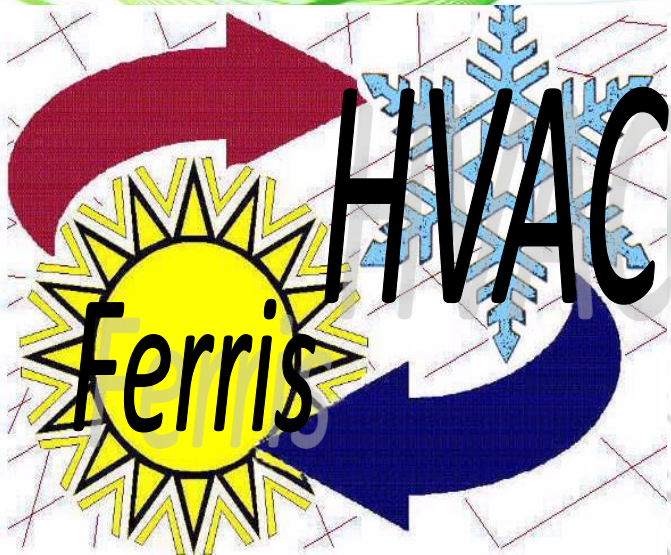# ASHRAE
# DL Presentation

## Hydronic Systems:
## Doing More with Less

**Douglas F Zentz**

**Associate Professor**

**HVAC Program**

**Ferris State University**

# Reminders

- **Cell phones – please silence**

- **Commercialism – ASHRAE observance!**

- **Please fill out the surveys**

- **My views and not ASHRAE's**

# Learning Objectives

- For water based systems to illustrate how water flow and water delta are directly related to overall heat transfer

- To illustrate that lower overall water flow results in a potential combination of smaller water pipes and/or smaller friction rates for the piping system

- To illustrate how higher water delta can help the operation of hydronic control valves and the control valve selection

- To illustrate how low flow/high delta water systems can help reduce first costs of a given project

- To illustrate how heat exchangers in general can easily work with high delta designs if the delta is properly adjusted to existing systems

# Introduction

- Water use for Energy Transfer is very common in Commercial and Industrial Heat Transfer

- Many systems used today are similar to those designed 70-60 years ago

  – Chilled water cooling with a 10 F delta

  – Cooling tower heat rejection with a 10 F delta

  – Hot water heating with a 20 F delta

- These were designed using what (?)
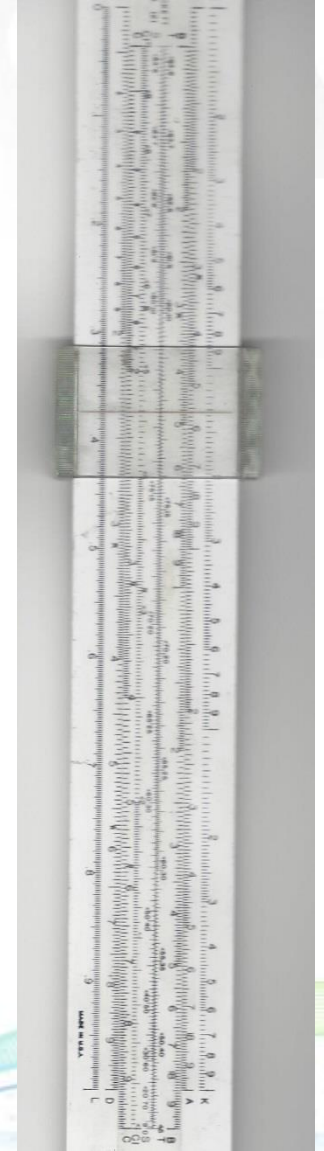
# Review of Heat Transfer

**Understanding the elements that drive energy flow**

– Variables involved

- **Fluid Flow** (gpm)

- **Temperature Delta** (difference between entering and leaving)

– Equation for Energy Flow in Heat Transfer for Water

- **Q = 500 x GPM x (Temperature 2 – Temperature 1)**

# Understanding History

- ## Slide Rule Engineering

  - ### 10 F delta water systems

    - Q = 500 x GPM x 10   or   GPM = Q/5000

    - For Chilled Water = 2.4 GPM/Ton

    - For Cooling Towers = 3 GPM/Ton (approximately)

    - For Heating Water = 1 GPM/10,000 Btuh or 1 GPM/10 MBH (for 20 F delta systems)

- ## Delta and Flow are directly linked

# Looking at Heat Exchangers

- ## Fluids within Heat Exchangers are Dynamic

  - LMTD is used

  - Changing the entering and leaving the same results in the same heat transfer

    - **10 F going to 20 F**

    - **Change both entering and leaving temperatures 5 F**

  - Thus – same heat transfer with less flow
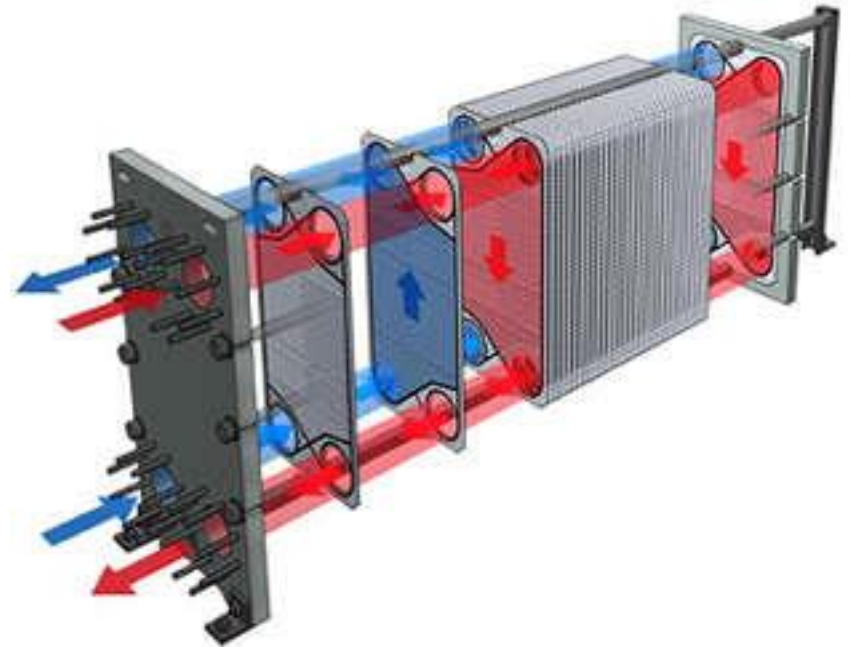
# Water Flow vs Heat Flow

- Water Systems with smaller design deltas require large reductions in fluid flow to reduce Heat Flow

    - 90% reduced fluid flow to get 50% reduced heat flow
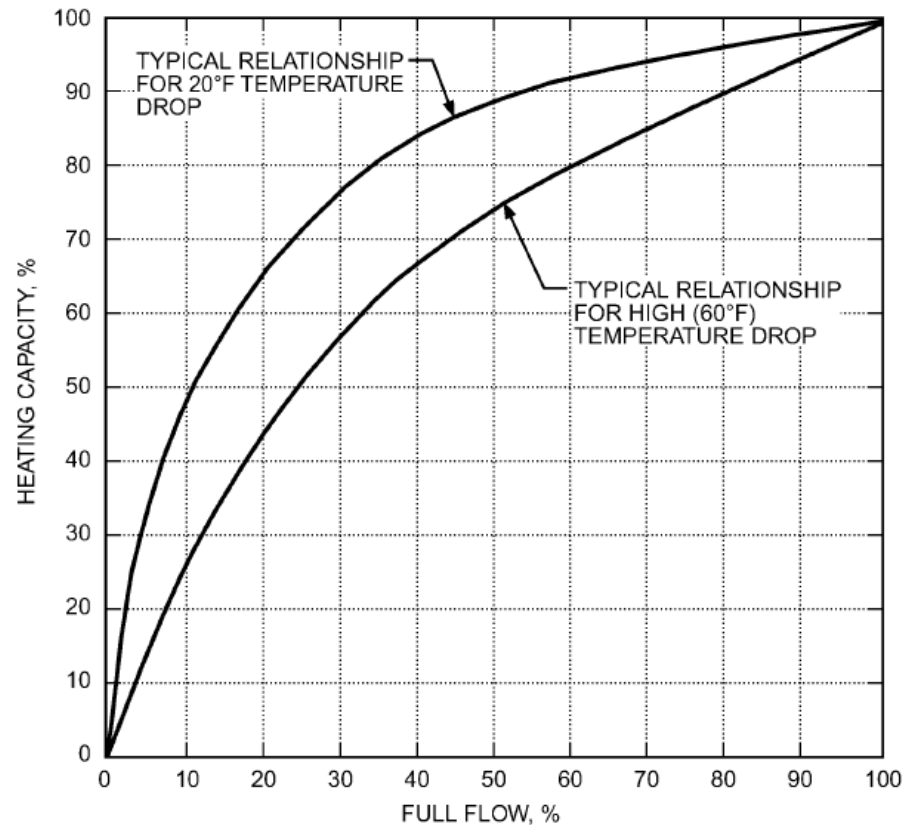


