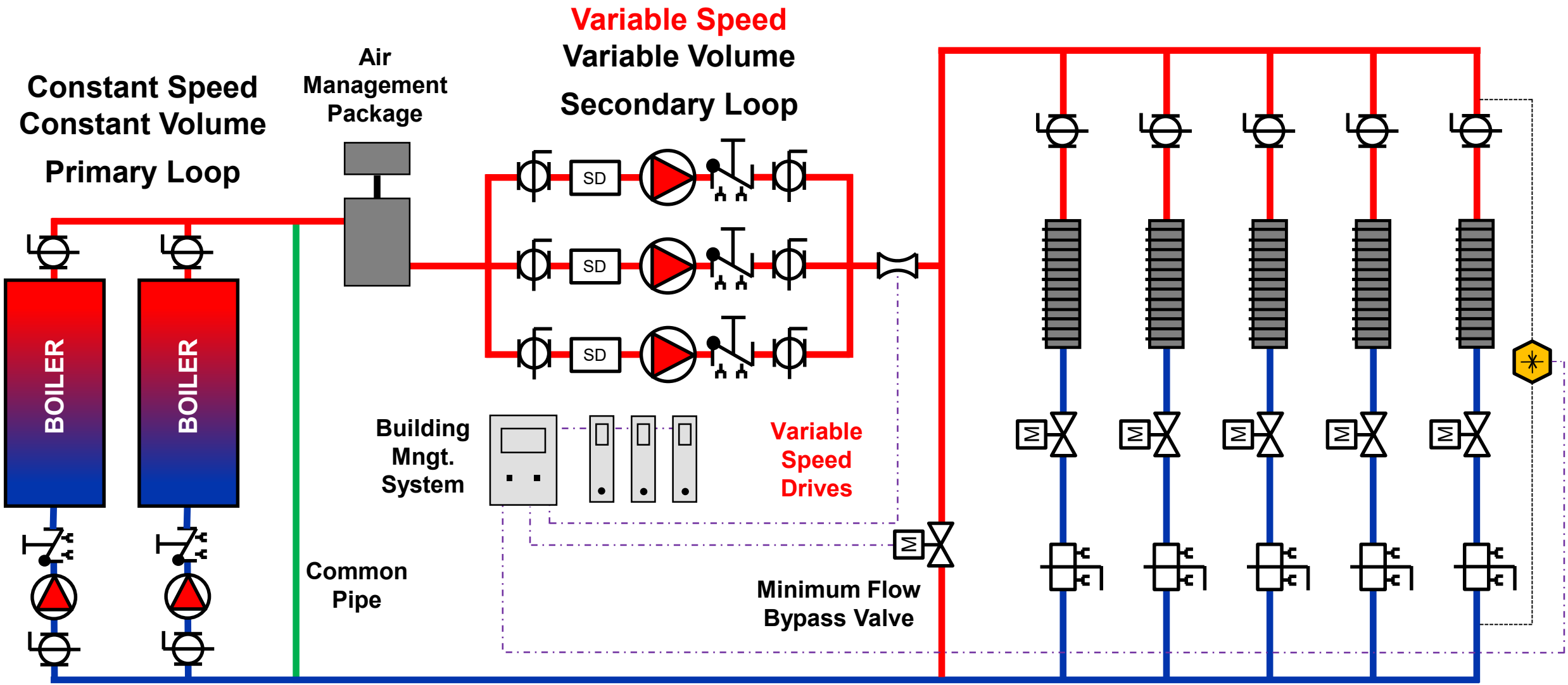

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Pump > e-1510 5BD

Back to Selection

e-1510 5BD

Duty Point Flow: 3000 US gpm: 3 pumps = 1000 US gpm ea
Duty Point Head: 50 ft
Discharge Size (in): 5
Discharge Velocity (fps): 48.0
Suction Size (in): 6
Suction Velocity (fps): 33.3
Weight: 692 lb

Motor: 20 hp
End Of Curve: 80%
NPSHr (ft): 12.1
Floor Space (ft²): 7.1

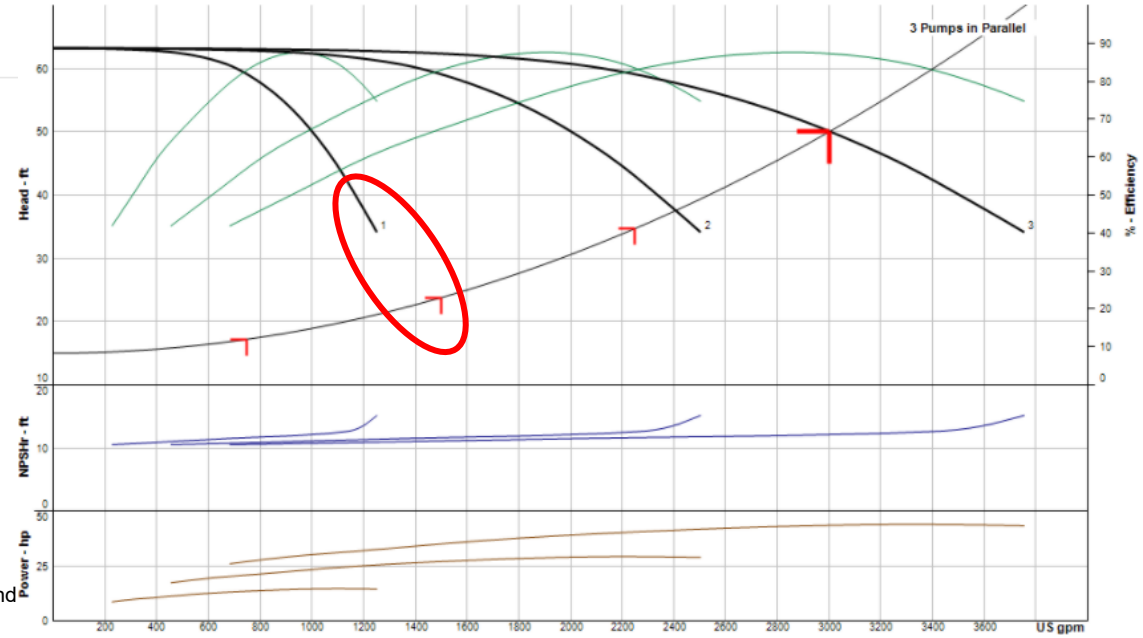
NOL (BHP) at 1770: 19.4
NOL Flow at 1770: 1199 US gpm
Runout Flow at 1770: 1375 US gpm
Shutoff Head at 1770: 76.3 ft

Operating Point

Flow: 1001 US gpm **Head:** 50.1 ft **Speed:** 1611 **Efficiency:** 86.6% **Point BHP:** 14.5

Maximum Duty Point (at rated motor speed)

Flow: 1123 US gpm **Head:** 59.1 ft **Speed:** 1770 **Efficiency:** 86.9% **Point BHP:** 19.3



