



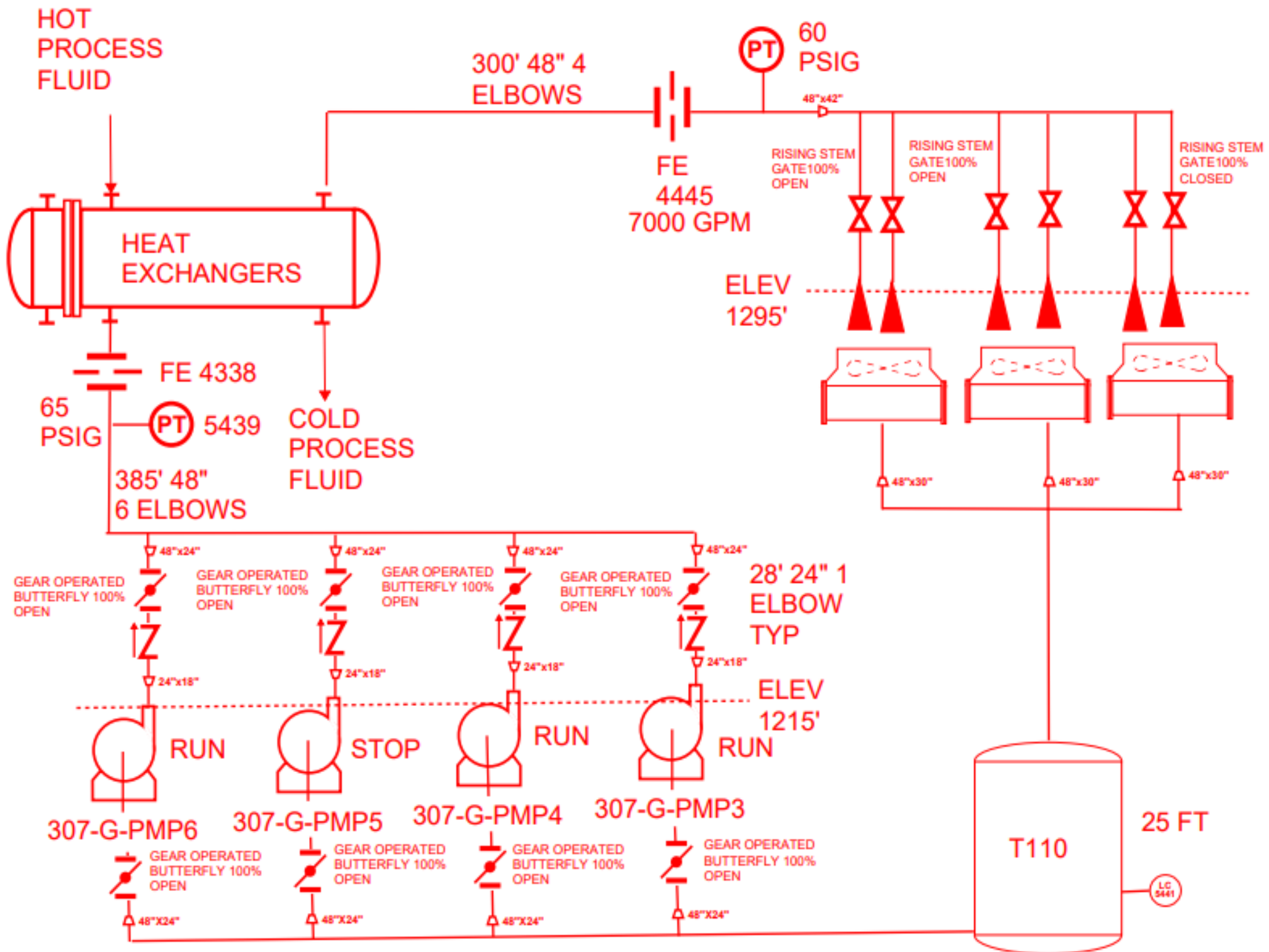
Pumping System Assessment

Week 2: Pump Curves and System Curves



Homework 1 review





DATE 12-9-69

REV. DATE 3/10/77 TRACED, METRIC ADDED P.A.D.

GOLDS PUMPS, INC.
SENECA FALLS, NEW YORK 13152

CENTRIFUGAL PUMP CHARACTERISTICS

RPM 1180 GDS 2068

MODEL 3415

SIZE 16 X 18-22H

IMP. DWG. 104-348

FILE NO. 104-724

PATTERN 56068

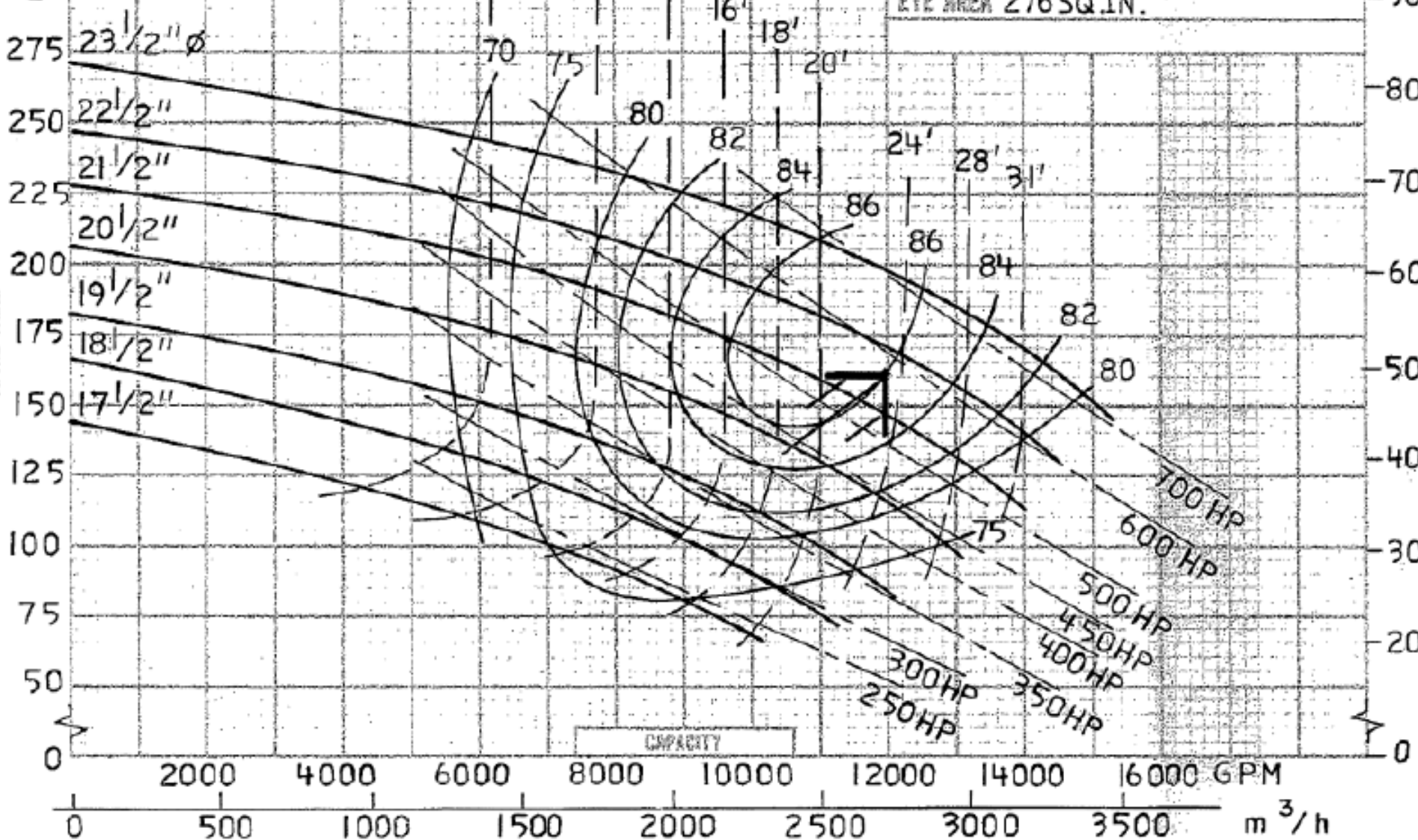
FILE NO. 56312

EYE AREA 276 SQ. IN.

FEET

Metres

NPSH R



CAPACITY

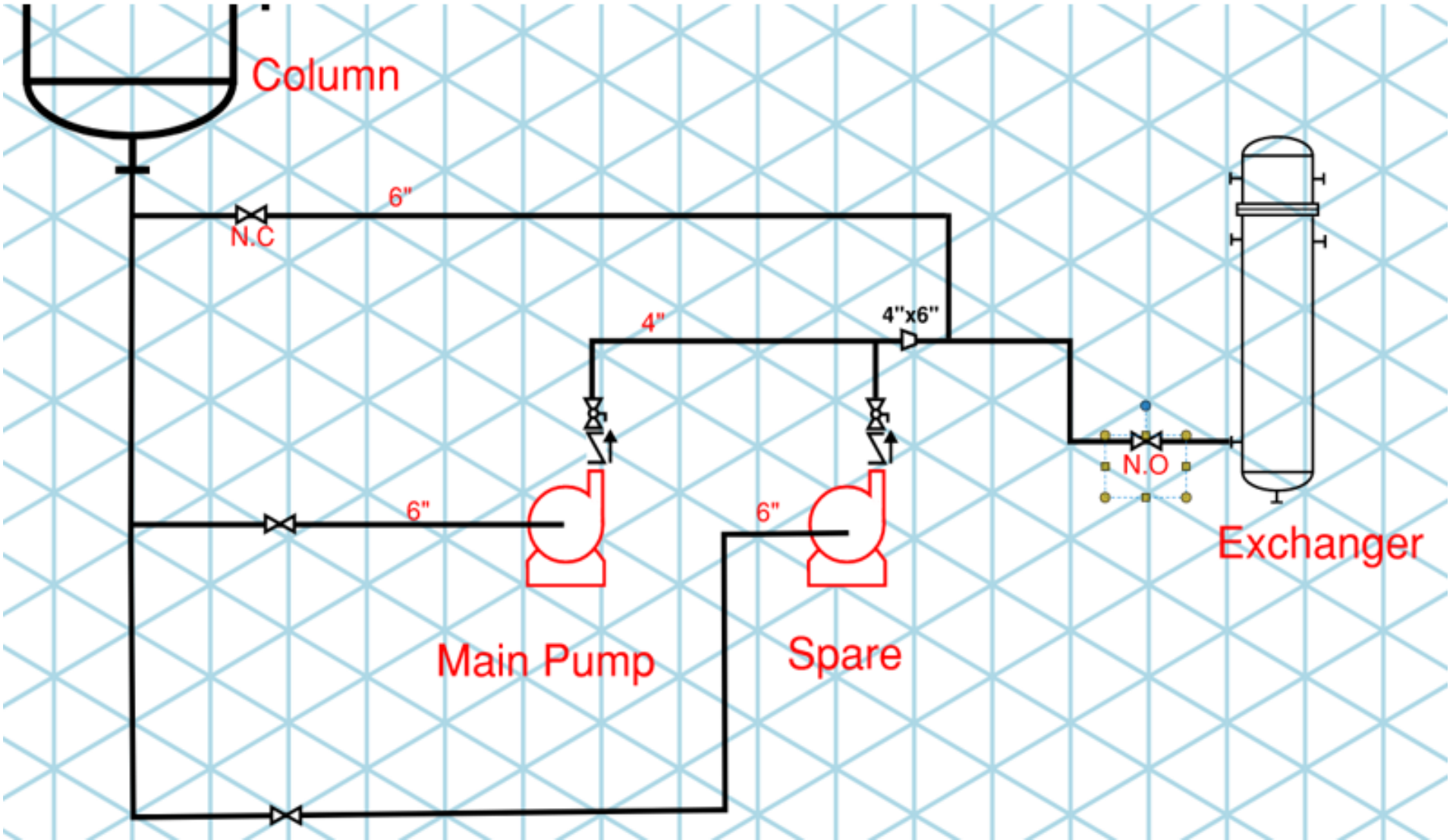
2000 4000 6000 8000 10000 12000 14000 16000 GPM

0 500 1000 1500 2000 2500 3000 3500 m³/h

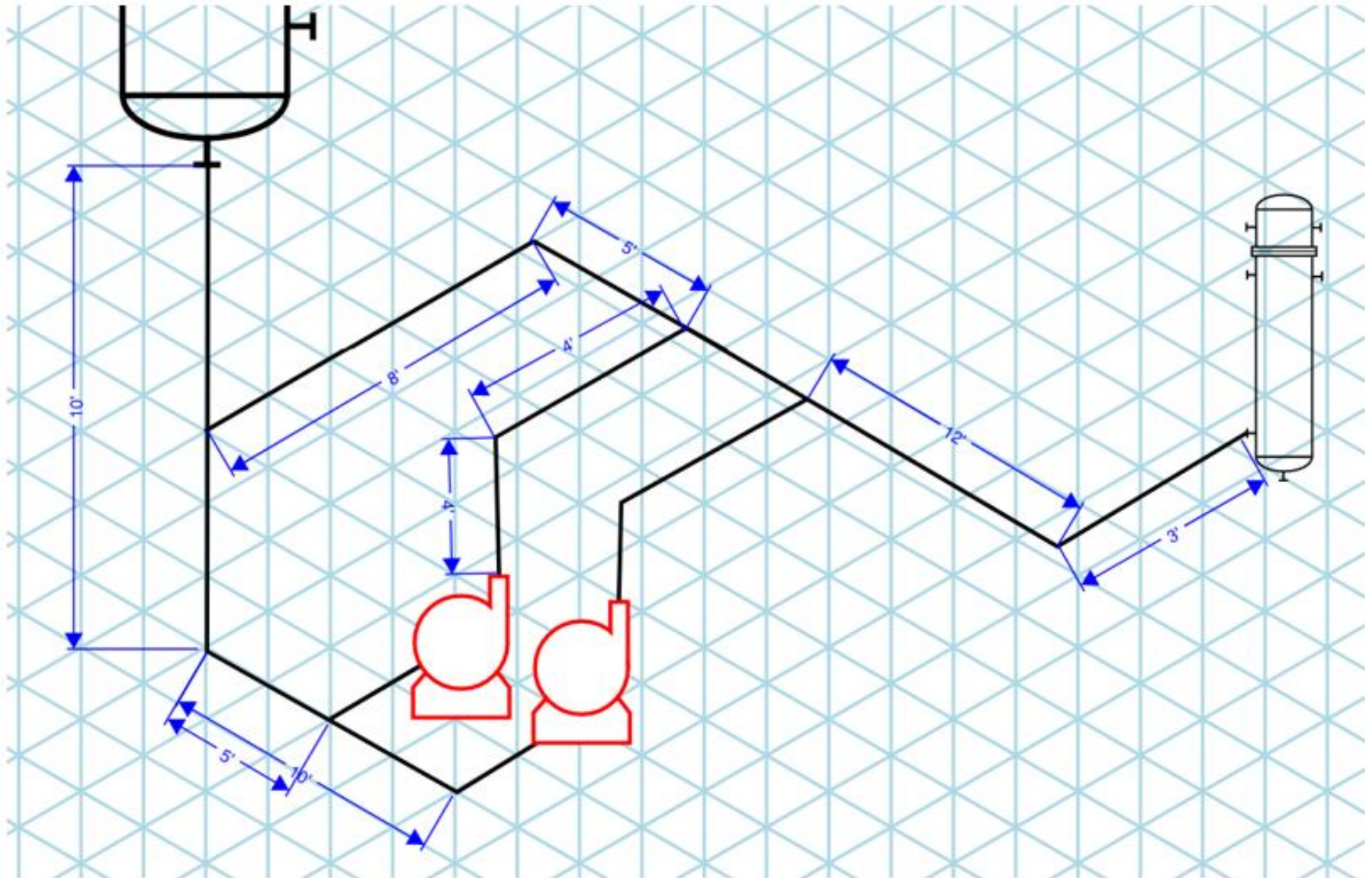
Homework 1 review

1. To save pumping energy we can reduce one or more of the following:
 - a. Flow
 - b. Head
 - c. Operating time
2. Is there flow control on the system? Does the required flow change? Do we sometimes over pressurize the header?
3. What in the motor voltage? Explore magnetic drives for 4160 volt systems.
4. Cooling tower fan control?
5. Are you paying sewer charges on cooling tower makeup water?

Homework 1 review

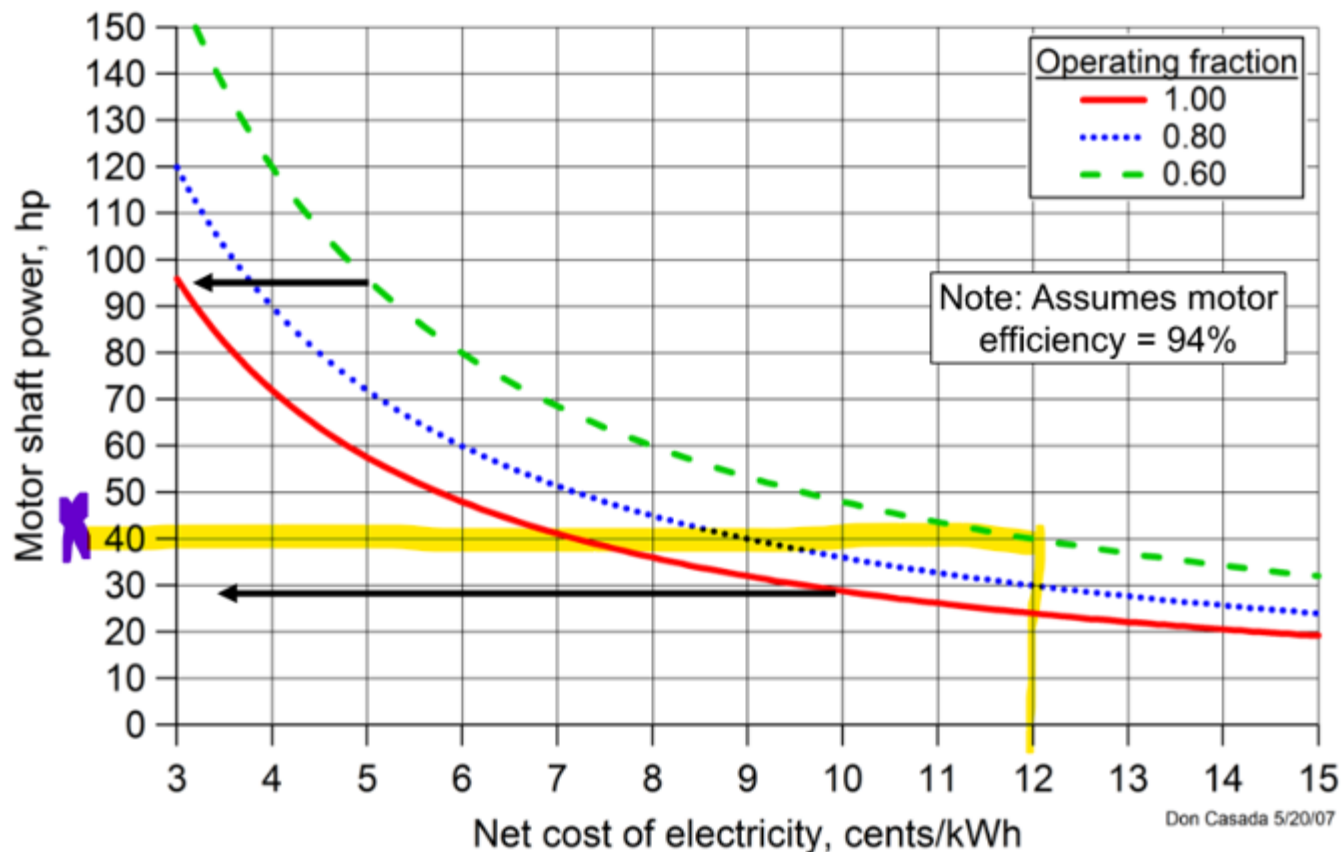


Homework 1 review



Homework 1 review

2. If a plant's net cost of electricity is \$0.12/kWh and their pumps typically operate 60% of the time, what is the minimum motor size on a pump that will cost \$20,000/year to operate? Hint: see slide 21. Answer: 40 HP



Homework 1 review

3. The flow control valve on a boiler feedwater pump typically operates 50% open with a flow rate of 200 gpm of water going to the boiler at 250 F. Plant engineers measure a pressure drop of 115 psi across the valve. If the pump efficiency is 72% and the motor efficiency is 92%, how many kW in motor input energy is being dropped across the valve?

Answer:

Density of water at 250 F is $58.82 \text{ lb}_m/\text{ft}^3$; the density of water at 60 F is $62.36 \text{ lb}_m/\text{ft}^3$; so, the specific gravity is $58.82/62.36 = 0.9432$.

The head loss across the valve is: $HL = (115 \text{ psi} \times 2.31)/0.9432 = 281.65 \text{ feet}$

The kW of pump motor power lost across the valve is:

$\text{kW} = (200 \text{ gpm} \times 281.65 \text{ feet} \times 0.9432 \times 0.746 \text{ kW/hp}) / (3960 \times 0.72 \times 0.92) = 15.11 \text{ kW}$

Homework 1 review

4. If the boiler feedwater pump in #3 above operates all the time and the cost of electrical energy is \$0.065/kWh and the demand charge is \$14.75/kW-mo, how much does the energy loss across the throttled valve cost the plant per year?

Answer:

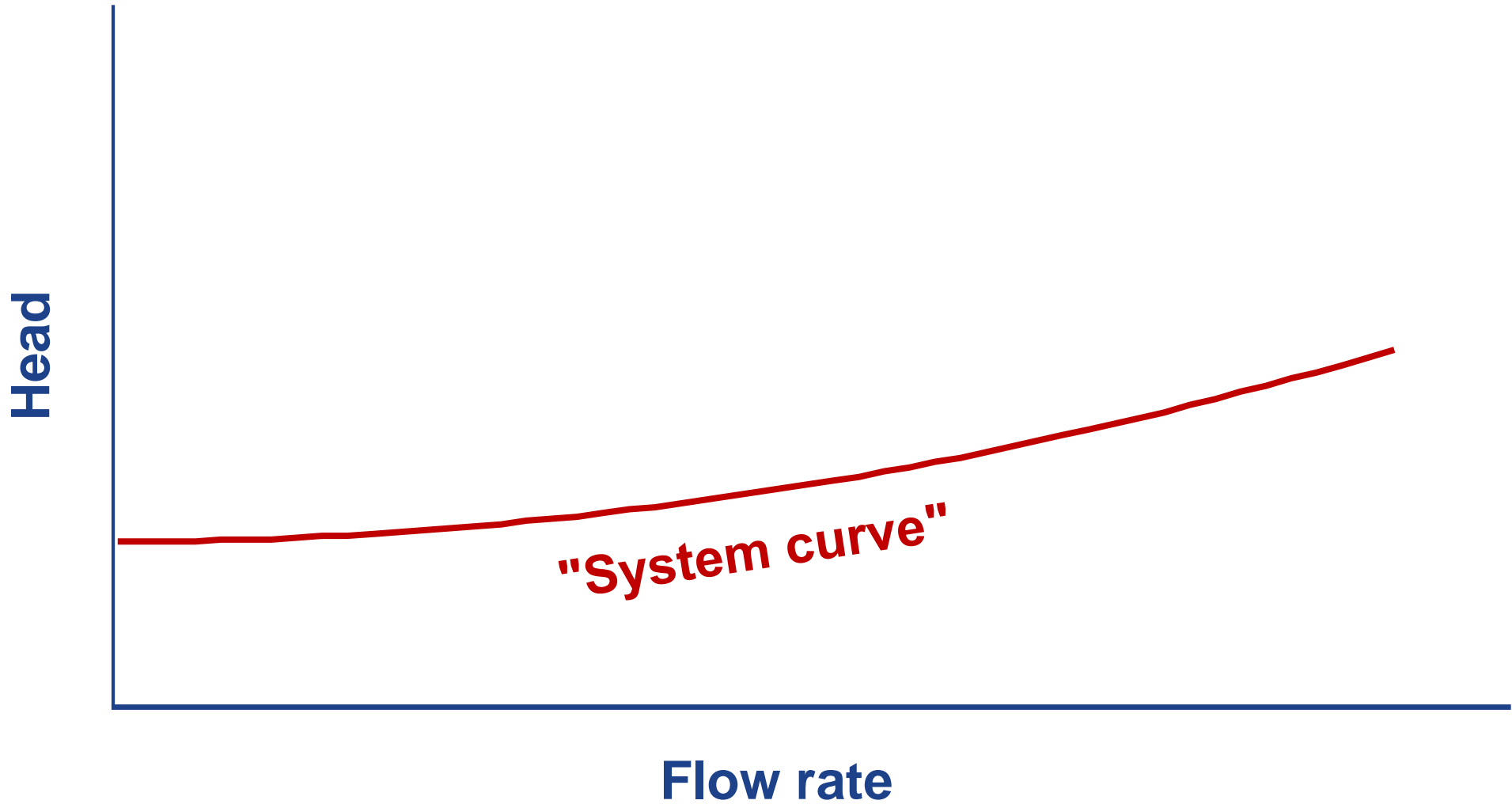
$$\text{Energy Cost} = (15.11 \text{ kW} \times 8760 \text{ hr/yr} \times \$0.065/\text{kWh}) = \$8,604/\text{yr}$$

$$\text{Demand Cost} = (15.11 \text{ kW} \times \$14.75/\text{kW} \times 12 \text{ mo/yr}) = \$2,674/\text{yr}$$

$$\text{Total Annual Cost} = \$11,278/\text{yr}$$

Pump Curves & System Curves

Let's start with the system curve



Energy is required to overcome two types of resistance to flow in systems

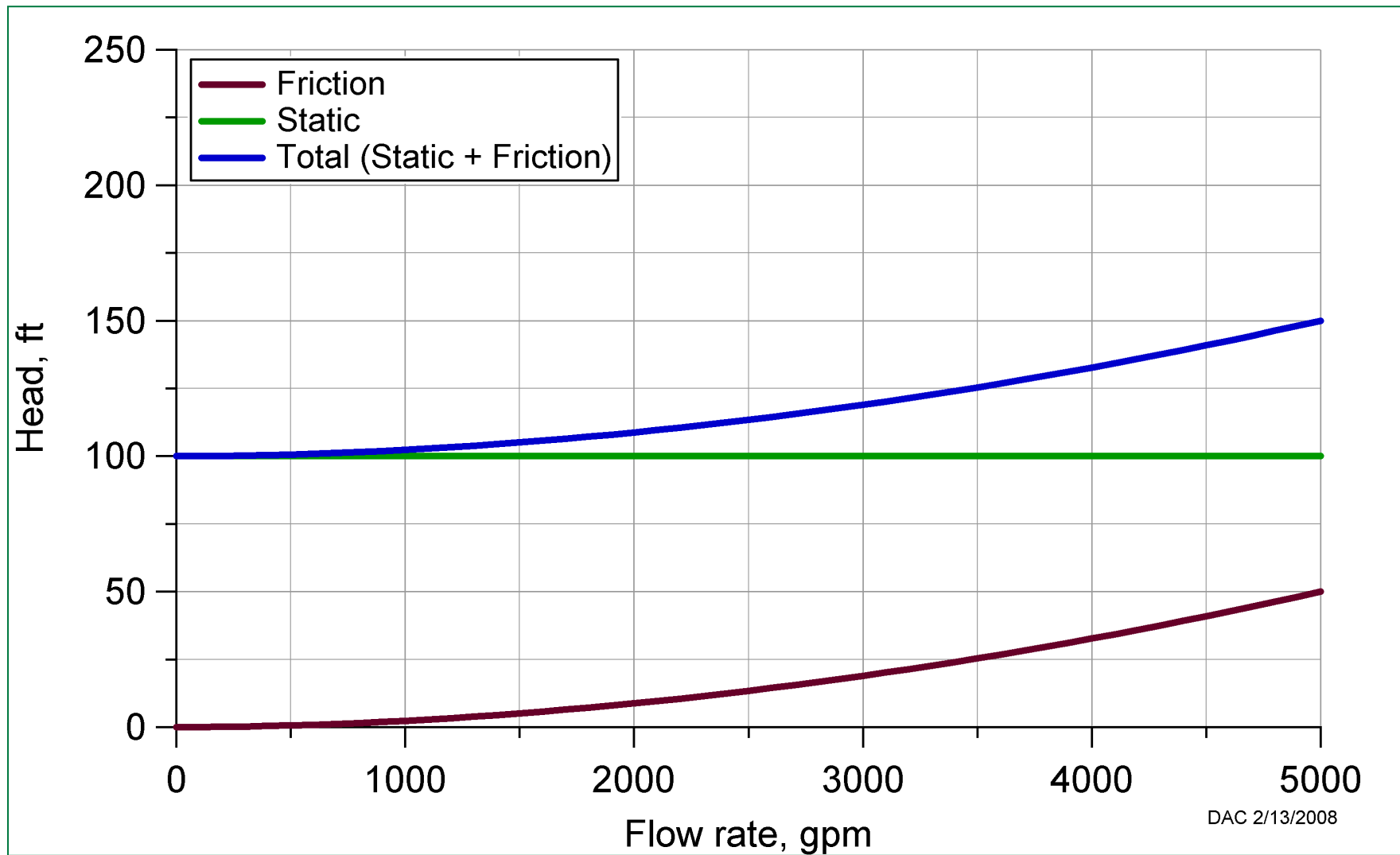
- Static head (independent of flow rate)
- Friction head (dependent on the flow rate)

$$H_{\text{total}} = H_{\text{static}} + H_{\text{friction}}$$

System curves show the two fundamental components - the static head and the frictional head

- Static head refers to the change in elevation from the suction to the discharge
- Tank over-pressures must be included in calculations
- This is basically the change in potential energy of fluid as it moves from the suction tank to the discharge tank
- Closed systems typically do not have static head
- Static heads can be positive, negative or zero

System curves are made up of two fundamental components - static head and frictional head

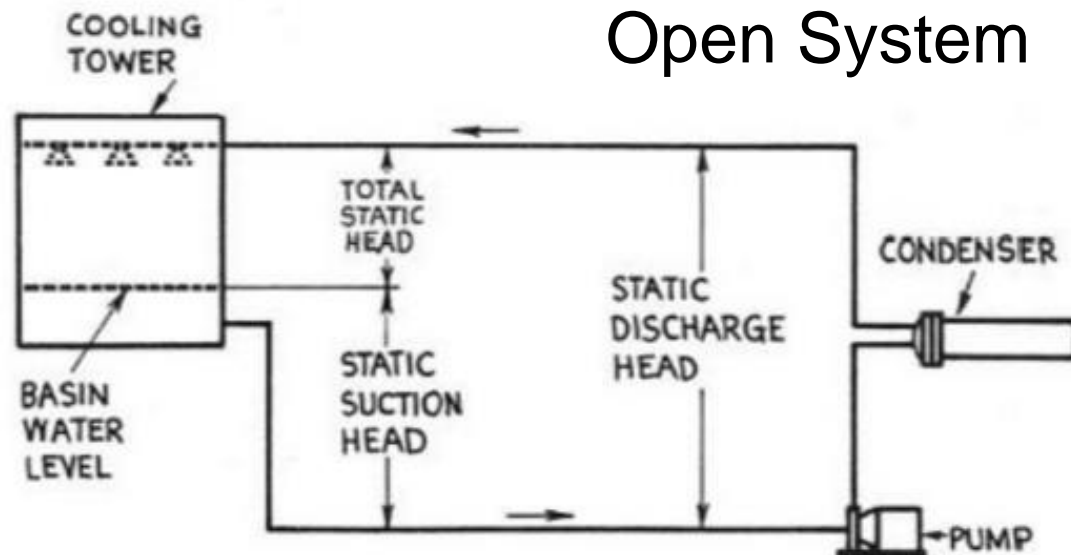


Poll question

- Do closed systems typically have any static head?
 - A. Yes
 - B. No

Open and Closed Piping Systems

- Piping systems for water transmission can be considered in two general categories:
 - Open systems
 - Closed or sealed systems
- Open systems are piping circuits, pumped or gravity circulated, that are open to the atmosphere at some point
- Closed systems are designed and installed as hermetically sealed systems that offer several advantages



Poll question

- Based on the results of your prescreening efforts, are the pumping systems in your plant:
 - Open
 - Closed
 - Both
 - Don't know

System Curves

System curves display the total head required to move different amounts of flow through the piping system

System curve equations:

$$H_{\text{total}} = H_{\text{static}} + k'Q^{1.9}$$

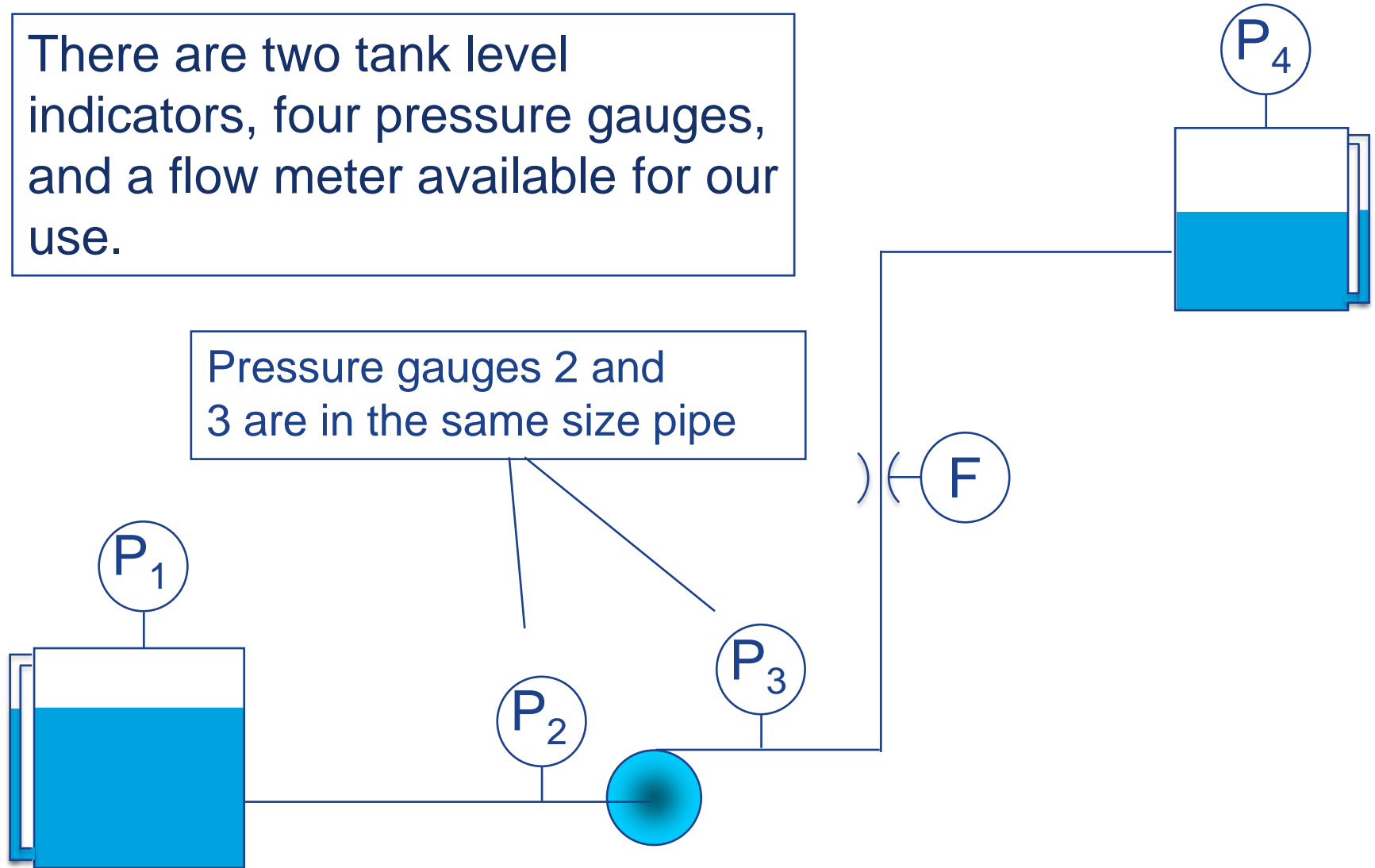
Closed piping systems have zero static head

Open piping systems generally have some static head

We'll use this system as an example: water is pumped from one tank to another

There are two tank level indicators, four pressure gauges, and a flow meter available for our use.