Fig. 32   **Heat Emission Versus Flow Characteristic of Typical Hot Water Heating Coil**

# Control Valves

- Open-Close (quick opening)

- 3-Way Mixing & 3-Way Diverting (linear)

- 2-way Flow Control (equal percentage)
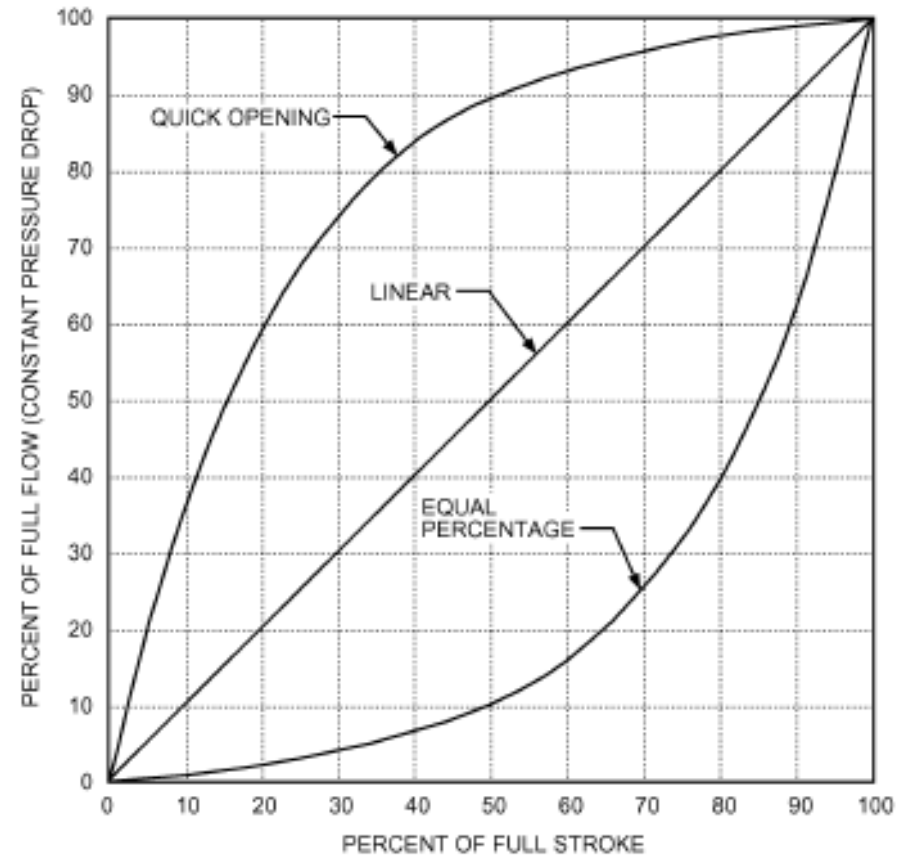


**Fig. 10    Typical Flow Characteristics of Valves**

# Control Valve Purpose

**TYPICAL CONTROL VALVE Cᵥ RATINGS**

| | |
|---|---|
| 3/4" | 3 |
| | 5 |
| | 8 |
| 1" | 4 |
| | 6 |
| | 9 |
| 1-1/4" | 7 |
| | 11 |
| | 18 |
| 1-1/2" | 9 |
| | 15 |
| | 21 |
| 2" | 12 |
| | 17 |
| | 26 |
| 2-1/2" | 18 |
| | 29 |
| | 36 |
| 3" | 31 |
| | 40 |
| | 57 |
| 4" | 53 |
| | 68 |
| | 82 |

Pump Curve

Low Load Condition

Design Condition

Control Valve P.D @ Reduced Flow

Control Valve P.D @ Design Flow

Piping P.D @ Design Flow

Piping P.D @ Reduced Flow

Ft. Head

GPM
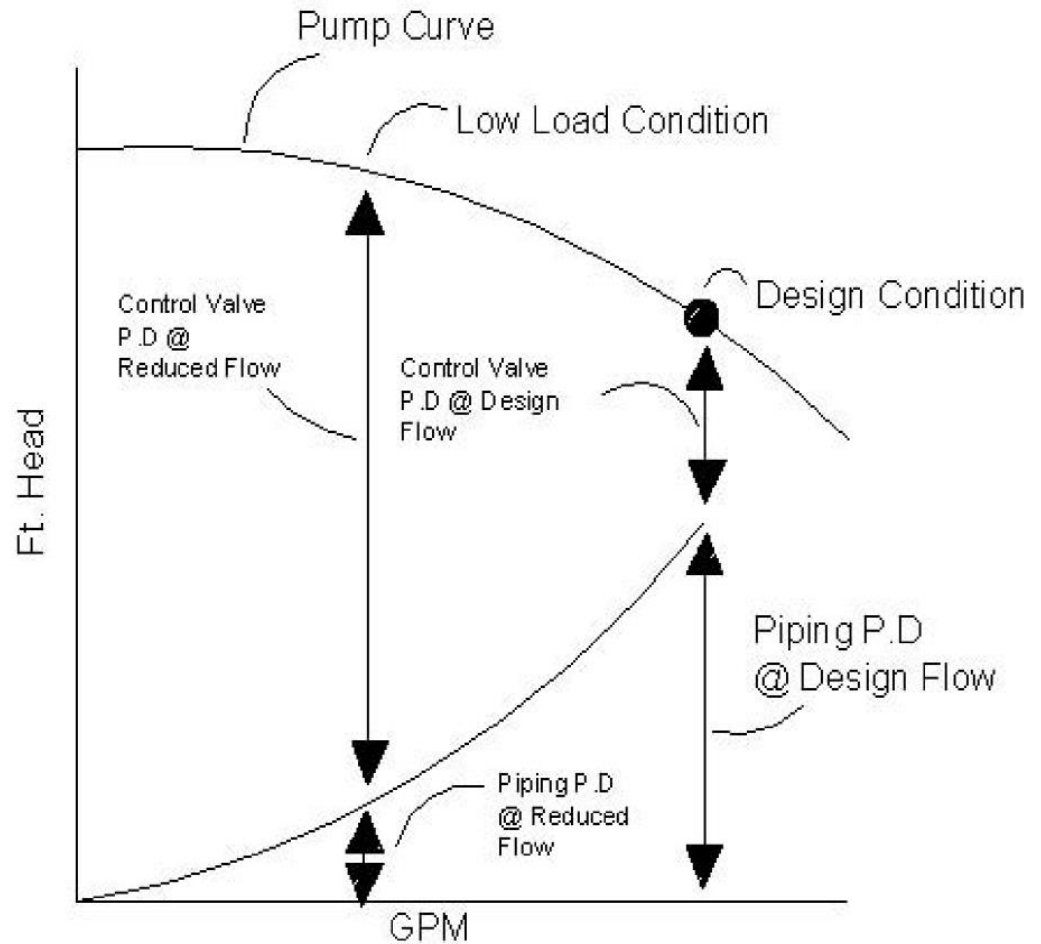
# Delta/Flow to Control

- 10 F delta system creates "X" Flow

- 20 F delta system creates "50% of X" flow

- Leads to reduced pumping requirements

  - BHP = [flow x head x S.G.]/[3960 x pump efficiency]

- Tends to create a bigger control range

# Pump Relationships

- Pump Curve – creates flow against resistance

- System Curve – represents system resistance to flow
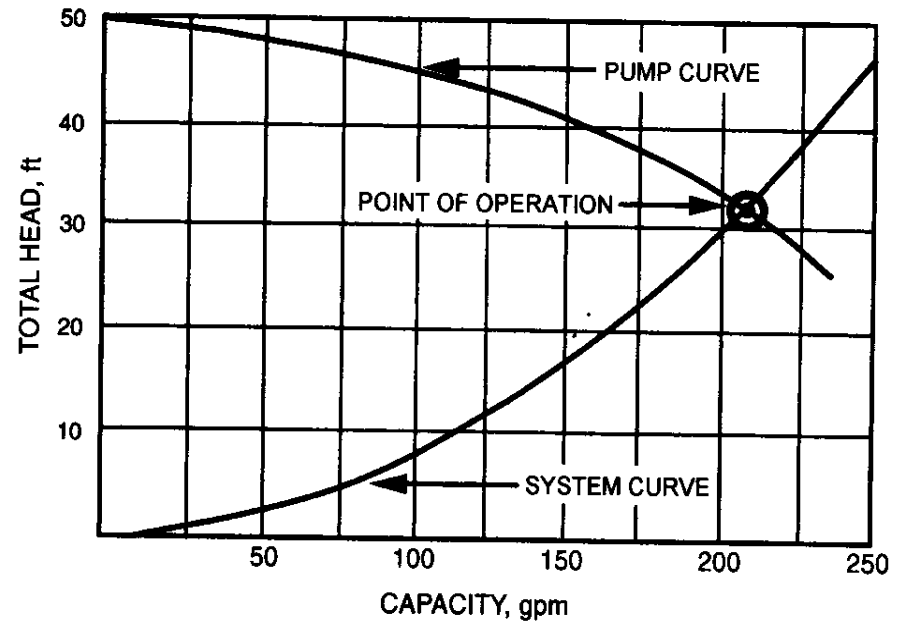
Fig. 17    System and Pump Curves