Add to Schedule Documents

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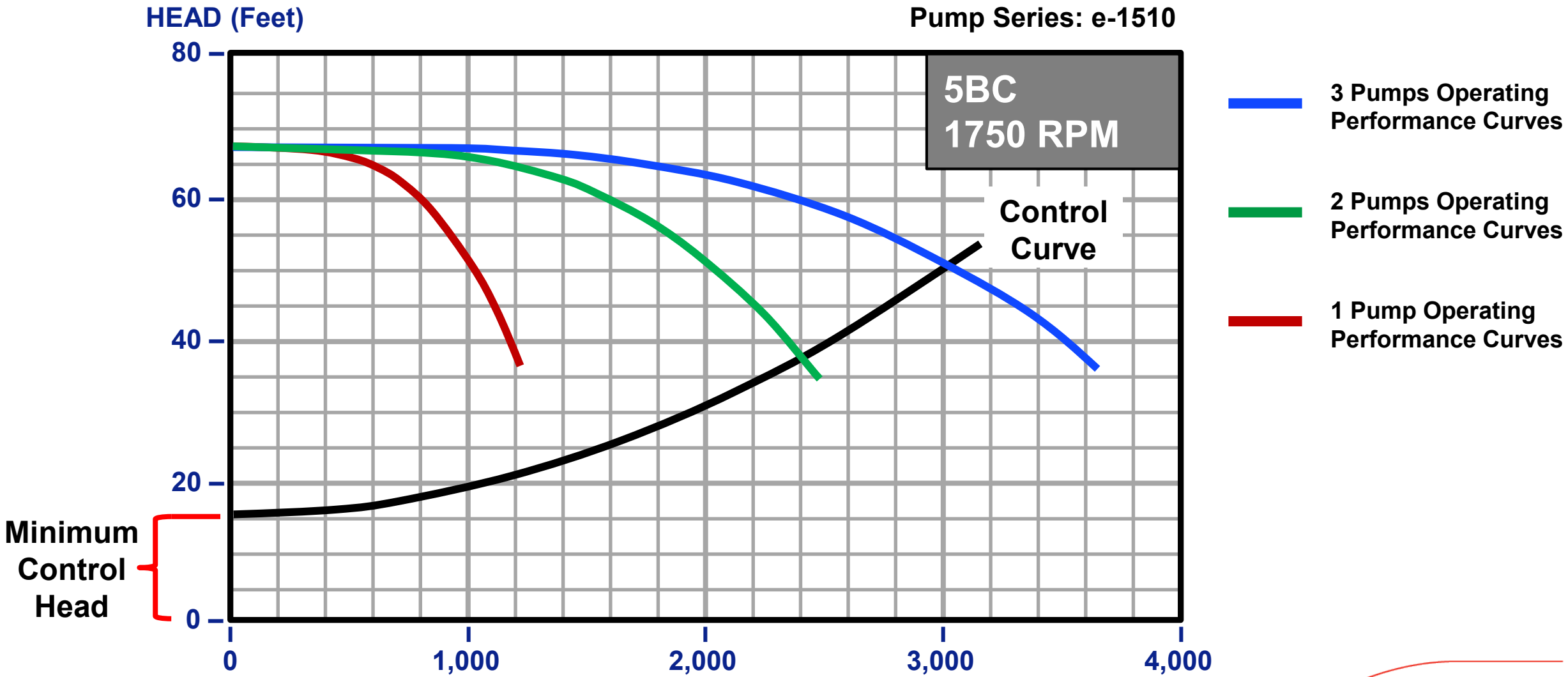
Can a single pump be used?



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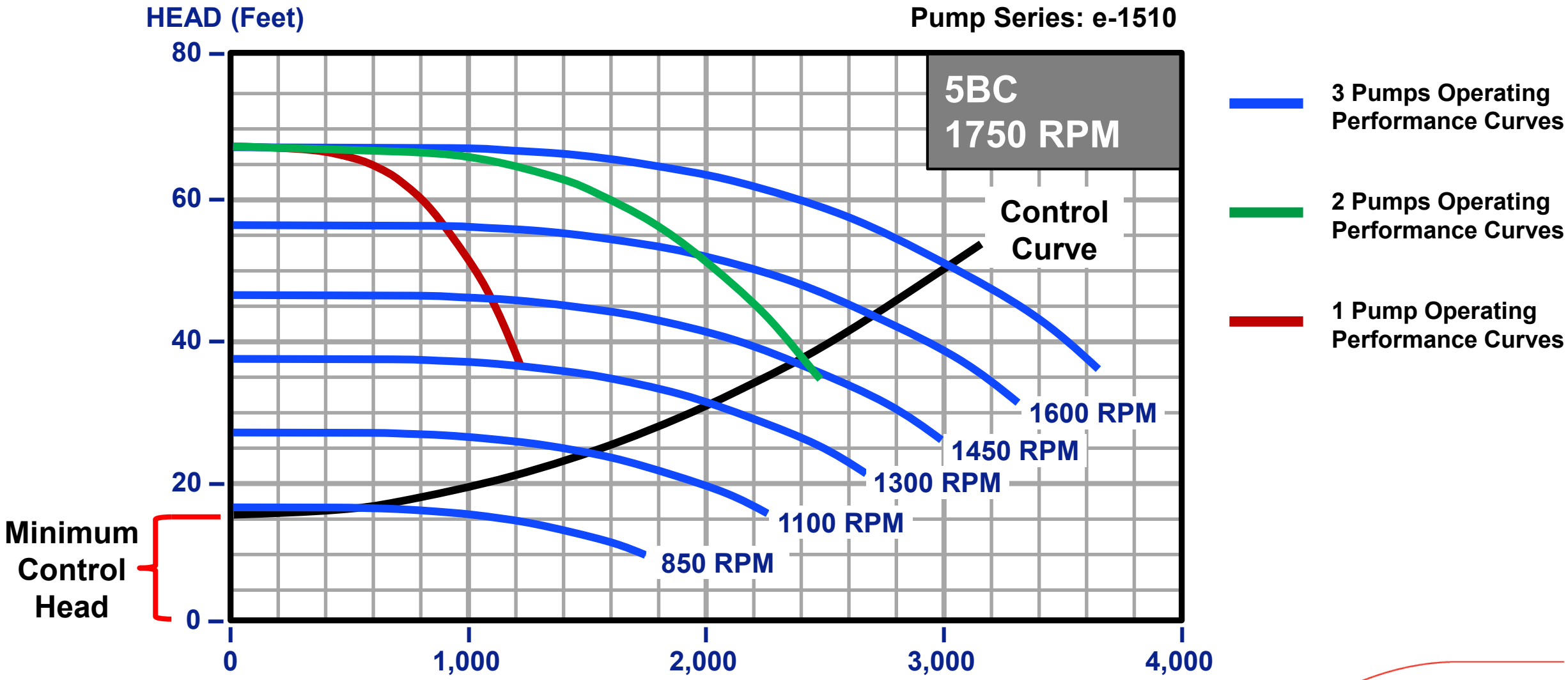