Pressure gauges 2 and 3 are in the same size pipe

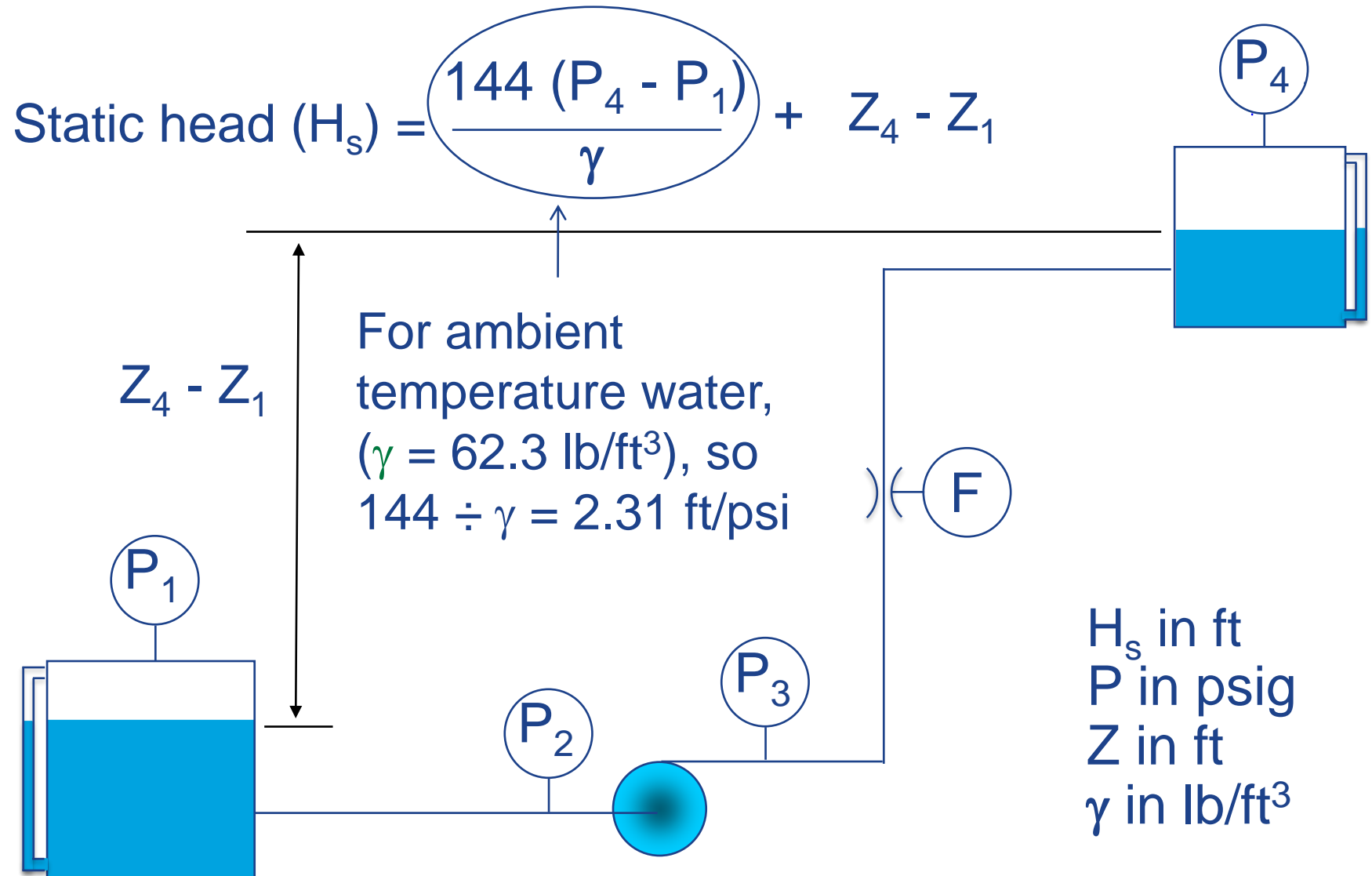


Nobody sells static or frictional head meters

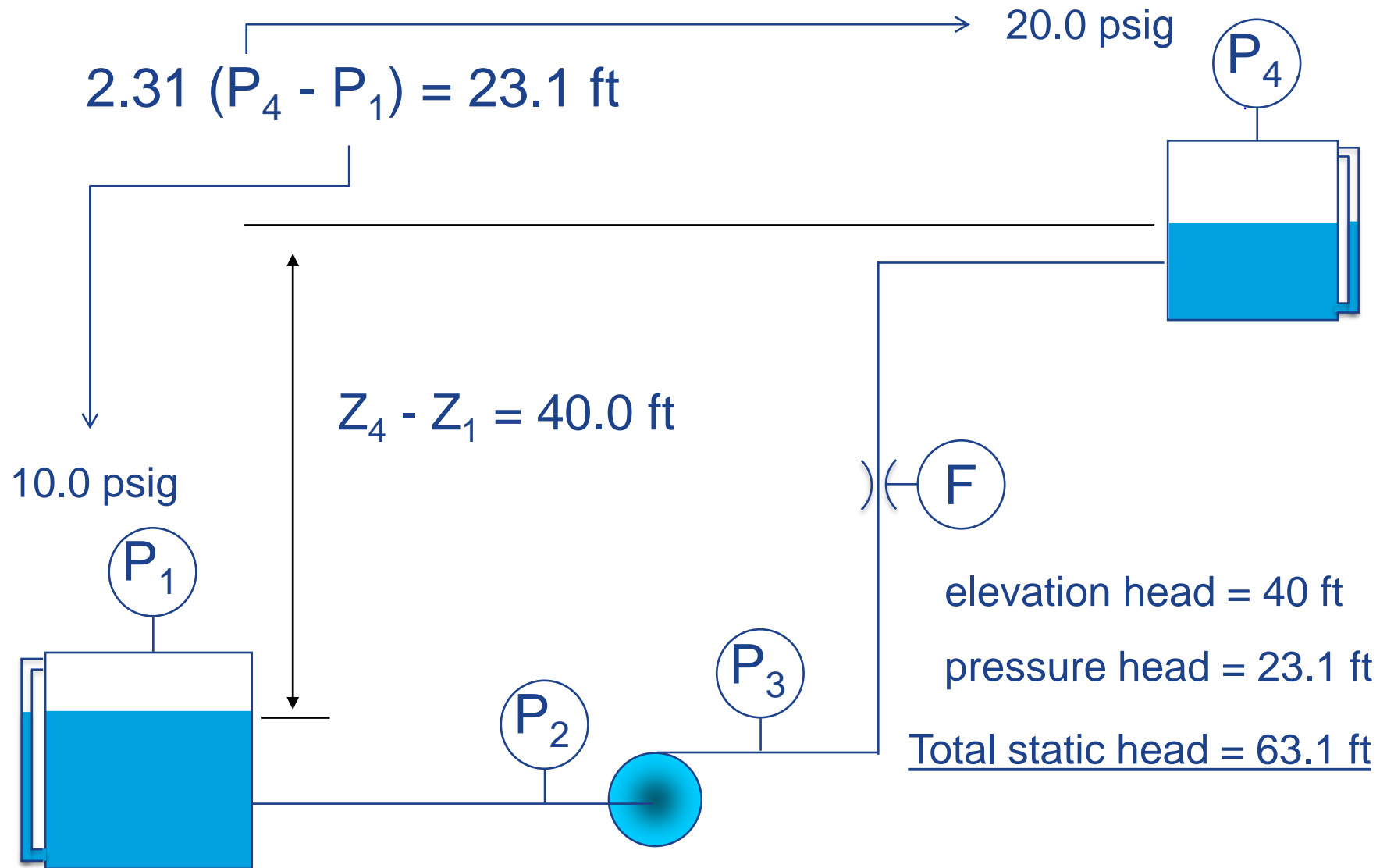
Fortunately, there's a back door, and there are only two pieces of information needed to unlock it:

- 1) The static head, which we can estimate, and
- 2) The total head at a single flow rate, which we can measure

The static head is made up of elevation, and sometimes pressure components



The static head is made up of elevation, and sometimes pressure components



Now that we've got the static head estimated,
we can go after the frictional head

Calculating the frictional head at one flow rate

$$H_{\text{tot}} = H_s + H_f \quad \text{or}$$

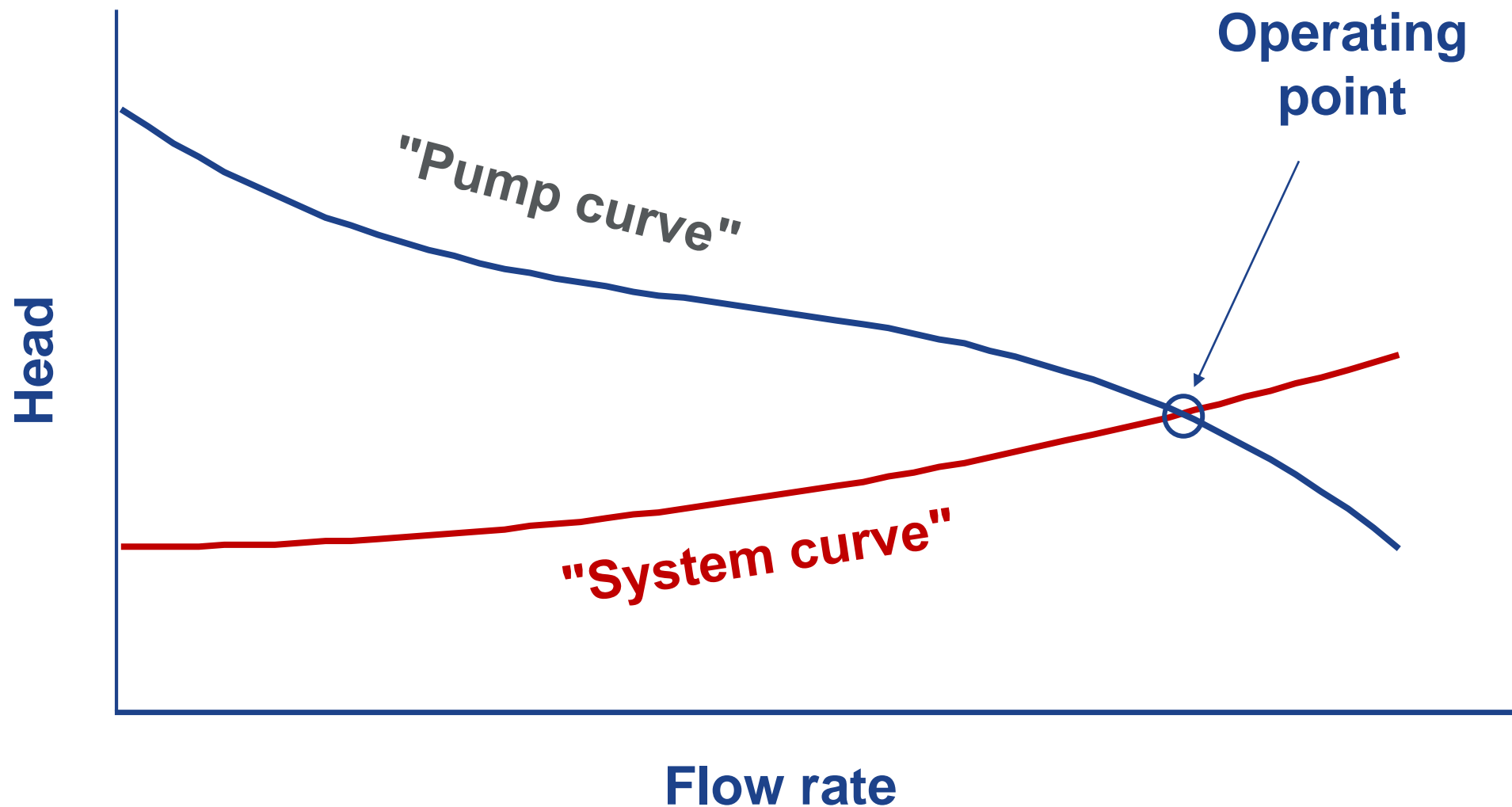
$$H_f = H_{\text{tot}} - H_s$$

So, a single point measurement of flow and total head, along with knowledge of the static head, gives us the frictional head at that flow rate

Our example system -
how can we get the total head (H_{tot})?

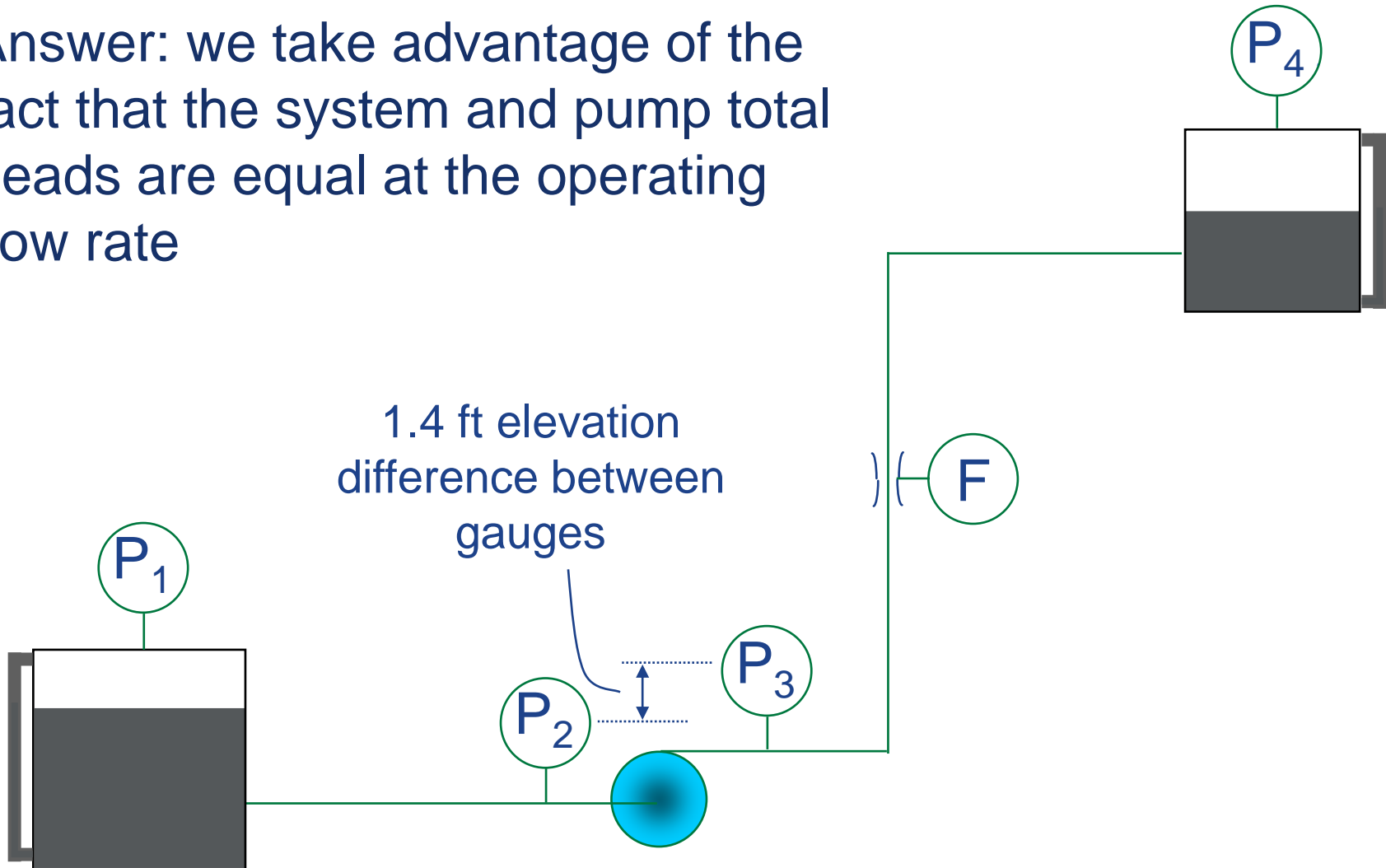
We take advantage of
one inviolable fact for
centrifugal pumping
systems

The system operating point is at the intersection of the pump and system head-capacity curves



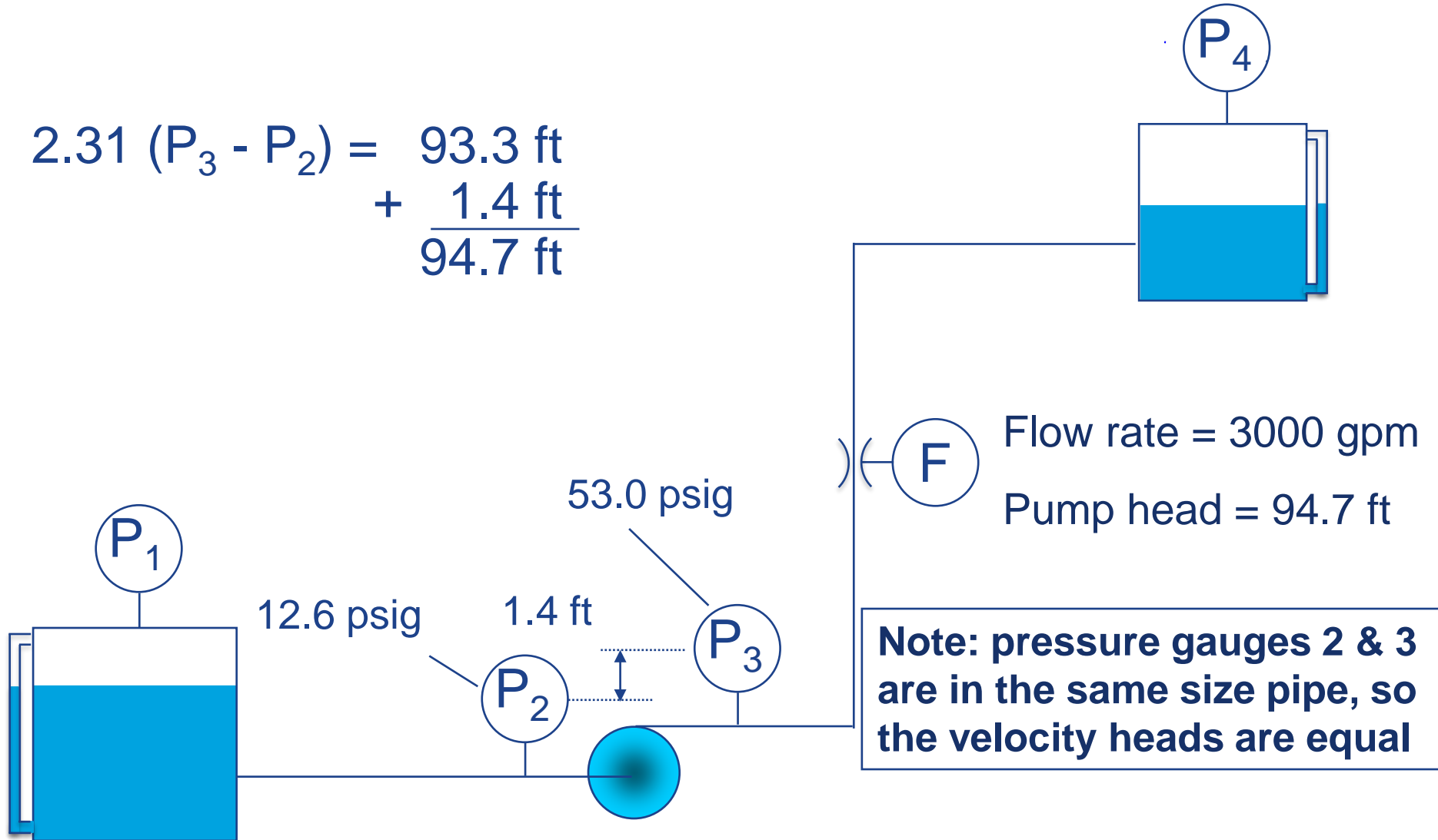
and we can measure the pump head

Answer: we take advantage of the fact that the system and pump total heads are equal at the operating flow rate



The system total head at any flow rate is the same thing as the pump total head - so we measure the pump head

$$2.31 (P_3 - P_2) = 93.3 \text{ ft} \\ + \frac{1.4 \text{ ft}}{94.7 \text{ ft}}$$

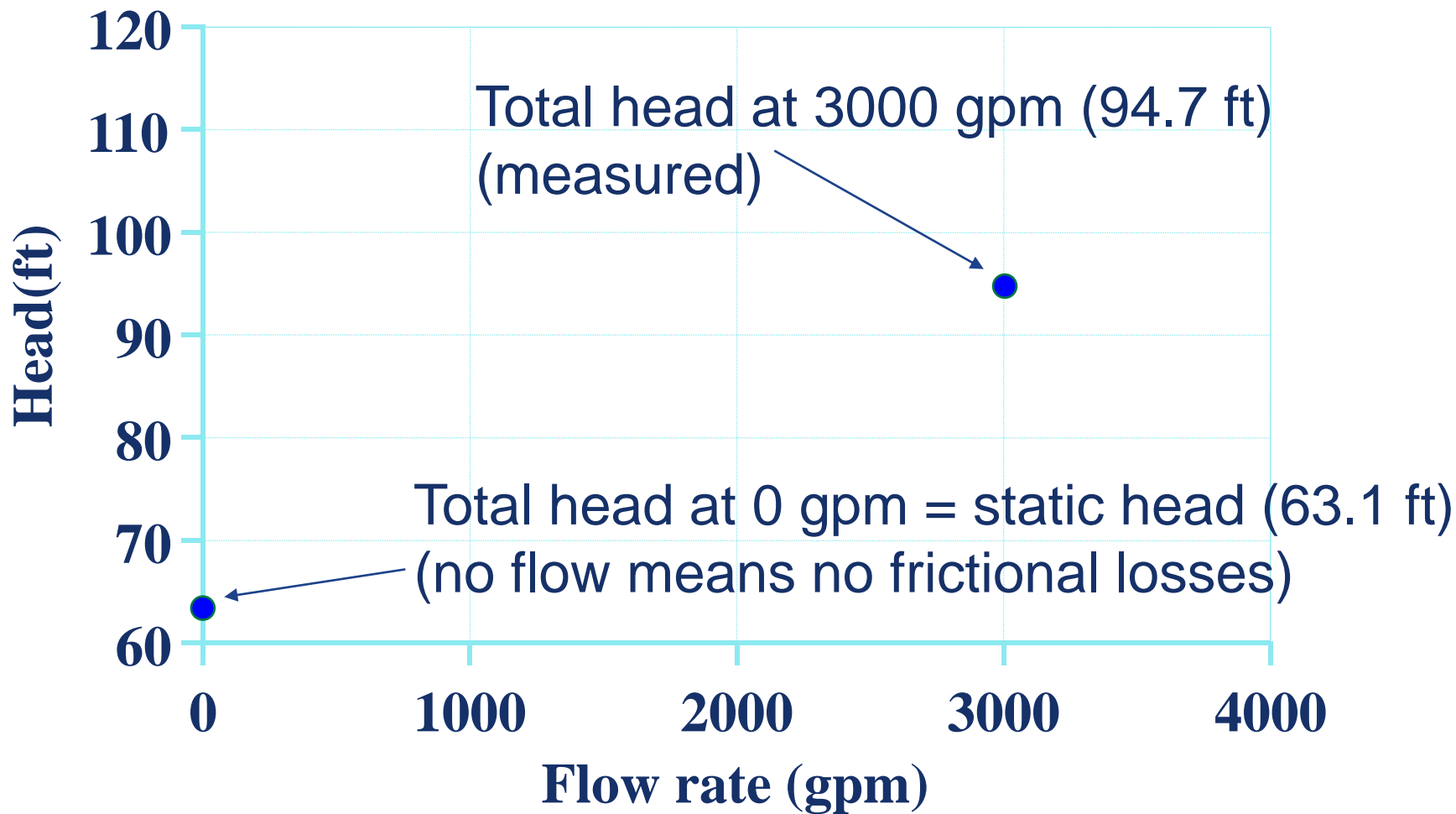


Note: pressure gauges 2 & 3 are in the same size pipe, so the velocity heads are equal

Points to remember.....

- For this example, it was assumed that the suction and discharge pipe diameters were identical. In the majority of cases, the pump discharge flange is smaller than the suction flange, typically one standard pipe size down. For example, a pump with a 12-inch suction might have a 10-inch discharge.
- But it is also common to find expanders/reducers in pump suction & discharge lines. The bottom line is that when taking pressure measurements, pay attention to the physical dimensions. Also note whether there are components, such as a discharge check valve, between the pump and the measurement point that create head losses.
- It is particularly important in relatively low head pumps to pay attention to velocity and loss component considerations, since they may represent a significant part of the total pump head.

We have two points on the system curve; now we just have to figure out how to connect them



A little algebra....

$$H_2 = H_s + KQ_2^2$$

$$H_1 = H_s + KQ_1^2$$

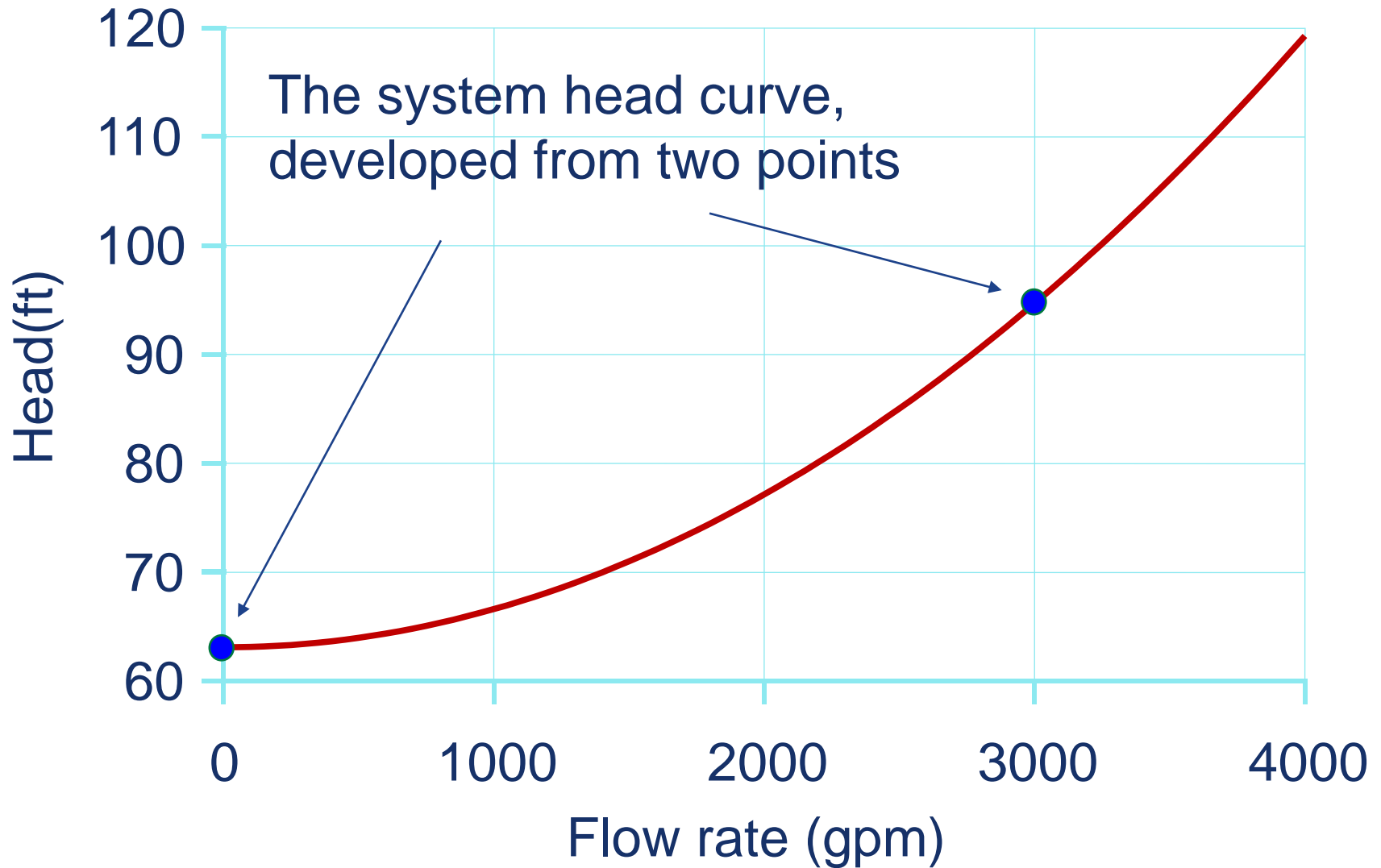
Subtracting yields

$$H_2 - H_1 = K(Q_2^2 - Q_1^2), \text{ so}$$

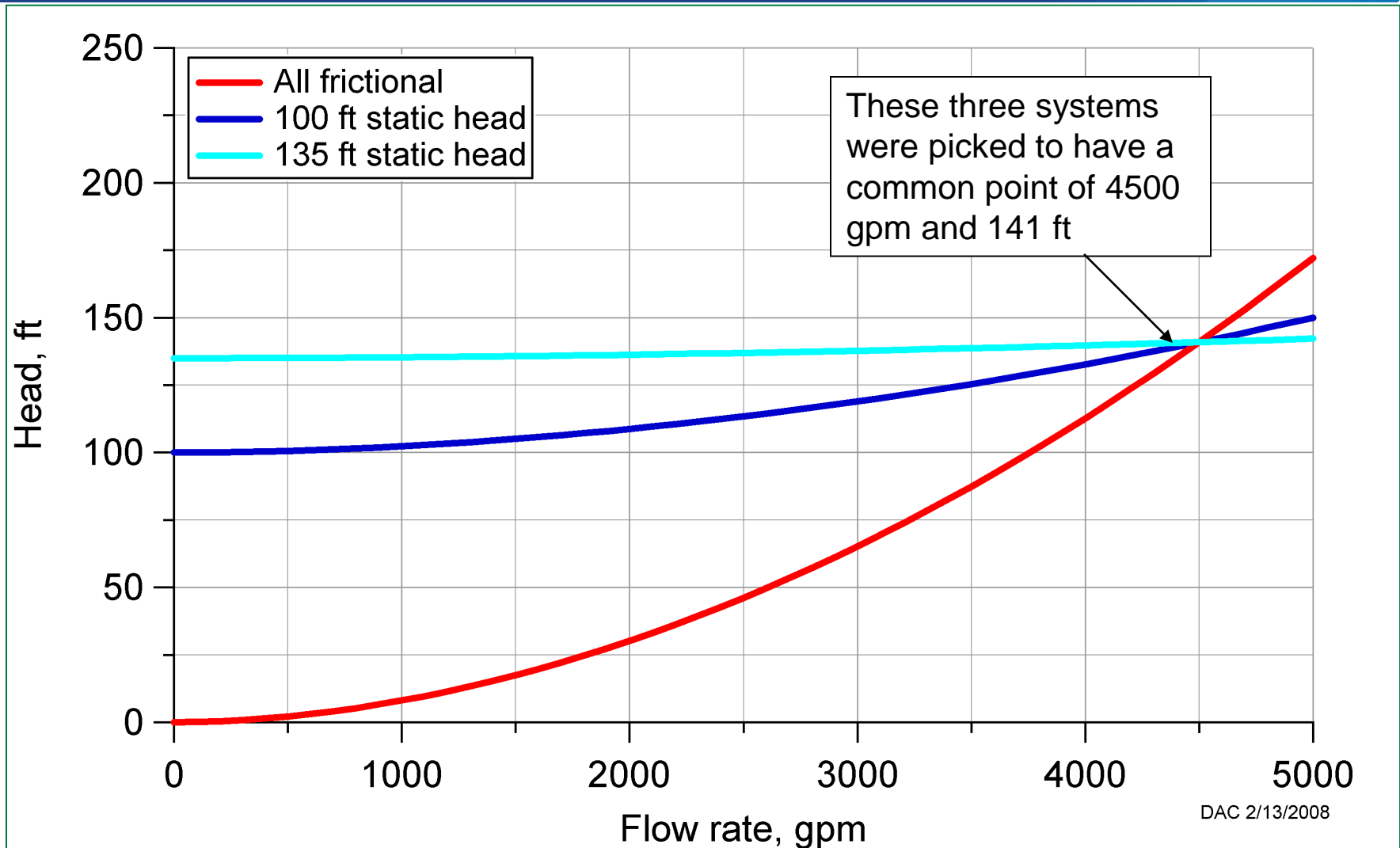
$$K = \frac{(H_2 - H_1)}{(Q_2^2 - Q_1^2)} \quad \text{and} \quad H_s = H_1 - KQ_1^2$$

Although the static head is known in this case, any two flow and head combinations will suffice.