# Pump Laws

**Table 1   Pump Affinity Laws**

| Function | Speed Change | Impeller Diameter Change |
| --- | --- | --- |
| Flow | $Q_2 = Q_1\left(\dfrac{N_2}{N_1}\right)$ | $Q_2 = Q_1\left(\dfrac{D_2}{D_1}\right)$ |
| Head | $h_2 = h_1\left(\dfrac{N_2}{N_1}\right)^2$ | $h_2 = h_1\left(\dfrac{D_2}{D_1}\right)^2$ |
| Horsepower | $bhp_2 = bhp_1\left(\dfrac{N_2}{N_1}\right)^3$ | $bhp_2 = bhp_1\left(\dfrac{D_2}{D_1}\right)^3$ |

# Typical Pump Curve
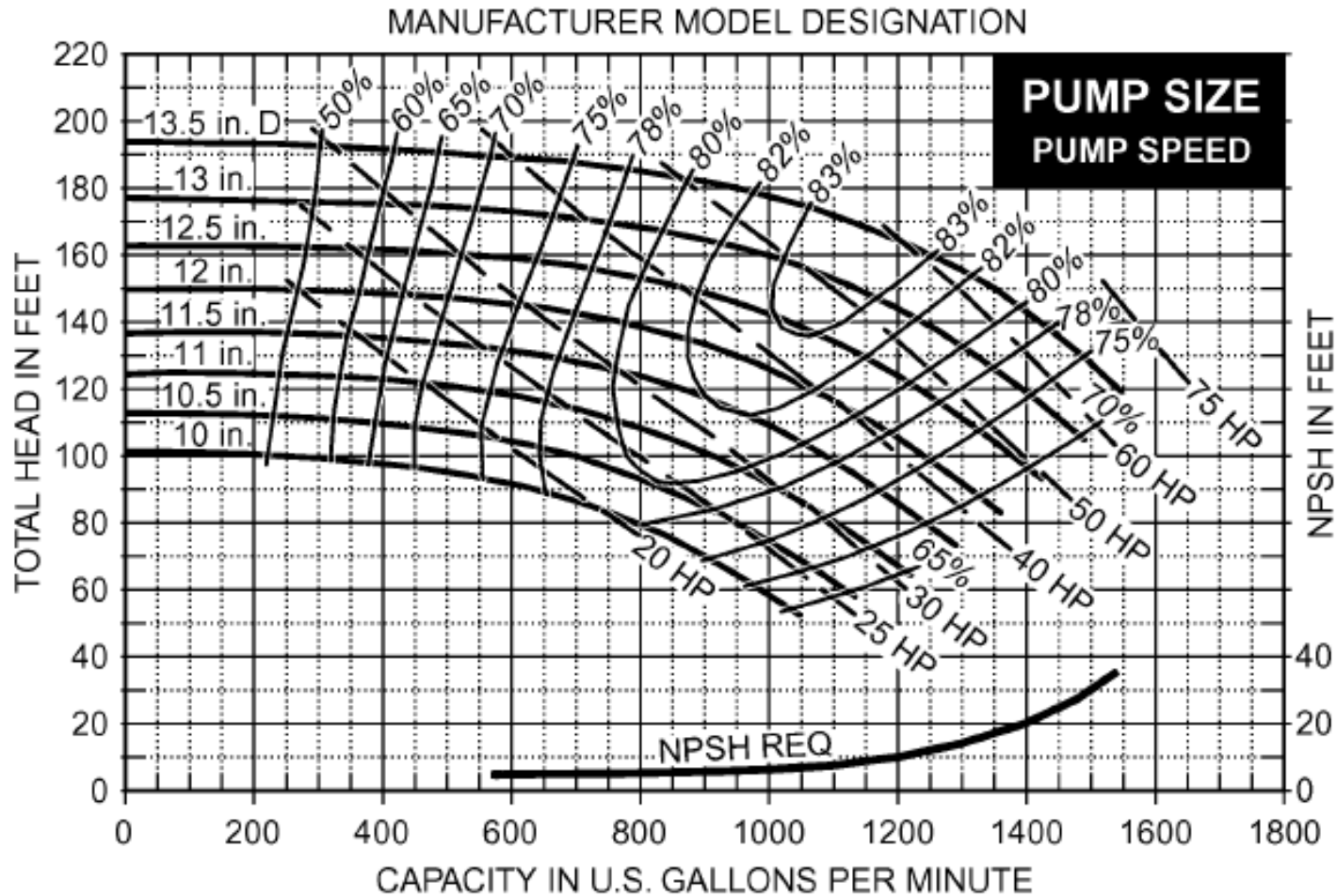


Fig. 4   Example of Manufacturer's Published Pump Curve

# Example Water System

- We will examine a traditional system

- Assume a chilled water system at 10 F delta with three remote coil banks and two primary chillers piped in a primary/secondary system.

- Let's look at the potential with:
  - 20 F delta approach
  - New control valves
  - New pumps

# Traditional Secondary System



Coil #1
50 Tons

120 GPM

Coil PD - 12'

Piping PD - 10'

Control Valve PD - 12'

Coil #1 Total PD - 34'

6"

3"

Valve #1
Cv - 53

Coil #2
75 Tons

180 GPM

Coil PD - 16'

Piping PD - 10'

Control Valve PD - 11'

Coil #2 Total PD - 37'

4"

Valve #2
Cv - 82

Coil #3
100 Tons

240 GPM

Coil PD - 8'

Piping PD - 10'

Control Valve PD - 20'

Coil #3 Total PD - 38'

4"

Valve #3
Cv - 82

45 F Supply

6"

540 GPM

55 F Return
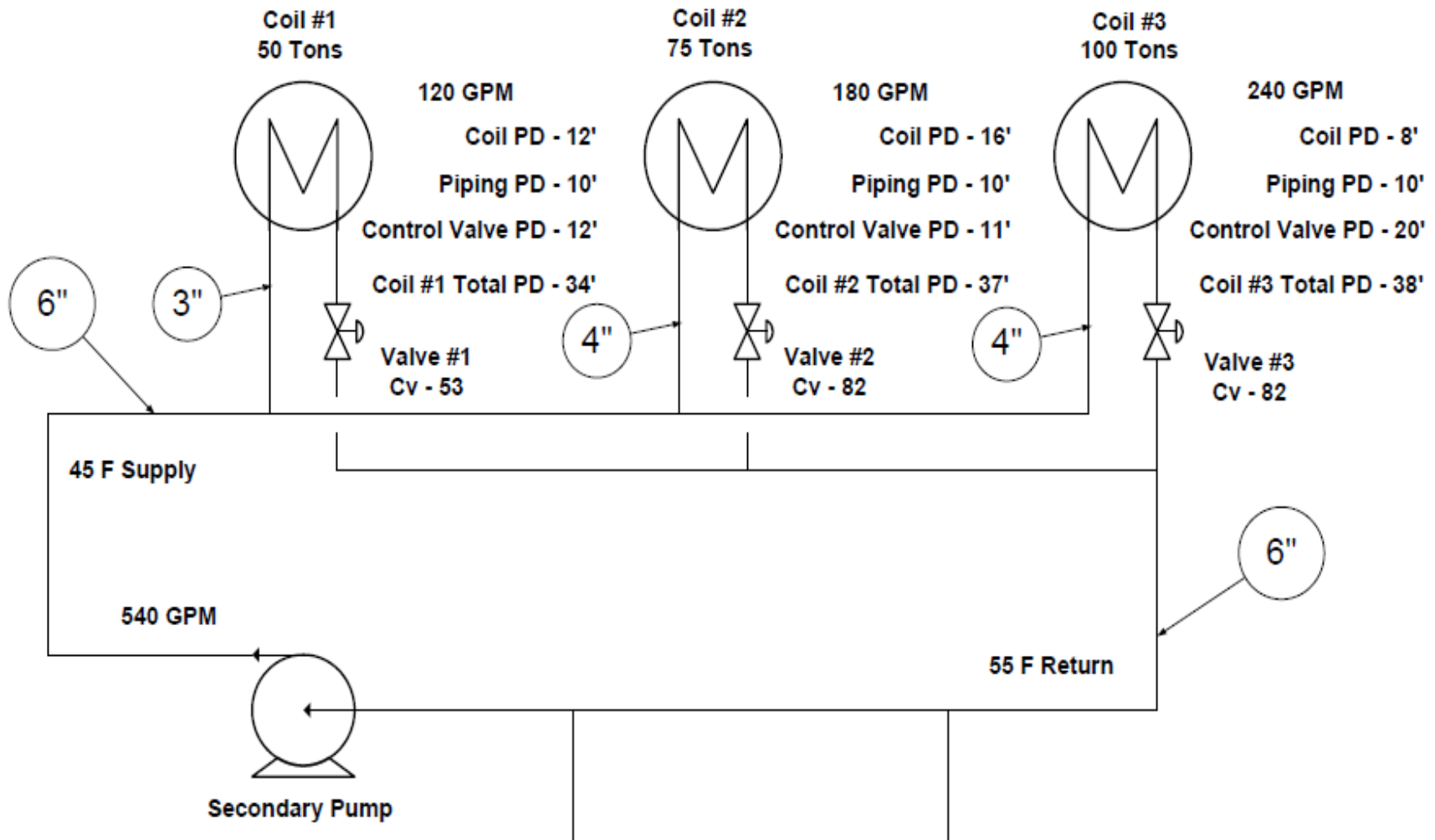
Secondary Pump

# Traditional Secondary Pump

- Need is 540 GPM at 38 ft. (w.c.) total head

- Pump selected – 84% efficient with 6.2 BHP

  – Selected motor is 7 1/2 Hp



Suction Size = 5 "
Discharge Size = 4 "