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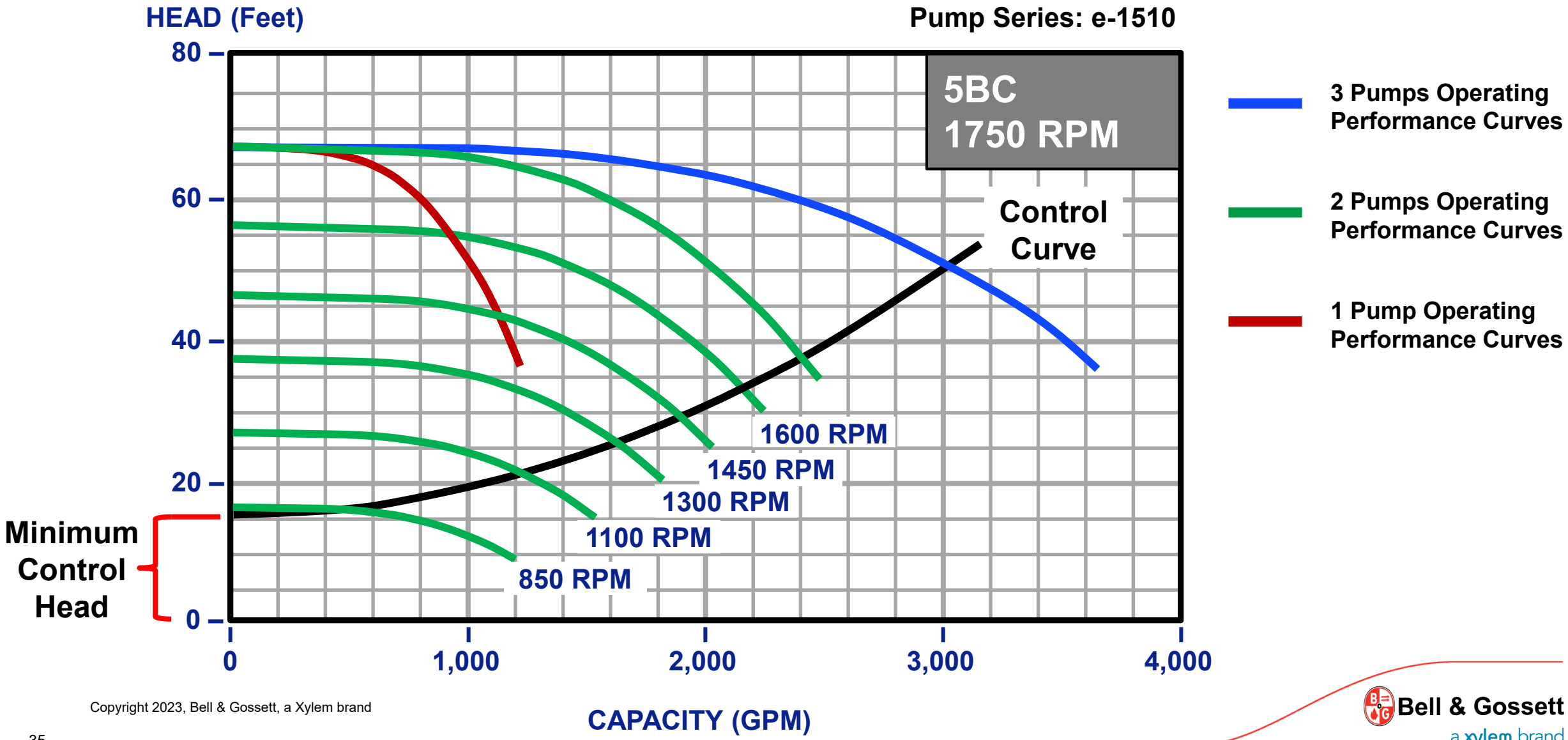

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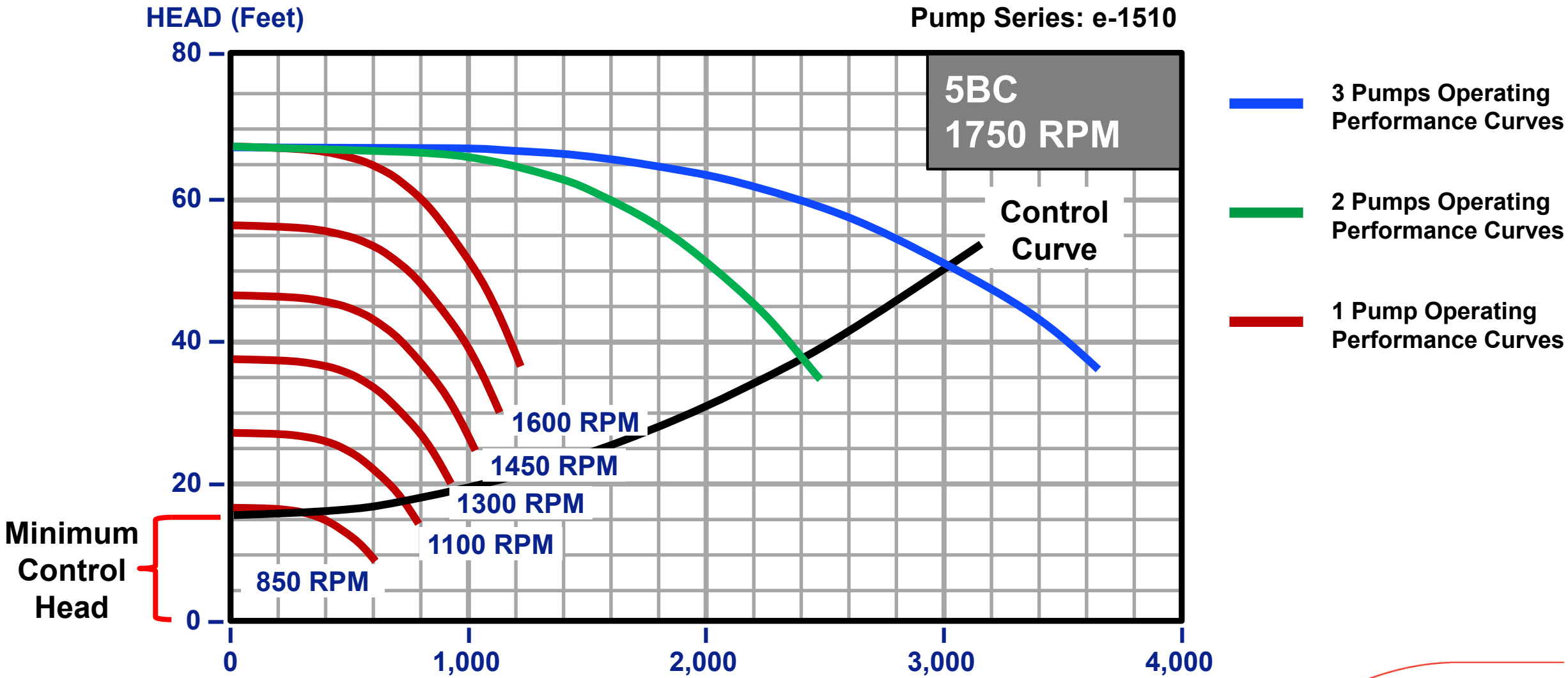

