

The Real Efficiency of Pumping Systems



Jen Muir

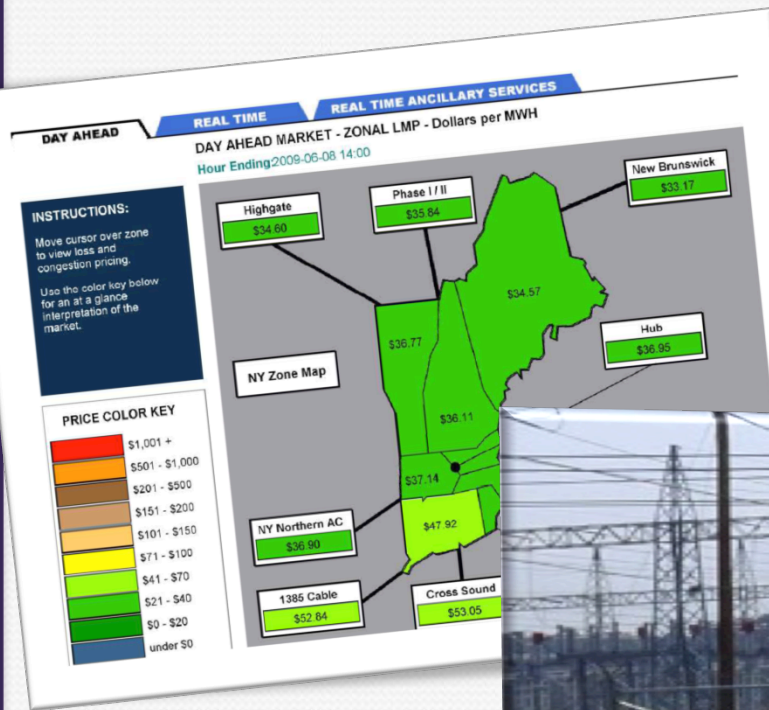
Jessica Dzwonkoski

JKMuir, LLC

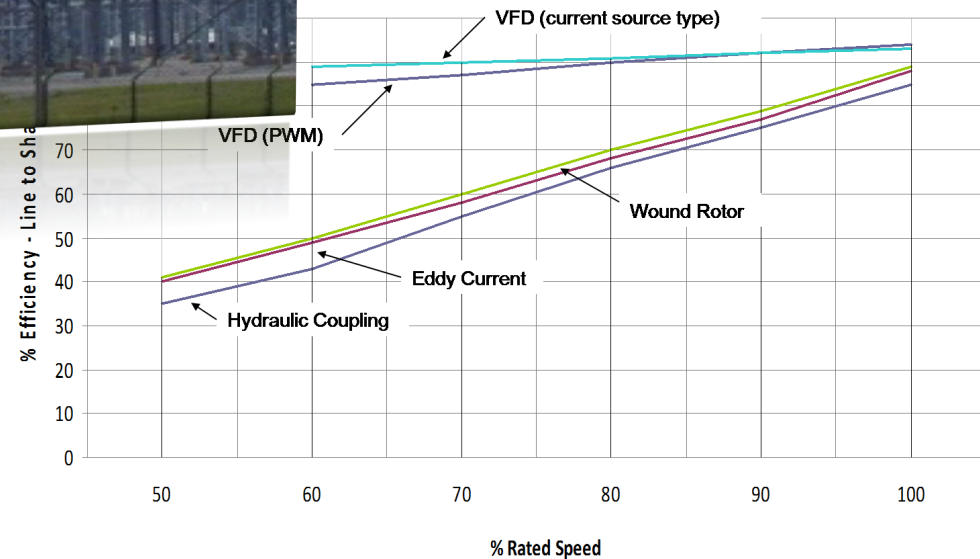
860-249-0989

JenMuir@jkmuir.com

Drilling Deeper



The "Low Hanging Fruit"