The resultant system curve



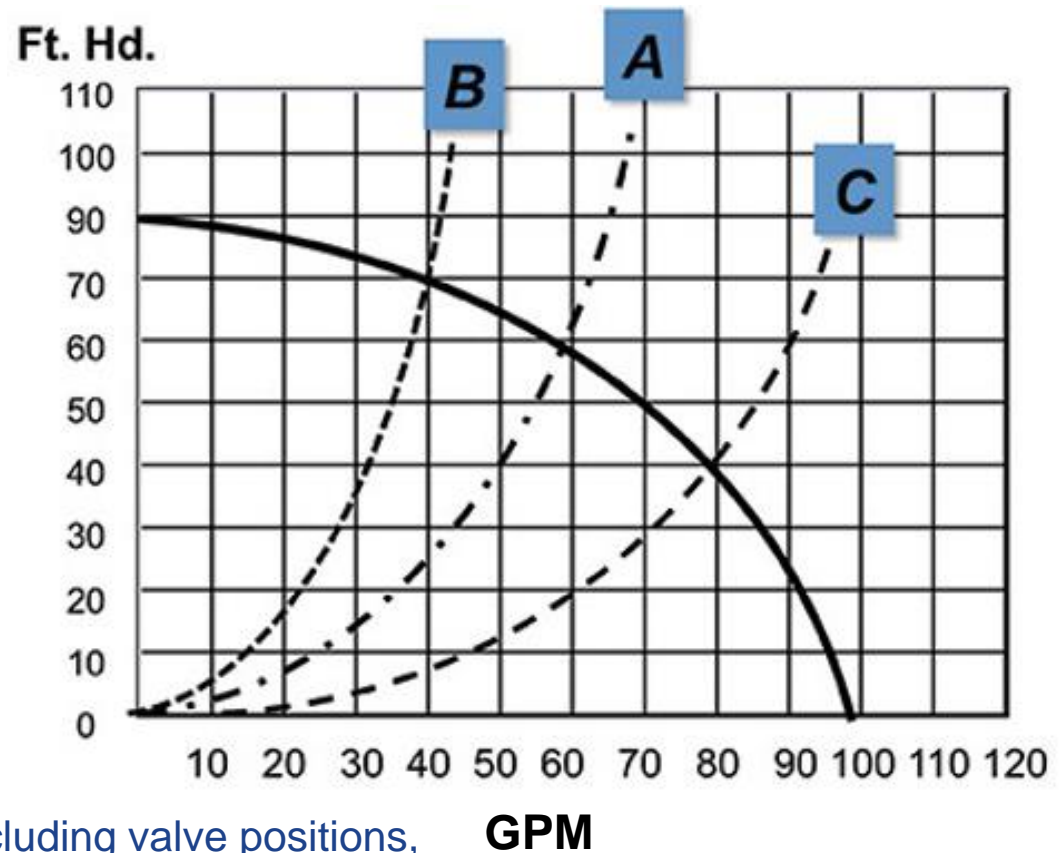
System head curves for three different systems



NOTE: These are three different systems

Where do system curves come from?

- New systems
 - Design calculations and/or hydraulic models
- Existing systems
 - Hydraulic models (lots of time and tolerance are handy assets for this)
 - Field measurements and basic layout information

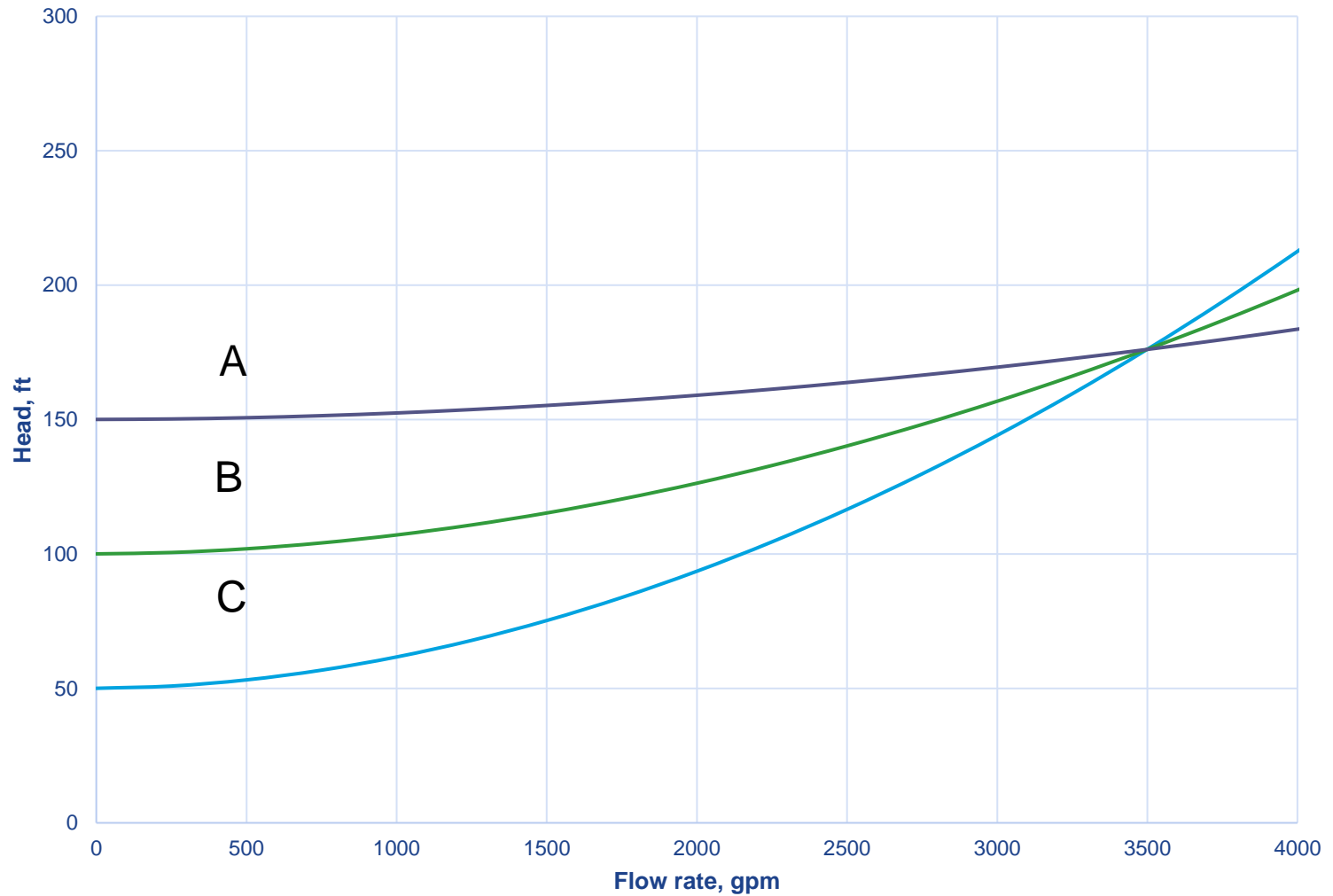


NOTES:

1. If anything in the system changes – including valve positions, flow paths, tank levels, etc., the system curve will change.
2. For systems with multiple suction sources and/or discharge receivers that have different amounts of static head, the system curve will have a more complex characteristic.

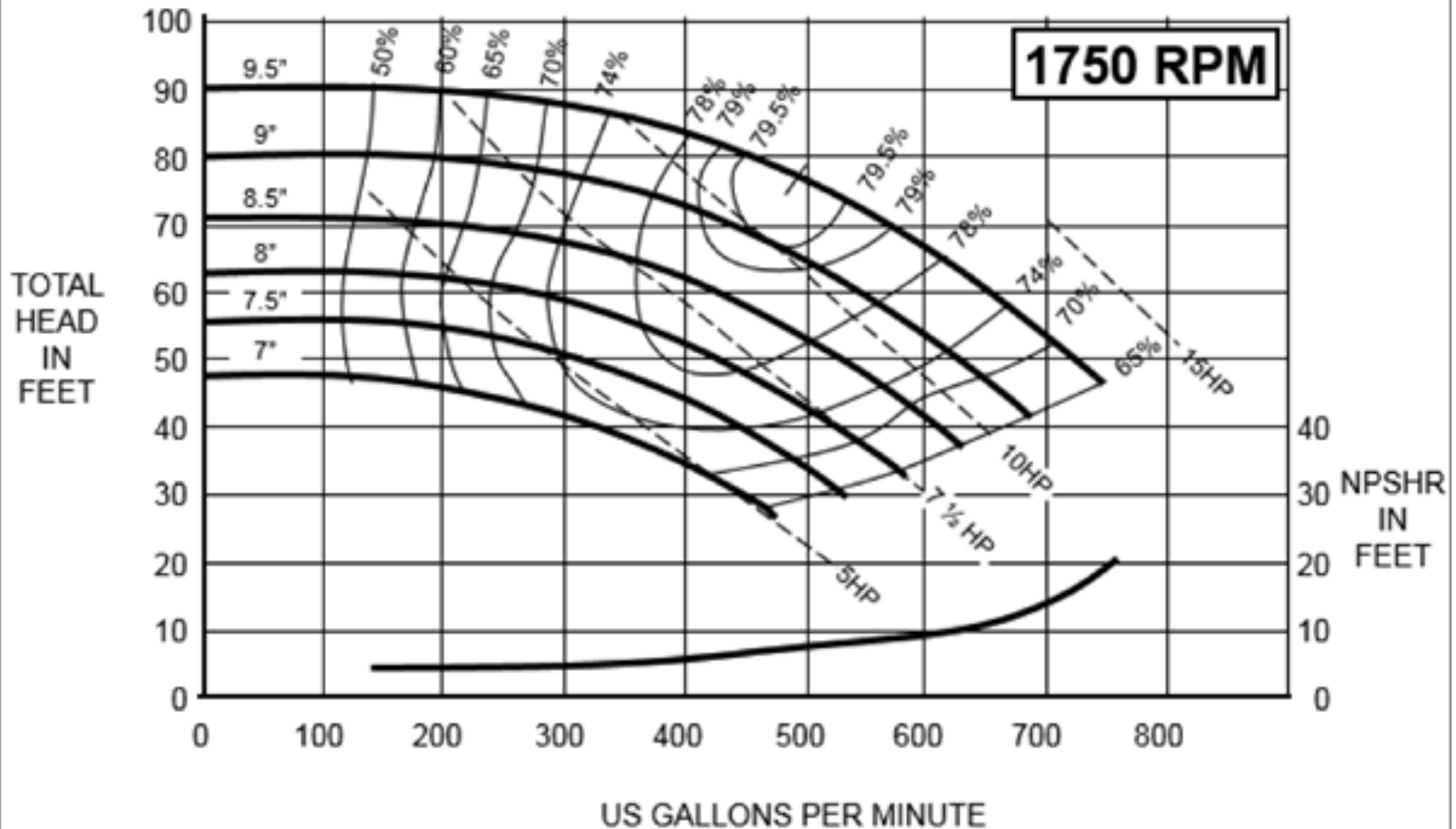
Poll question

Which system has the most frictional head?

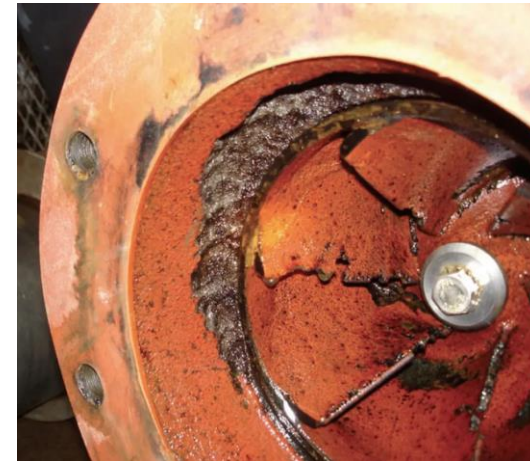
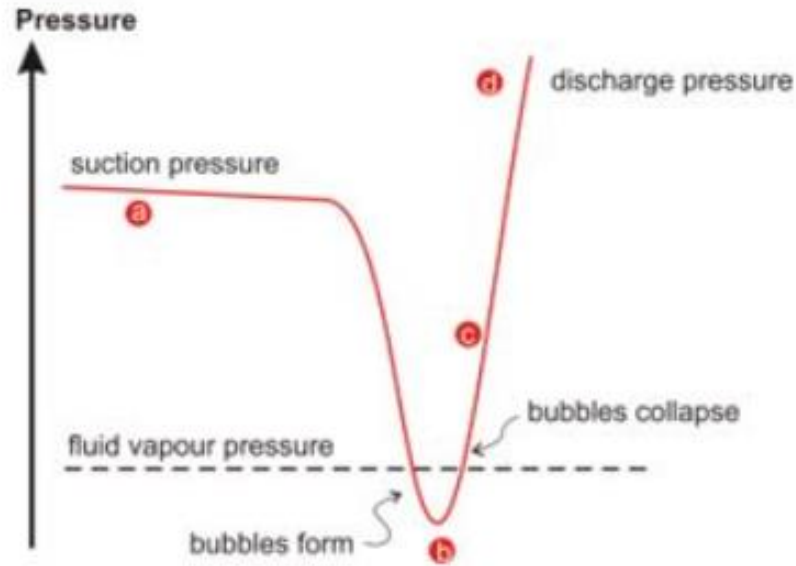
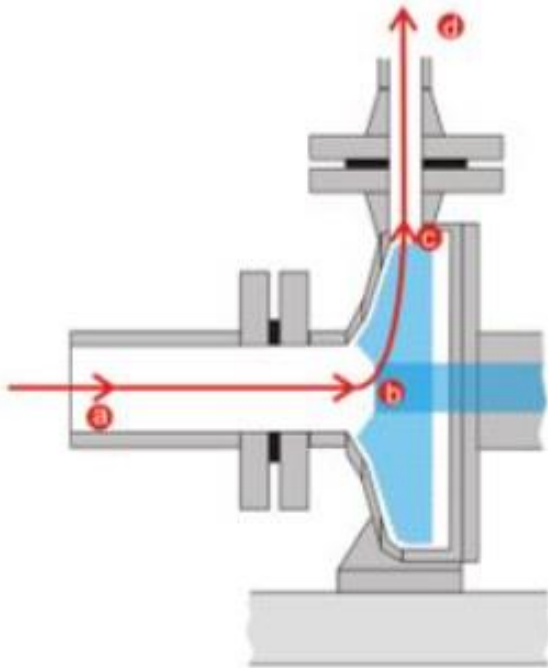


Pump performance characteristics

Typical Single Stage Pump Curve



Pump Cavitation – Boil water within the pump



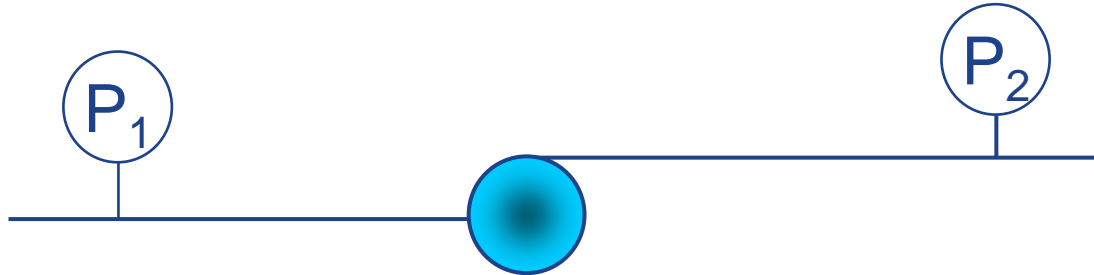
NPSHR and NPSHA

- NPSHA stands for Net Positive Suction AVAILABLE and NPSHR stands for Net Positive Suction Head REQUIRED.
- What is the difference between NPSHA and NPSHR? Well, firstly NPSH is a measure of the pressure experienced by the fluid at the suction of the pump. This is always quoted in feet rather than as a pressure because head is a fluid independent property.
- NPSHA (available) is a property of the system and is calculated by the system designer giving a value of the pressure on the suction side of the pump.
- NPSHR (required) is a property of the pump. This is calculated by the manufacturer as the point where cavitation occurs. (Published curves represent a 3% reduction in pump performance.)

There are four types of performance curves that are used to characterize pumps

- Head
- Shaft power
- Efficiency
- Net positive suction head required (NPSHR)

The Bernoulli relationship is slightly modified to define the pump head



$$\frac{V_1^2}{2g} + \frac{2.31 P_1}{s.g.} + Z_1 + H_{\text{pump}} = \frac{V_2^2}{2g} + \frac{2.31 P_2}{s.g.} + Z_2$$

or

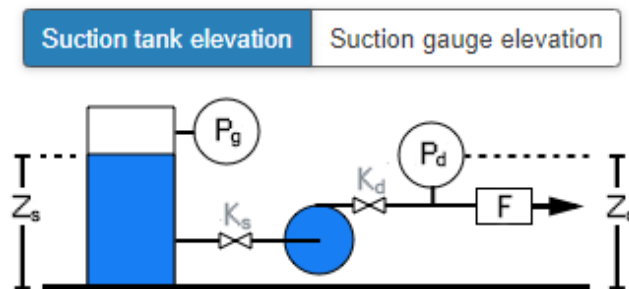
$$H_{\text{pump}} = \left(\frac{V_2^2}{2g} + \frac{2.31 P_2}{s.g.} + Z_2 \right) - \left(\frac{V_1^2}{2g} + \frac{2.31 P_1}{s.g.} + Z_1 \right)$$

H_{pump} = Pump head at a given flow rate

MEASUR Pump Head Calculator



PUMP HEAD TOOL



K_s represents all suction losses from the tank to the pump

K_d represents all discharge losses from the pump to the gauge P_d

Fluid Specific Gravity	<input type="text" value="1.002"/>
Flow Rate	<input type="text" value="3000"/> gpm
Suction	
Pipe diameter (ID)	<input type="text" value="12"/> in
Tank gas overpressure (P_g)	<input type="text" value="0"/> psi
Tank fluid surface elevation (Z_s)	<input type="text" value="10"/> ft
Line loss coefficients (K_s)	<input type="text" value="0.5"/>
Discharge	
Pipe diameter (ID)	<input type="text" value="12"/> in
Gauge pressure (P_d)	<input type="text" value="124"/> psi
Gauge elevation (Z_d)	<input type="text" value="10"/> ft
Line loss coefficients (K_d)	<input type="text" value="1"/>

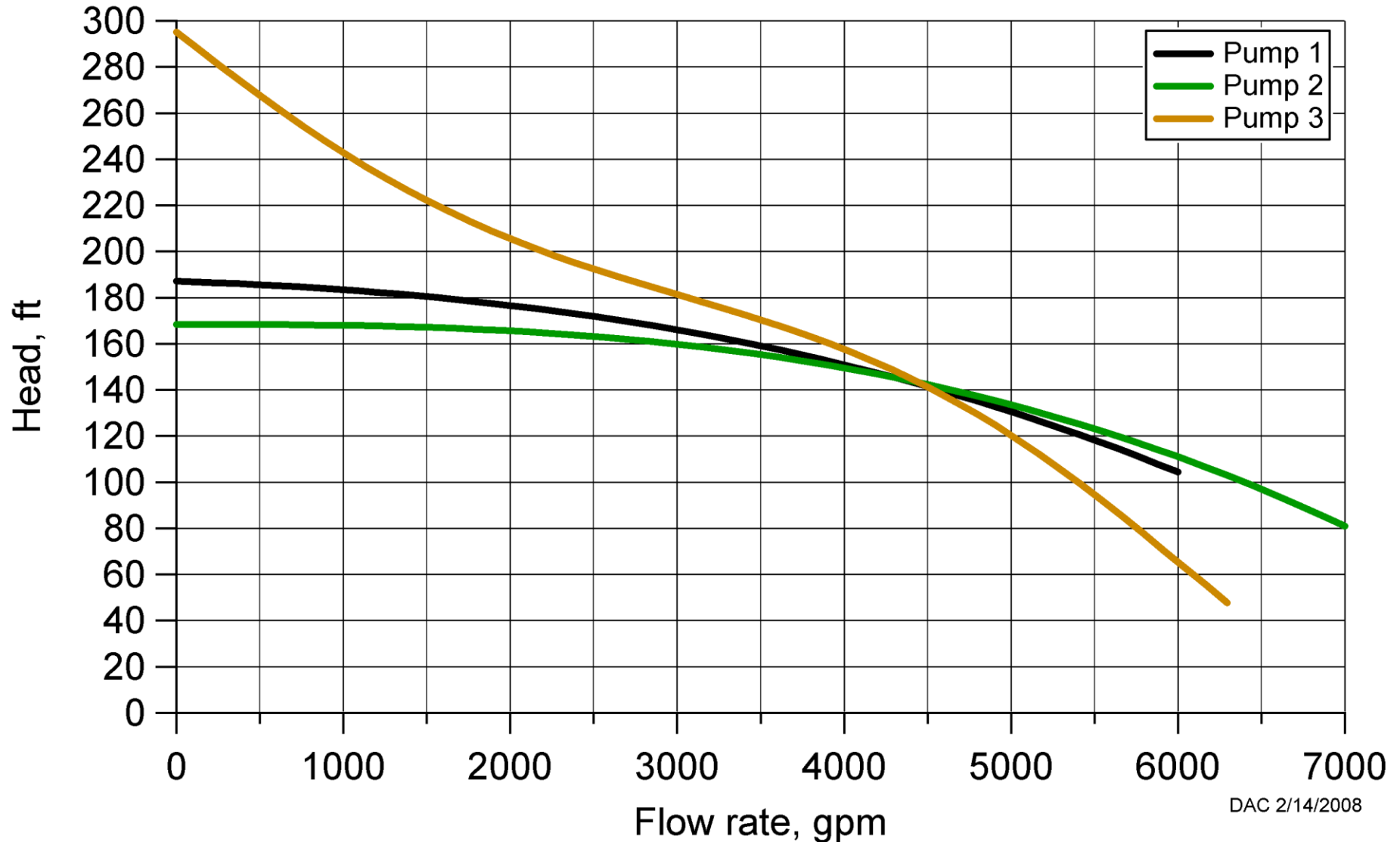
Generate Example

Reset Data

MEASUR Pump Head Calculator Results

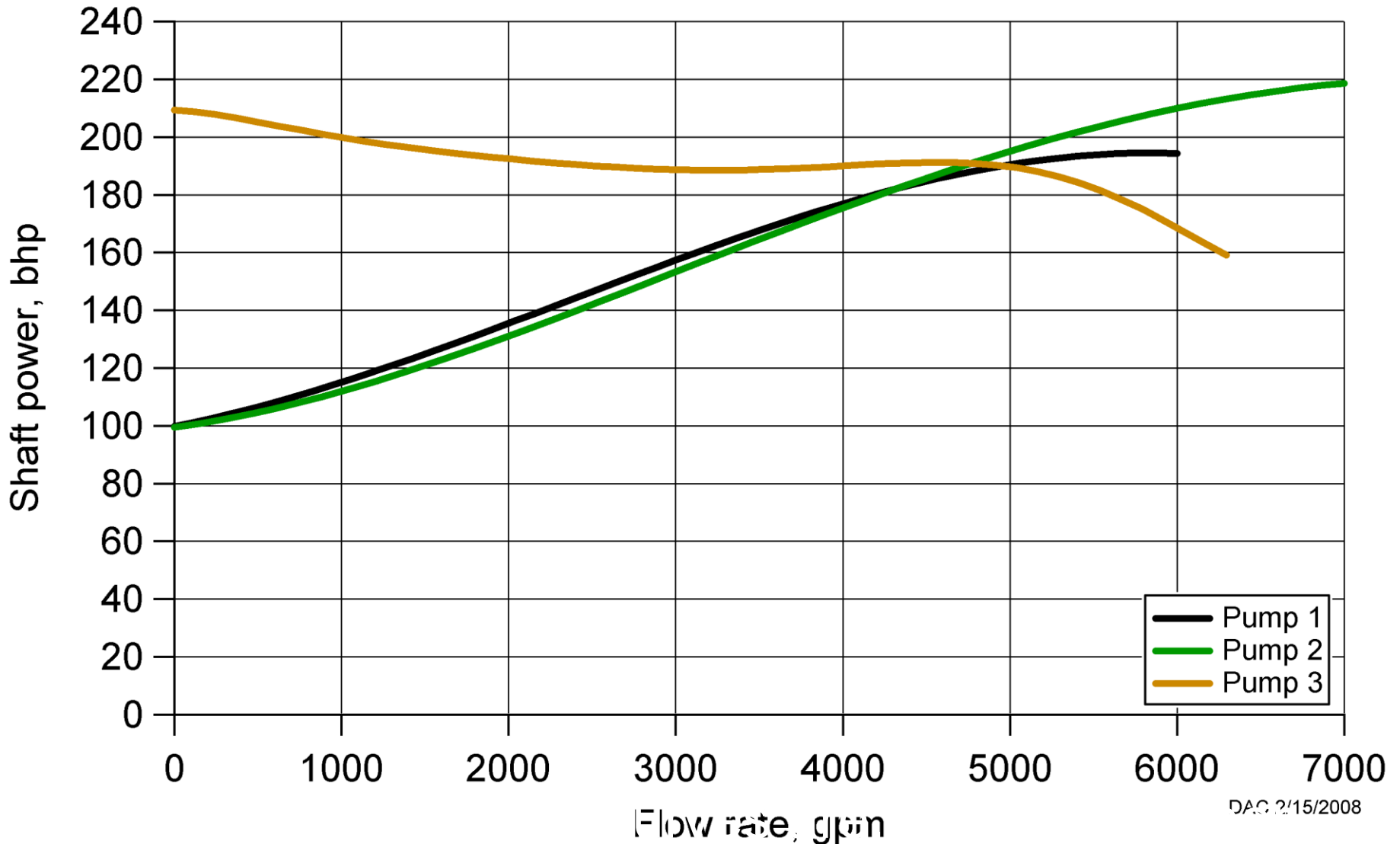
RESULTS	HELP
Result Data	
Differential Elevation Head	0.0 ft
Differential Pressure Head	285.97 ft
Differential Velocity Head	1.13 ft
Estimated Suction Friction Head	0.56 ft
Discharge Friction Head	1.13 ft
Pump Head	288.78 ft

Pump curve shapes vary: Head curves for three pump designs



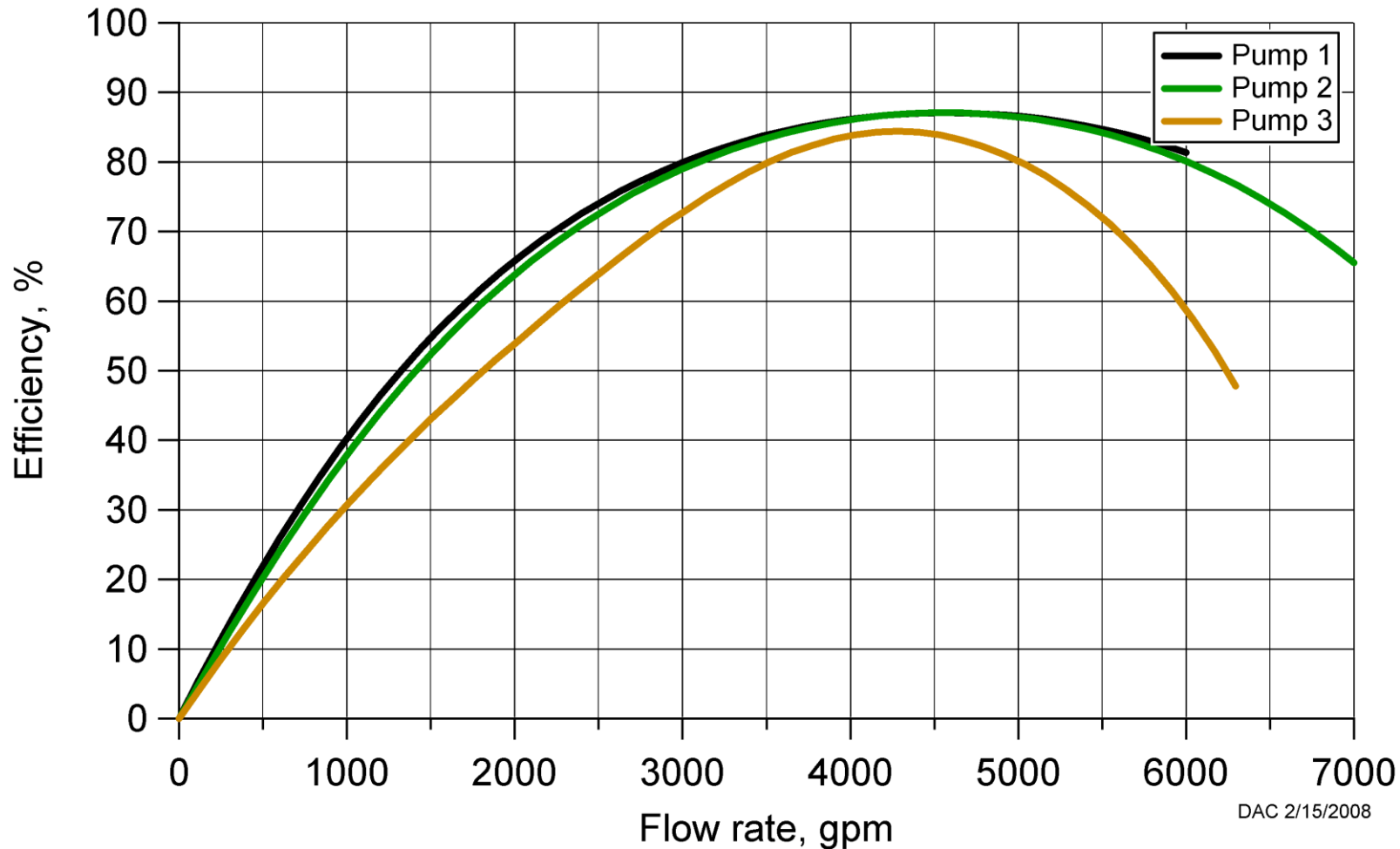
DAC 2/14/2008

Shaft power curves for the three pumps



DAG 2/15/2008

Efficiency curves for the three pumps



Pump efficiency = fluid power output / shaft power input

= $\text{gpm} \times \text{ft} \times \text{s.g.} / (39.60 \times \text{shaft hp})$ for efficiency expressed in %