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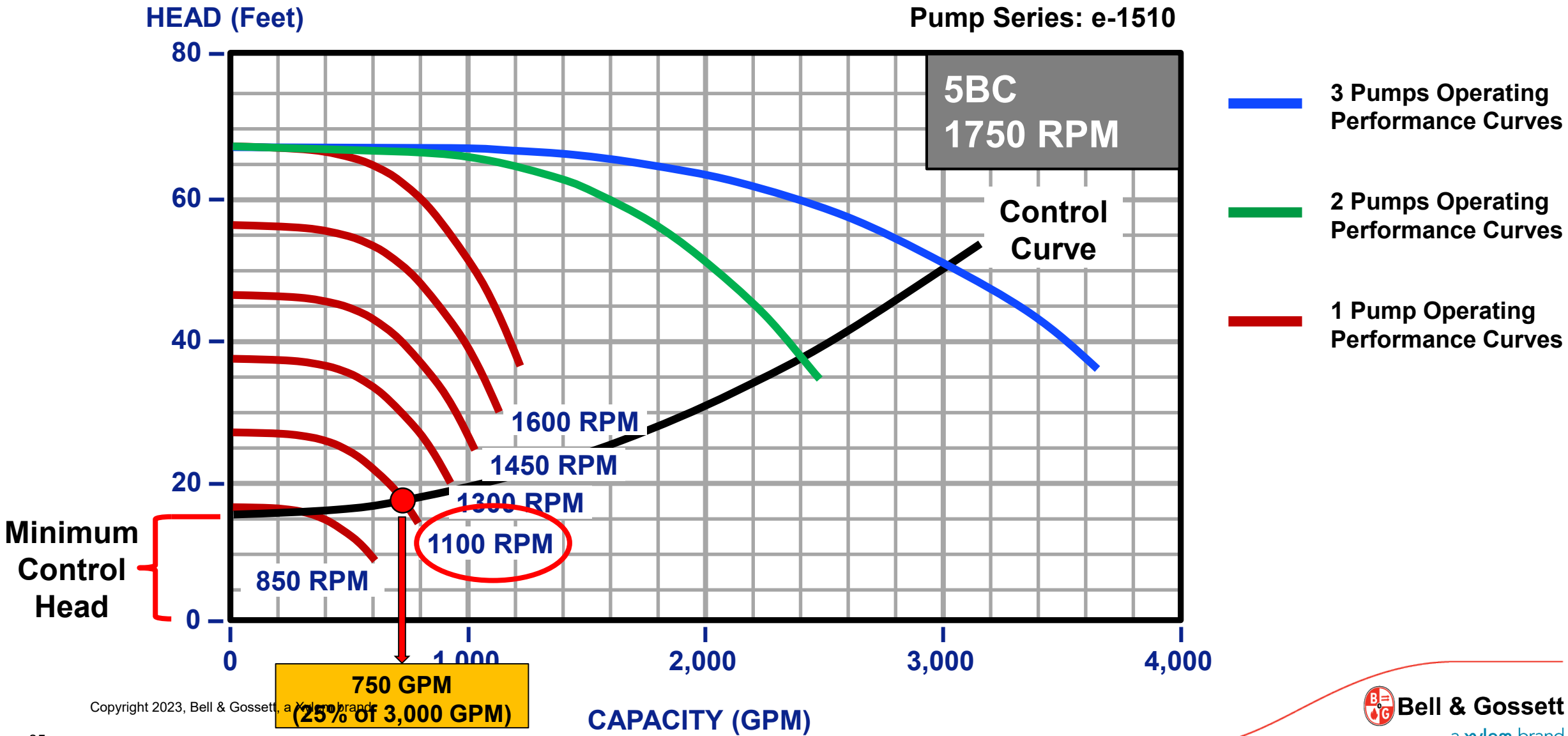

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Performance | Overview | Operating Cost | **Best Efficiency Staging** | Dimensions

Single pump variable staging possible?			Yes		
System curve crosses full speed curve			No	Yes	Yes
Load	Weighting	Best eff	1 Pump	2 Pumps	3 Pumps
100%	1%	86.6%			86.6
75%	42%	87.3%		79.8%	87.3%
50%	45%	85.3%		85.3%	84.1%
25%	12%	79.5%	66.5%	79.5%	65.4%
Optimal Staging PLEV		85.5%			

Courtesy of B&G ESP-Systemwize Selection Software

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Let's Solve Water

The Closing Tip

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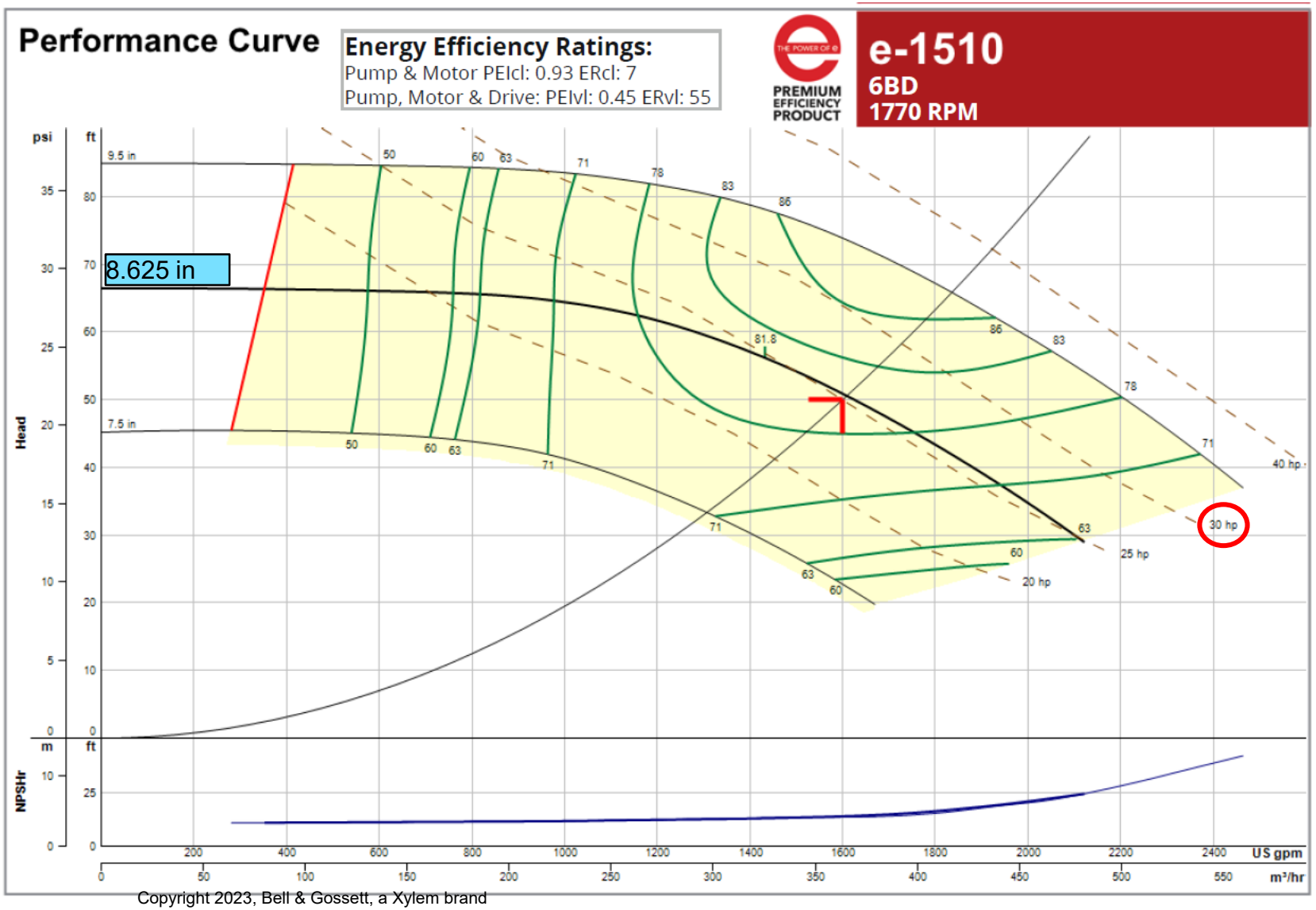
Trimmed to Duty Point