Introduction



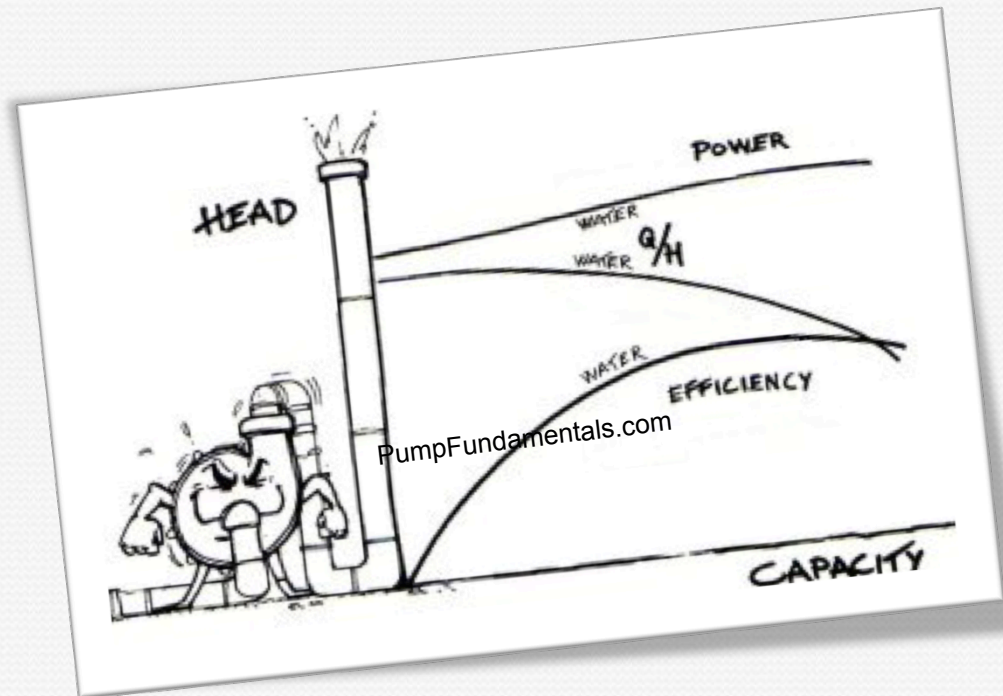
Photo: CNN.com

“If we want to avoid extreme energy, we need extreme efficiency.”

-Daniel Gross, “Moneybox” column and senior editor at Newsweek

Presentation Outline

- Basic Hydraulics
- Pump System Overview
 - System and Pump Curves
- Pump Efficiency
- Pump Efficiency Testing
- Examples



Pump System Efficiency

- Factors to consider:
 - Pump specifications and design (Best Efficiency Point)
 - Inefficiencies & losses at each point

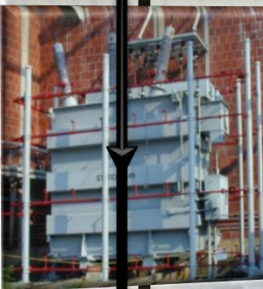
• **Goal: Maximize flow delivered per unit of input energy.**