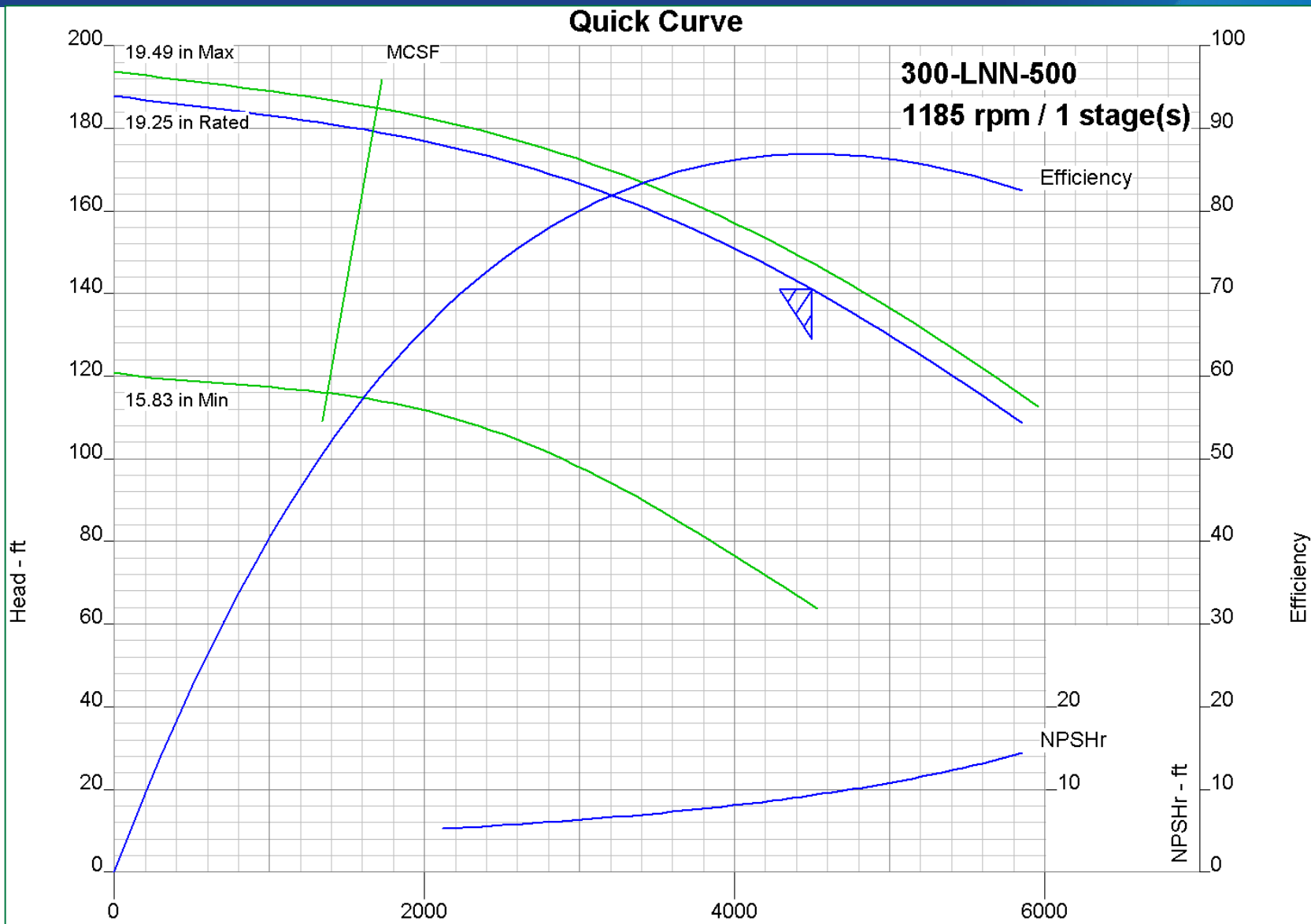
Pump manufacturers provide performance curves in a variety of ways

(Following examples are from pump mfr. performance curve software programs or electronic curves)

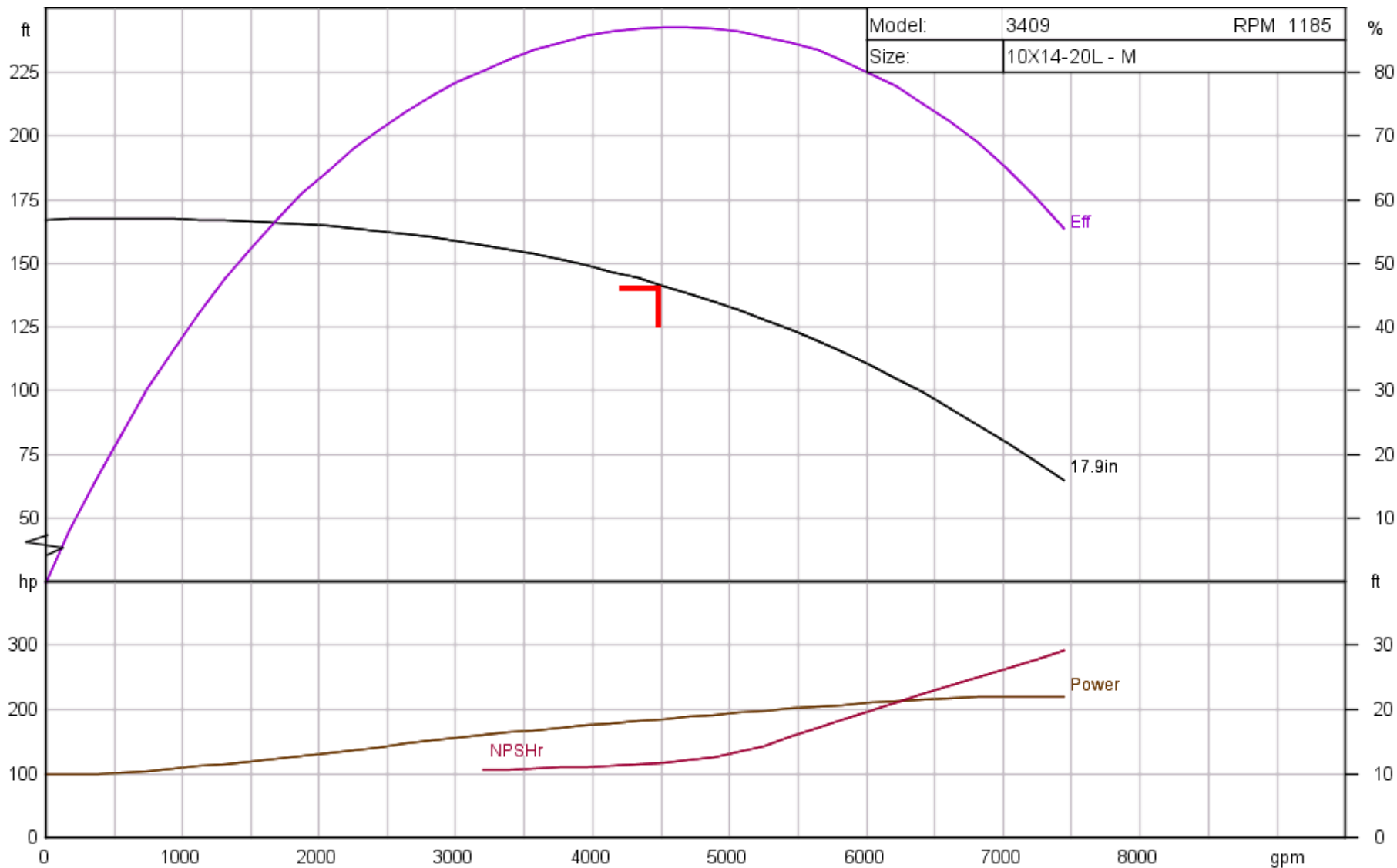
References:

1. Flowserve Pros+ SE, v 3.3.1, www.flowserve.com
2. Goulds Pump Selection System, www.gouldspumps.com/pss.html
3. Grundfos WinCAPS, v. 7.80.16, www.grundfos.com/web/homeus.nsf
4. Floway, www.weirclearliquid.com/
5. Flygt FLYPS, v. 3.1, <http://www.flygt.com/>

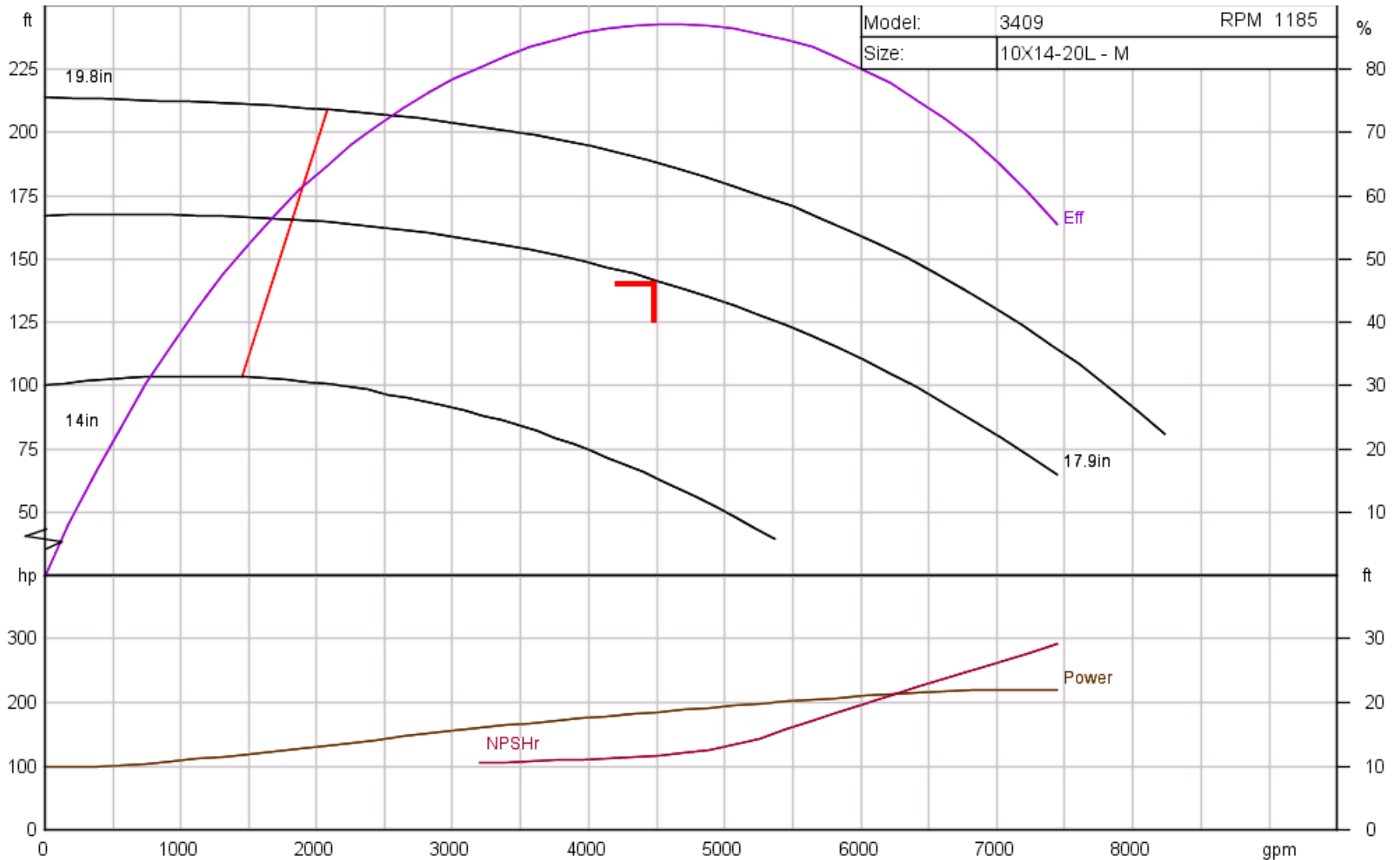
Pump 1 line curves plus min/max impeller size head curves



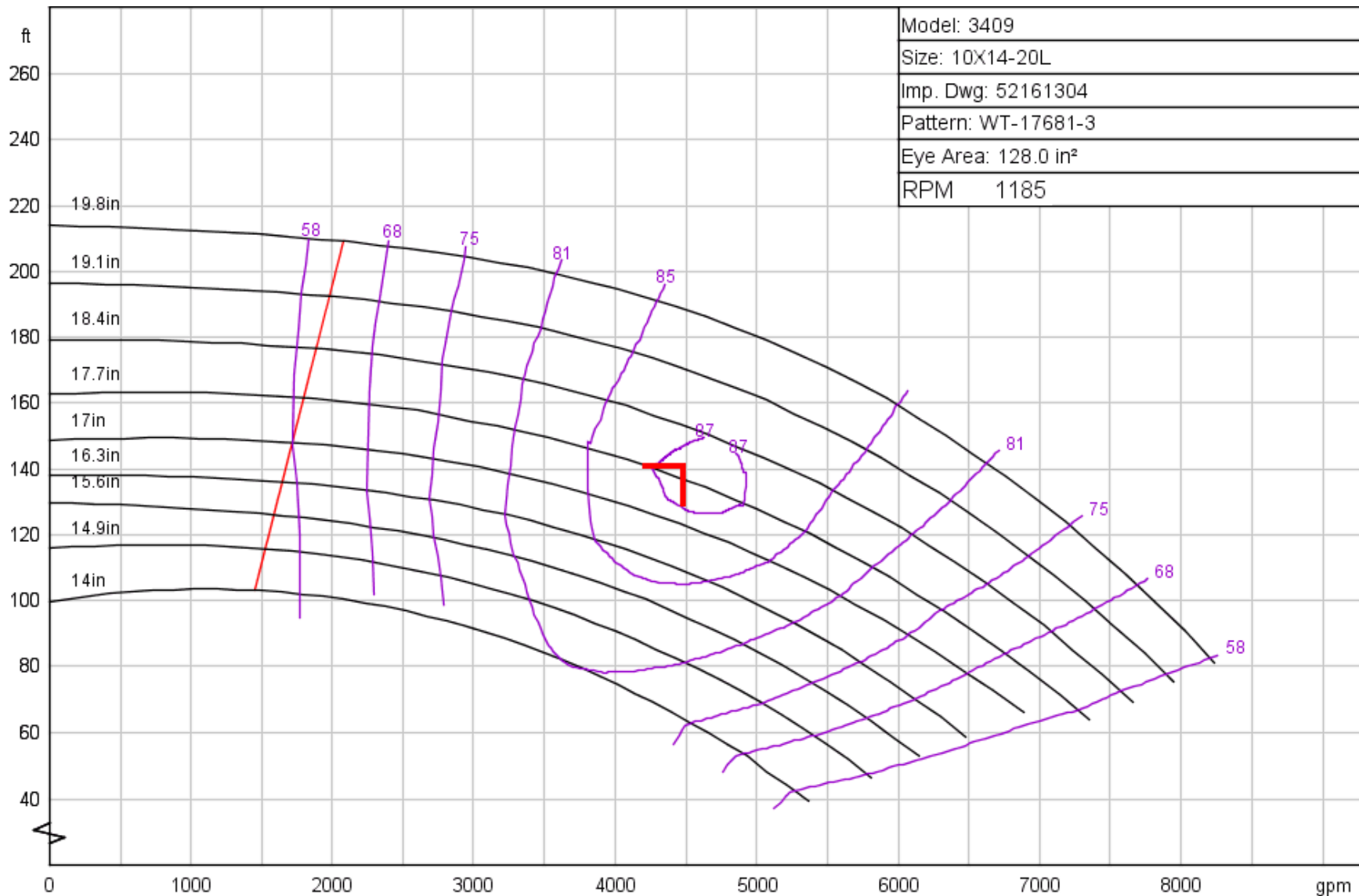
Pump 2 line curves for head, efficiency, shaft power, NPSHR



Pump 2 line curves + head curve for max/min impeller diameters

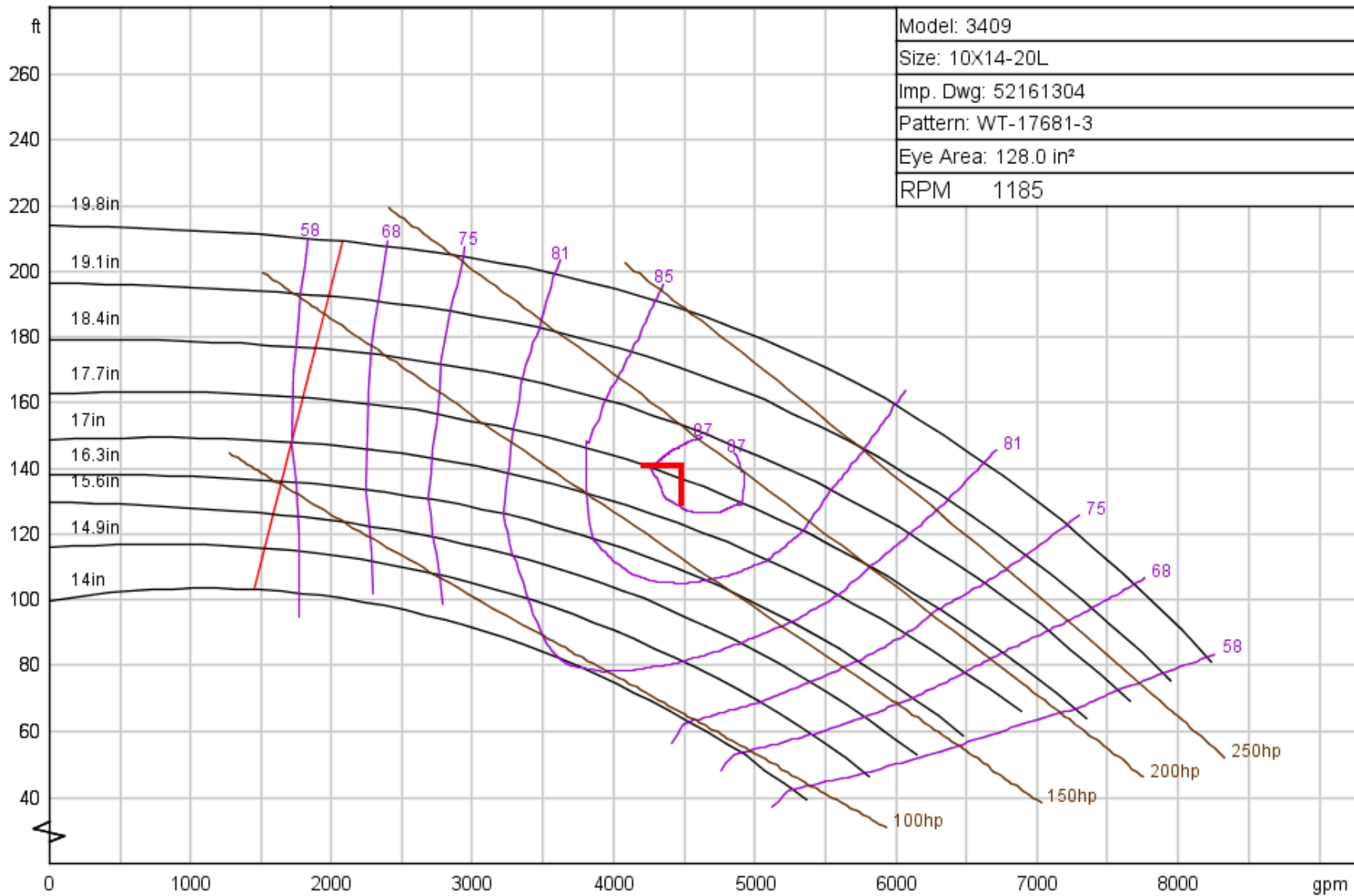


Pump 2 range of impeller sizes, isoefficiency lines

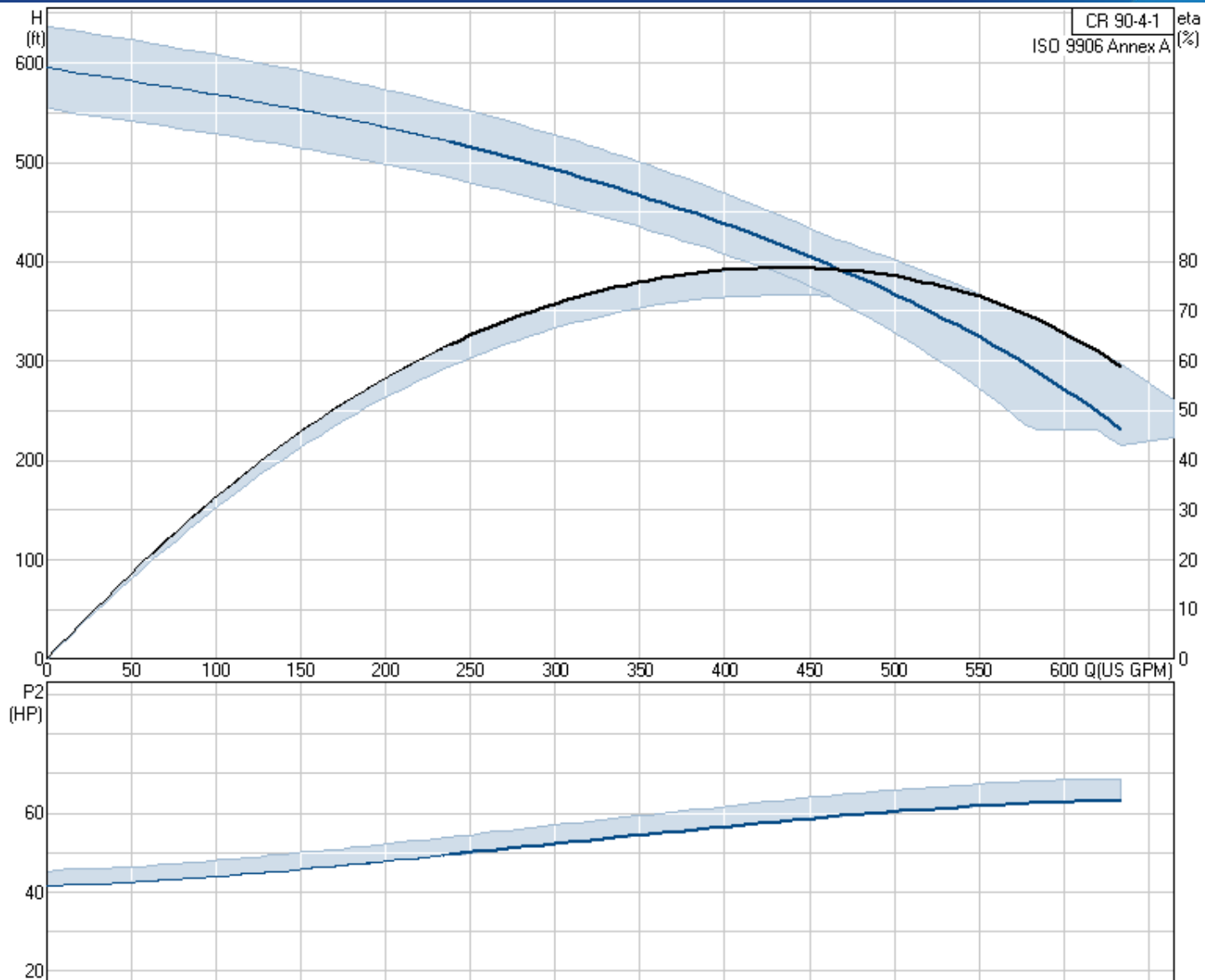


Model: 3409
Size: 10X14-20L
Imp. Dwg: 52161304
Pattern: WT-17681-3
Eye Area: 128.0 in ²
RPM 1185

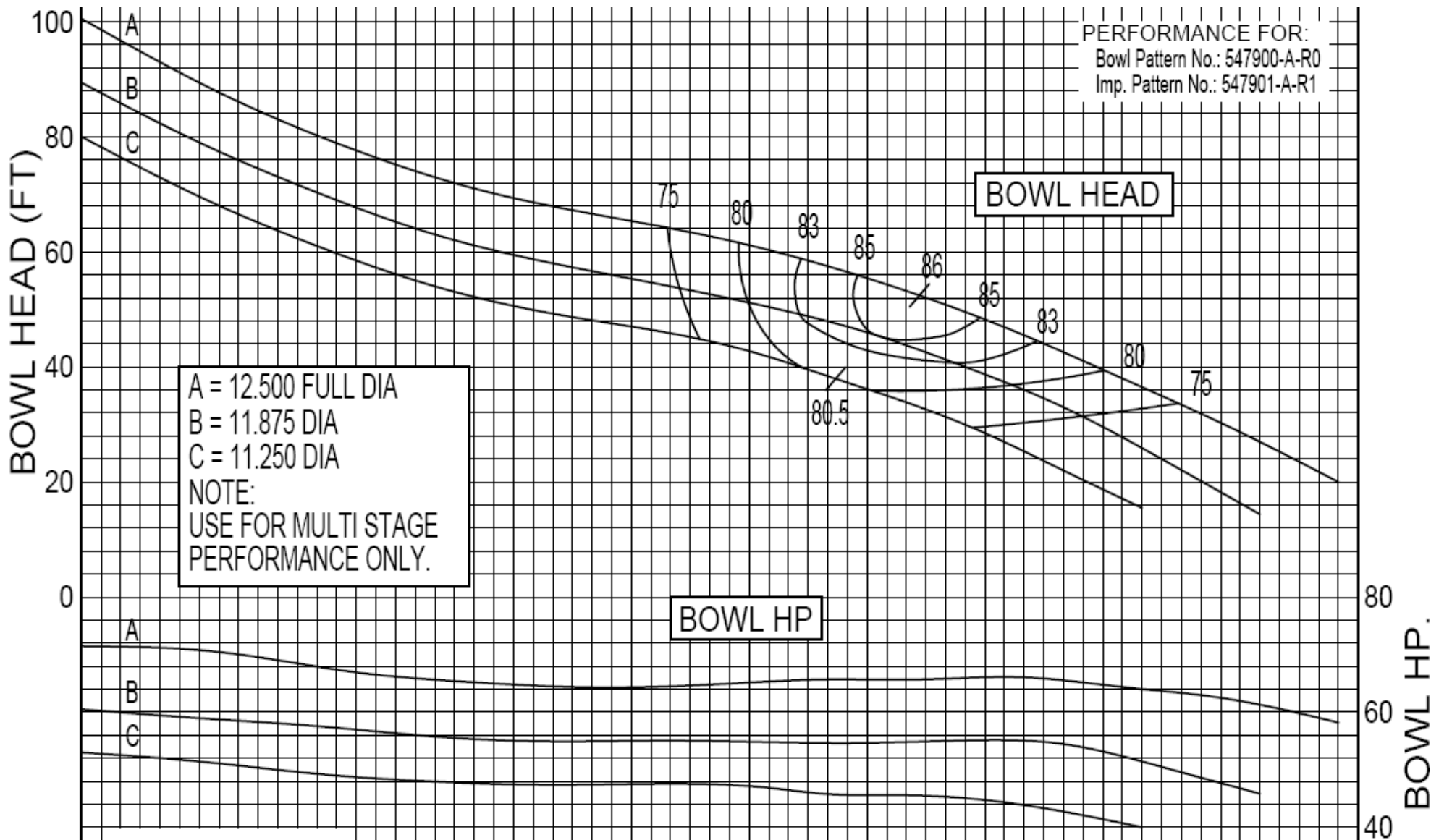
Same as previous slide + shaft power curves



Curves with ISO tolerance bands



Vertical turbine pump catalog curves are commonly provided in individual stage (bowl) performance format

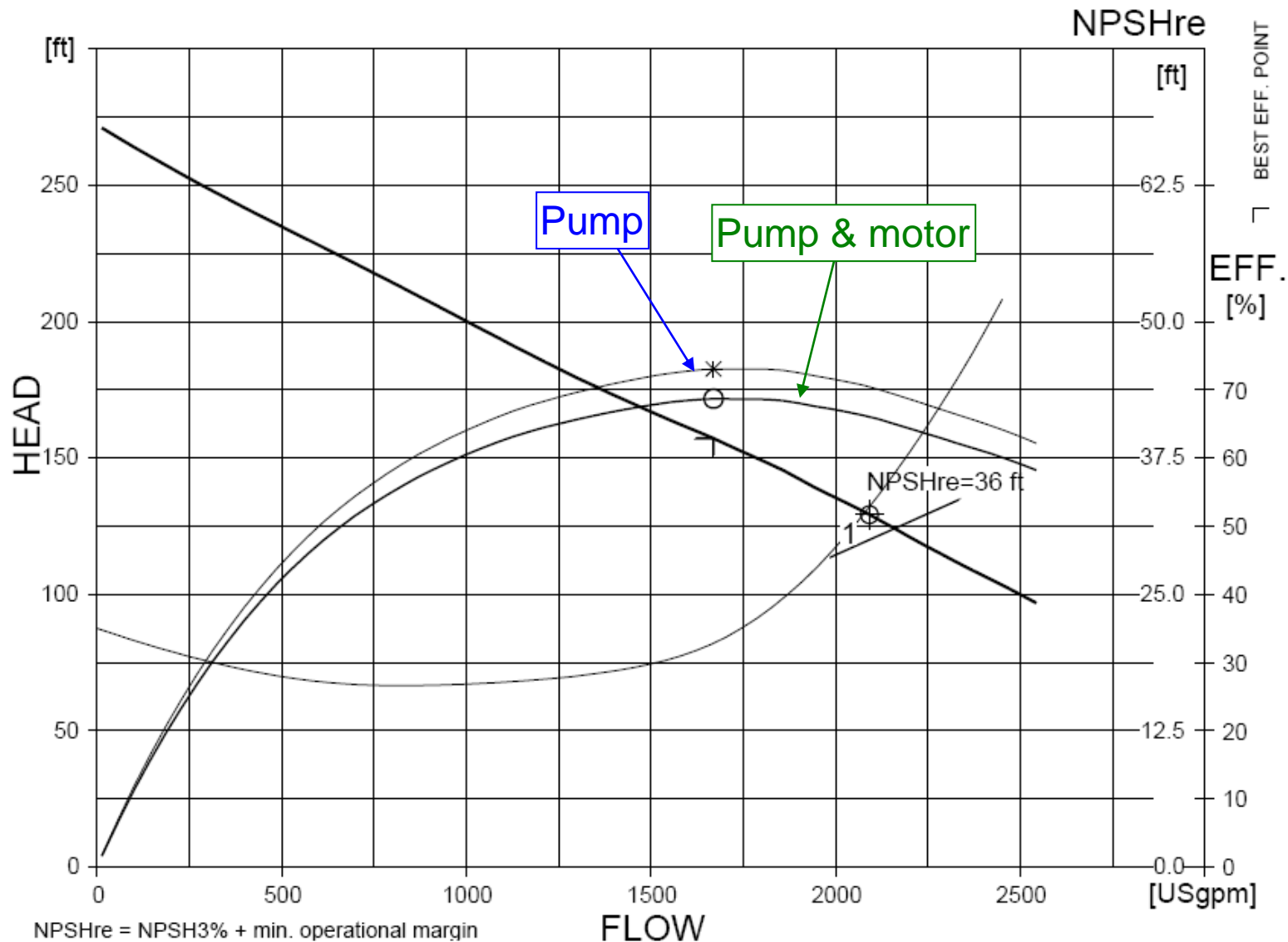


Vertical Turbine Pump

Vertical turbine pumps are commonly used in all types of applications, from moving process water in industrial plants to providing flow for cooling towers at power plants, from pumping raw water for irrigation, to boosting water pressure in municipal pumping systems, and for many other pumping applications.