Pump Selection Summary	
Duty Point Flow	1600 US gpm
Duty Point Head	50 ft
Control Head	0 ft
Duty Point Pump Efficiency	79.7 %
Part Load Efficiency Value (PLEV)	0.0 %
Impeller Diameter	8.625 in
Motor Power	30 hp
Duty Point Power	25.3 bhp
Motor Speed	1800 rpm
RPM @ Duty Point	1770 rpm
NPSHr	14.3 ft
Minimum Shutoff Head	66.4 ft
Minimum Flow at RPM	329 US gpm
Flow @ BEP	1432 US gpm
Fluid Temperature	68 °F
Fluid Type	Water
Weight *(approx. - consult rep for exact)*	928 lbs
Pump Floor Space Calculation	8.74 ft²

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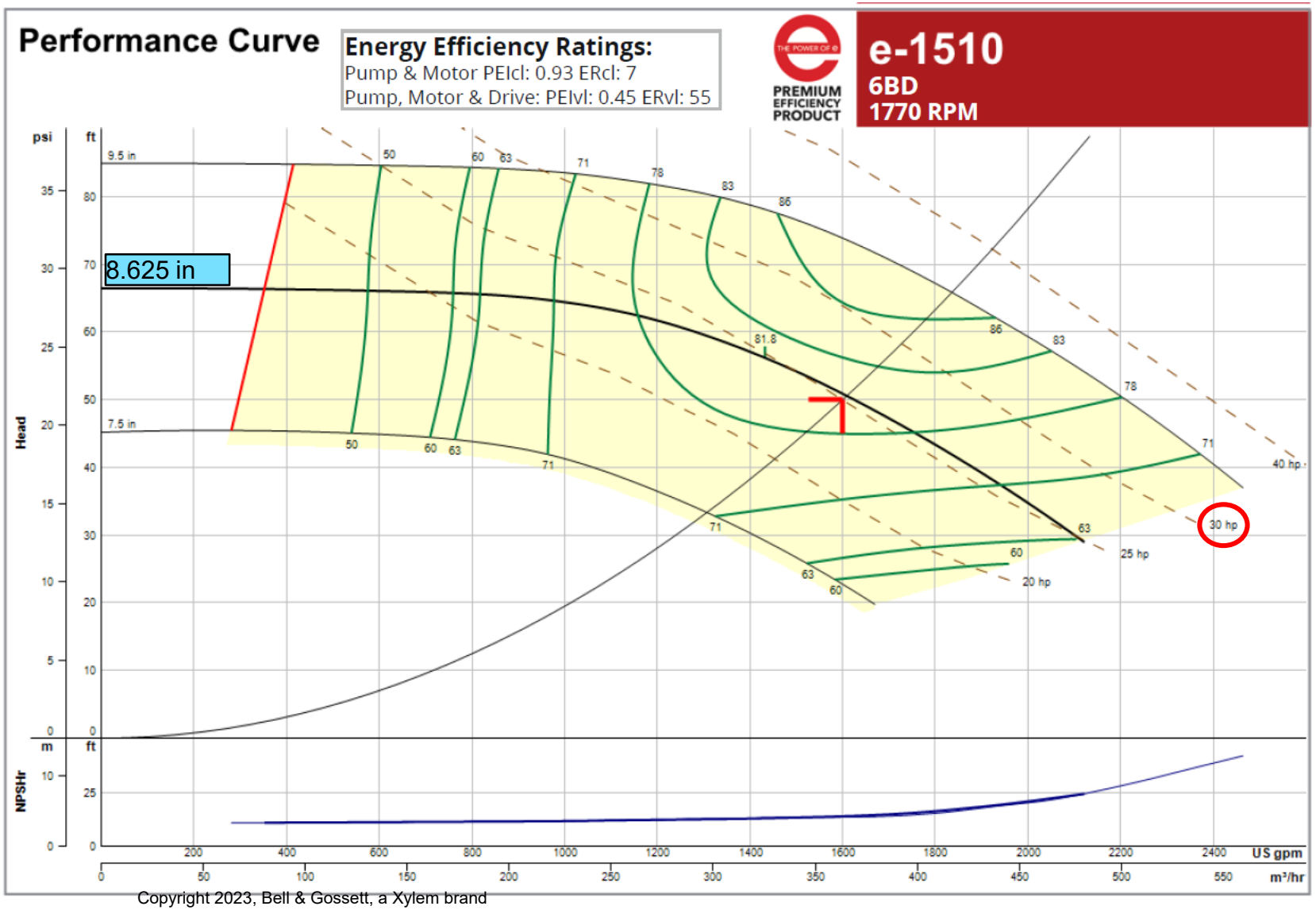
Trimmed to Duty Point



Pump Selection Summary	
Duty Point Flow	1600 US gpm
Duty Point Head	50 ft
Control Head	0 ft
Duty Point Pump Efficiency	79.7 %
Part Load Efficiency Value (PLEV)	0.0 %
Impeller Diameter	8.625 in
Motor Power	30 hp
Duty Point Power	25.3 bhp
Motor Speed	1800 rpm
RPM @ Duty Point	1770 rpm
NPSHr	14.3 ft
Minimum Shutoff Head	66.4 ft
Minimum Flow at RPM	329 US gpm
Flow @ BEP	1432 US gpm
Fluid Temperature	68 °F
Fluid Type	Water
Weight *(approx. - consult rep for exact)*	928 lbs
Pump Floor Space Calculation	8.74 ft²