Min Imp Dia = 5 "
Max Imp Dia = 7 "
Cut Dia = 7 "

Design Capacity =540.0 GPM
Design Head =38.0 Feet
Motor Size =7.5 HP
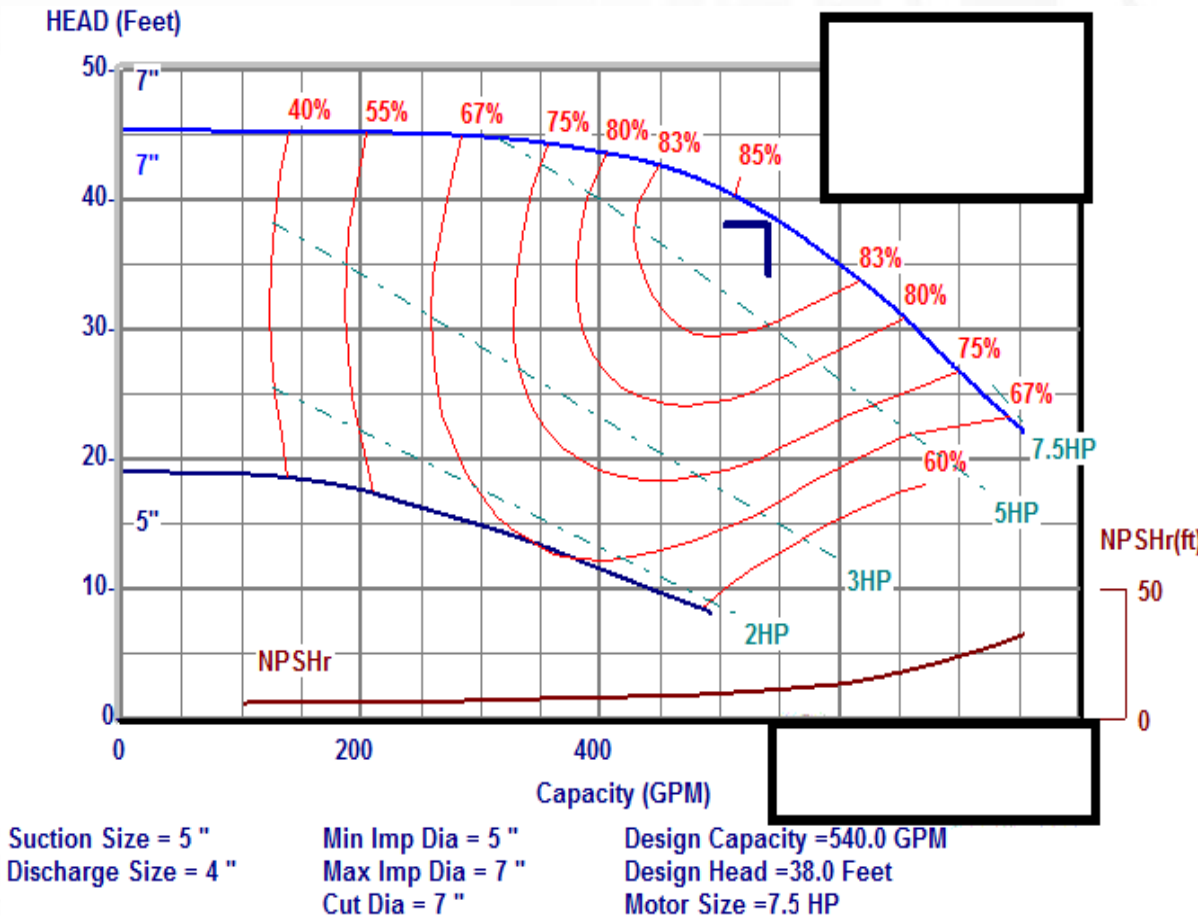
# Traditional Primary System
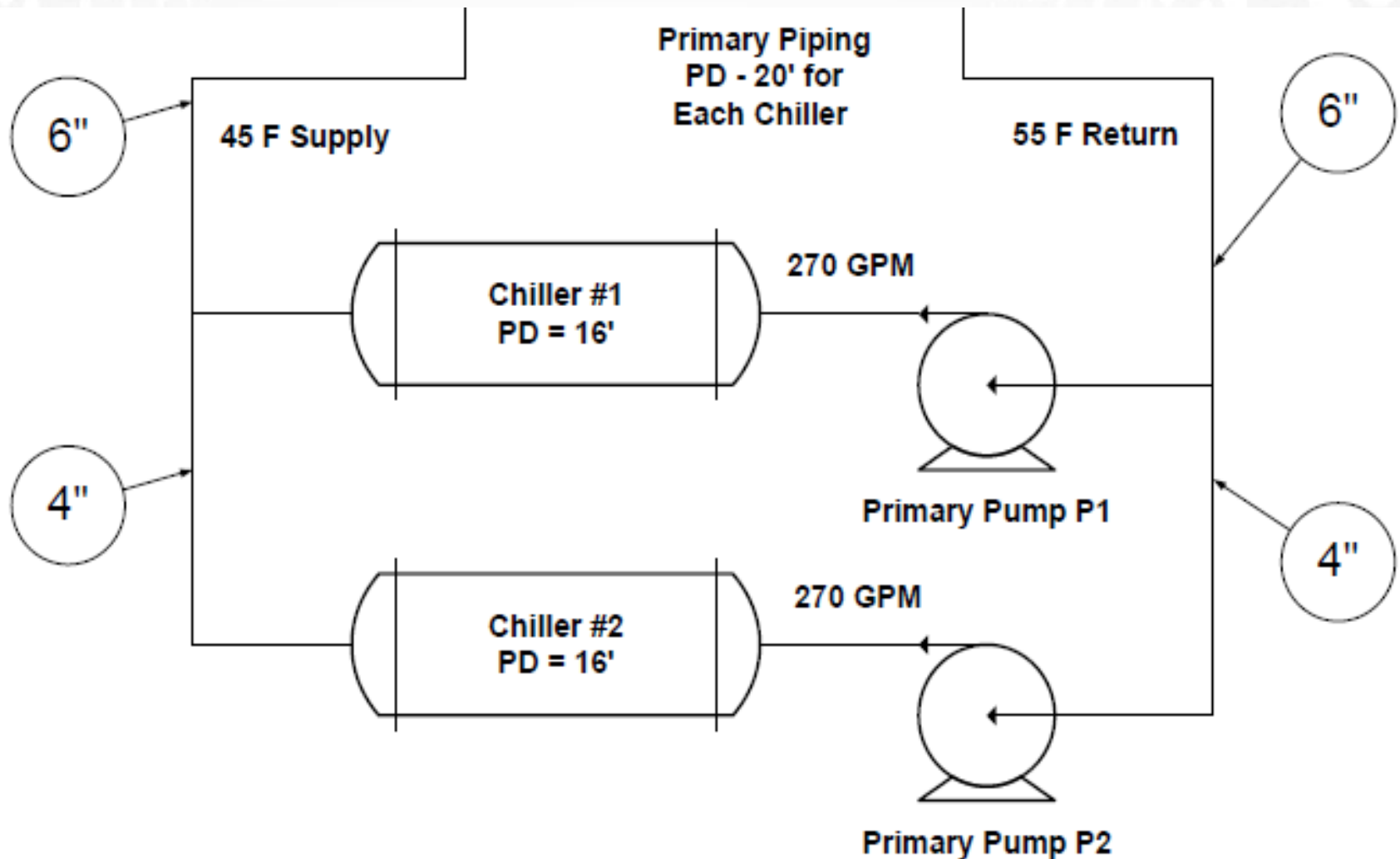
# Traditional Primary Pumps