Submersible pump and combined pump & motor (sometimes called wire-to-water) efficiency curves



NPSHre = NPSH3% + min. operational margin
 Performance with clear water and ambient temp 40 °C

Break

Pump affinity laws and parallel or series pump operation

Pump affinity laws can be used to predict pump curves for different speeds and impeller diameters

Speed

$$\left(\frac{Q_1}{Q_2} \right) = \left(\frac{N_1}{N_2} \right)^1$$

$$\left(\frac{H_1}{H_2} \right) = \left(\frac{N_1}{N_2} \right)^2$$

$$\left(\frac{P_1}{P_2} \right) = \left(\frac{N_1}{N_2} \right)^3$$

$$\left(\frac{\eta_1}{\eta_2} \right) = \left(\frac{N_1}{N_2} \right)^0$$

Q = flow rate
N = speed

H = head
D = diameter

Diameter

$$\left(\frac{Q_1}{Q_2} \right) = \left(\frac{D_1}{D_2} \right)^1$$

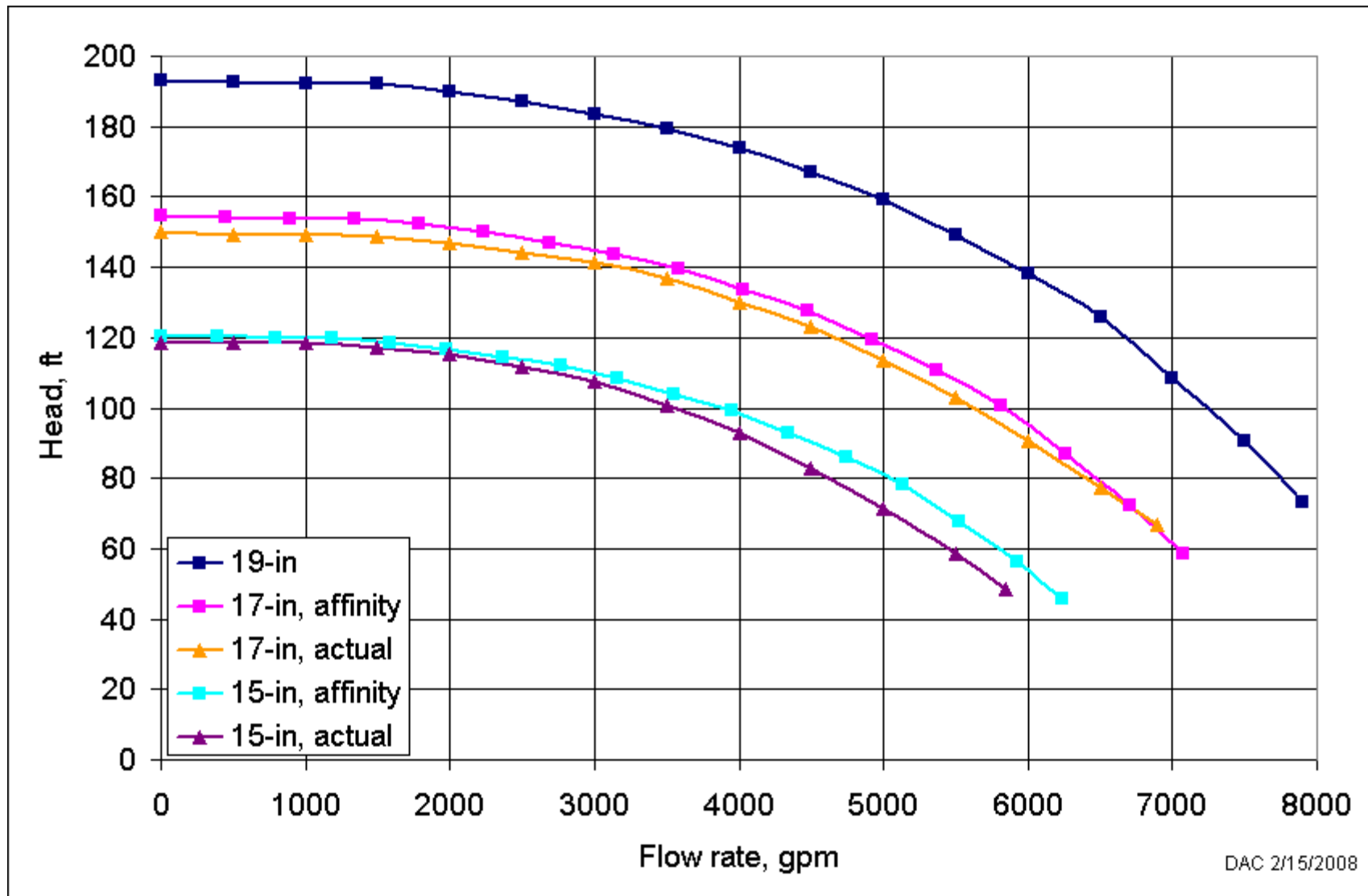
$$\left(\frac{H_1}{H_2} \right) = \left(\frac{D_1}{D_2} \right)^2$$

$$\left(\frac{P_1}{P_2} \right) = \left(\frac{D_1}{D_2} \right)^3$$

$$\left(\frac{\eta_1}{\eta_2} \right) = \left(\frac{D_1}{D_2} \right)^0$$

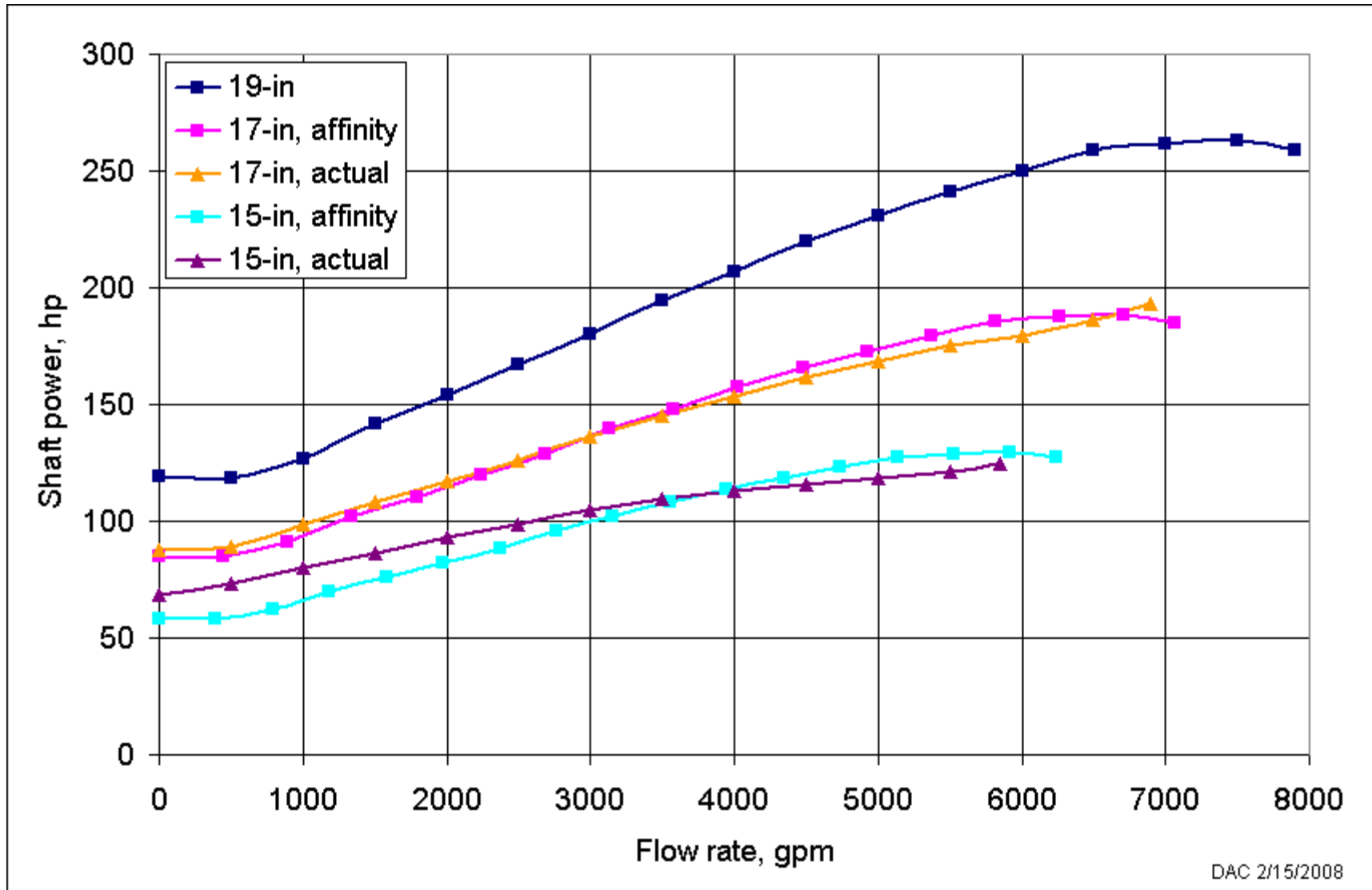
P = power
 η = efficiency

The affinity laws aren't perfect for diameter changes: head curves



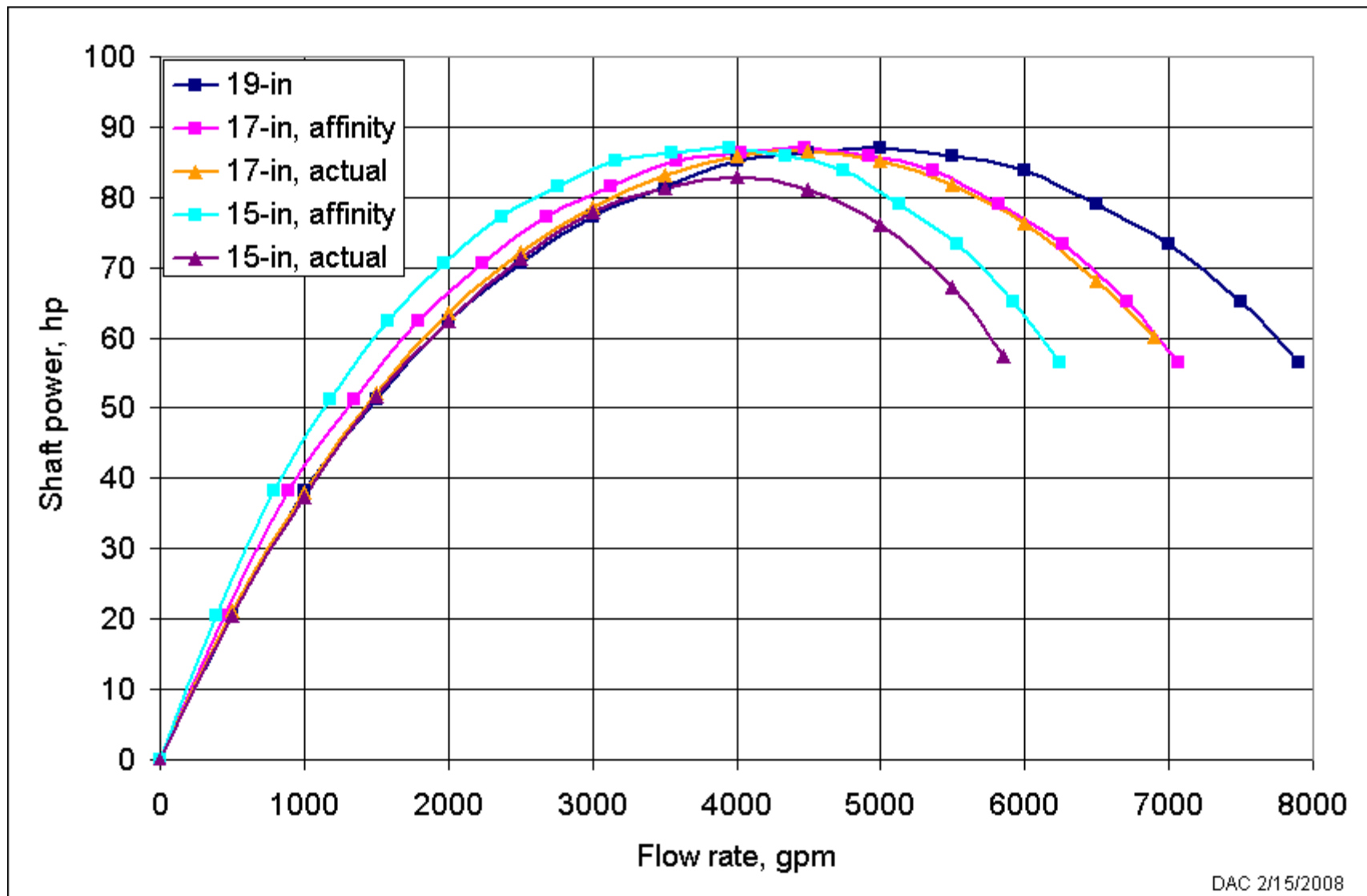
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The affinity laws aren't perfect for diameter changes: power curves



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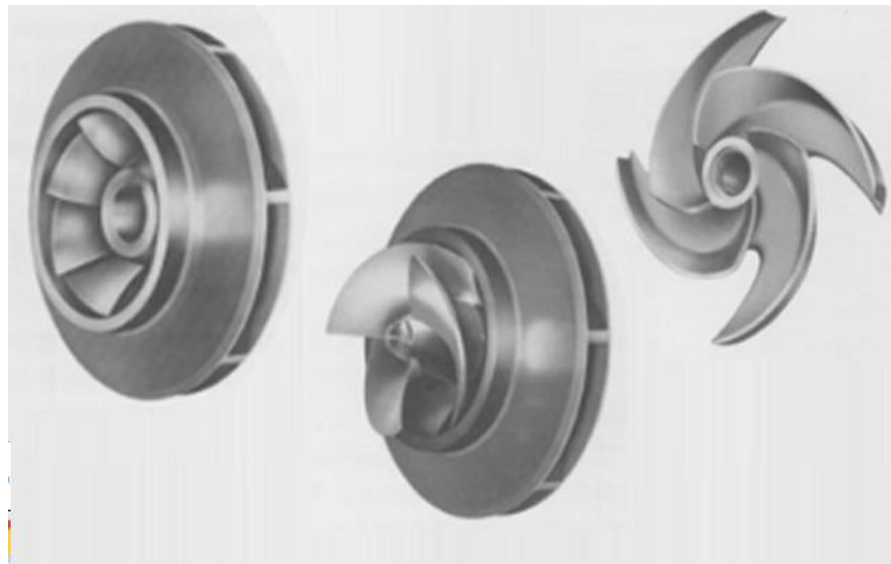
The affinity laws aren't perfect for diameter changes: efficiency curves



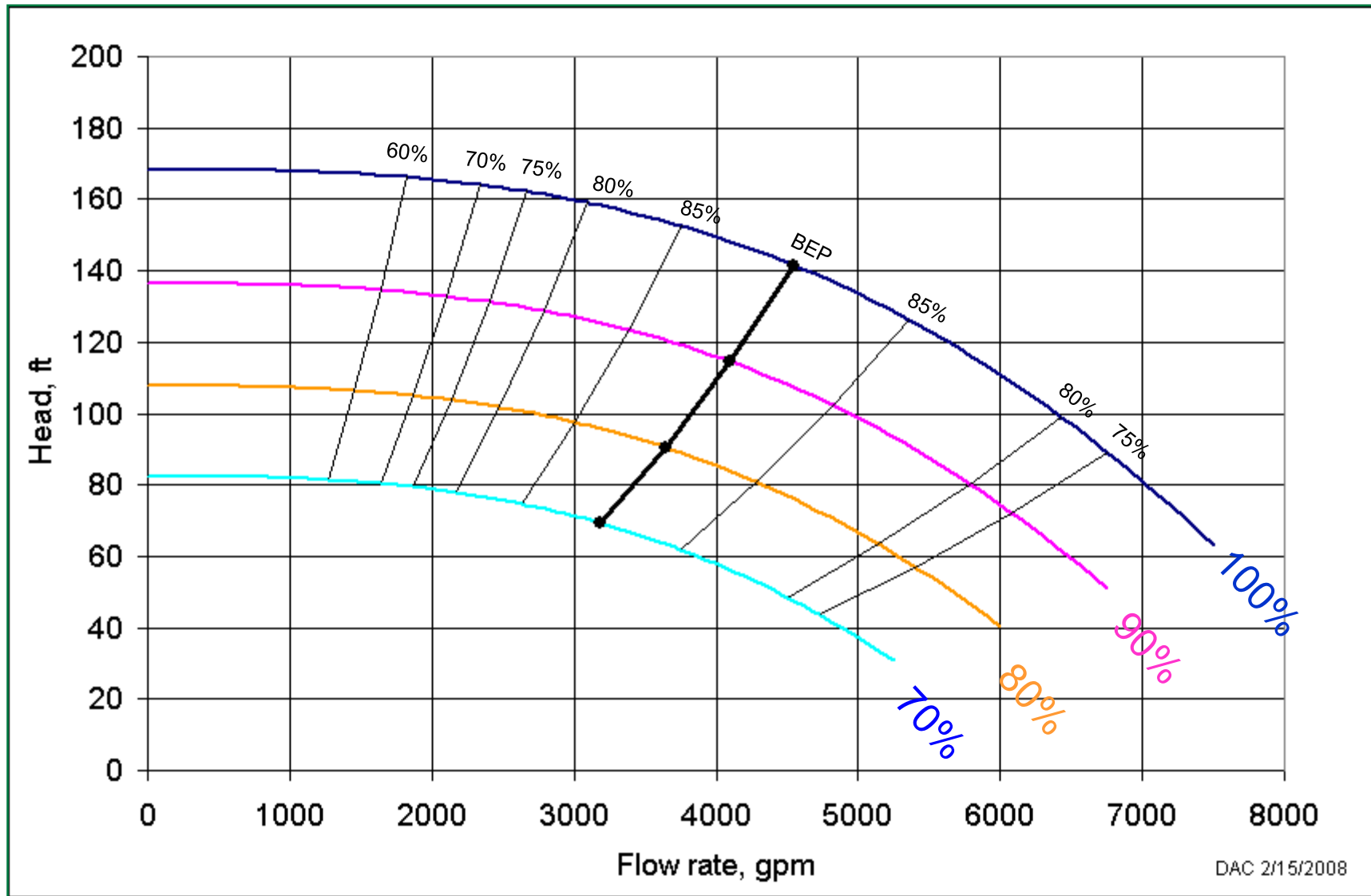
Considering a trim in impeller diameter?

Recommendations:

1. Get actual performance curves from the manufacturer, especially if the trim change being considered is large
2. Do a field performance test of the existing pump



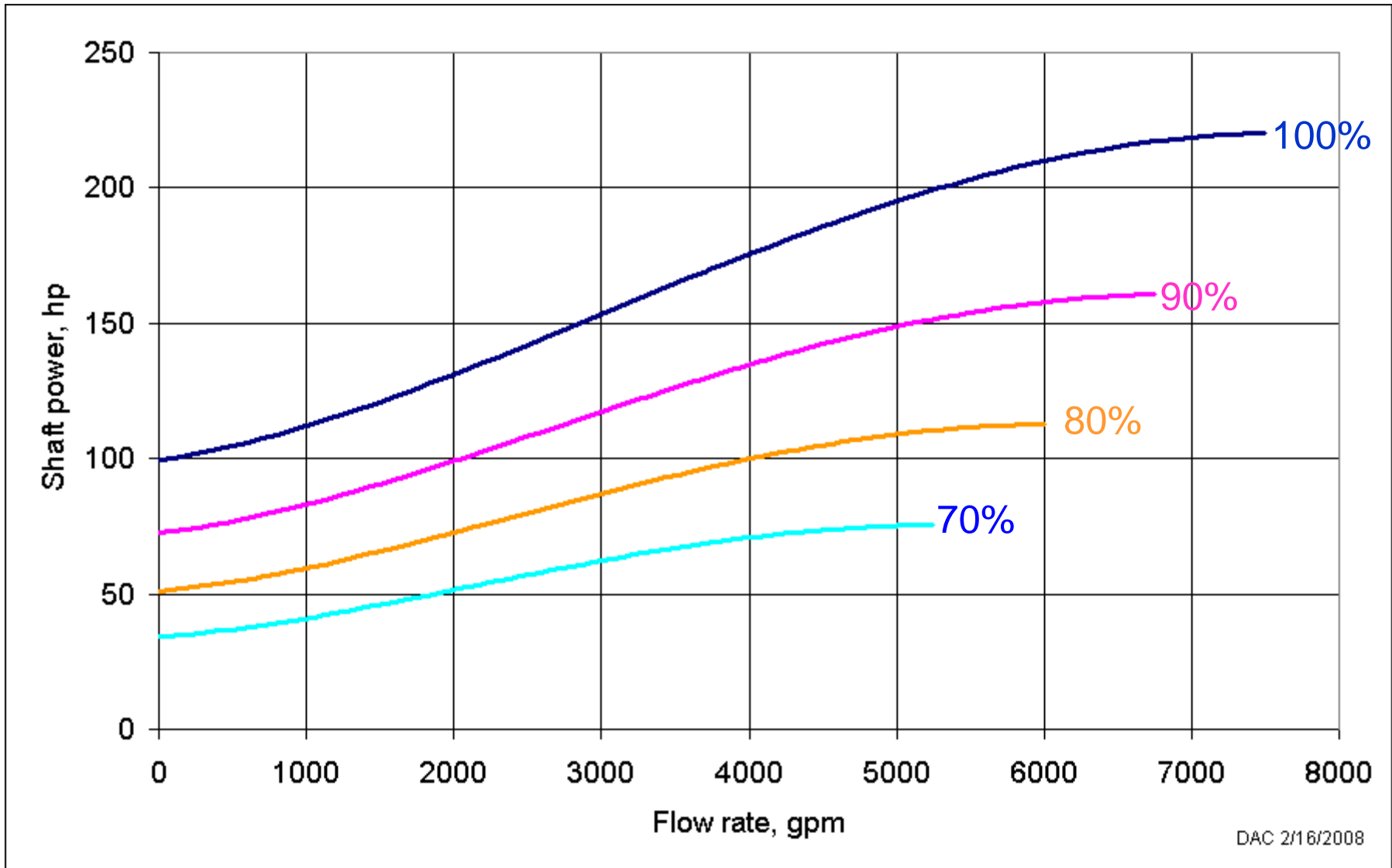
But the affinity laws generally hold up very well with speed changes



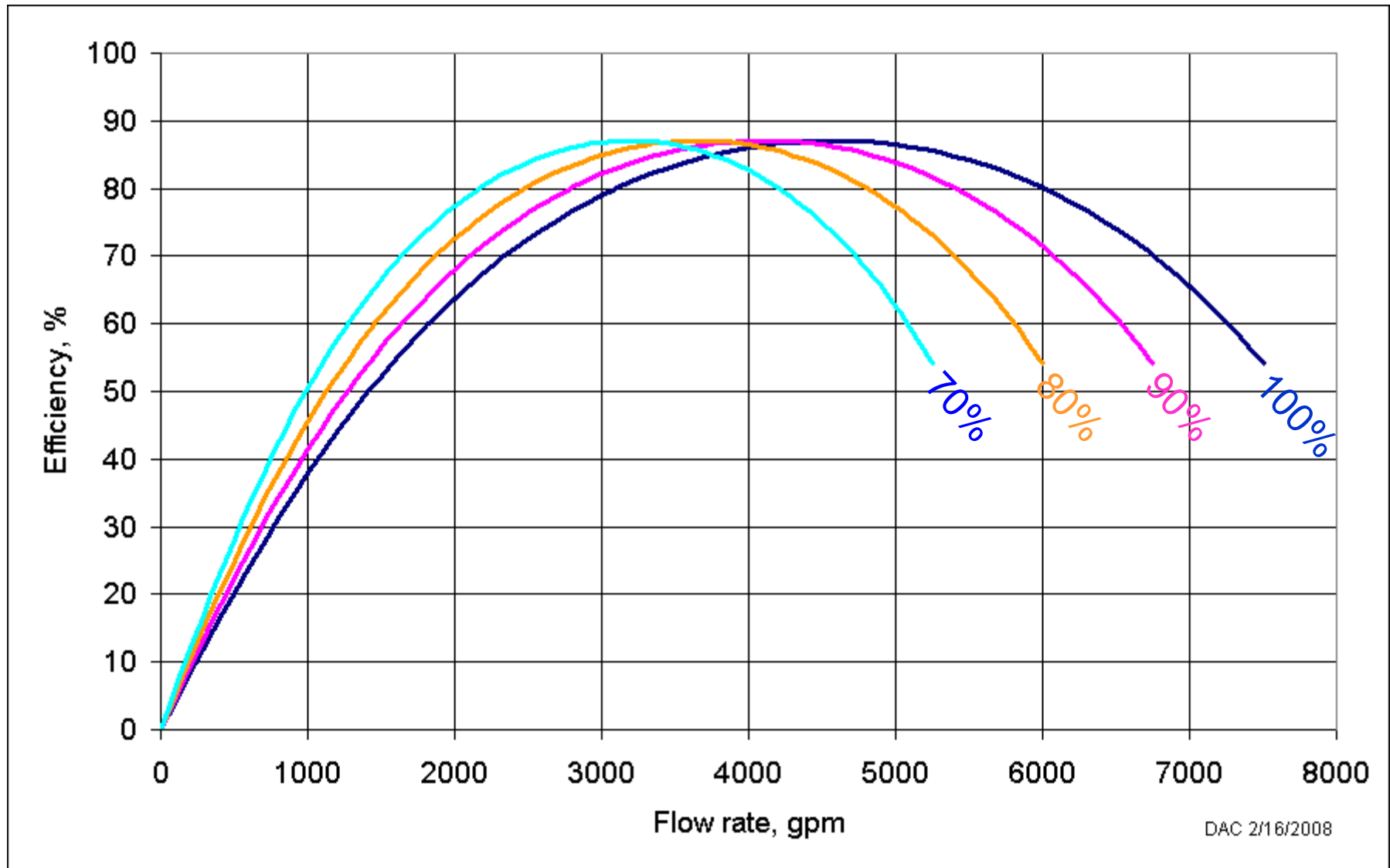
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Note: same pump as previous slides, impeller size = 17.9 inches

Shaft power curves at four speeds



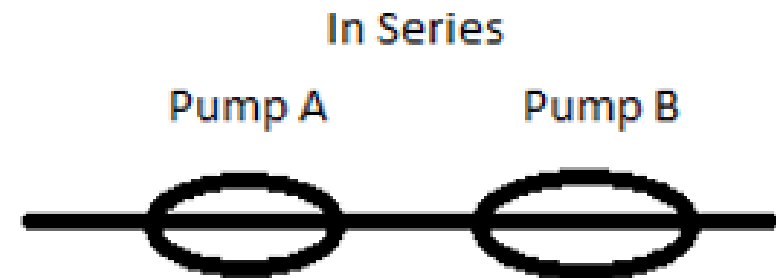
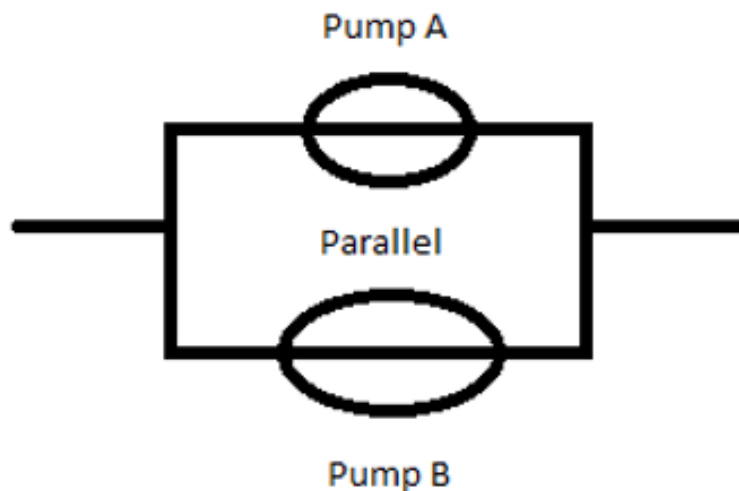
Efficiency curves at four speeds



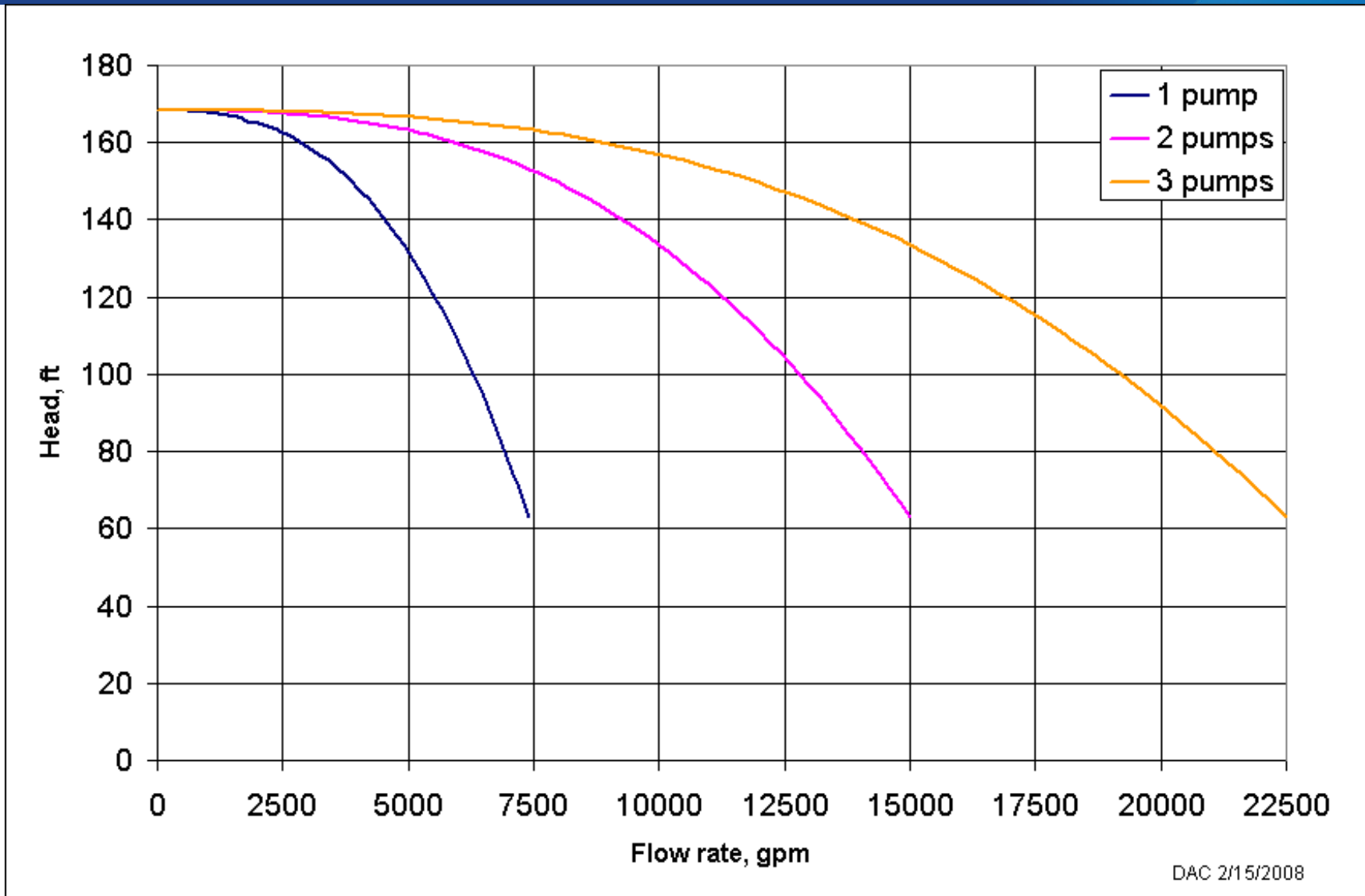
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Parallel and series pumping “laws”, like the pump affinity laws apply to the pump curves only

- Parallel pumps - sum the flow rates at a given head
- Series pumps - sum the heads at a given flow rate

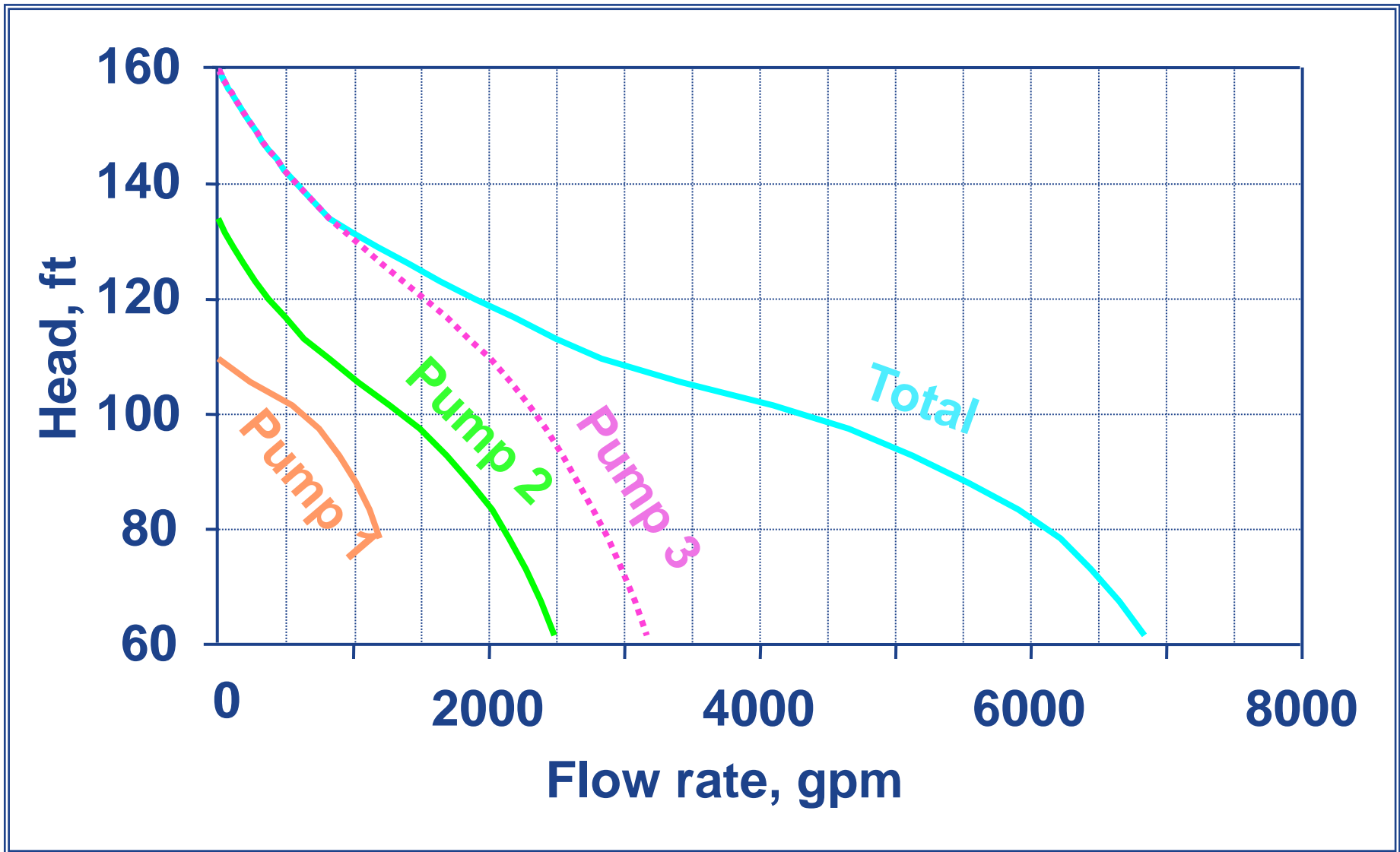


Parallel pumps can help adapt to changing system requirements and provide redundancy



DAC 2/15/2008

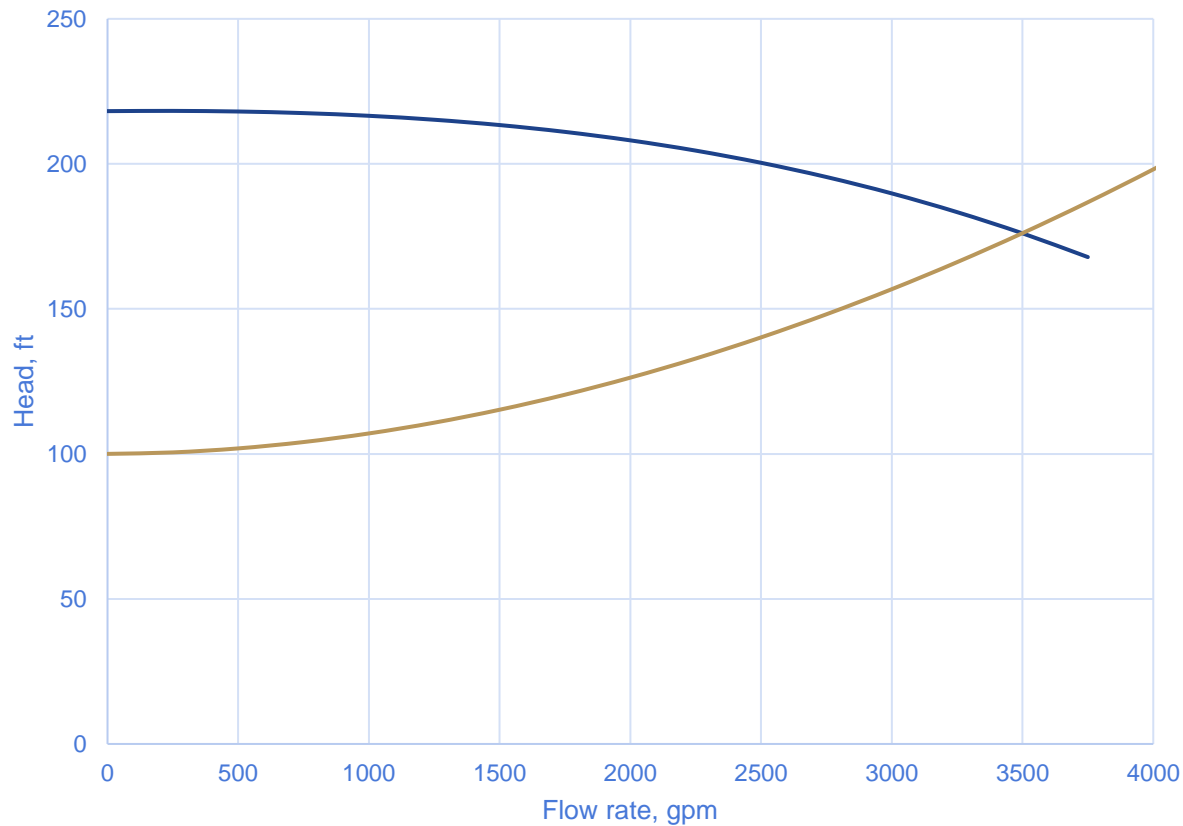
Unlike pumps can also be used in parallel, but with caution



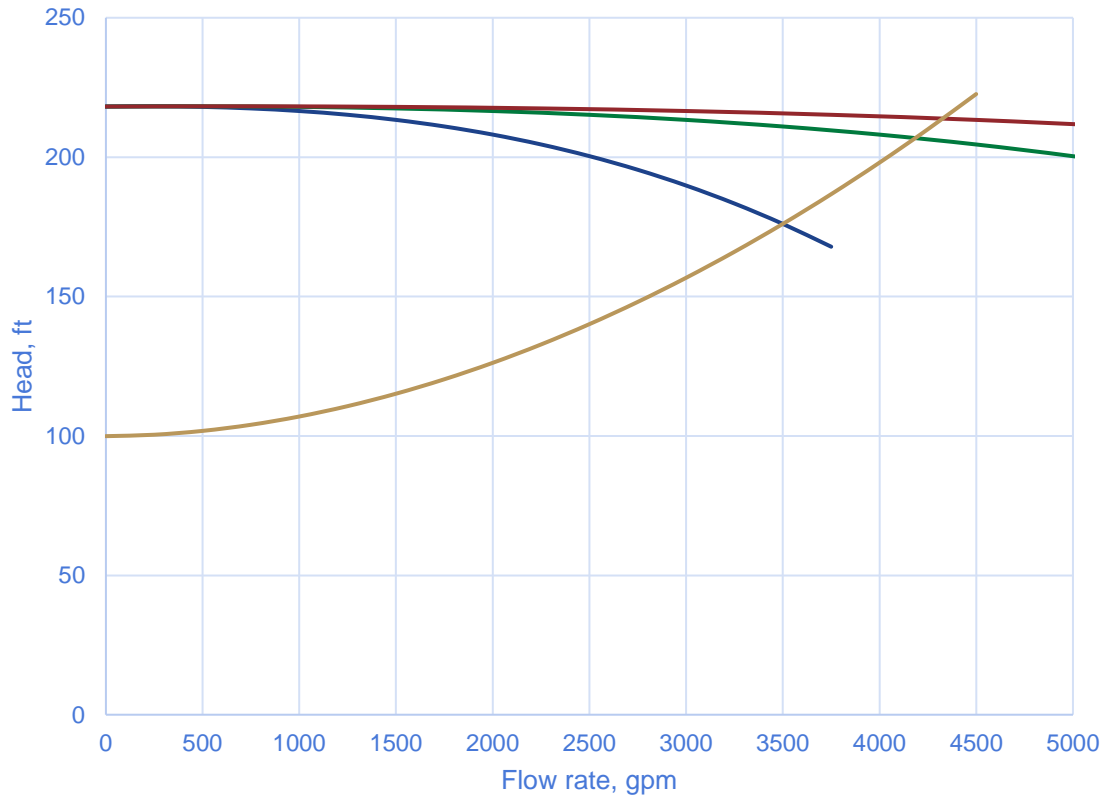
Poll question

What increase in flow would you expect from adding an additional parallel pump?