Utility
feed



Transformer



Breaker/
starter



VFD



Motor



Pump

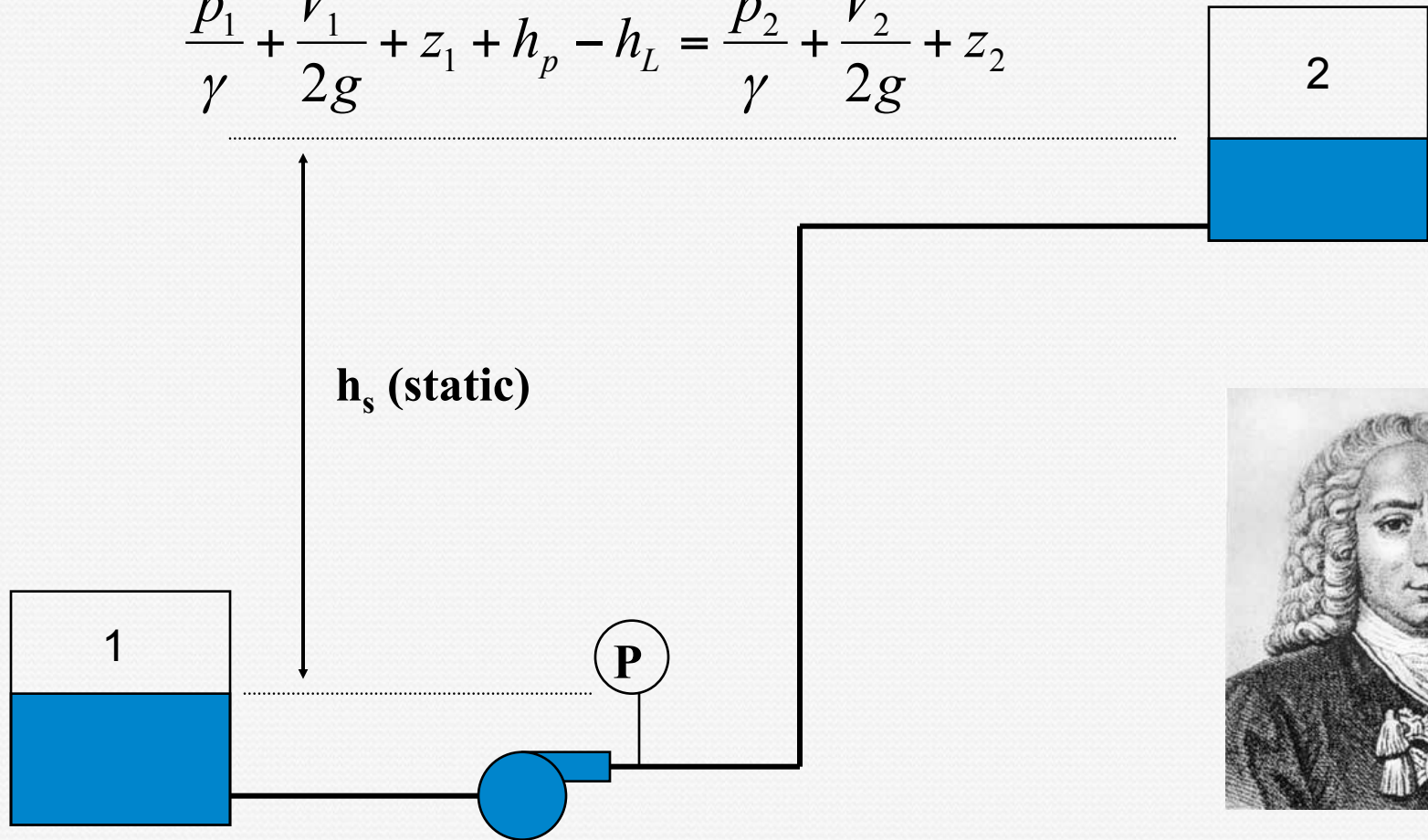


Fluid system

Basic Hydraulics

- It's all about Bernoulli!

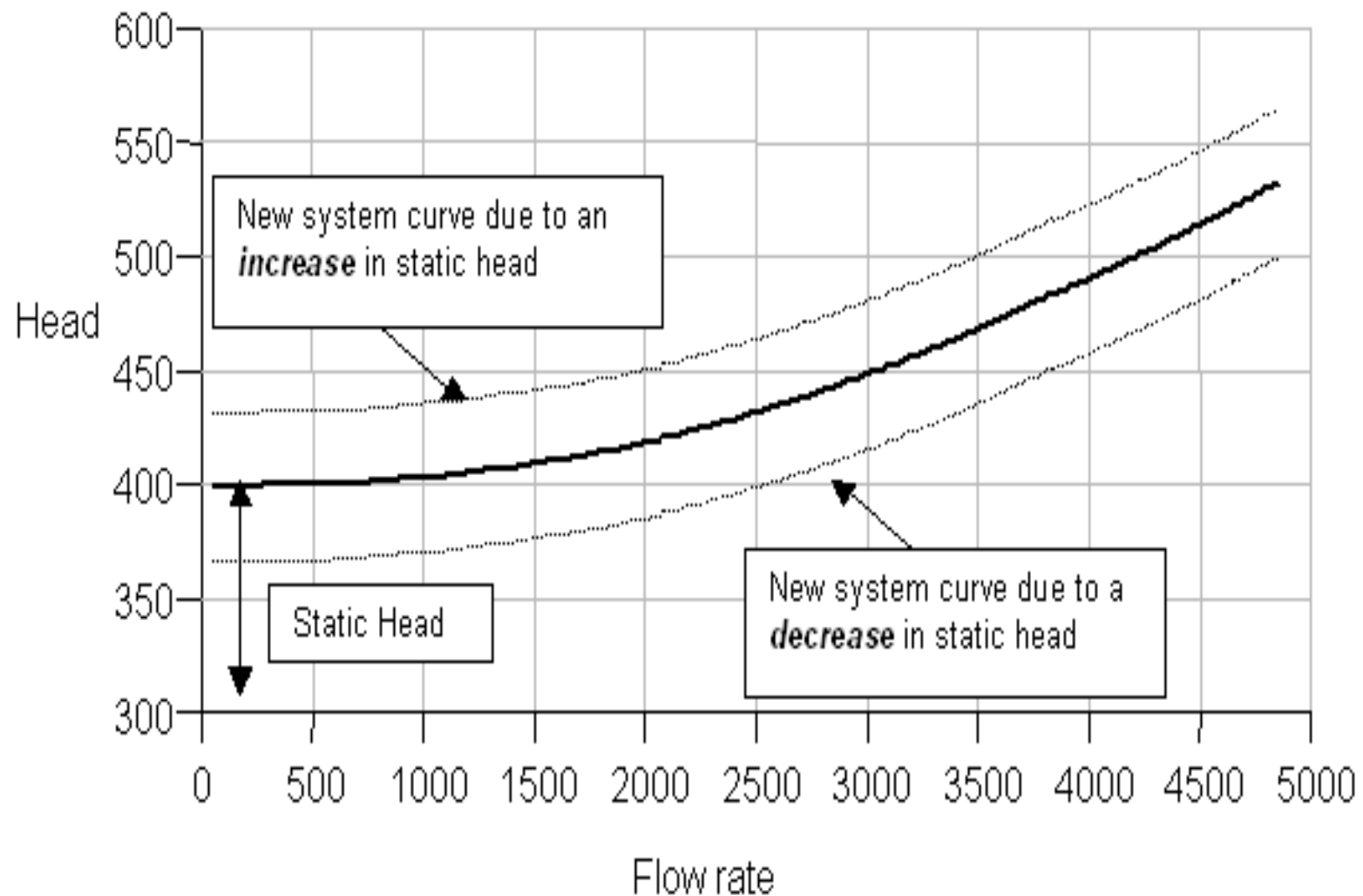
$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_p - h_L = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$