- Need (for each) is 270 GPM at 36 ft. (w.c.) total head

- Pump selected – 81% efficient with 3.1 BHP

  – Selected motor is 5 Hp



HEAD (Feet)

9.5"
9.375"
55%  67%  74%  78% 81%  83%  84%
83%
81%
78% 74%
67%
5HP
7"
NPSHr(ft)
3HP
2HP
1.5HP
NPSHr
Capacity (GPM)

Suction Size = 4 "          Min Imp Dia = 7 "          Design Capacity =270.0 GPM
Discharge Size = 3 "       Max Imp Dia = 9.5 "       Design Head =36.0 Feet
                              Cut Dia = 9.375 "           Motor Size =5 HP

# Traditional Total Pumping

- Primary pumps – 3.1 BHP (ea.) = 6.2 BHP

- Secondary pump – 6.2 BHP

- Total pump power = 12.4 BHP

# Low Flow/High Delta System

- Chilled water supply will be 40 F and the return water temperature will be 60 F

  - Shifting the delta 5 F at each end

  - Creating a 20 F delta and 50% required flow to the same system

# Low Flow/High Delta Secondary System

**Coil #1**
**50 Tons**

**60 GPM**

**Coil PD – 3'**

**Piping PD – 2.5'**

**Control Valve PD - 12'**

**Coil #1 Total PD – 17.5'**

**Valve #1**
**Cv - 26**

**Coil #2**
**75 Tons**

**90 GPM**

**Coil PD – 4'**

**Piping PD – 2.5'**

**Control Valve PD - 12'**

**Coil #2 Total PD – 18.5'**

**Valve #2**
**Cv - 40**

**Coil #3**
**100 Tons**

**120 GPM**

**Coil PD – 2'**

**Piping PD – 2.5'**

**Control Valve PD – 12'**

**Coil #3 Total PD – 16.5'**

**Valve #3**
**Cv - 53**

**40 F Supply**

**270 GPM**

**60 F Return**

**Secondary Pump**

# Low Flow/High Delta Secondary Pump

- Need is 270 GPM at 18.5 ft. (w.c.) total head

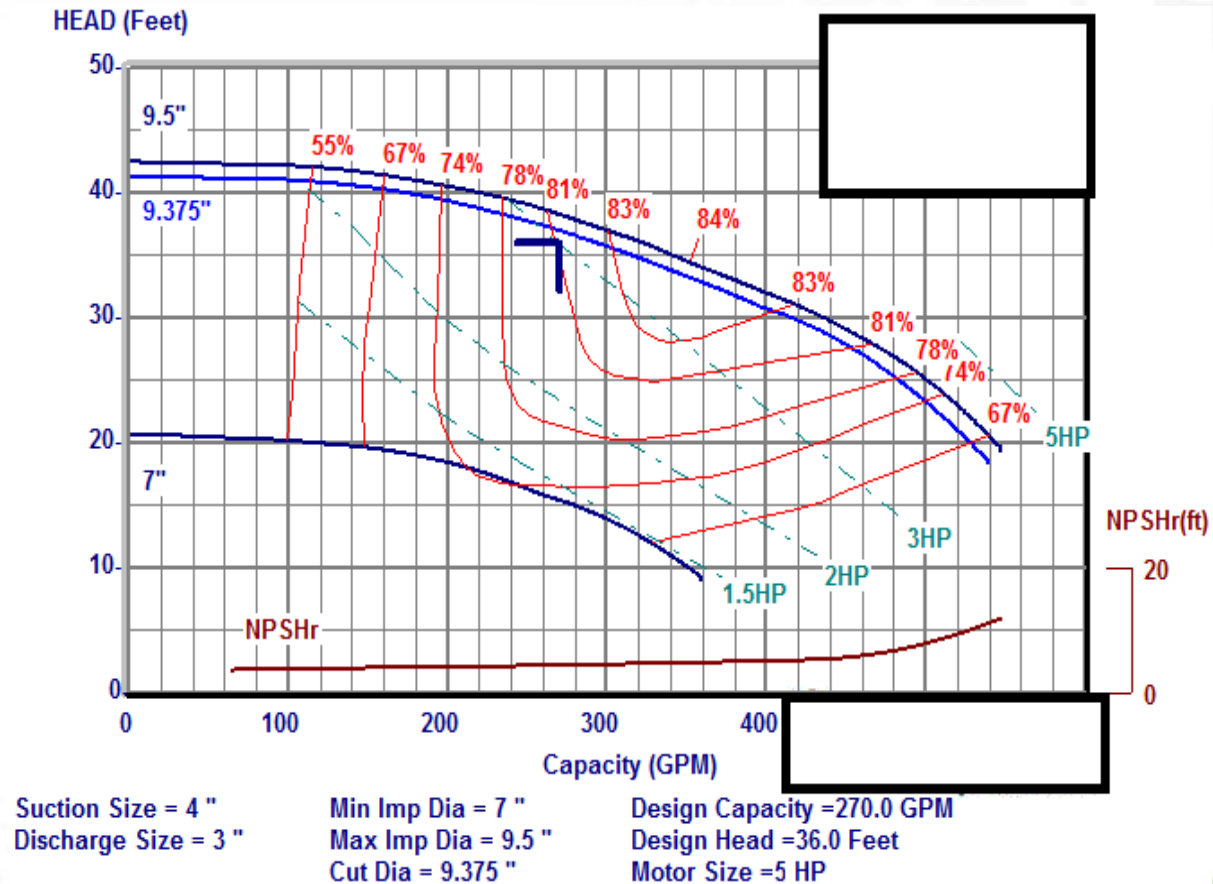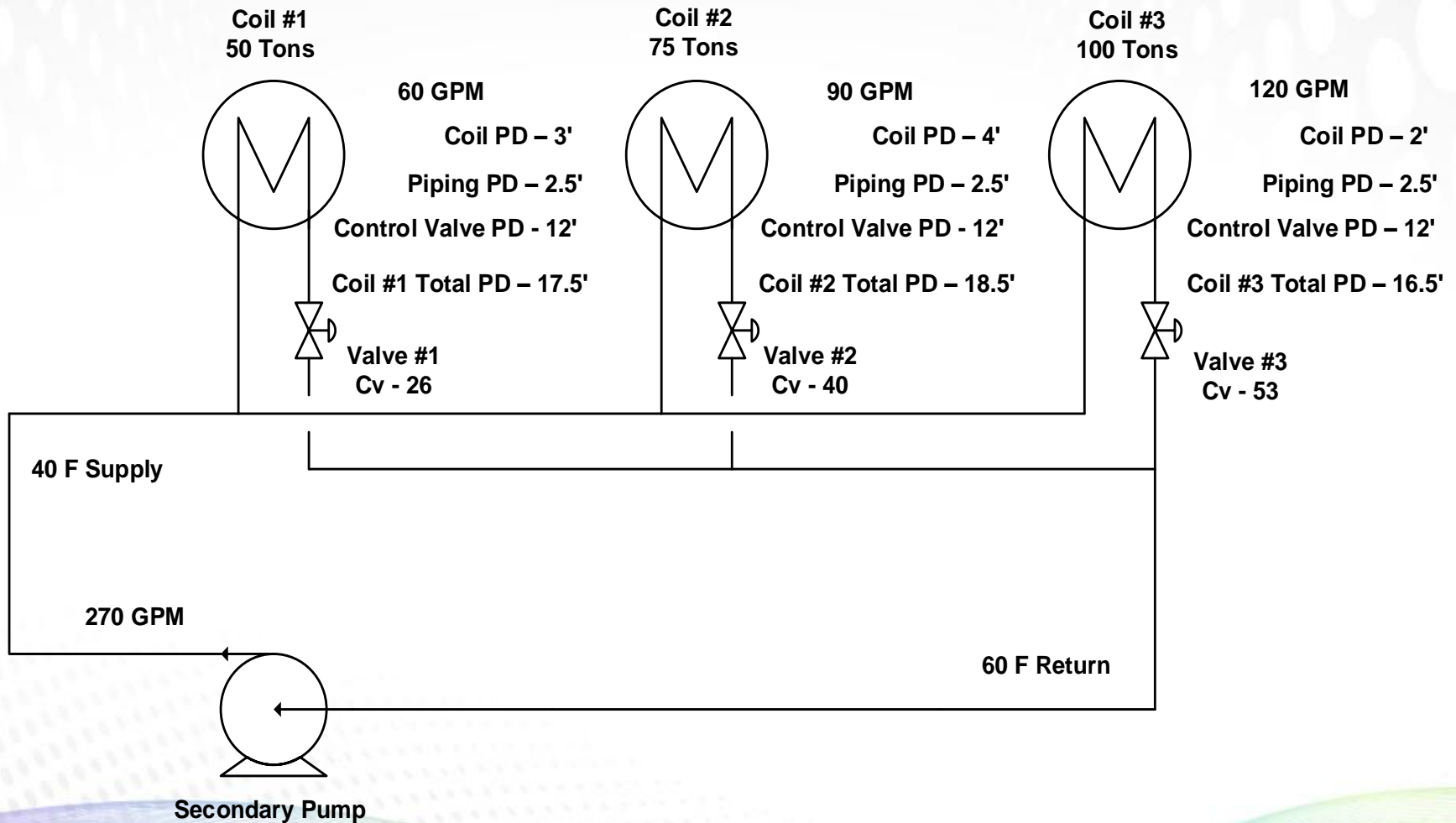- Pump selected – 76% efficient with 1.7 BHP