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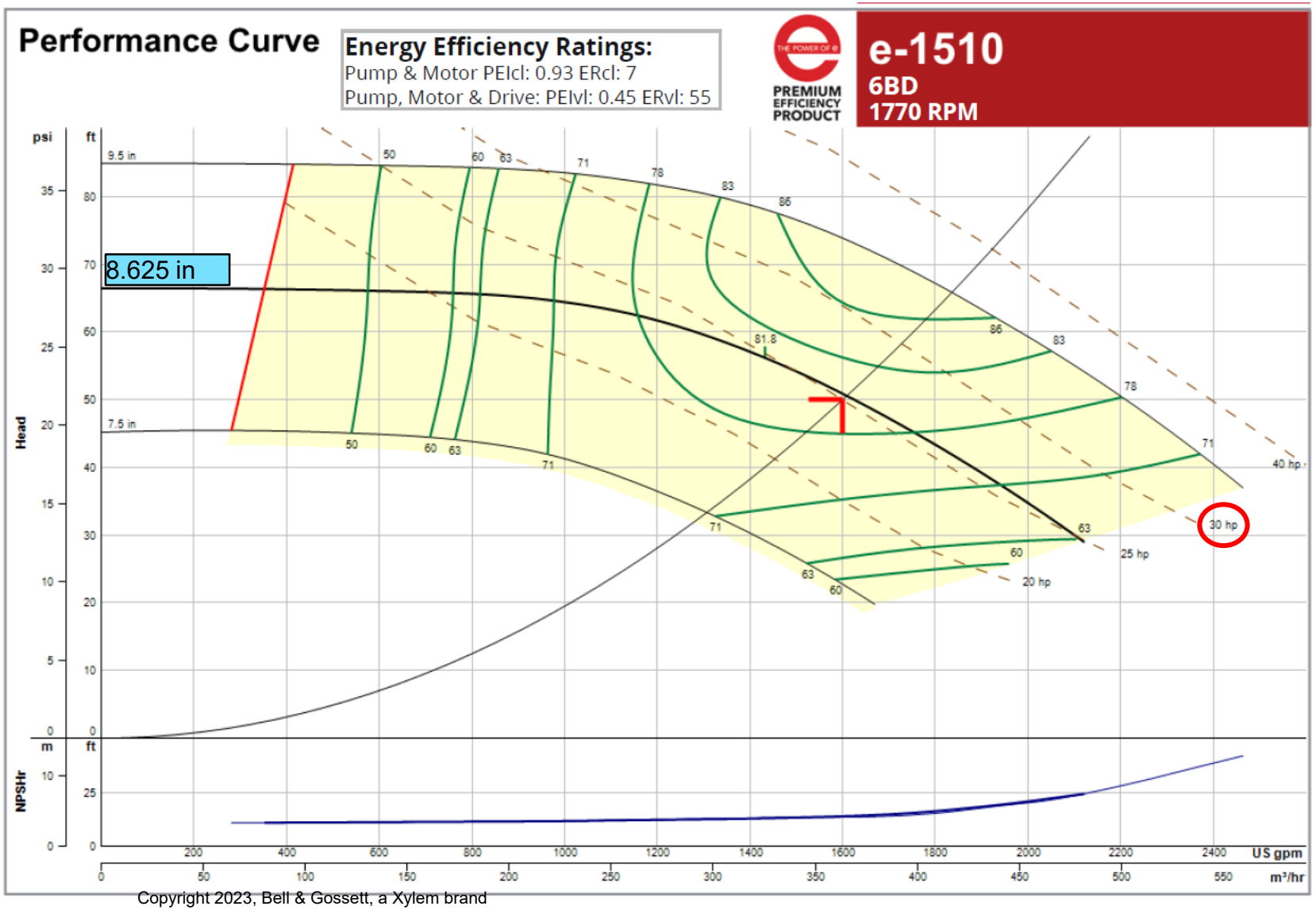
Trimmed to Duty Point



Pump Selection Summary	
Duty Point Flow	1600 US gpm
Duty Point Head	50 ft
Control Head	0 ft
Duty Point Pump Efficiency	79.7 %
Part Load Efficiency Value (PLEV)	0.0 %
Impeller Diameter	8.625 in
Motor Power	30 hp
Duty Point Power	25.3 bhp
Motor Speed	1800 rpm
RPM @ Duty Point	1770 rpm
NPSHr	14.3 ft
Minimum Shutoff Head	66.4 ft
Minimum Flow at RPM	329 US gpm
Flow @ BEP	1432 US gpm
Fluid Temperature	68 °F
Fluid Type	Water
Weight *(approx. - consult rep for exact)*	928 lbs
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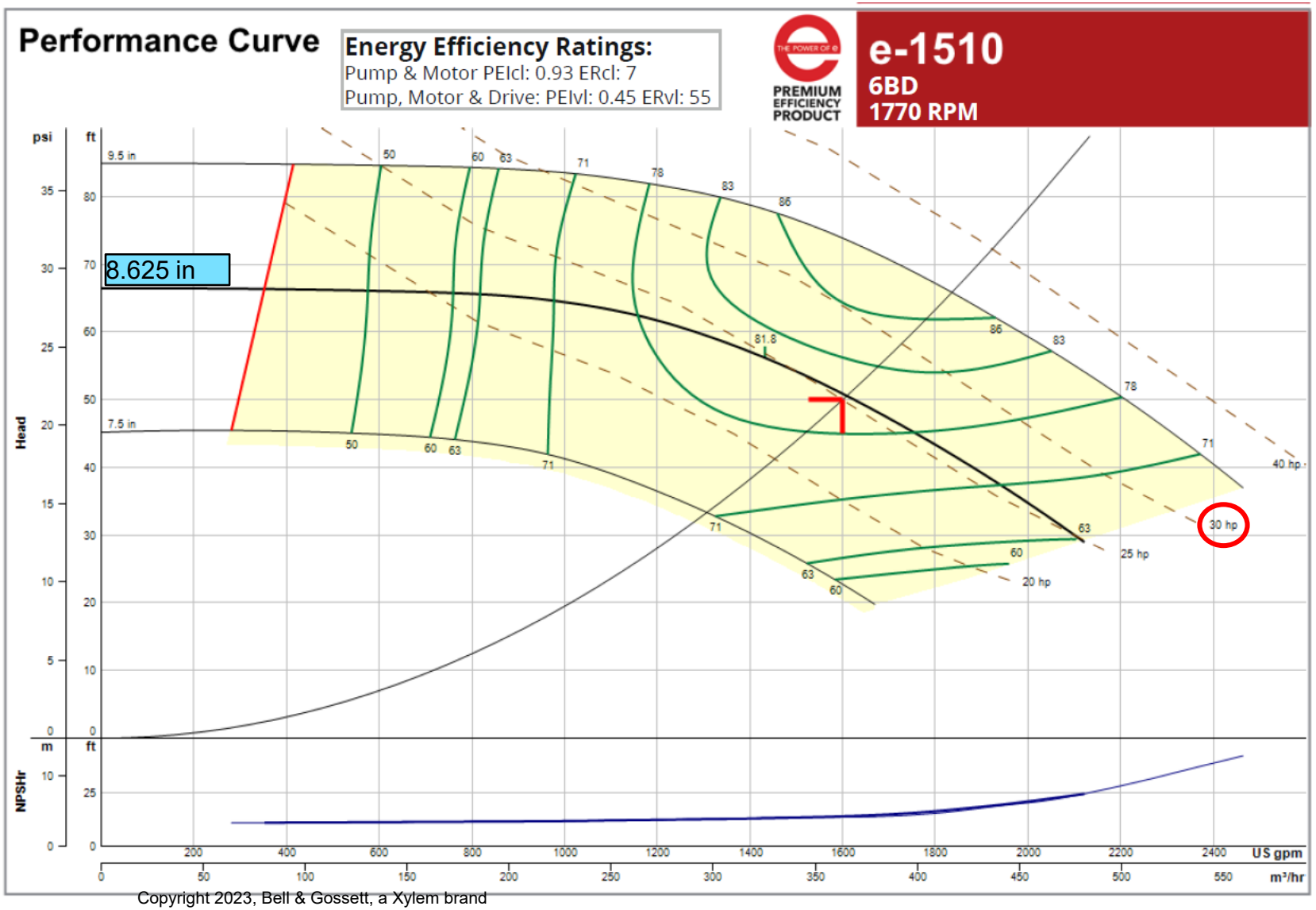
Trimmed to Duty Point