- A. 100%
- B. 80%
- C. 60%
- D. 40%
- E. 20%

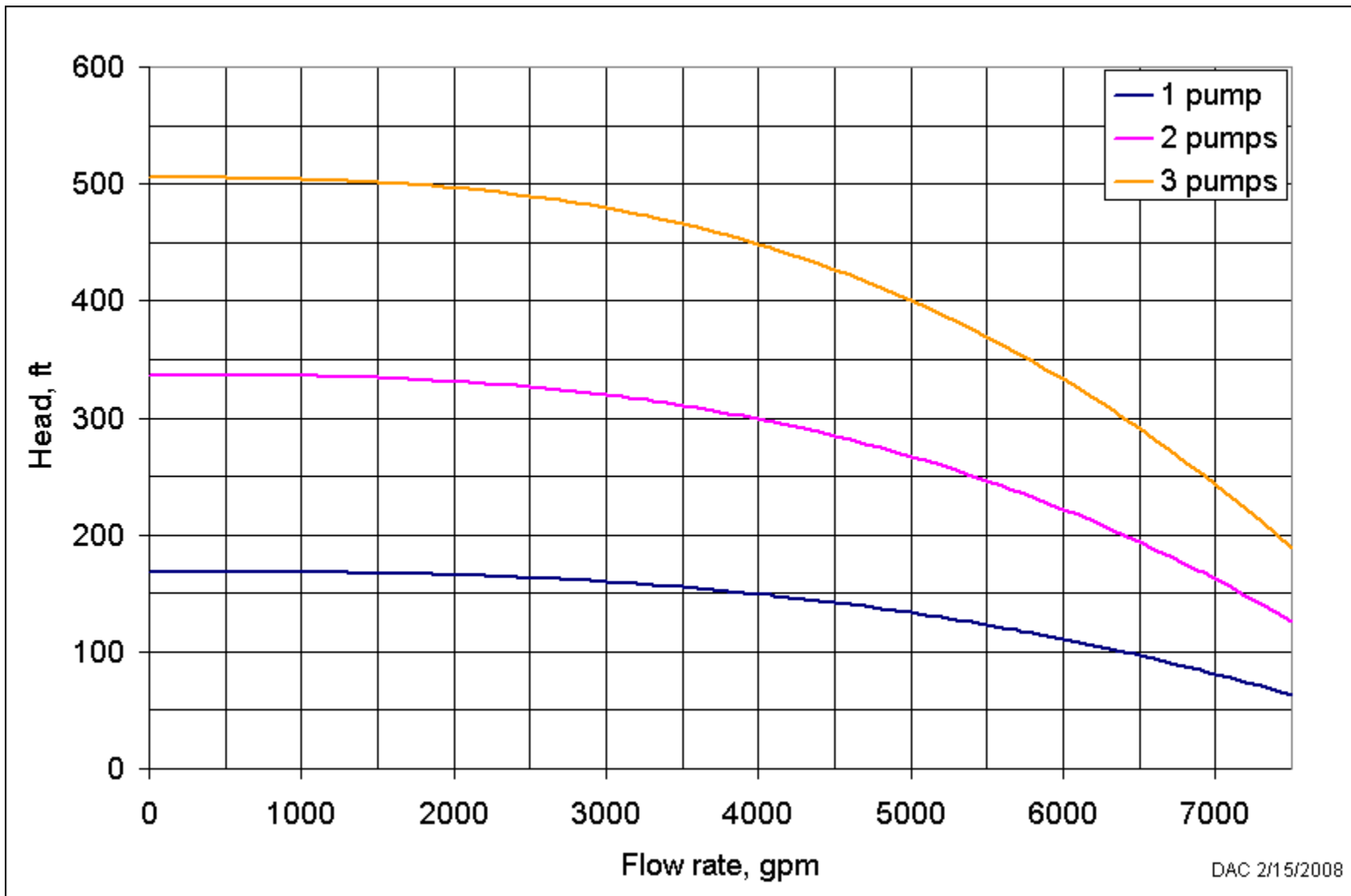


More pumps does not necessarily mean much more flow

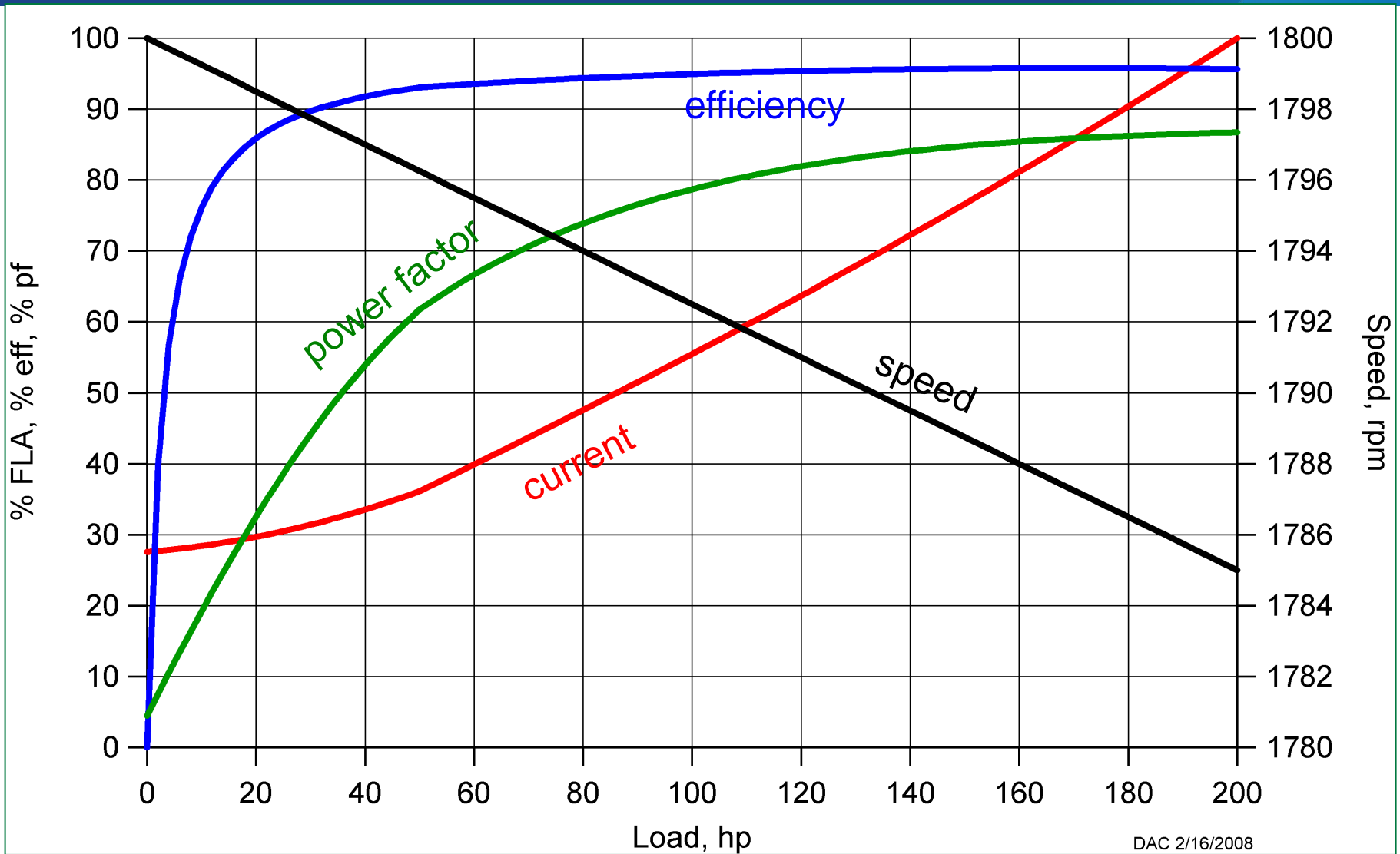


Pumps operating	Flow rate, gpm	Head, ft	% increase in flow
1	3500	176.1	0
2	4185	206.8	19.6%
3	4325	213.8	23.6%

Identical pumps in series; add head at a given flow rate to estimate overall performance

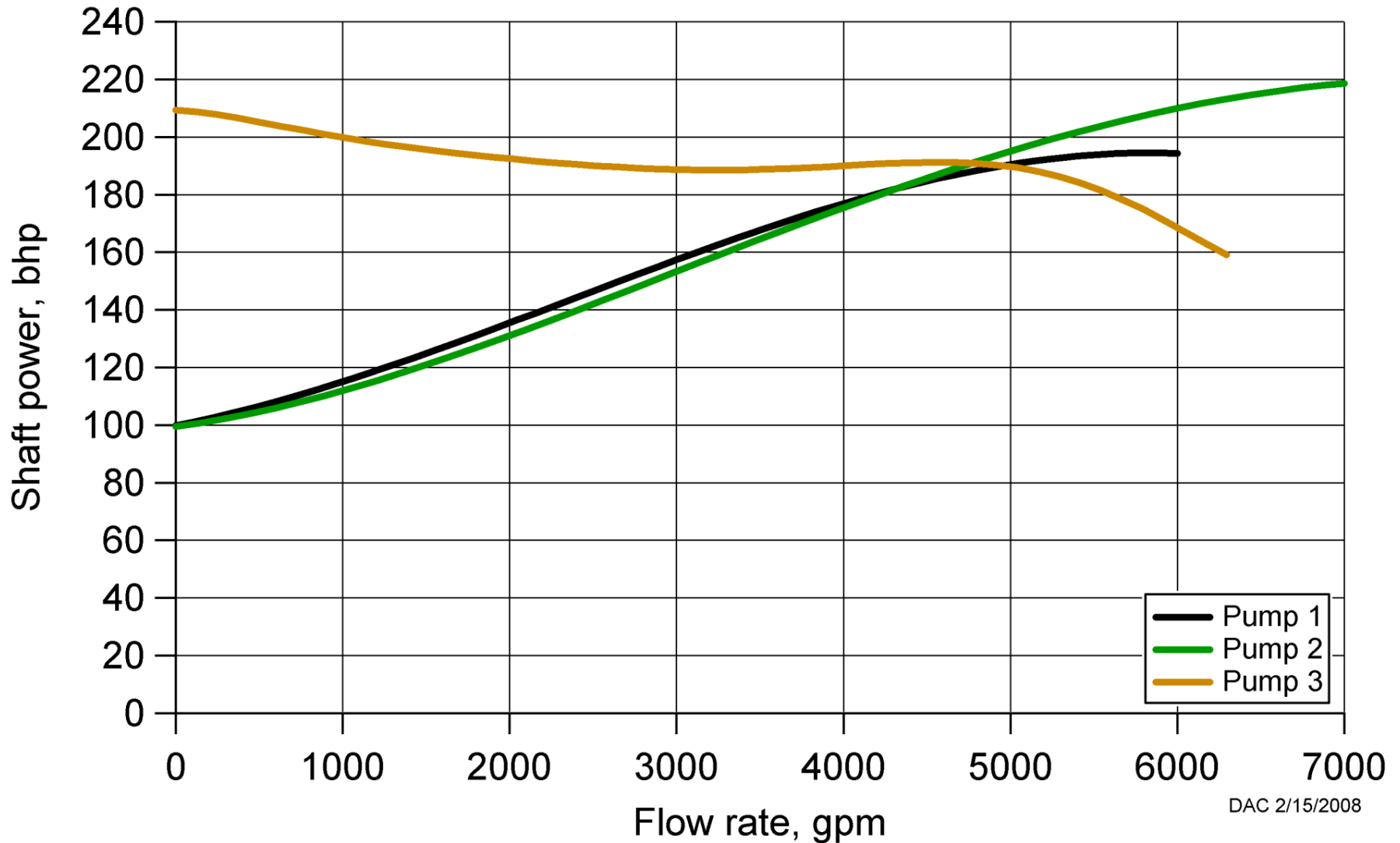


Typical motor performance characteristics (200 hp energy-efficient, 4-pole)



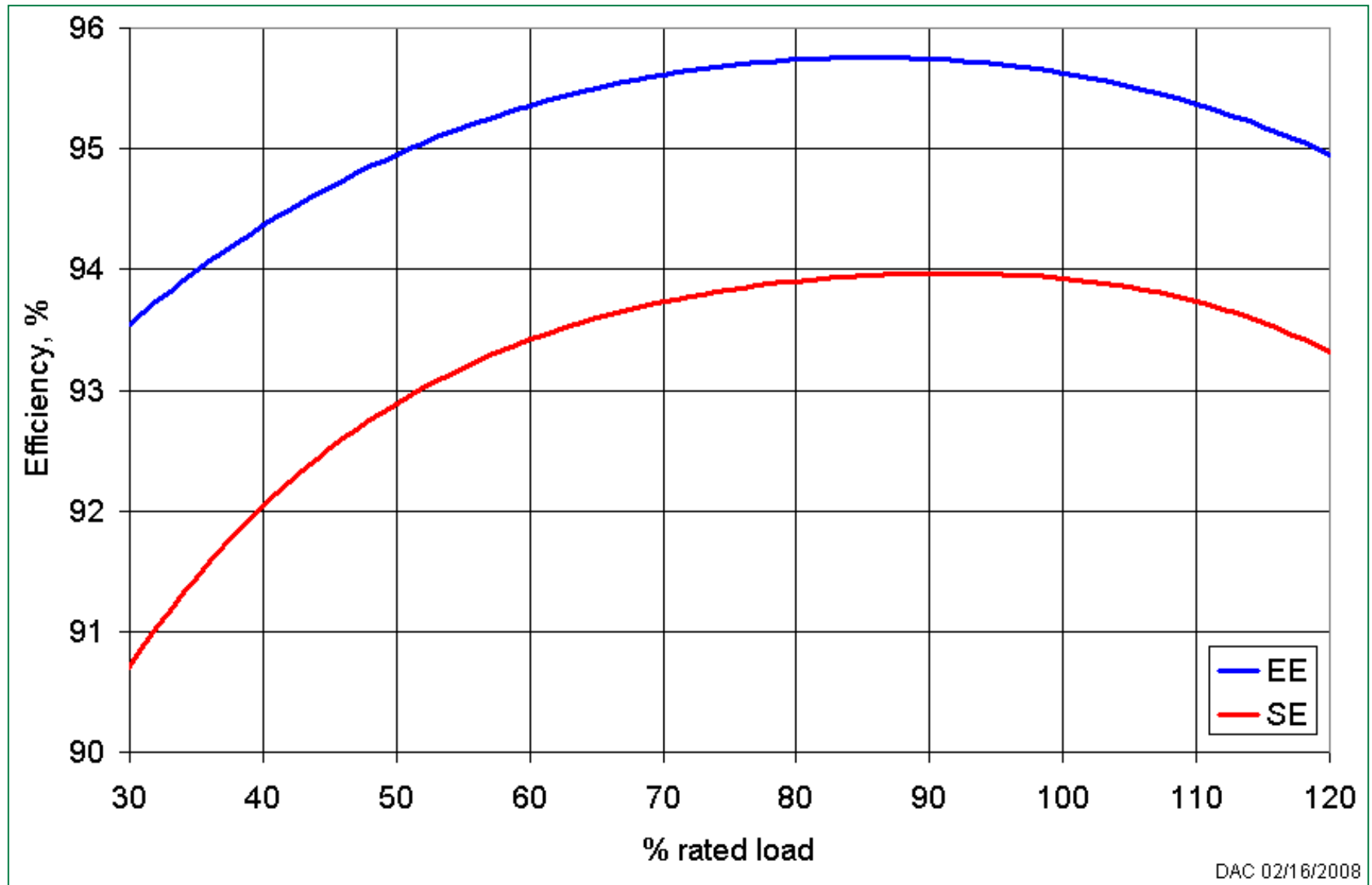
DAC 2/16/2008

First, let's review what kind of load the pump puts on the motor (at rated speed conditions)

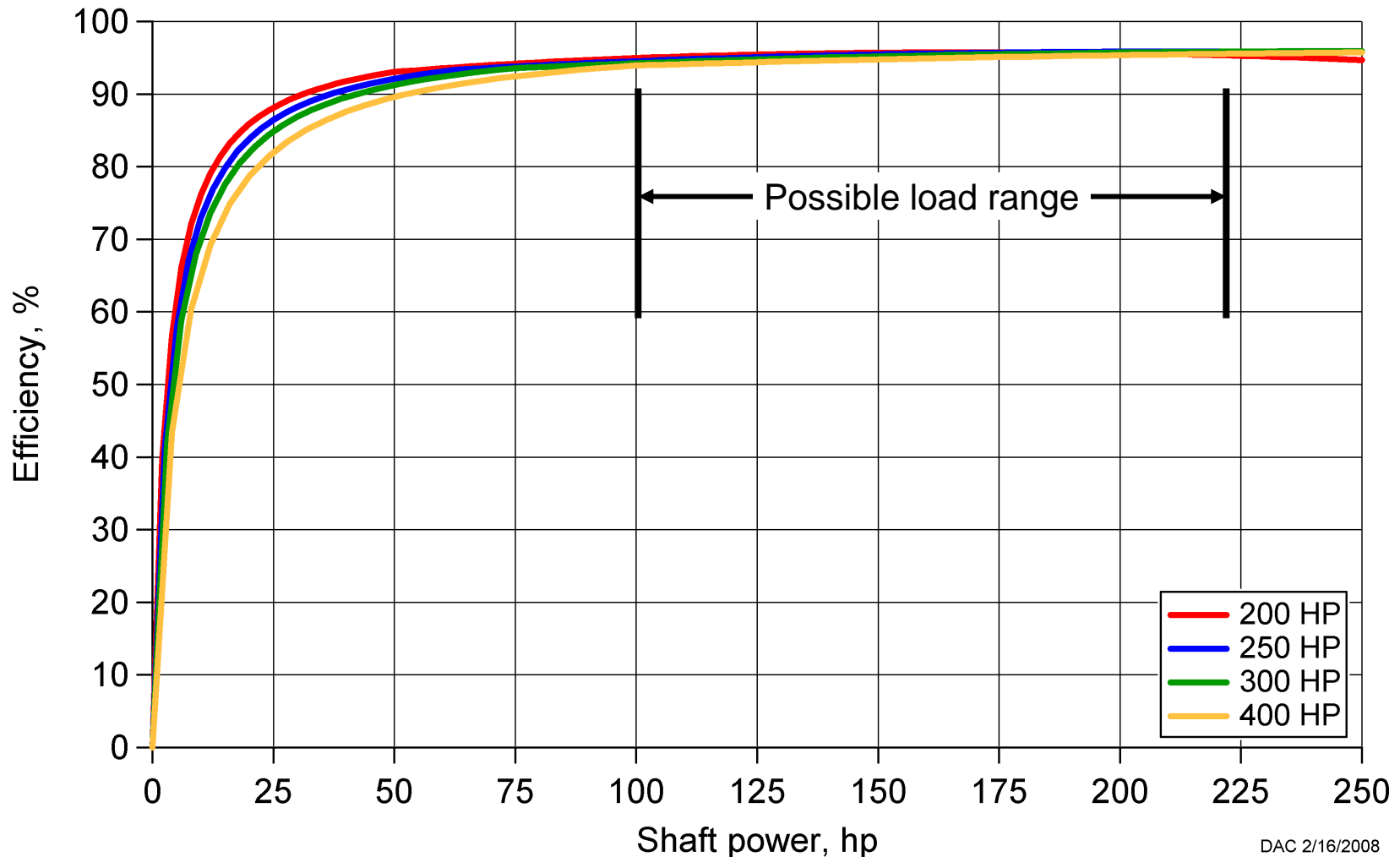


DAC 2/15/2008

Typical motor efficiencies for 200 hp, 4-pole motors over the normal pump load range



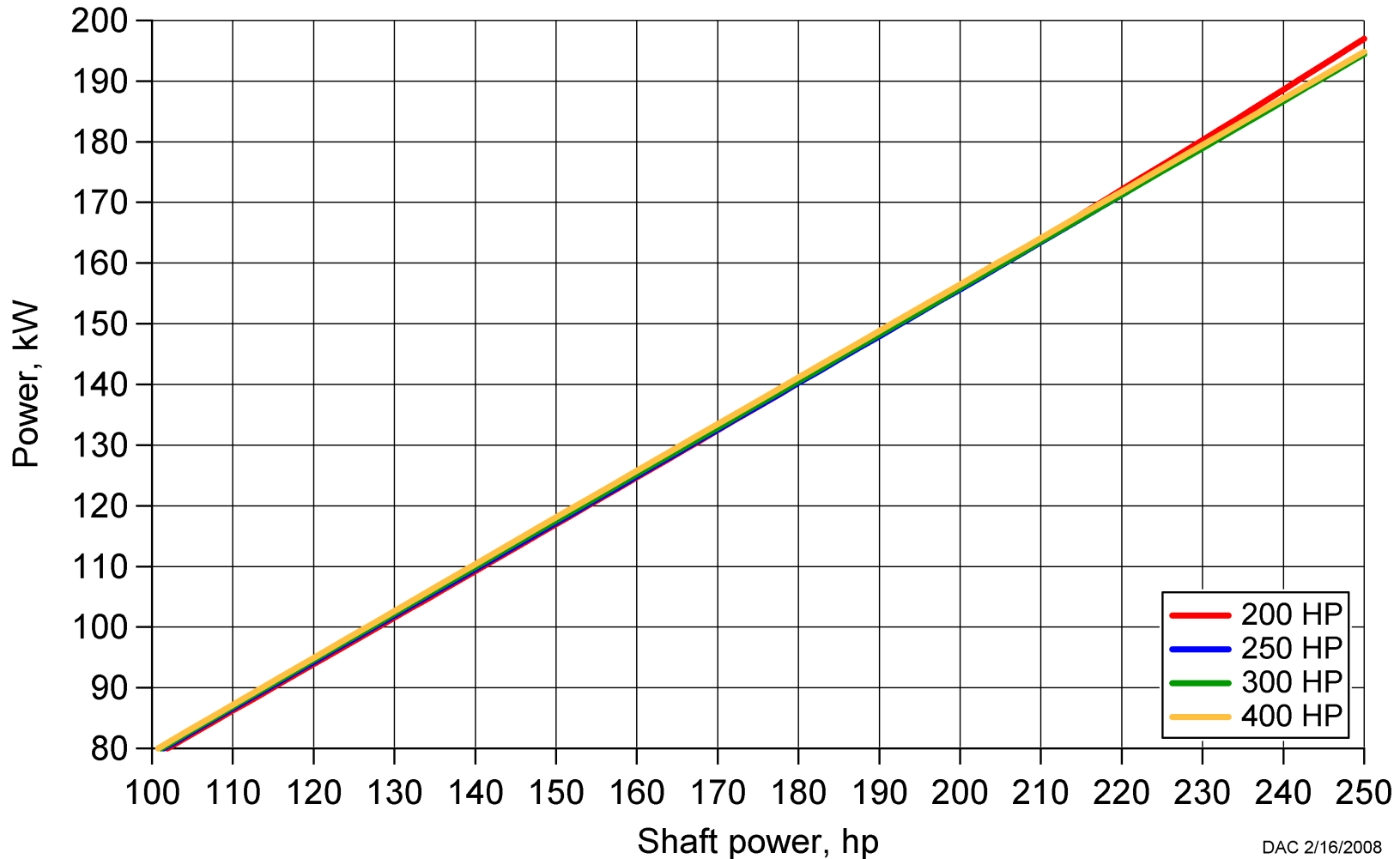
What would be the effect of an oversized motor on motor efficiency?



DAC 2/16/2008

For this size equipment, the efficiency difference is miniscule – an order of magnitude less than the errors of high quality field measurements

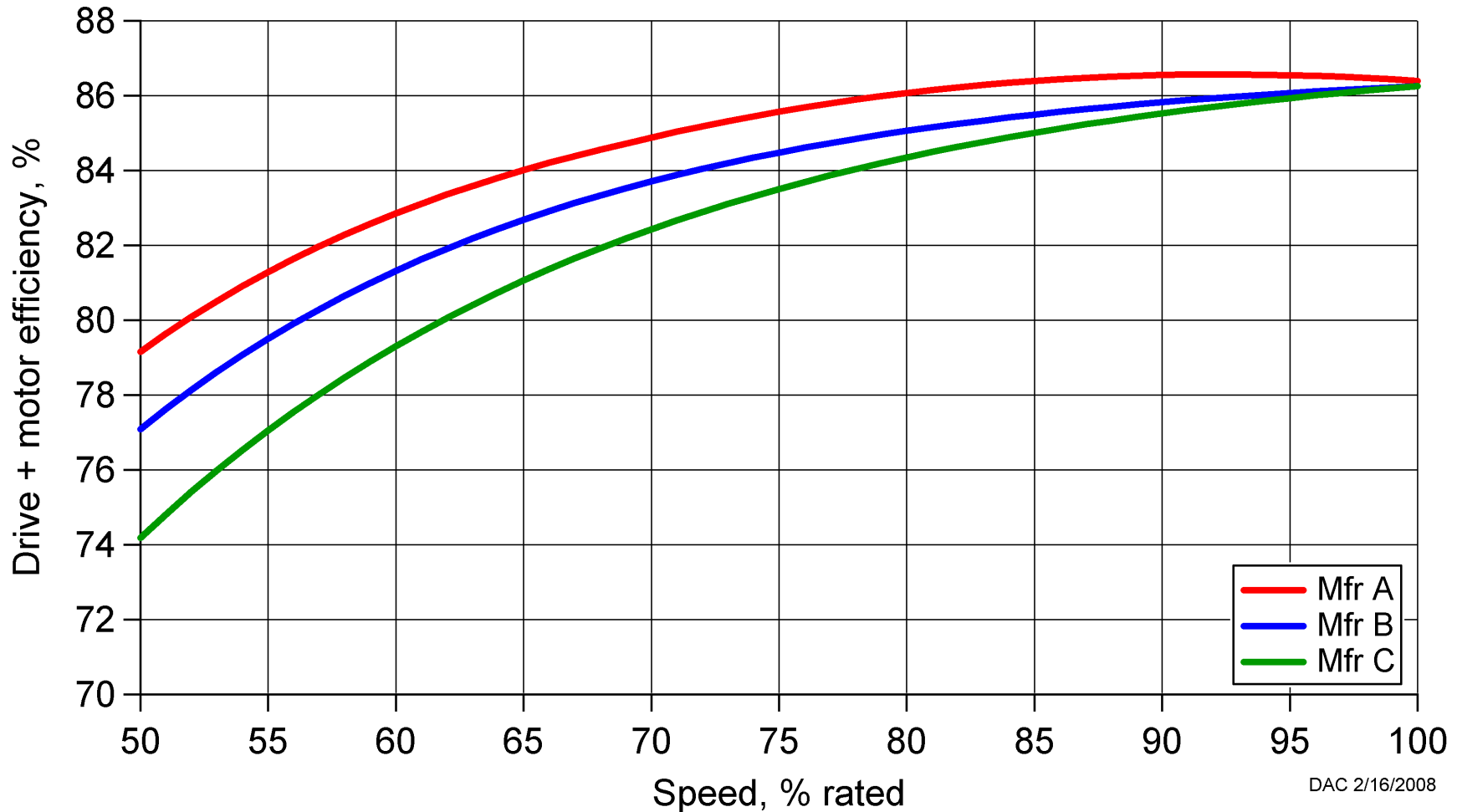
The difference in electric power consumption from oversized motors is trivial



NOTE: The effect of oversizing the pump can be tremendously important, so never attempt to apply this pattern to the other side of the coupling.