  – Selected motor is 3 Hp



Suction Size = 4 "
Discharge Size = 3 "

Min Imp Dia = 7 "
Max Imp Dia = 9.5 "
Cut Dia = 7.5 "

Design Capacity = 270.0 GPM
Design Head = 18.5 Feet
Motor Size = 2 HP

# Low Flow/High Delta Primary System



Primary Piping
PD - 5' for
Each Chiller

40 F Supply

60 F Return

Chiller #1
PD = 4'

135 GPM

Primary Pump P1

Chiller #2
PD = 4'

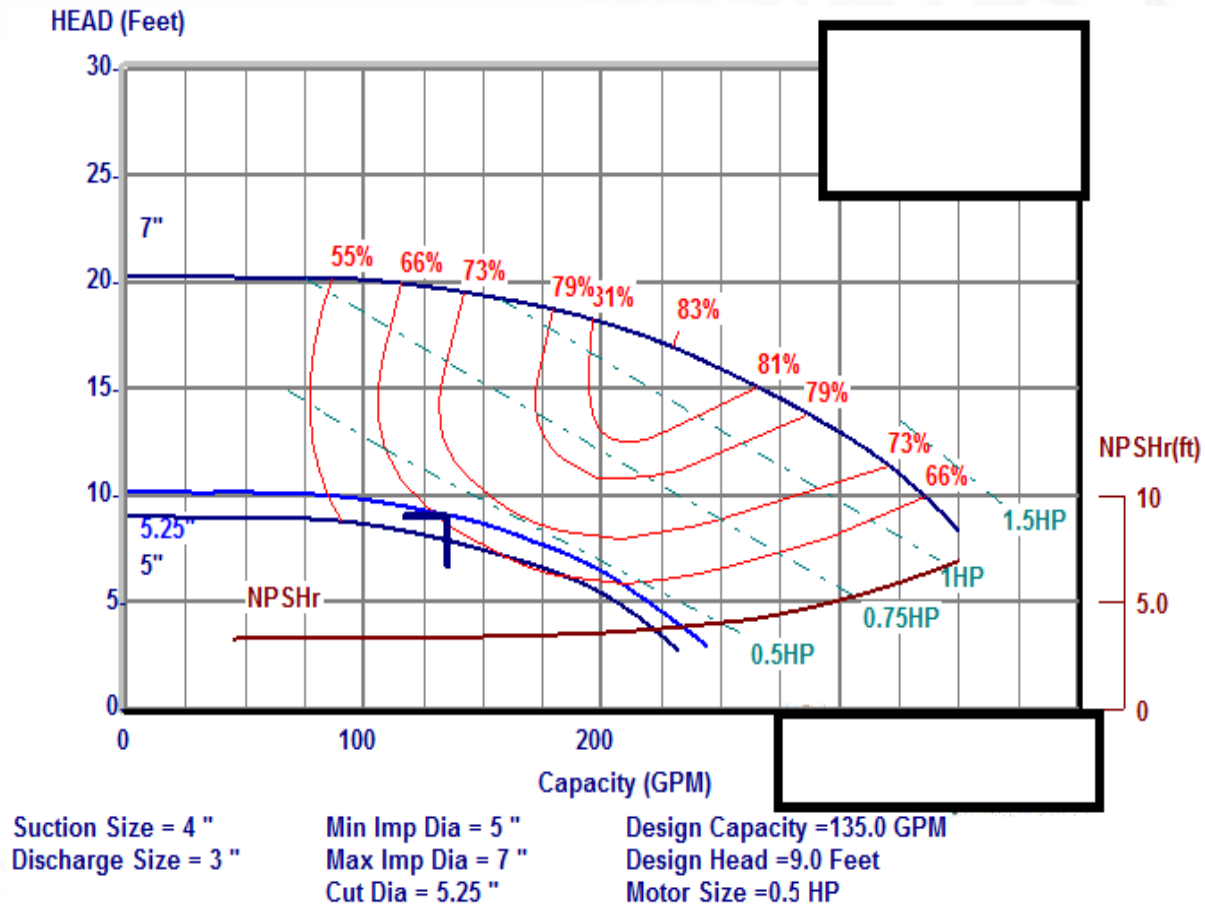135 GPM
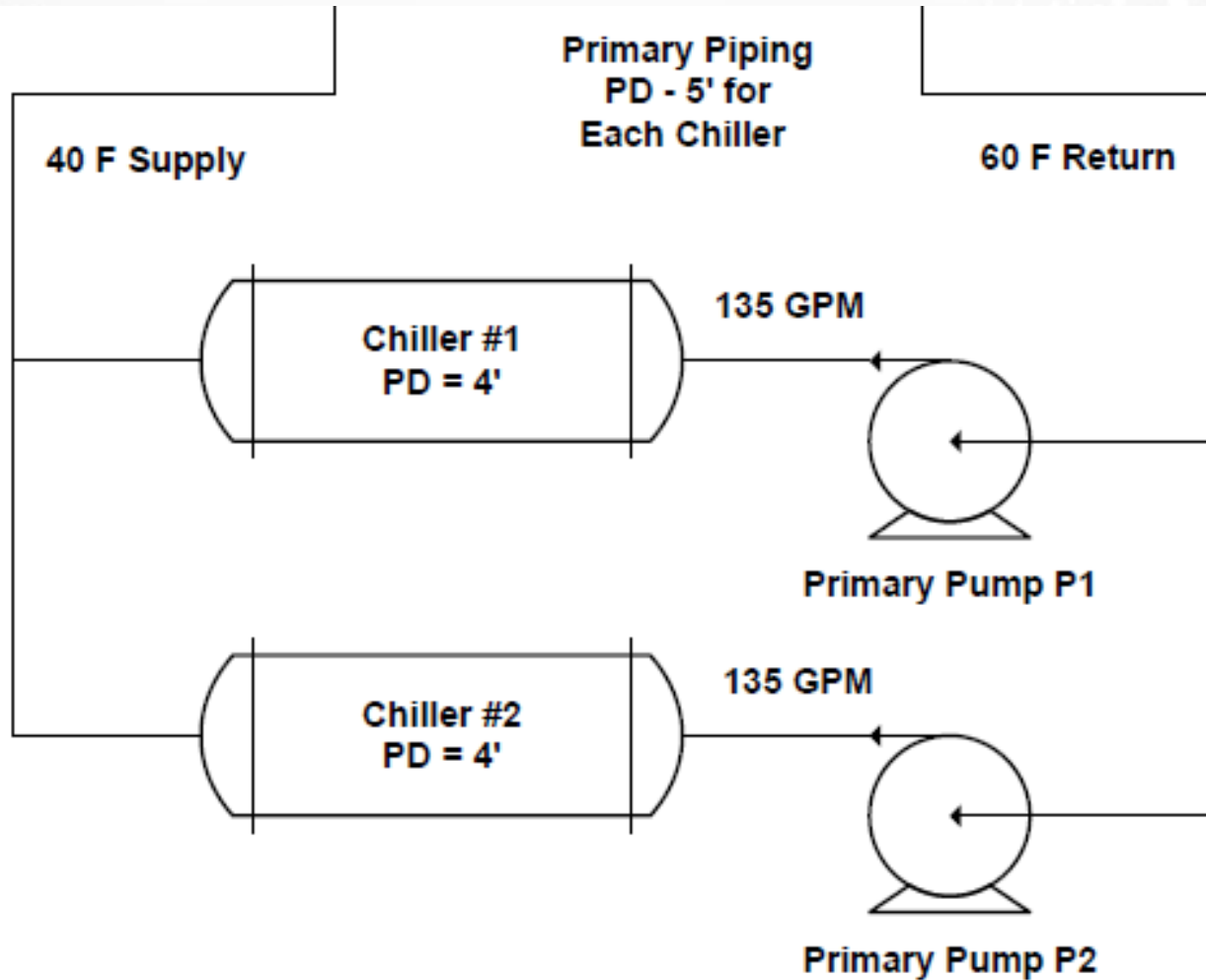
Primary Pump P2

# Low Flow/High Delta Primary Pumps

- Need (for each) is 135 GPM at 9 ft. (w.c.) total head

- Pump selected – 68% efficient with 0.5 BHP

    – Selected motor is 1 Hp



HEAD (Feet)

Capacity (GPM)

NPSHr(ft)

Suction Size = 4 "
Discharge Size = 3 "