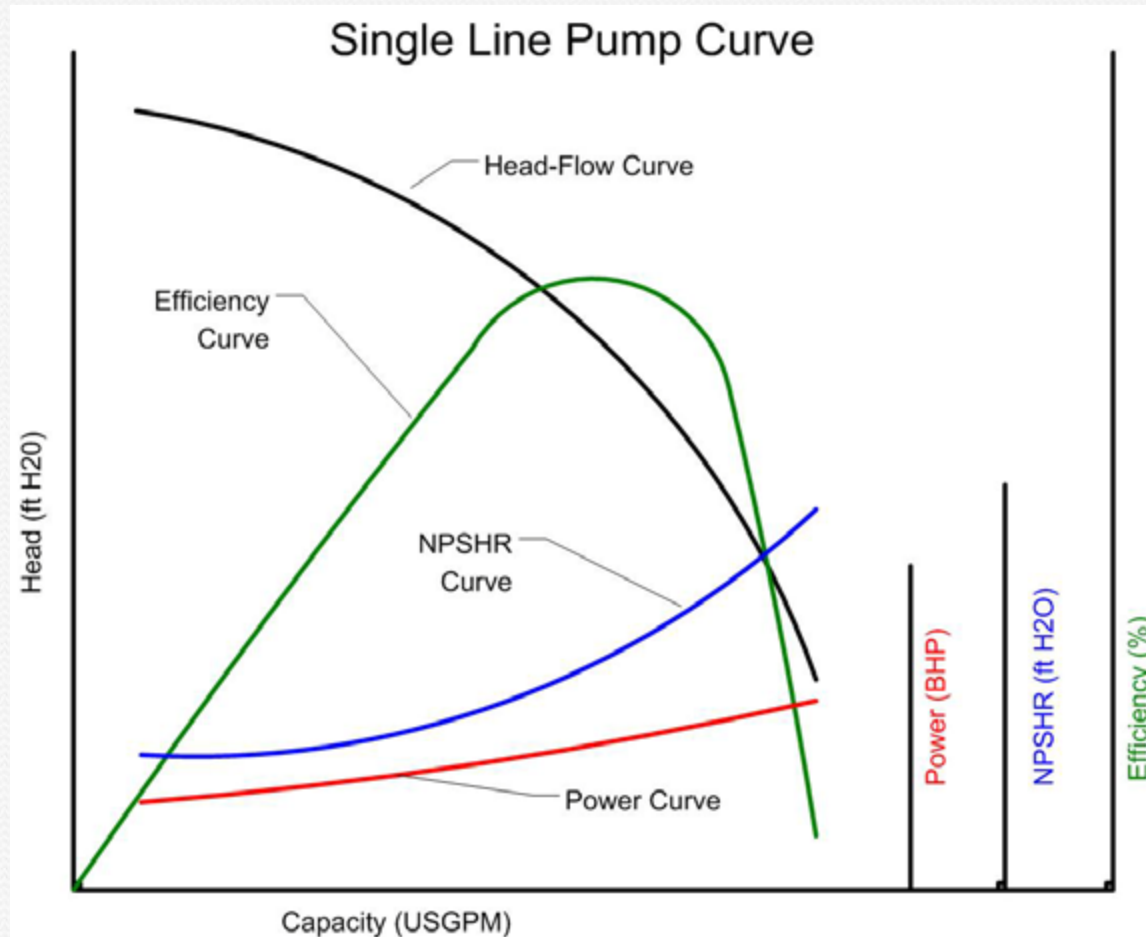
Basic Hydraulics – System Curve

- Energy required for pumps to move water
 - Depends on system conditions / system curve
- Bernoulli energy components:
 - Elevation (static head - h_s)
 - Difference in water elevations
 - Velocity head (h_v)
 - Function of flow and pipe size
 - Headloss due to friction (h_L)
 - Affected by pipe material and number of fittings