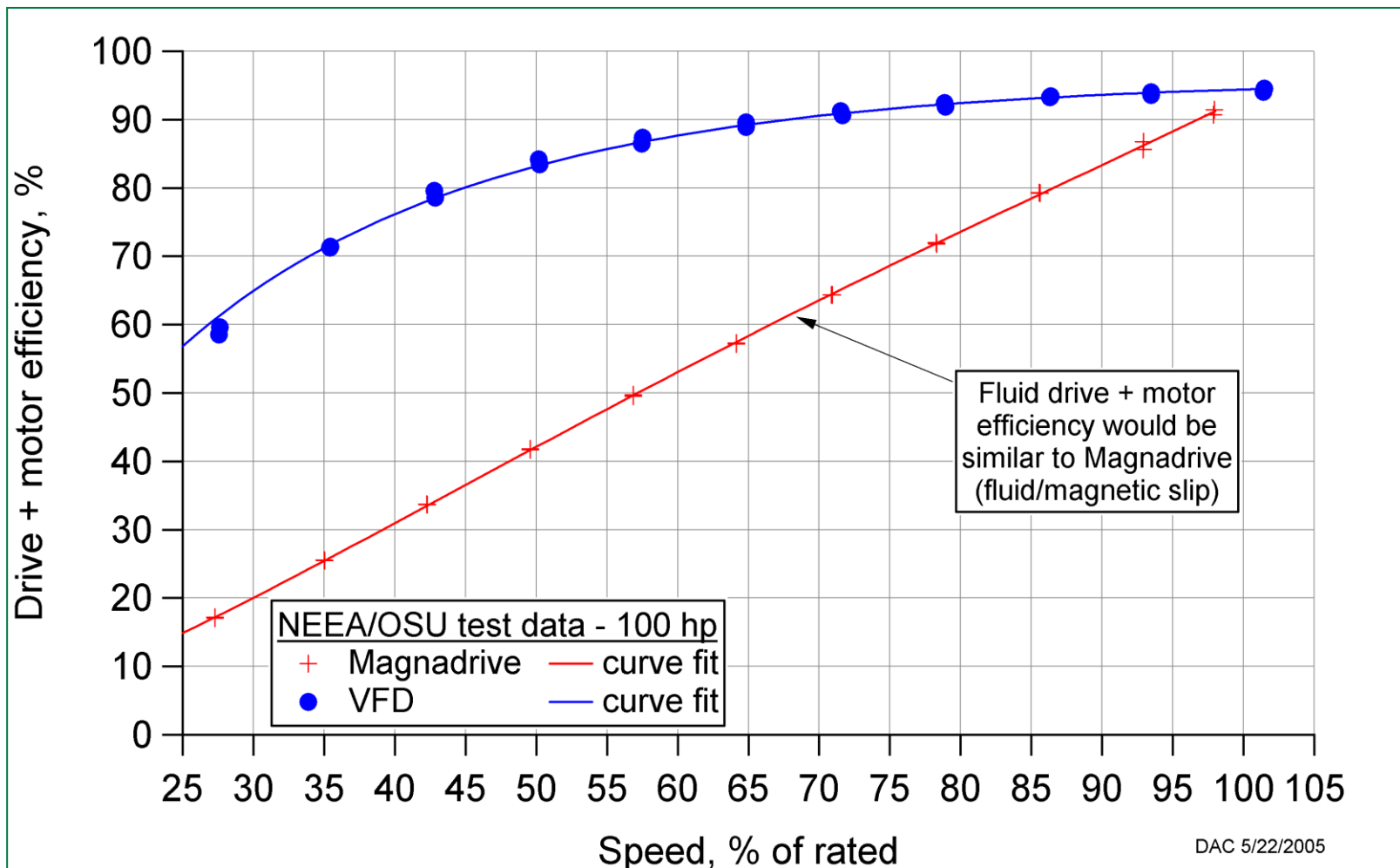
Variable speed drive performance characteristics

Combined motor & adjustable frequency drive results demonstrate high drive efficiencies



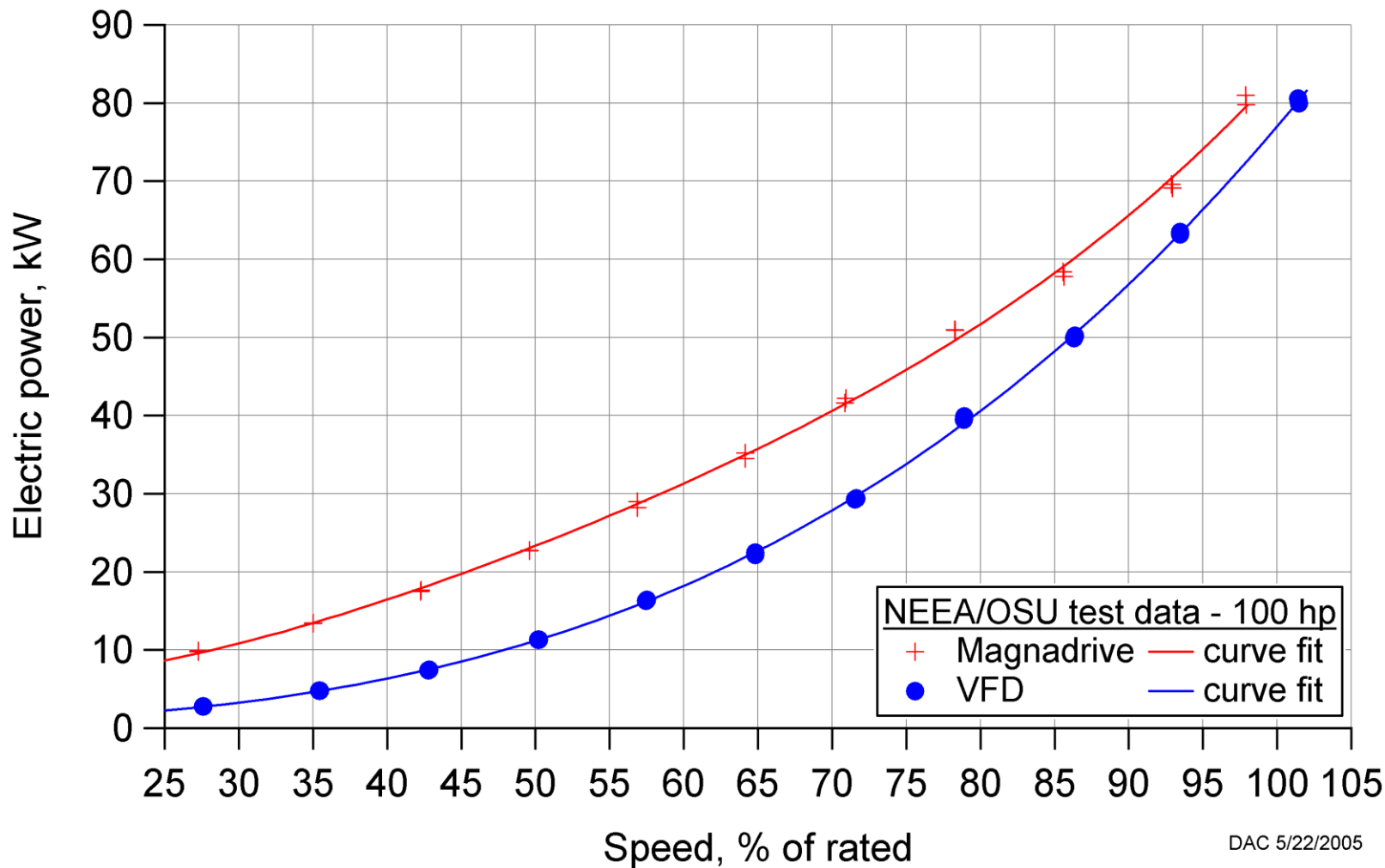
79 Source: Tests conducted at Y-12 plant motor test facility by Don Casada, Oak Ridge National Laboratory

Comparison of motor + drive efficiencies: AFD and mechanical-side drives



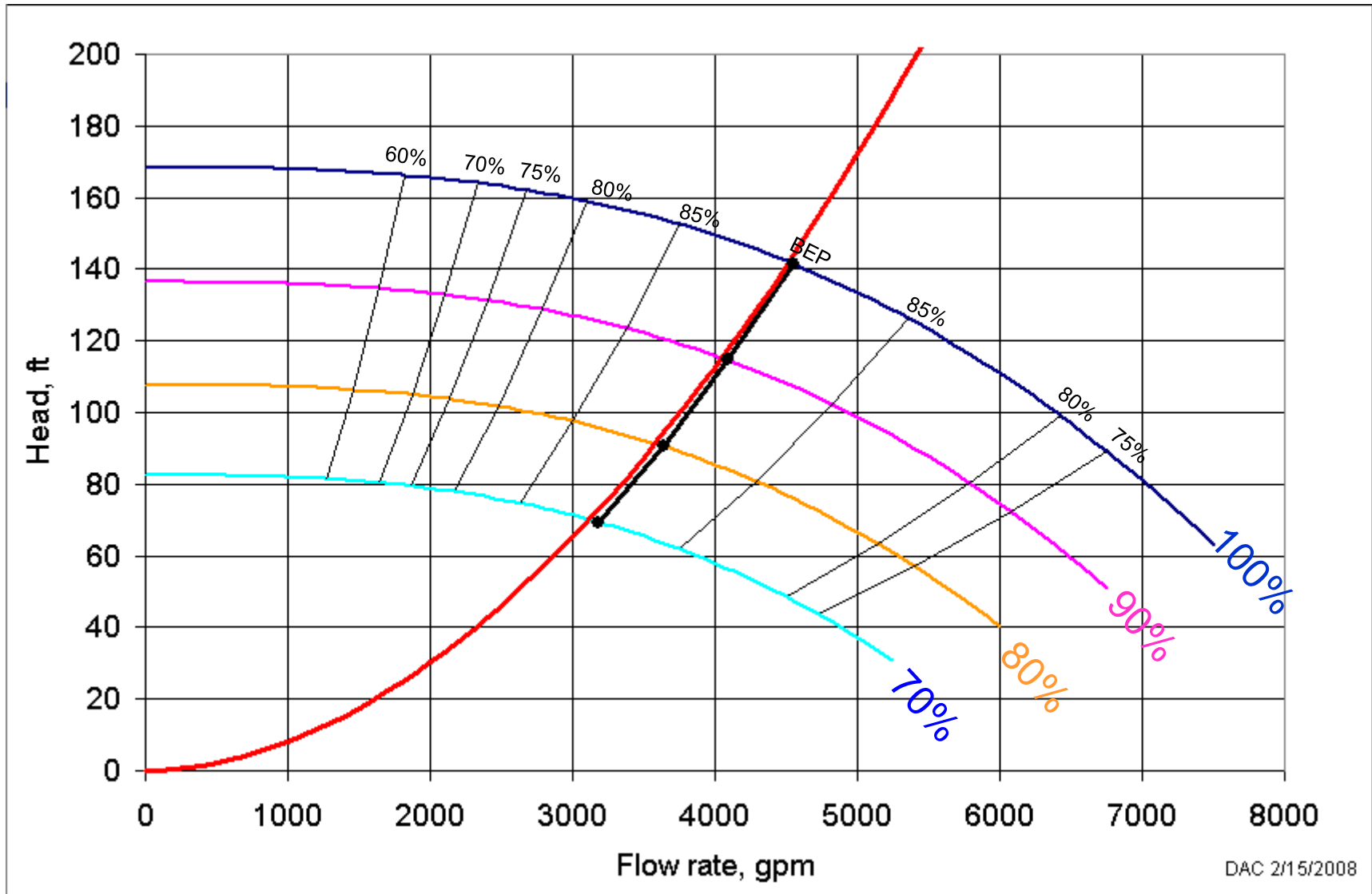
Source: Product Testing: Northwest Energy Efficiency Alliance, Report 00-048, by Oregon State University, March 2000.

But drive efficiency can be misleading - what is more important is the effect on power

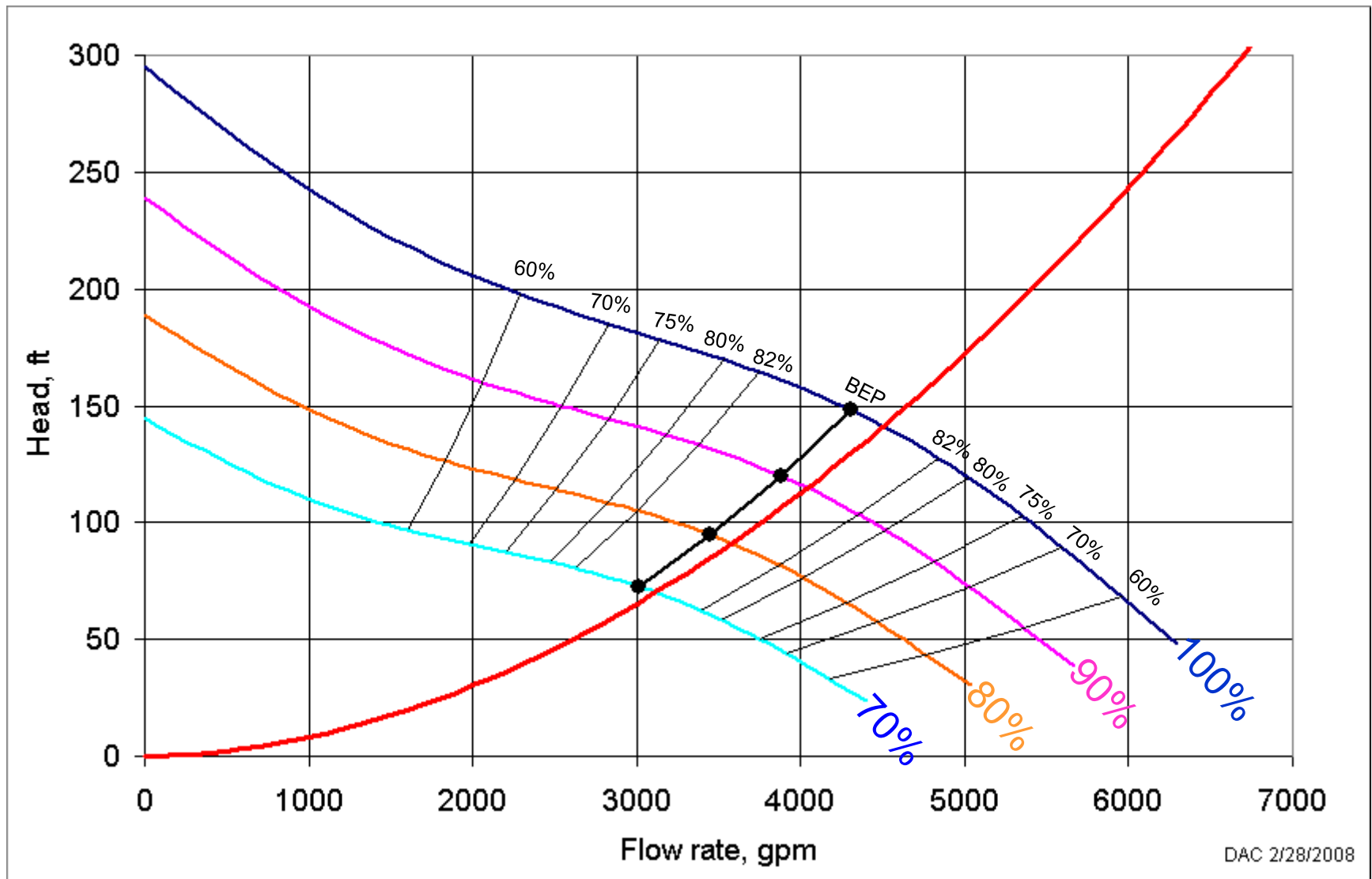


What happens if we reduce pump speed in the three systems types mentioned earlier?

Change in speed for the all frictional system results in maintenance of constant pump efficiency (Pump 2)

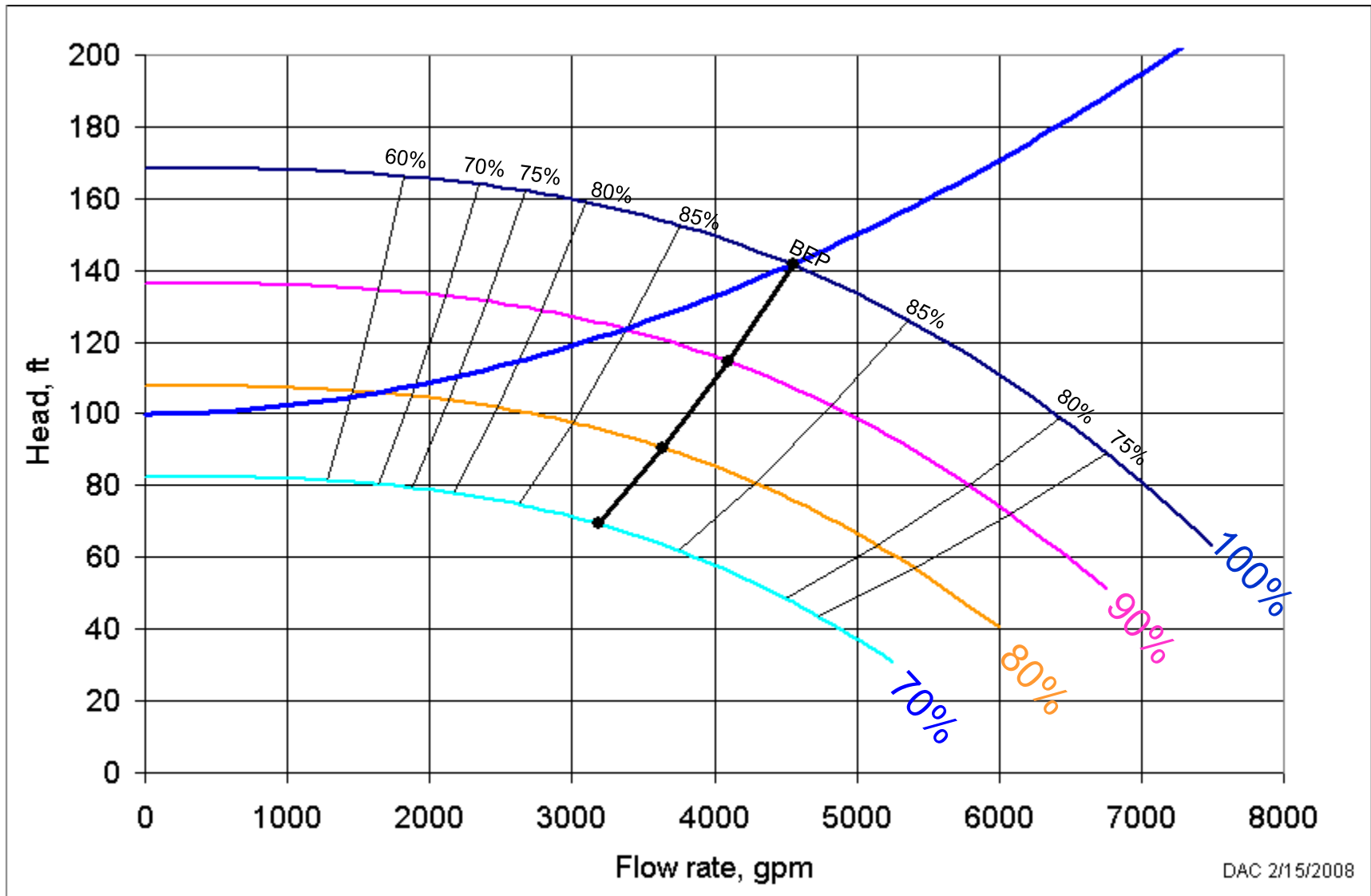


Change in speed for the all frictional system results in maintenance of constant pump efficiency (Pump 3)



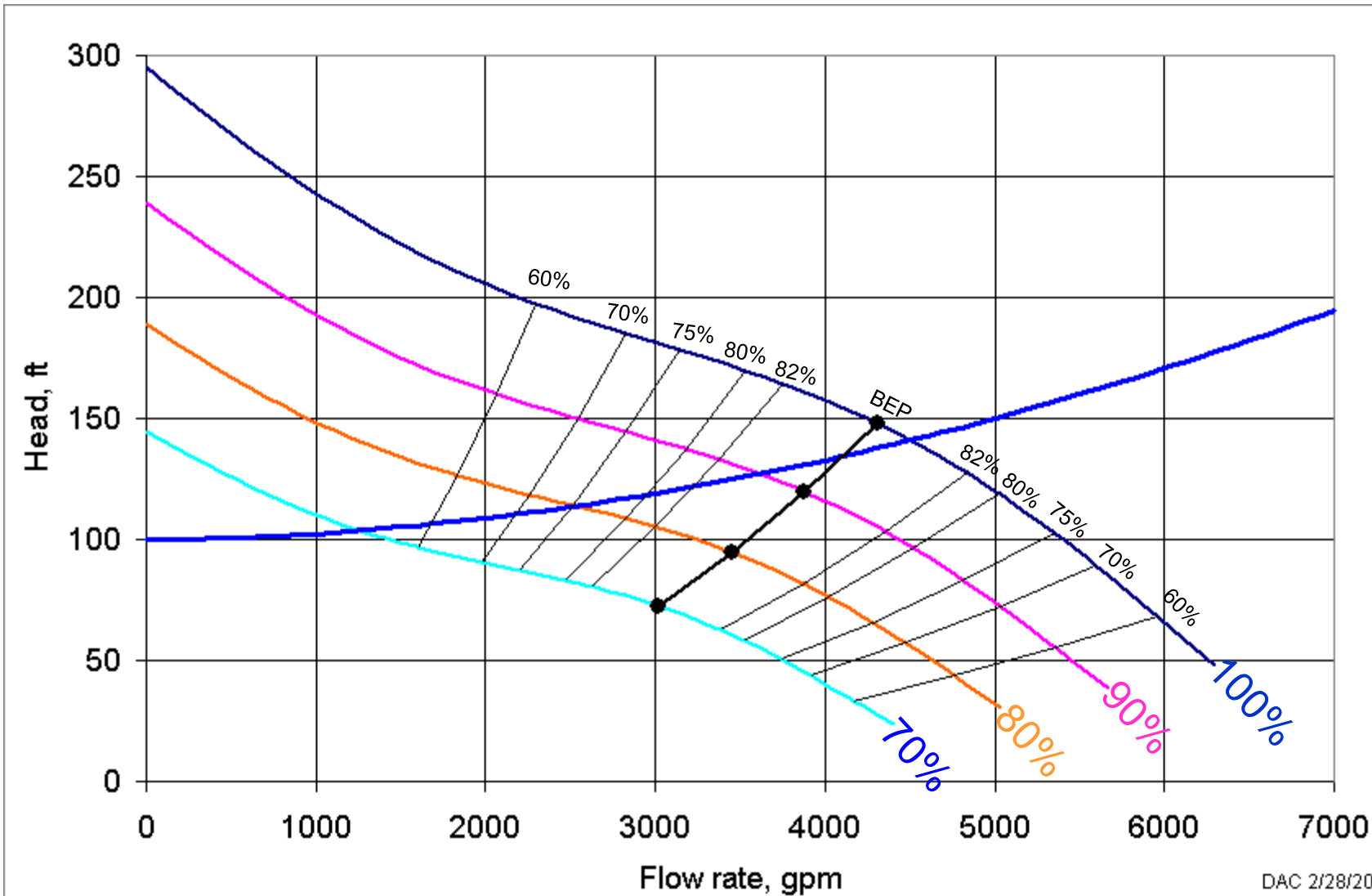
DAC 2/28/2008

Change in speed for the 100-ft static system with Pump 2 results in loss of flow at ~78% speed



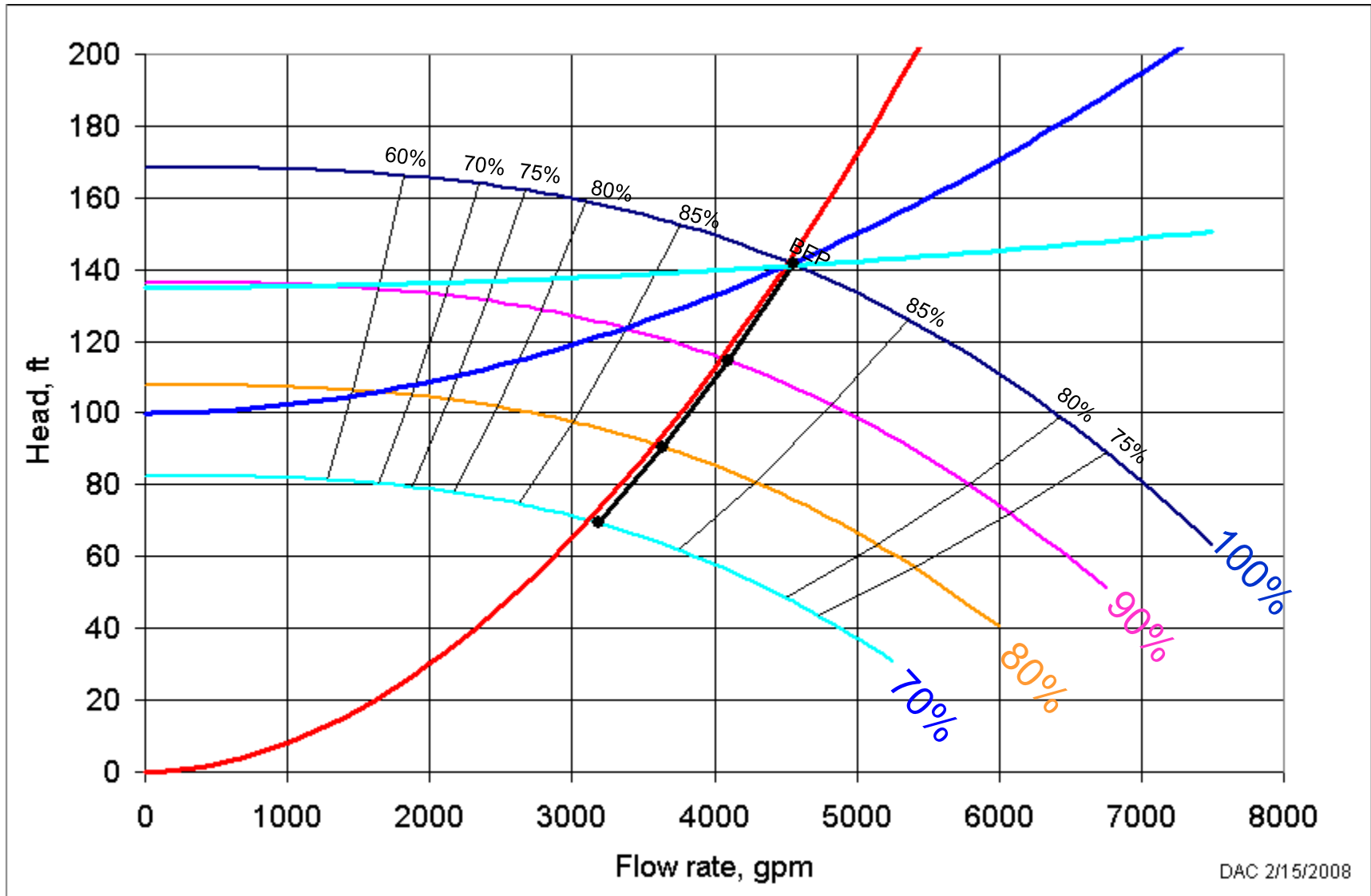
DAC 2/15/2008

The steeper head-capacity curve for pump 3 makes for improved turndown and controllability



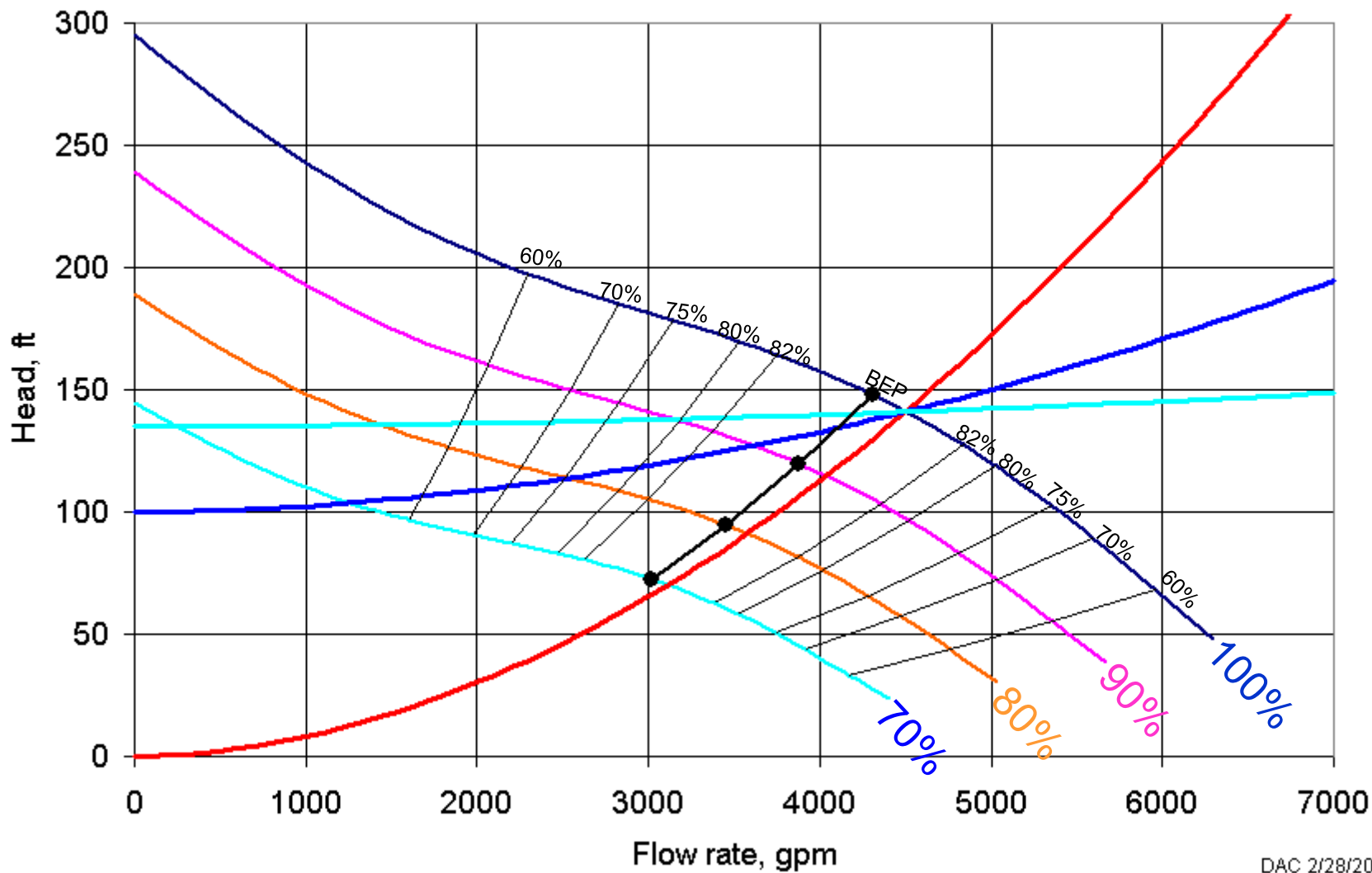
DAC 2/28/2008

All three system curves with P2, variable speed



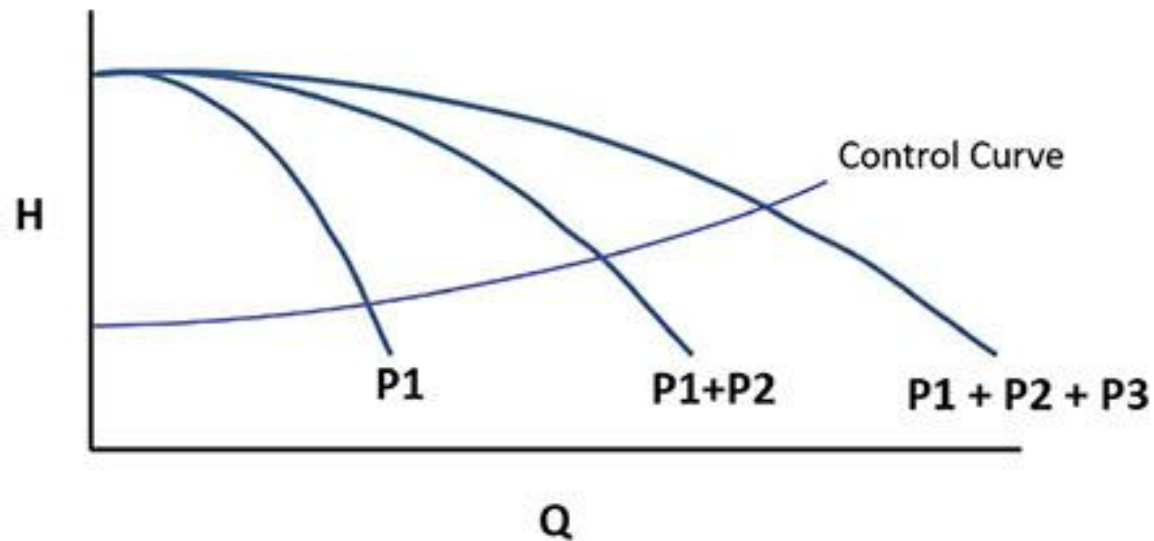
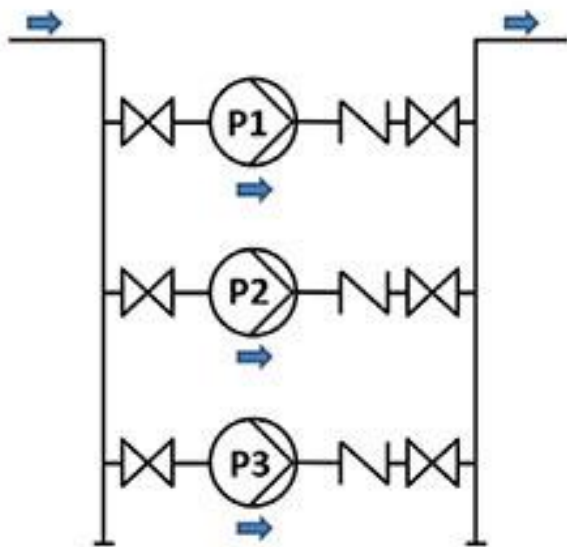
DAC 2/15/2008