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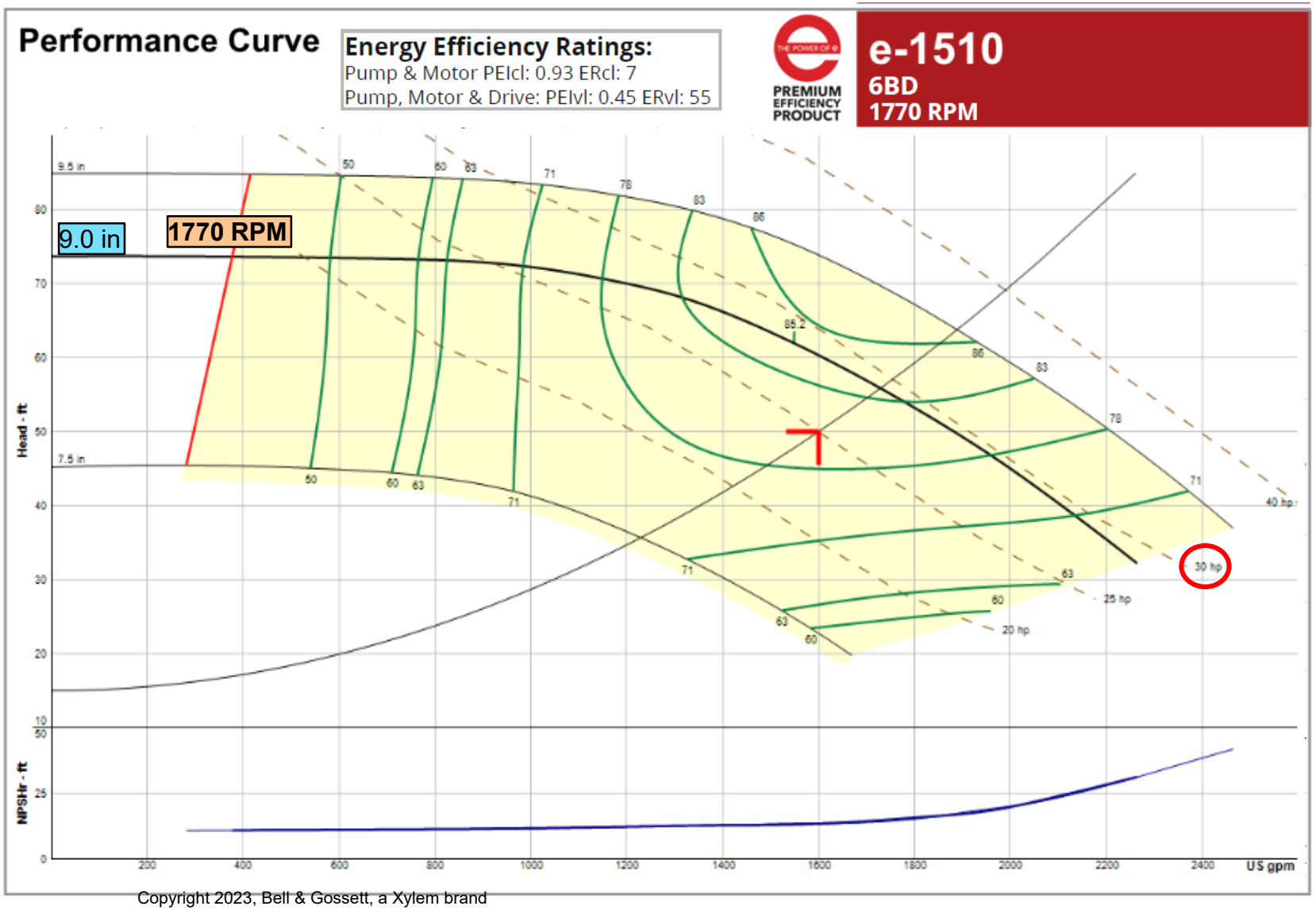
Trimmed to Largest Diameter for Motor Size



Pump Selection Summary	
Duty Point Flow	1600 US gpm
Duty Point Head	50 ft
Control Head	15 ft
Duty Point Pump Efficiency	84 %
Part Load Efficiency Value (PLEV)	80.9 %
Impeller Diameter	9 in
Motor Power	30 hp
Duty Point Power	24 bhp
Motor Speed	1800 rpm
RPM @ Duty Point	1662 rpm
NPSHr	12.8 ft
Minimum Shutoff Head	65 ft
Minimum Flow at RPM	334 US gpm
Flow @ BEP	1454 US gpm
Fluid Temperature	68 °F
Fluid Type	Water
Weight *(approx. - consult rep for exact)*	928 lbs
Pump Floor Space Calculation	8.74 ft²