Min Imp Dia = 5 "
Max Imp Dia = 7 "
Cut Dia = 5.25 "

Design Capacity =135.0 GPM
Design Head =9.0 Feet
Motor Size =0.5 HP
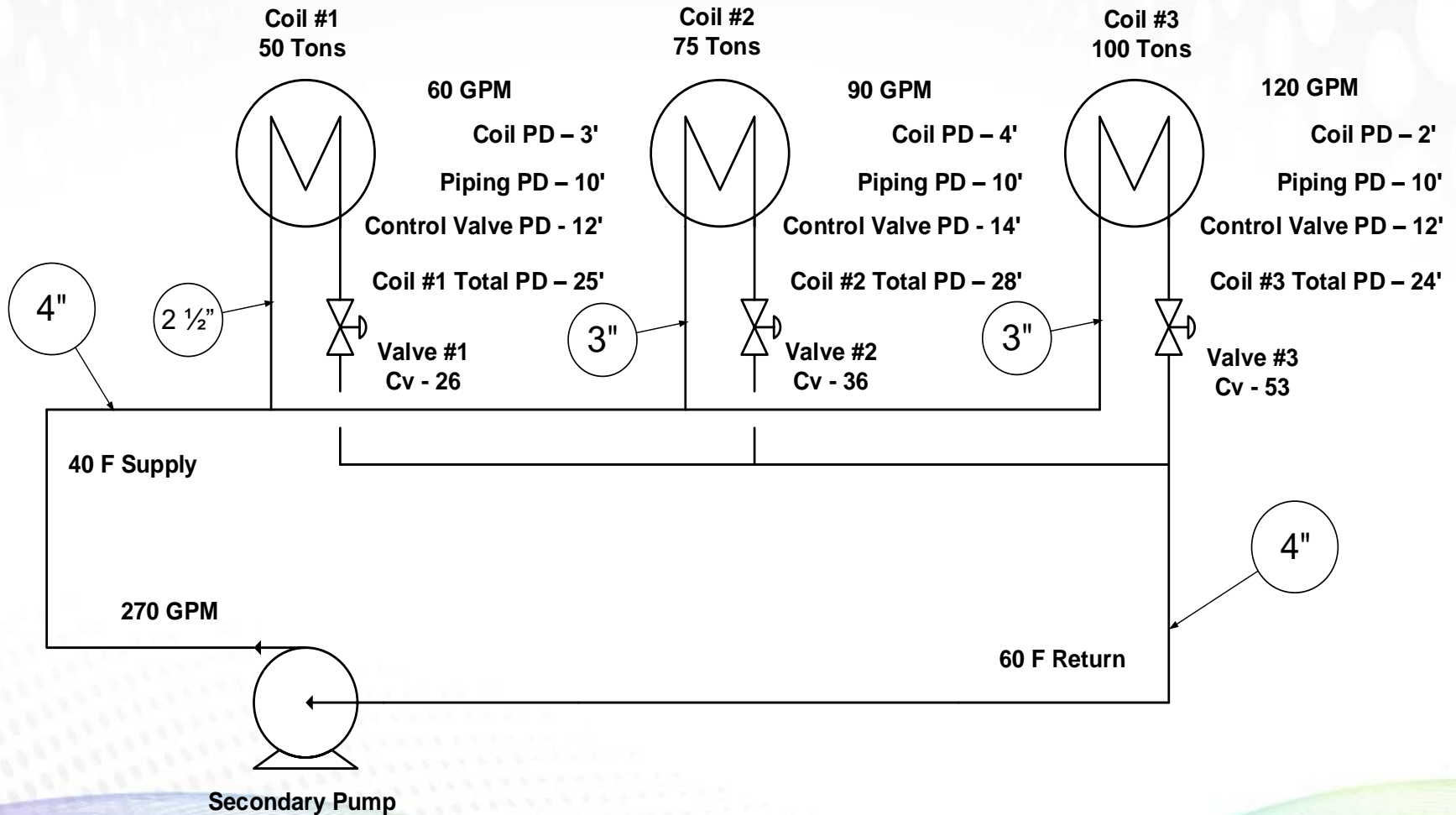
# Low Flow/High Delta Total Pumping

- Primary pumps – 0.5 BHP (ea.) = 1.0 BHP

- Secondary pump – 1.7 BHP

- Total pump power = 2.7 BHP

- Savings due to Low Flow/High Delta

  – 12.4 BHP minus 2.7 BHP = 9.7 BHP

# Example of Potential Savings

- Transferring 9.7 BHP to annual savings ($)

- $ = 9.7 BHP x 746 watts/BHP x 1kW/1000 watts x 1000 hours/year x $0.125/kWh x 1/0.85