All three system curves with P3, variable speed

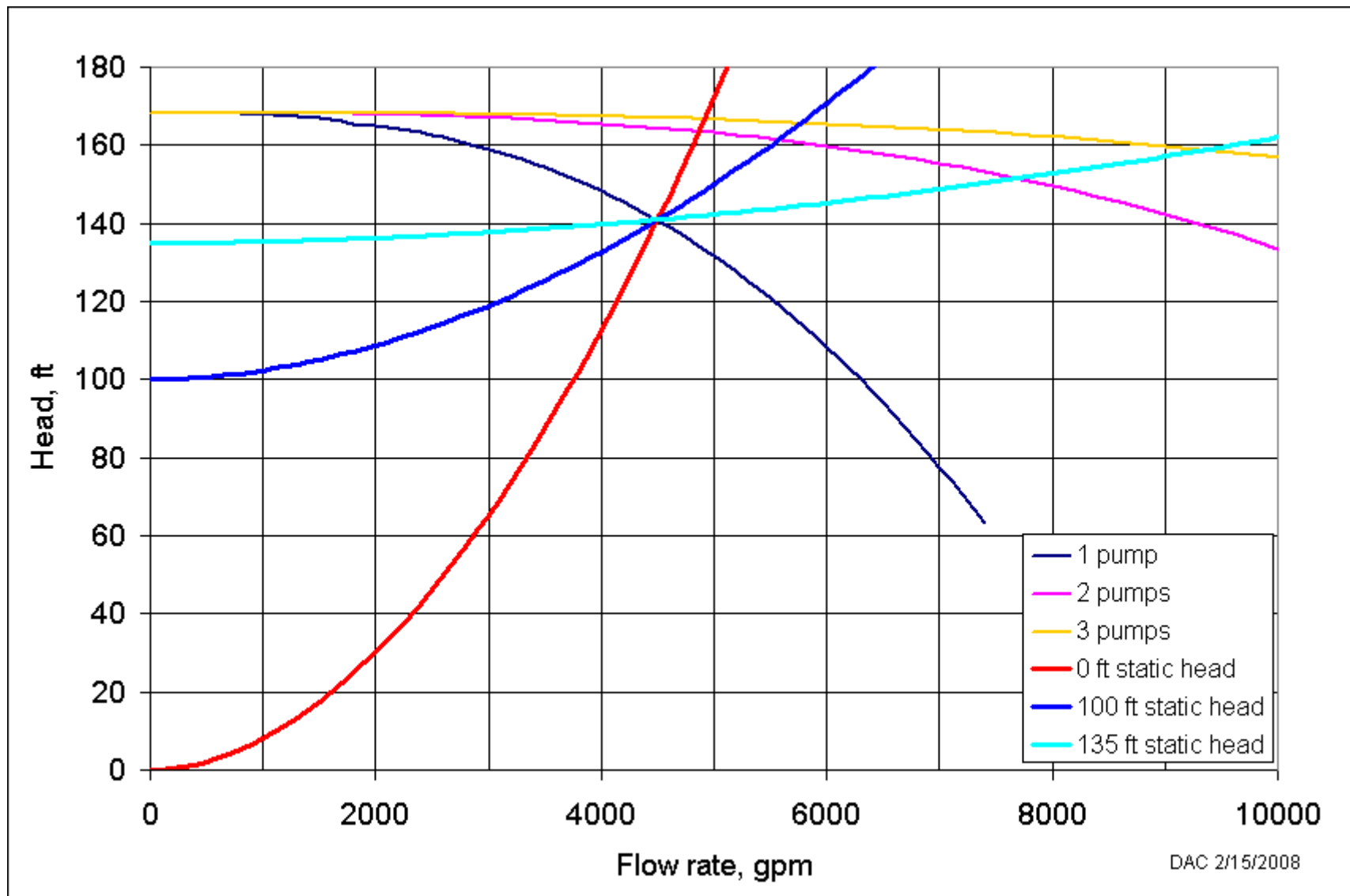


DAC 2/28/2008

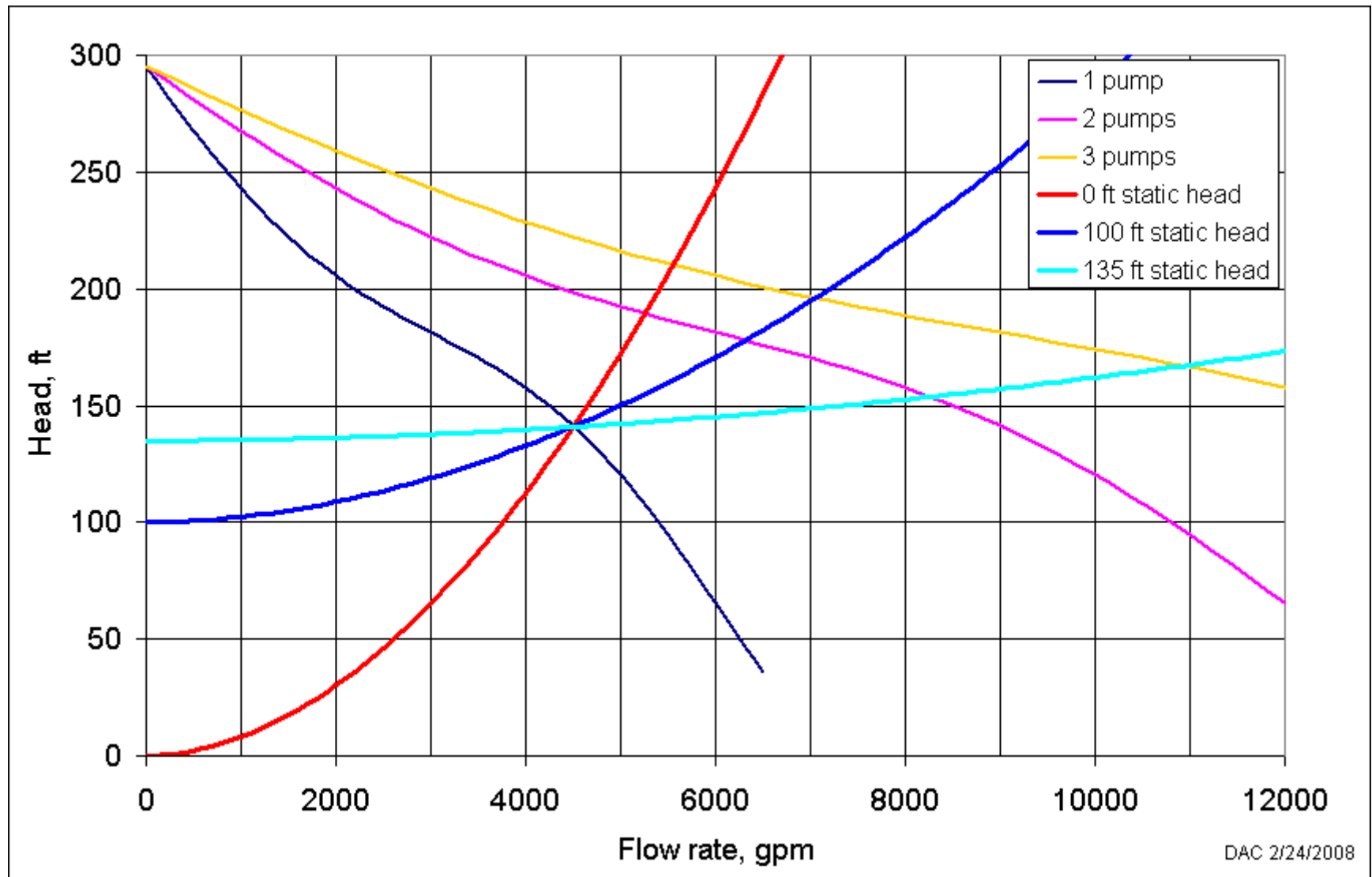
How about parallel pump operation with different system types?



Parallel pump response also depends on the nature of the system and pump curves (P2)



Parallel pump response also depends on the nature of the system and pump curves (P3)



An Introduction to the Pumping Assessment Tool in MEASUR

- Goal: to assist pump users in quantifying potential energy and cost savings
- Relies on process or field-measured fluid and electrical data
- Hydraulic Institute pump efficiency-estimating algorithms used to estimate achievable pump efficiency
- Published motor manufacturer data (motors in the Motormaster database plus other published motor data) were used to develop curve fit-based performance predictions

Open the MEASUR Software



U.S. DEPARTMENT OF
ENERGY
Energy Efficiency &
Renewable Energy

Add New ▾

Home

All Assessments

- Demo 2020
- Huntington Plant TH
- Huntington Plant 2 TH
- TH Test
- Bendix Huntington
 - Huntington
 - AIST Event
 - ADM Mexico MO
 - TVA Workshop Boiler 2
 - Session 4 Example
 - CA Test
 - ADM Boiler Fan
 - Boiler 4 - ADM Mexico
 - Cedar Rapids Cogen
 - TCO Boiler
 - TCO Boiler
 - TCO Steam
 - Nashville Stratas
 - Blower ADM Utilities

MEASUR

Welcome to the most efficient way to manage and optimize your facilities' systems and equipment.

Create an assessment to model your system and find opportunities for efficiency or run calculations from one of our many property and equipment calculators.

Get started with one of the following options.

If you need help at any point along the way, click on a [User Manual](#) icon.



[View Assessments](#)



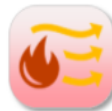
[Equipment Calculators](#)



[Pump
Assessment](#)



[Compressed Air
Assessment](#)



[Process Heating
Assessment](#)



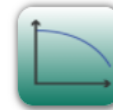
[Fan
Assessment](#)



[Steam
Assessment](#)



[Treasure
Hunt](#)



OF
Y

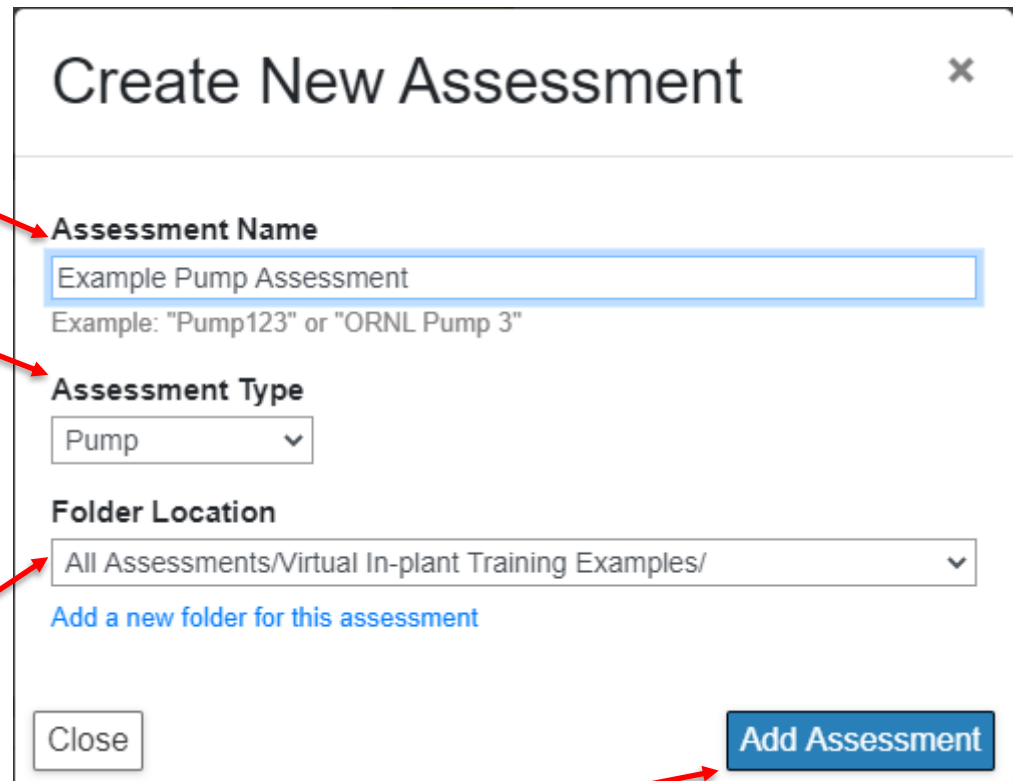
Energy Efficiency &
Renewable Energy

Create New Pump Assessment

Name the Assessment

Select the Assessment Type

Select where you want the file saved on your computer



The screenshot shows a dialog box titled "Create New Assessment" with a close button (X) in the top right corner. It contains three main sections: "Assessment Name" with a text input field containing "Example Pump Assessment" and a subtext "Example: 'Pump123' or 'ORNL Pump 3'"; "Assessment Type" with a dropdown menu showing "Pump"; and "Folder Location" with a dropdown menu showing "All Assessments/Virtual In-plant Training Examples/" and a link "Add a new folder for this assessment". At the bottom left is a "Close" button and at the bottom right is a blue "Add Assessment" button. Red arrows from the text boxes on the left point to the "Assessment Name" field, the "Assessment Type" dropdown, the "Folder Location" dropdown, and the "Add Assessment" button.

Finally, Click on Add Assessment

System Setup – Assessment Settings

MEASUR Demo 2020 Last modified: Jul 6, 2023

System Setup Assessment Diagram Report Sankey Calculators

1 Assessment Settings 2 Operations 3 Pump & Fluid 4 Motor 5 Field Data

DEMO 2020 SETTINGS

Language
Currency
Units of Measure
Head Measurement
Flow Measurement
Power Measurement
Pressure Measurement
Temperature Measurement

Translate Application Using Google Translate

\$

Imperial
 Metric
 Custom

Feet (ft)

Gallons per minute (gpm)

Horse Power (hp)

Pounds per Square Inch (psi)

Degrees Fahrenheit (°F)

System basics
Your system basics helps define the units of measure and other information related to the system you are modeling for this assessment. Units of Measure are inherited by default from your Application Settings. Units of Measure can be customized for this assessment.

Start here

Then here

Select the language and units you want to work with

Finally, Click on Operations to continue

System Setup – Assessment Settings

MEASUR Demo 2020
Last modified: Jul 6, 2023

System Setup Assessment Diagram Report Sankey Calculators

1 Assessment Settings 2 Operations 3 Pump & Fluid 4 Motor 5 Field Data

OPERATIONS

Operating Hours: 7884 hrs/yr
Electricity Cost: 0.13 \$/kWh

CARBON EMISSIONS

Zip code: 38501
eGRID Subregion: SRTV
Total Emission Output Rate: 430.78 kg CO₂/MWh

HELP

Operations Help
Enter measured data to calculate your system's annual savings potential.

Operating Hours
Annual operating hours of the pump.

Minimum	Maximum
0 hrs/yr	8760 hrs/yr

Now here

Still here

Enter Hours of Operation, Electric Cost & Zip Code

Finally, Pump & Fluid to continue

System Setup – Pump & Fluid

MEASUR Demo 2020
Last modified: Jul 6, 2023

System Setup Assessment Diagram Report Sankey Calculators

1 Assessment Settings 2 Operations 3 Pump & Fluid 4 Motor 5 Field Data

PUMP

Pump Type: End Suction ANSI/API
Pump Speed: 1190 rpm
Drive: Direct Drive

FLUID

Fluid Type: Water
Fluid Temperature: 60 °F
Specific Gravity: 1.005
Kinematic Viscosity: 1.21 cSt
Stages: - + 1

HELP
Pump & Fluid Help
Enter measured data to calculate your system's annual savings potential.

Still here

Now here

Input pump and fluid information

Finally, Click on Motor to continue

System Setup – Motor

Still here

Now here

MEASUR

Demo 2020

Last modified: Jul 6, 2023

System Setup

Assessment Diagram Report Sankey Calculators



1 Assessment Settings 2 Operations

3 Pump & Fluid

4 Motor

5 Field Data

MOTOR

Line Frequency
Rated Motor Power
Motor RPM
Efficiency Class
Rated Voltage
Full-Load Amps
[Estimate Full-Load Amps](#)

60 Hz	▼
350	hp
1180	rpm
Energy Efficient	▼
2300	V
81.13	A

HELP

Motor Help

Enter measured data to calculate your system's annual savings potential.

Line Frequency

Line Frequency is the mains supply frequency. In North America, the standard frequency is 60 HZ. Elsewhere, 50 HZ is often the standard.

The only use of this input is to determine the number of poles, based on the specified motor speed.

Input Motor information

Finally, Click on Field Data to continue

System Setup – Estimate Full Load Amps

MEASUR



Demo 2020

Last modified: Jul 6, 2023

System Setup

Assessment

Diagram

Report

1

Assessment Settings

2

Operations

3

Pump & Fluid

4

Motor

MOTOR

Line Frequency

60 Hz

Rated Motor Power

350

hp

Motor RPM

1180

rpm

Efficiency Class

Energy Efficient

Rated Voltage

2300

V

Full-Load Amps

81.13

A

[Estimate Full-Load Amps](#)

Can estimate full load motor amps by clicking here

System Setup – Field Data

Still here

Now here

MEASUR Demo 2020 Last modified: Jul 6, 2023

System Setup Assessment Diagram Report Sankey Calculators

1 Assessment Settings 2 Operations 3 Pump & Fluid 4 Motor 5 Field Data

FIELD DATA

Flow Rate: 4500 gpm
Head: 193.2 ft
Load Estimation Method: Current
Motor Current: 77 A
Measured Voltage: 2320 V

RESULTS

	Baseline
Percent Savings (%)	—
Pump efficiency (%)	66
Motor rated power (hp)	350
Motor shaft power (hp)	334.1
Pump shaft power (hp)	334.1
Motor efficiency (%)	95.6
Motor power factor (%)	84.3
Percent Loaded (%)	95
Drive efficiency (%)	100
Motor current (A)	77
Motor power (kW)	260.8
Annual CO2 Emissions (tonne CO ₂)	1,477.5
Annual CO2 Emissions Savings (tonne CO ₂)	—
Annual Energy (MWh)	2,056
Annual Energy Savings (MWh)	—
Annual Cost (\$)	267,256
Annual Savings (\$)	—

Input Field Data

Baseline Results

After Field Data, move on to the Assessment

System Setup – Calculate Pump Head

MEASUR



Demo 2020

Last modified: Jul 6, 2023

System Setup

Assessment

Diagram Re

1 Assessment Settings

2 Operations

3 Pump & Fluid

4 Motor

FIELD DATA

Flow Rate

4500

gpm

Head

193.2

ft

[Calculate Head](#)

Load Estimation Method

Current

▼

Motor Current

77

A

Measured Voltage

2320

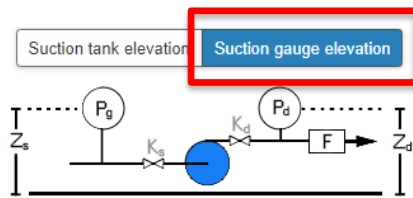
V

Go to the pump head calculator by clicking here

System Setup – Pump Head Calculator



PUMP HEAD TOOL



K_s represents all suction losses from the tank to the pump
 K_d represents all discharge losses from the pump to the gauge P_d

Fluid Specific Gravity	1.002		
Flow Rate	2000 gpm		
Suction		Discharge	
Pipe diameter (ID)	12 in	Pipe diameter (ID)	12 in
Gauge pressure (P_g)	5 psi	Gauge pressure (P_d)	124.8 psi
Gauge elevation (Z_s)	10 ft	Gauge elevation (Z_d)	10 ft
Line loss coefficients (K_s)	0.5	Line loss coefficients (K_d)	1

Input Field Data

RESULTS

HELP

Result Data

Differential Elevation Head	0.0 ft
Differential Pressure Head	276.28 ft
Differential Velocity Head	0.0 ft
Estimated Suction Friction Head	0.25 ft
Discharge Friction Head	0.5 ft
Pump Head	277.03 ft

Copy Table

Pump Head

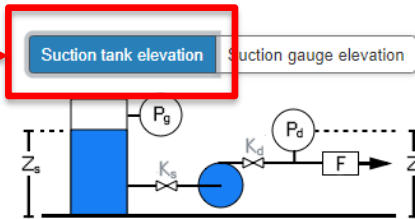
Two Different Geometries: Suction Gauge

System Setup – Pump Head Calculator

MEASUR



PUMP HEAD TOOL



K_s represents all suction losses from the tank to the pump

K_d represents all discharge losses from the pump to the gauge P_d

Fluid Specific Gravity	<input type="text" value="1.002"/>
Flow Rate	<input type="text" value="2000"/> gpm
Suction	
Pipe diameter (ID)	<input type="text" value="12"/> in
Tank gas overpressure (P_g)	<input type="text" value="0"/> psi
Tank fluid surface elevation (Z_s)	<input type="text" value="10"/> ft
Line loss coefficients (K_s)	<input type="text" value="0.5"/>
Discharge	
Pipe diameter (ID)	<input type="text" value="12"/> in
Gauge pressure (P_d)	<input type="text" value="124"/> psi
Gauge elevation (Z_d)	<input type="text" value="10"/> ft
Line loss coefficients (K_d)	<input type="text" value="1"/>

Input Field Data

RESULTS

HELP

Result Data

Differential Elevation Head	0.0 ft
Differential Pressure Head	285.97 ft
Differential Velocity Head	0.5 ft
Estimated Suction Friction Head	0.25 ft
Discharge Friction Head	0.5 ft
Pump Head	287.22 ft

Copy Table

Pump Head

Two Different Geometries: Suction Tank

103

Assessment View – Novice

MEASUR Demo 2020
Last modified: Jul 7, 2023

System Setup **Assessment** Diagram Report Sankey Calculators

Explore Opportunities
Novice View

Modify All Conditions
Expert View

Selected Scenario View / Add Scenarios

RESULTS SANKEY HELP

Explore Opportunities to view results

Now that you have setup your system and have baseline information, create duplicate baseline conditions to find efficiency opportunities.

Explore Opportunities

Now here

Novice View

Click Explore Opportunities to evaluate a potential project

Evaluate Potential Project

Name the Opportunity

Add New Scenario ×

The Modify All Conditions section is an expert view, allowing you to change any input. You can create many different scenarios, to compare changes to your system. Notes for each loss page can be added in the right tab (NOTES), these will be added to your final report. Data will be copied from your current baseline condition.

Scenario Name

Trim Impeller and Open Throttled Va

Create

Click on Create

Assessment View – Novice

Explore Opportunities Modify All Conditions
Novice View Expert View

Trim Impeller Selected Scenario View / Add Scenarios

SELECT POTENTIAL ADJUSTMENT PROJECTS

Select potential adjustment projects to explore opportunities to increase efficiency and the effectiveness of your system.

[Add New Scenario](#)

Modification Name:

Install VFD

Install More Efficient Drive

Install More Efficient Pump

Baseline Pump Type: End Suction ANSI/API

Modification: Pump Efficiency [Optimize Pump](#)

%

The efficiency of your pump has been calculated based on your system setup. Either directly modify your efficiency or click "Optimize Pump" to estimate your pump efficiency based on a different pump type.

Reduce System Flow Rate

Reduce System Head Requirement

Baseline Head: 193 ft

Modification Head: ft [Calculate Head](#)

Adjust Operational Data

Install More Efficient Motor

RESULTS

	Baseline	Trim Impeller
Percent Savings (%)	—	12.0%
Pump efficiency (%)	66	62
Motor rated power (hp)	350	350
Motor shaft power (hp)	334.1	294.6
Pump shaft power (hp)	334.1	294.6
Motor efficiency (%)	95.6	95.5
Motor power factor (%)	84.3	83.3
Percent Loaded (%)	95	84
Drive efficiency (%)	100	100
Motor current (A)	77	69
Motor power (kW)	260.8	230.1
Annual CO2 Emissions (tonne CO ₂)	1,477.5	1,303.5
Annual CO2 Emissions Savings (tonne CO ₂)	—	174
Annual Energy (MWh)	2,056	1,814
Annual Energy Savings (MWh)	—	242
Annual Cost (\$)	267,256	235,782
Annual Savings (\$)	—	31,474

Select the type of project

Have throttled pump with constant flow

Assessment View – Novice

MEASUR

Demo 2020

Last modified: Jul 7, 2023

System Setup **Assessment** Diagram Report Sankey Calculators



Explore Opportunities **Novice View** Modify All Conditions Expert View

Trim Impeller
Selected Scenario [View / Add Scenarios](#)

SELECT POTENTIAL ADJUSTMENT PROJECTS

Select potential adjustment projects to explore opportunities to increase efficiency and the effectiveness of your system.

[Add New Scenario](#)

Modification Name:

Install VFD

Install More Efficient Drive

Install More Efficient Pump

Baseline Pump Type: End Suction ANSI/API

Modification Pump Efficiency: % [Optimize Pump](#)

The efficiency of your pump has been calculated based on your system setup. Either directly modify your efficiency or click "Optimize Pump" to estimate your pump efficiency based on a different pump type.

Reduce System Flow Rate

Reduce System Head Requirement

Baseline Head: 193 ft

Modification Head: ft [Calculate Head](#)

	RESULTS		SANKEY	HELP
	Baseline	Trim Impeller		
Percent Savings (%)	--	--		
Pump efficiency (%)	66	62		
Motor rated power (hp)	350	350		
Motor shaft power (hp)	334.1	294.6		
Pump shaft power (hp)	334.1	294.6		
Motor efficiency (%)	95.6	95.5		
Motor power factor (%)	84.3	83.3		
Percent Loaded (%)	95	84		
Drive efficiency (%)	100	100		
Motor current (A)	77	69		
Motor power (kW)	260.8	230.1		
Annual CO2 Emissions (tonne CO2)	1,477.5	1,303.5		
Annual CO2 Emissions Savings (tonne CO2)	--	174		
Annual Energy (MWh)	2,056	1,814		
Annual Energy Savings (MWh)	--	242		
Annual Cost (\$)	267,256	235,782		
Annual Savings (\$)	--	31,474		

Reduce Pump Head by 33 Feet by Trimming the Impeller and Opening the Throttled Valve. Pump efficiency falls by 4%.

Assessment View – Expert

MEASUR Demo 2020
Last modified: Jul 7, 2023

System Setup **Assessment** Diagram Report Sankey Calculators

Explore Opportunities **Modify All Conditions**
Novice View Expert View

Operations Pump Fluid Motor Field Data

BASELINE

Pump Type: End Suction ANSI/API
Pump Speed: 1190 rpm
Drive: Direct Drive

Fluid Type: Water
Fluid Temperature: 60 °F
Specific Gravity: 1.005
Kinematic Viscosity: 1.21 cSt
Stages: - + 1

MODIFICATION

Now that you have setup your system and have baseline information, create duplicate baseline conditions to find efficiency opportunities.

Add Modified Condition

Data will be copied from your current baseline condition.

HELP

Use a for opportunity... system. First determining... (flow) are correct for your system needs. If they are not, consider the effects of changing your pump's operating conditions to meet demand, using your manufacturers pump curve. Your pumping system can also be modified by improving pump or motor efficiency, or drive type.

Expert View

Now here

Click Modified Condition to evaluate a potential project

Assessment View – Expert

MEASUR Demo 2020 Last modified: Jul 7, 2023

System Setup **Assessment** Diagram Report Sankey Calculators

Trim Impeller Selected Scenario [View / Add Scenarios](#)

Explore Opportunities **Modify All Conditions** *Novice View* *Expert View*

Operations **Pump Fluid** Motor Field Data

BASELINE

Pump Type: End Suction ANSI/API
Pump Speed: 1190 rpm
Drive: Direct Drive

Fluid Type: Water
Fluid Temperature: 60 °F
Specific Gravity: 1.005
Kinematic Viscosity: 1.21 cSt
Stages: - + 1

TRIM IMPELLER

Pump Efficiency: **62** %
Optimize Pump
The efficiency of your pump has been calculated based on your system setup. Either directly modify your efficiency or click "Optimize Pump" to estimate your pump efficiency based on a different pump type.

Pump Speed: 1190 rpm
Drive: Direct Drive

Fluid Type: Water
Fluid Temperature: 60 °F
Specific Gravity: 1.005
Kinematic Viscosity: 1.21 cSt
Stages: - + 1

RESULTS

	Baseline	Trim Impeller
Percent Savings (%)	---	0.0%
Pump efficiency (%)	66	62
Motor rated power (hp)	350	350
Motor shaft power (hp)	334.1	355.8
Pump shaft power (hp)	334.1	355.8
Motor efficiency (%)	95.6	95.5
Motor power factor (%)	84.3	84.6
Percent Loaded (%)	95	102
Drive efficiency (%)	100	100
Motor current (A)	77	82
Motor power (kW)	260.8	277.8
Annual CO2 Emissions (tonne CO ₂)	1,477.5	1,573.9
Annual CO2 Emissions Savings (tonne CO ₂)	—	-96.5
Annual Energy (MWh)	2,056	2,190
Annual Energy Savings (MWh)	—	-134
Annual Cost (\$)	267,256	284,705
Annual Savings (\$)	—	-17,450

Adjust pump efficiency here!

Pump efficiency dropped to 62%

Assessment View – Expert

MEASUR Demo 2020 Last modified: Jul 7, 2023

System Setup **Assessment** Diagram Report Sankey Calculators

Explore Opportunities **Modify All Conditions** Novice View Expert View

Trim Impeller Selected Scenario View / Add Scenarios

Operations Pump Fluid Motor **Field Data**

BASELINE

Flow Rate	4500	gpm
Head	193.2	ft
Calculate Head		
Load Estimation Method	Current	
Motor Current	77	A
Measured Voltage	2320	V

TRIM IMPELLER

Flow Rate	4500	gpm
Head	160	ft
Calculate Head		
Measured Voltage	2320	V
Implementation Costs		\$

RESULTS

	Baseline	Trim Impeller
Percent Savings (%)	—	12.0%
Pump efficiency (%)	66	62
Motor rated power (hp)	350	350
Motor shaft power (hp)	334.1	294.6
Pump shaft power (hp)	334.1	294.6
Motor efficiency (%)	95.6	95.5
Motor power factor (%)	84.3	83.3
Percent Loaded (%)	95	84
Drive efficiency (%)	100	100
Motor current (A)	77	69
Motor power (kW)	260.8	230.1
Annual CO2 Emissions (tonne CO ₂)	1,477.5	1,303.5
Annual CO2 Emissions Savings (tonne CO ₂)	—	174
Annual Energy (MWh)	2,056	1,814
Annual Energy Savings (MWh)	—	242
Annual Cost (\$)	267,256	235,782
Annual Savings (\$)	—	31,474

Adjust pump head here!

Pump head dropped to 160 feet

Compare Existing Pump to Optimal Pump

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Optimal Pump
Selected Scenario [View / Add Scenarios](#)

Operations **Pump Fluid** Motor Field Data

BASELINE

Pump Type: End Suction ANSI/API

Pump Speed: 1190 rpm

Drive: Direct Drive

Fluid Type: Water

Fluid Temperature: 60 °F

Specific Gravity: 1.005

Kinematic Viscosity: 1.21 cSt

Stages: - + 1

OPTIMAL PUMP

Pump Efficiency: 66.02 %

[Optimize Pump](#)

The efficiency of your pump has been calculated based on your system setup. Either directly modify your efficiency or click "Optimize Pump" to estimate your pump efficiency based on a different pump type.

Pump Speed: 1190 rpm

Drive: Direct Drive

Fluid Type: Water

Fluid Temperature: 60 °F

Specific Gravity: 1.005

Kinematic Viscosity: 1.21 cSt

Stages: - + 1

RESULTS

	Baseline	Optimal Pump
Percent Savings (%)	—	—
Pump efficiency (%)	66	66
Motor rated power (hp)	350	350
Motor shaft power (hp)	334.1	334.1
Pump shaft power (hp)	334.1	334.1
Motor efficiency (%)	95.6	95.6
Motor power factor (%)	84.3	84.3
Percent Loaded (%)	95	95
Drive efficiency (%)	100	100
Motor current (A)	77	77
Motor power (kW)	260.8	260.7
Annual CO2 Emissions (tonne CO₂)	1,477.5	1,477.4
Annual CO2 Emissions Savings (tonne CO₂)	—	0.1
Annual Energy (MWh)	2,056	2,056
Annual Energy Savings (MWh)	—	00
Annual Cost (\$)	267,256	267,240
Annual Savings (\$)	—	16

To evaluate an “optimized” pump based on Hydraulic Institute algorithms click here

Optimize Pump w/ Hydraulic Institute Algorithms

BASELINE

Pump Type: End Suction ANSI/API

Pump Speed: 1190 rpm

Drive: Direct Drive

Fluid Type: Water

Fluid Temperature: 60 °F

Specific Gravity: 1.005

Kinematic Viscosity: 1.21 cSt

Stages: - + 1

OPTIMAL PUMP

Pump Type: End Suction ANSI/API

Pump Efficiency: 88.69 %
Known Efficiency

The efficiency of your pump has been calculated based on your flow rate and selected pump type. Click "Known Efficiency" to use the efficiency calculated by your system setup.

Pump Speed: 1190 rpm

Drive: Direct Drive

Fluid Type: Water

Fluid Temperature: 60 °F

Specific Gravity: 1.005

Kinematic Viscosity: 1.21 cSt

Stages: - + 1

RESULTS HELP NOTES

	Baseline	Optimal Pump
Percent Savings (%)	---	25.0%
Pump efficiency (%)	66	88.7
Motor rated power (hp)	350	350
Motor shaft power (hp)	334.1	248.7
Pump shaft power (hp)	334.1	248.7
Motor efficiency (%)	95.6	95.3
Motor power factor (%)	84.3	81.5
Percent Loaded (%)	95	71
Drive efficiency (%)	100	100
Motor current (A)	77	59
Motor power (kW)	260.8	194.6
Annual CO2 Emissions (tonne CO ₂)	1,477.5	1,102.6
Annual CO2 Emissions Savings (tonne CO ₂)	---	374.8
Annual Energy (MWh)	2,056	1,534
Annual Energy Savings (MWh)	---	522
Annual Cost (\$)	267,256	199,457
Annual Savings (\$)	---	67,799

**Same flow and same head –
Original Pump Efficiency is 66.0%
Optimal Pump is 88.7%**

The End for Session 2



The End