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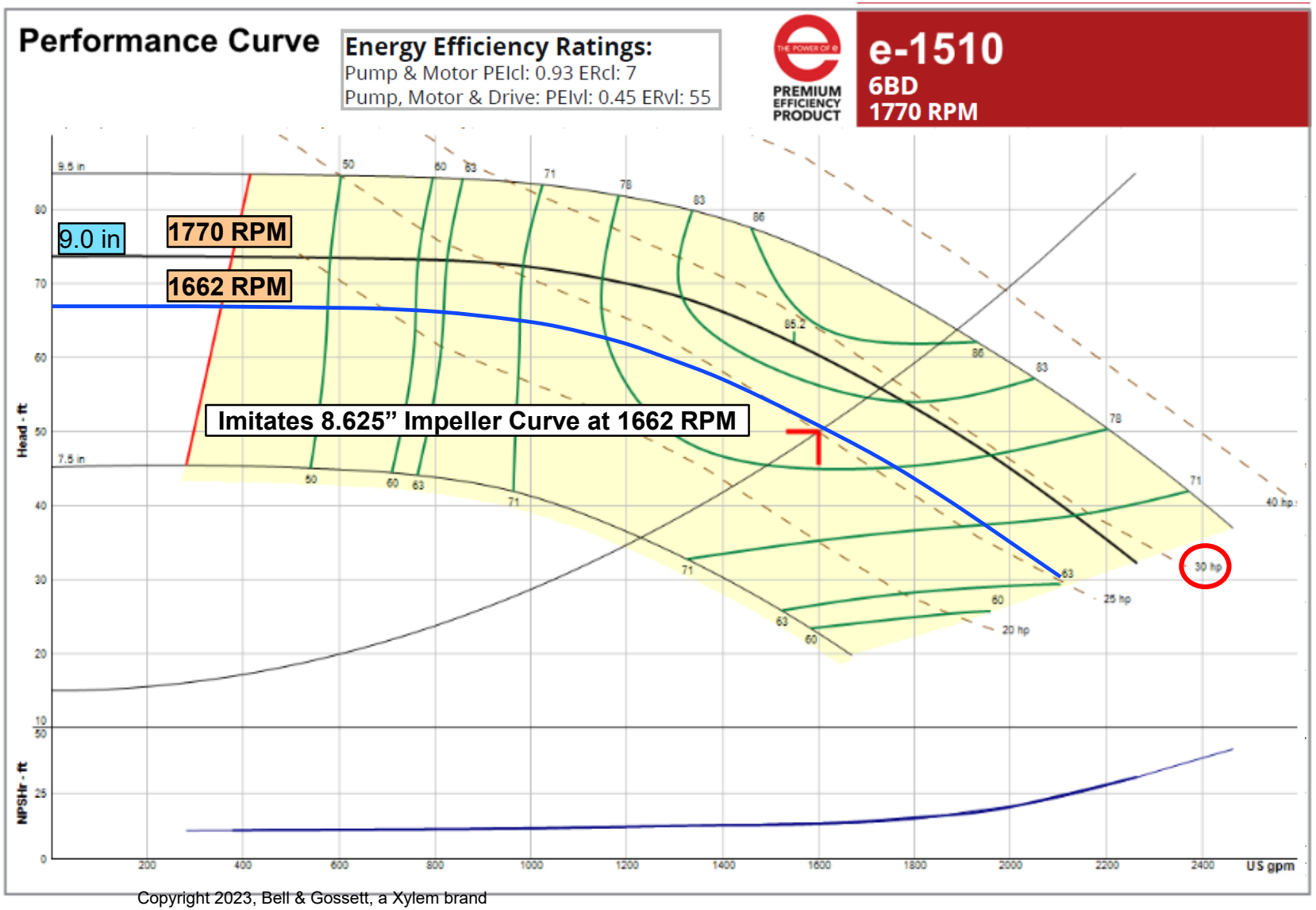
Trimmed to Largest Diameter for Motor Size



Pump Selection Summary

Duty Point Flow	1600 US gpm
Duty Point Head	50 ft
Control Head	15 ft
Duty Point Pump Efficiency	84 %
Part Load Efficiency Value (PLEV)	80.9 %
Impeller Diameter	9 in
Motor Power	30 hp
Duty Point Power	24 bhp
Motor Speed	1800 rpm
RPM @ Duty Point	1662 rpm
NPSHr	12.8 ft
Minimum Shutoff Head	65 ft
Minimum Flow at RPM	334 US gpm
Flow @ BEP	1454 US gpm
Fluid Temperature	68 °F
Fluid Type	Water
Weight *(approx. - consult rep for exact)*	928 lbs
Pump Floor Space Calculation	8.74 ft²

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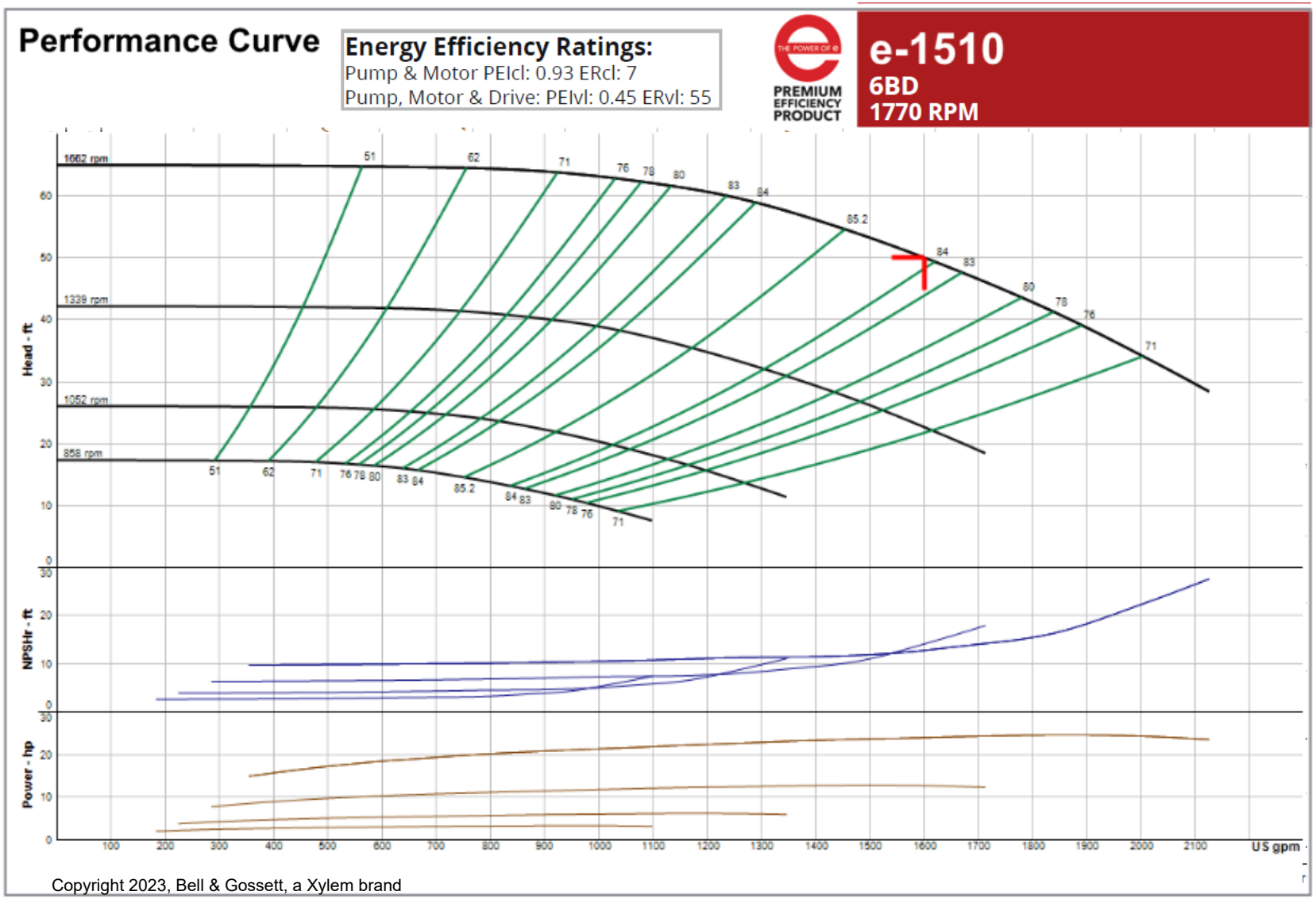
Largest Diameter at Reduced Speed to meet Duty Point



Efficiency Gain:

84% - 79.7% = 4.3%

BHP Reduction:

25.3 – 24.0 = 1.3 BHP

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