- $ = 1064.14

# Low Flow/High Delta Secondary System



**Coil #1**
**50 Tons**

**Coil #2**
**75 Tons**

**Coil #3**
**100 Tons**

**60 GPM**

**Coil PD – 3'**

**Piping PD – 10'**

**Control Valve PD - 12'**

**Coil #1 Total PD – 25'**

**90 GPM**

**Coil PD – 4'**

**Piping PD – 10'**

**Control Valve PD - 14'**

**Coil #2 Total PD – 28'**

**120 GPM**

**Coil PD – 2'**

**Piping PD – 10'**

**Control Valve PD – 12'**

**Coil #3 Total PD – 24'**

**4"**

**2 ½"**

**3"**

**3"**

**Valve #1**
**Cv - 26**

**Valve #2**
**Cv - 36**

**Valve #3**
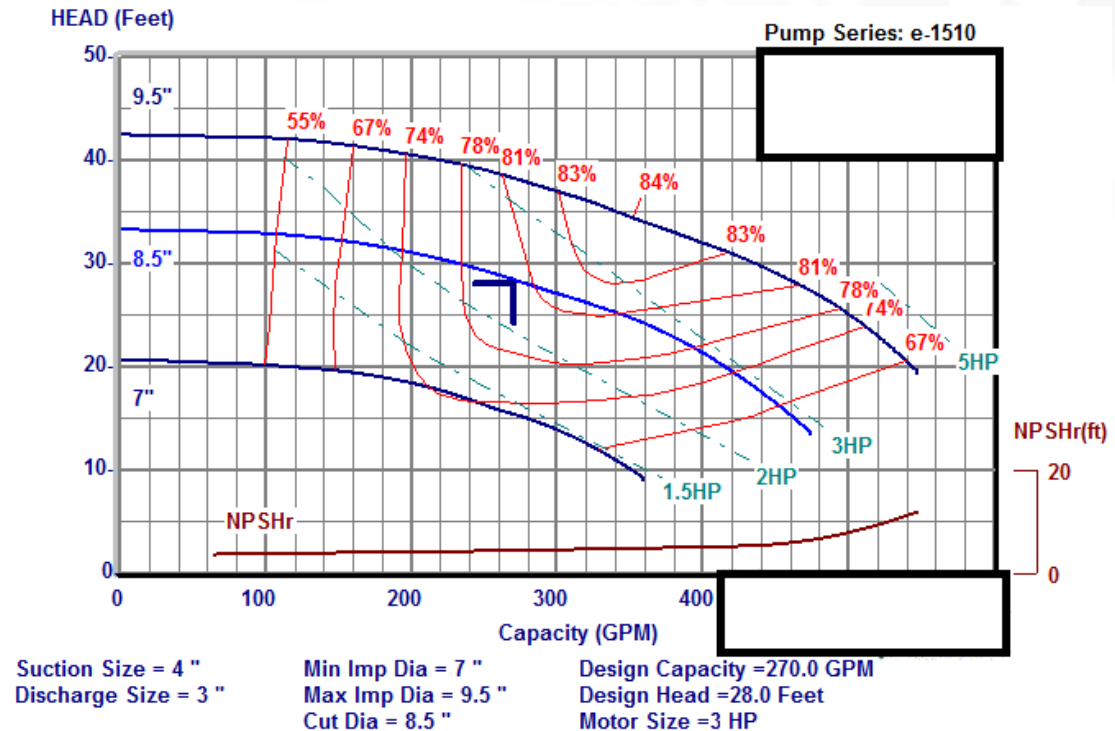**Cv - 53**

**40 F Supply**

**4"**

**270 GPM**
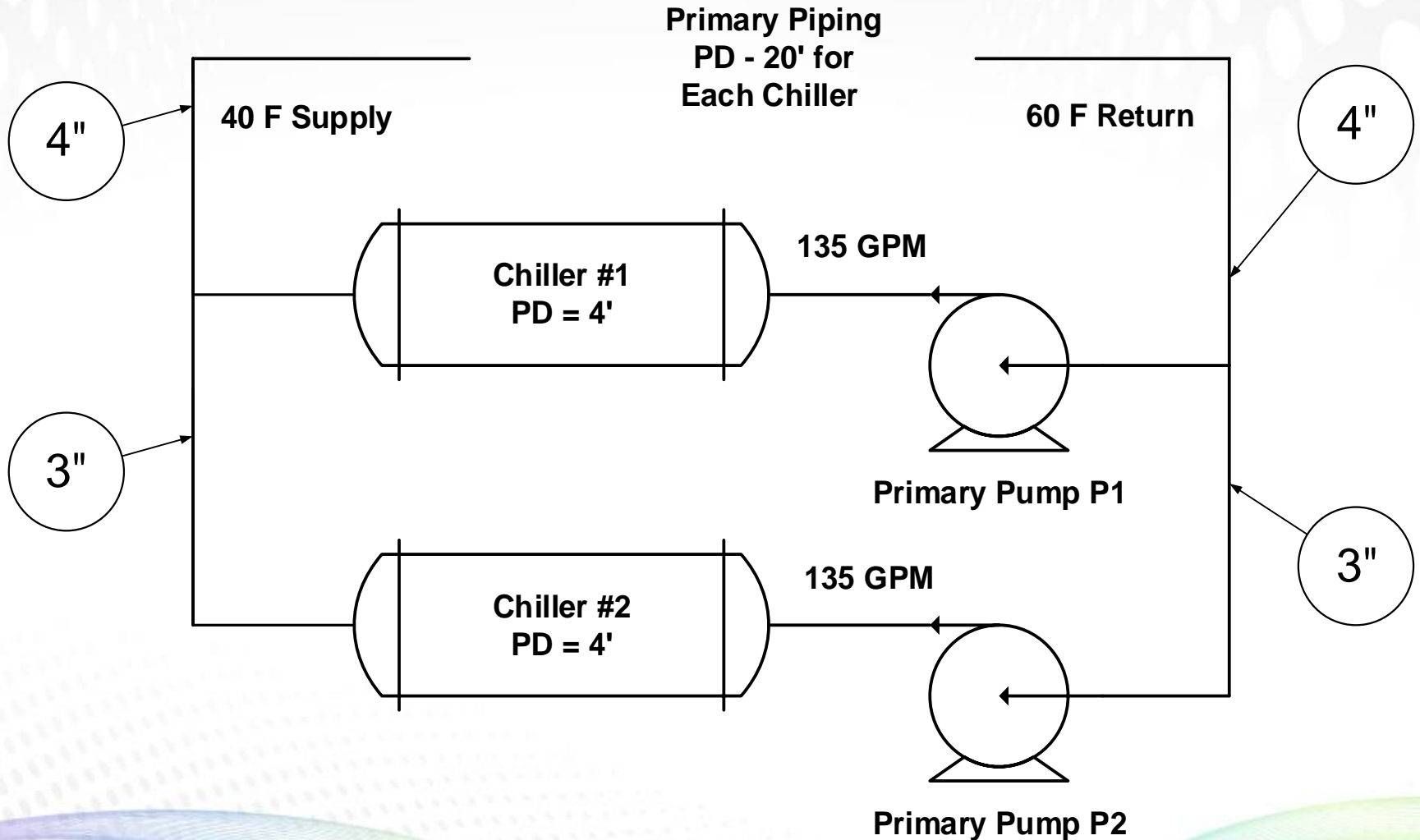
**60 F Return**

**Secondary Pump**

# Low Flow/High Delta Secondary Pump

- Need is 270 GPM at 28 ft. (w.c.) total head

- Pump selected – 80.5% efficient with 2.4 BHP

  – Selected motor is 3 Hp



**HEAD (Feet)**

Pump Series: e-1510

9.5"

8.5"

7"

55% 67% 74% 78% 81% 83% 84% 83% 81% 78% 74% 67%

5HP

3HP

2HP

1.5HP

NPSHr

NPSHr(ft)

**Capacity (GPM)**

Suction Size = 4 "
Discharge Size = 3 "

Min Imp Dia = 7 "
Max Imp Dia = 9.5 "
Cut Dia = 8.5 "

Design Capacity =270.0 GPM
Design Head =28.0 Feet
Motor Size =3 HP

# Low Flow/High Delta Primary System



**Primary Piping PD - 20' for Each Chiller**

4"

**40 F Supply**

**60 F Return**

4"

Chiller #1
PD = 4'

**135 GPM**

3"

**Primary Pump P1**

3"

Chiller #2
PD = 4'

**135 GPM**

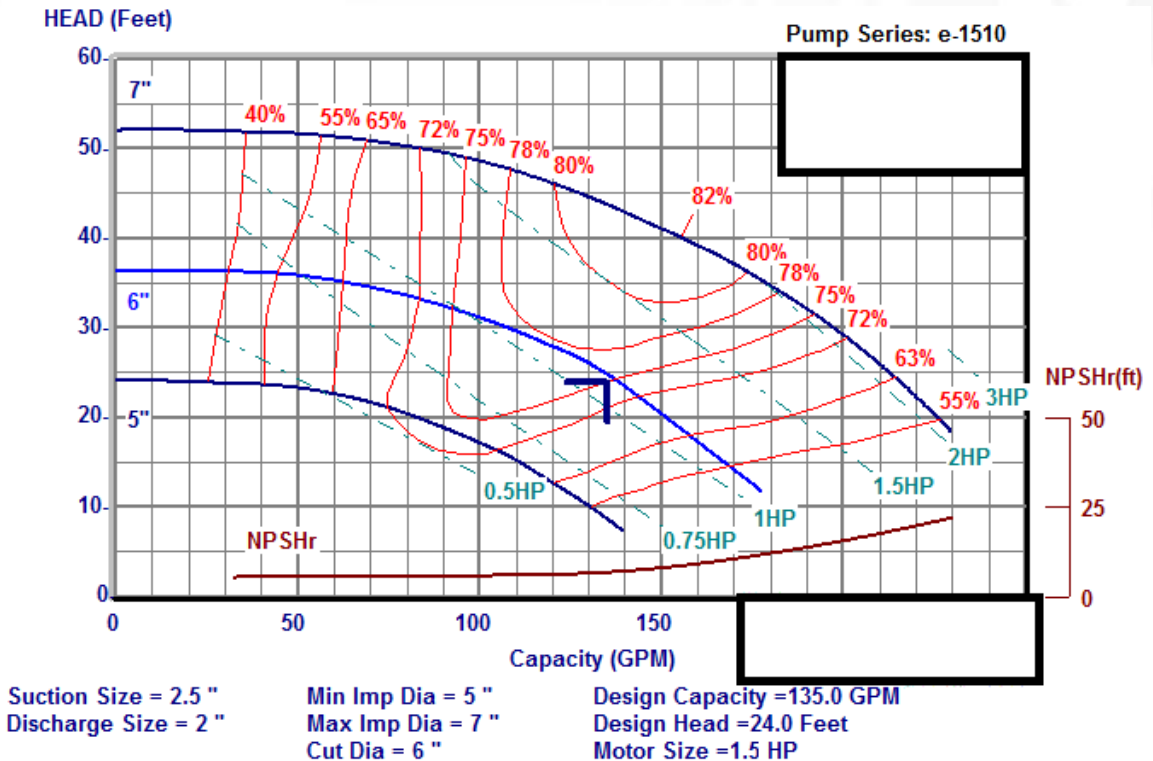**Primary Pump P2**

# Low Flow/High Delta Primary Pumps

- Need (for each) is 135 GPM at 24 ft. (w.c.) total head

- Pump selected – 75% efficient with 1.1 BHP

  – Selected motor is 1.5 Hp



Suction Size = 2.5 "
Discharge Size = 2 "

Min Imp Dia = 5 "
Max Imp Dia = 7 "
Cut Dia = 6 "

Design Capacity =135.0 GPM
Design Head =24.0 Feet
Motor Size =1.5 HP

# Low Flow/High Delta Total Pumping

- Primary pumps – 1.1 BHP (ea.) = 2.2 BHP

- Secondary pump – 2.4 BHP

- Total pump power = 4.6 BHP

- Savings due to Low Flow/High Delta

  - 12.4 BHP minus 4.6 BHP = 7.8 BHP

# Other Benefits

- Reduced installation costs (smaller pipes, valves, insulation, etc..)

- Potential for reduced supply air temperature due to lower chilled water supply temp to coils
  - Creates lower required total airflows to each space
  - Potential savings due to less ductwork and smaller air handlers
  - Promotes better "dew point" control (IEQ)
  - Cascade usage to enhance the higher delta

- Promotes better hot water systems with larger deltas
  - Easier for return temperatures to be used with condensing boilers

- Lower Flow Systems tend to create better flow to mass relationships (tend to avoid short circuiting)

# Recap of thoughts

- Water has a very high affinity to energy

- Heat exchangers can be adjusted to transfer the same energy with lower flow rates

- A lower flow rate results in a higher water "Delta" and this creates a potential for wider control range and better control

- Lower flow rates can produce lower pump BHP and result in operational cost savings

- Other benefits can be obtained due to changes in water loop temperatures (reduced install costs, reduced airflow, etc..)

# Questions?



Douglas Zentz

zentzd@ferris.edu