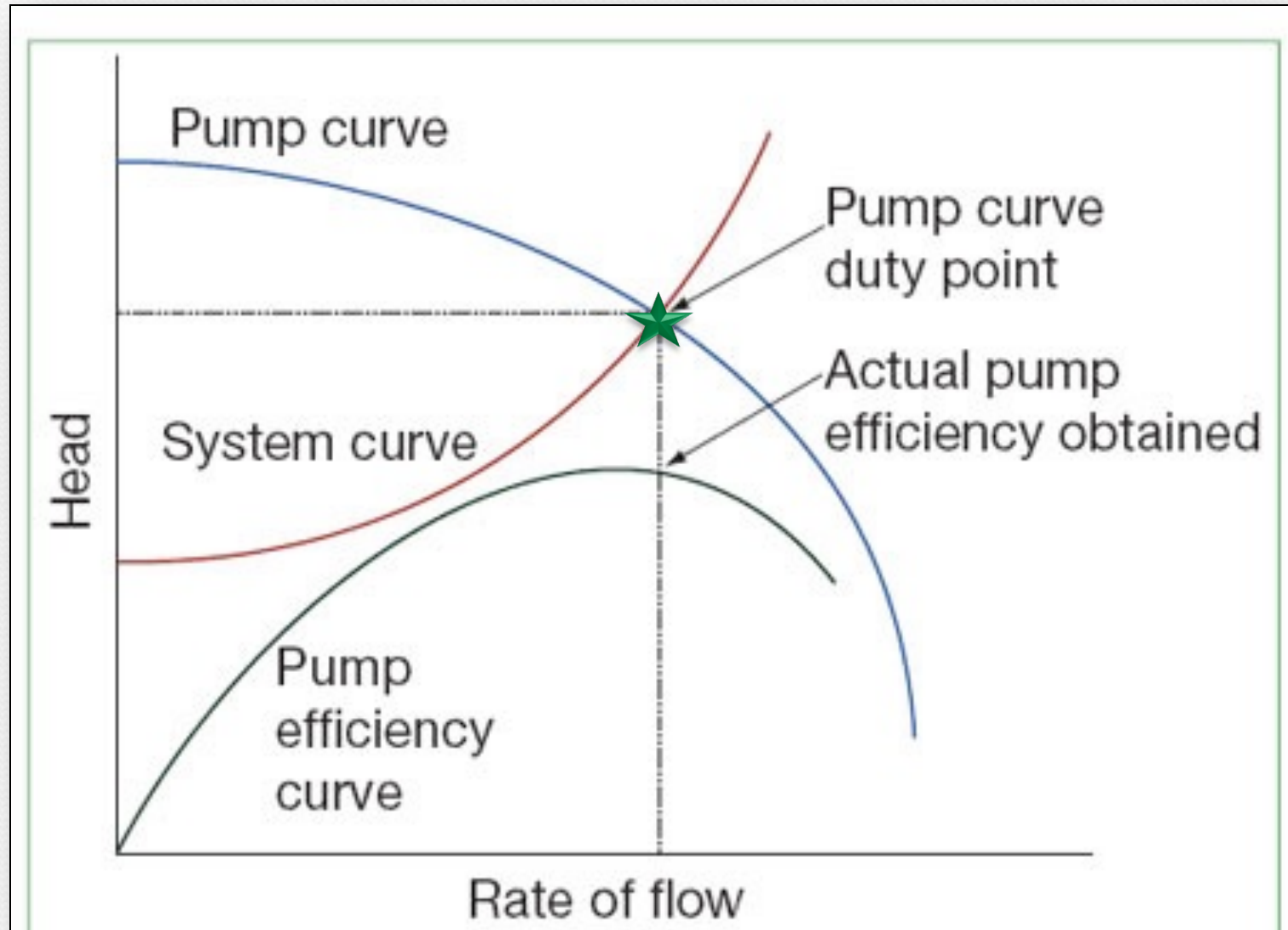
Basic Hydraulics – System Curve



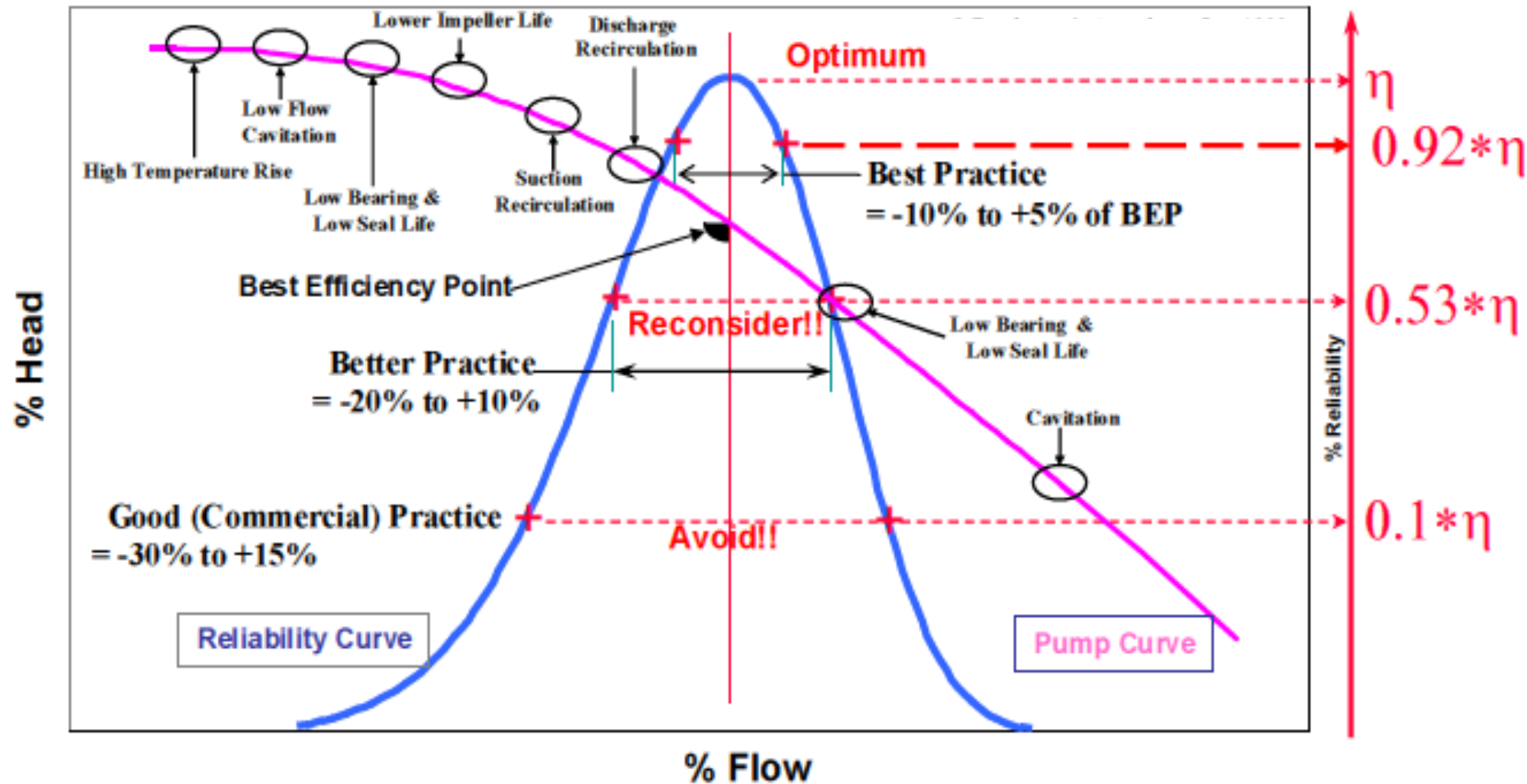
Basic Hydraulics – Pump Curve



Pump Duty Point – Where System and Pump Curves Meet



Pump Design - Best Efficiency Point



Pump Power

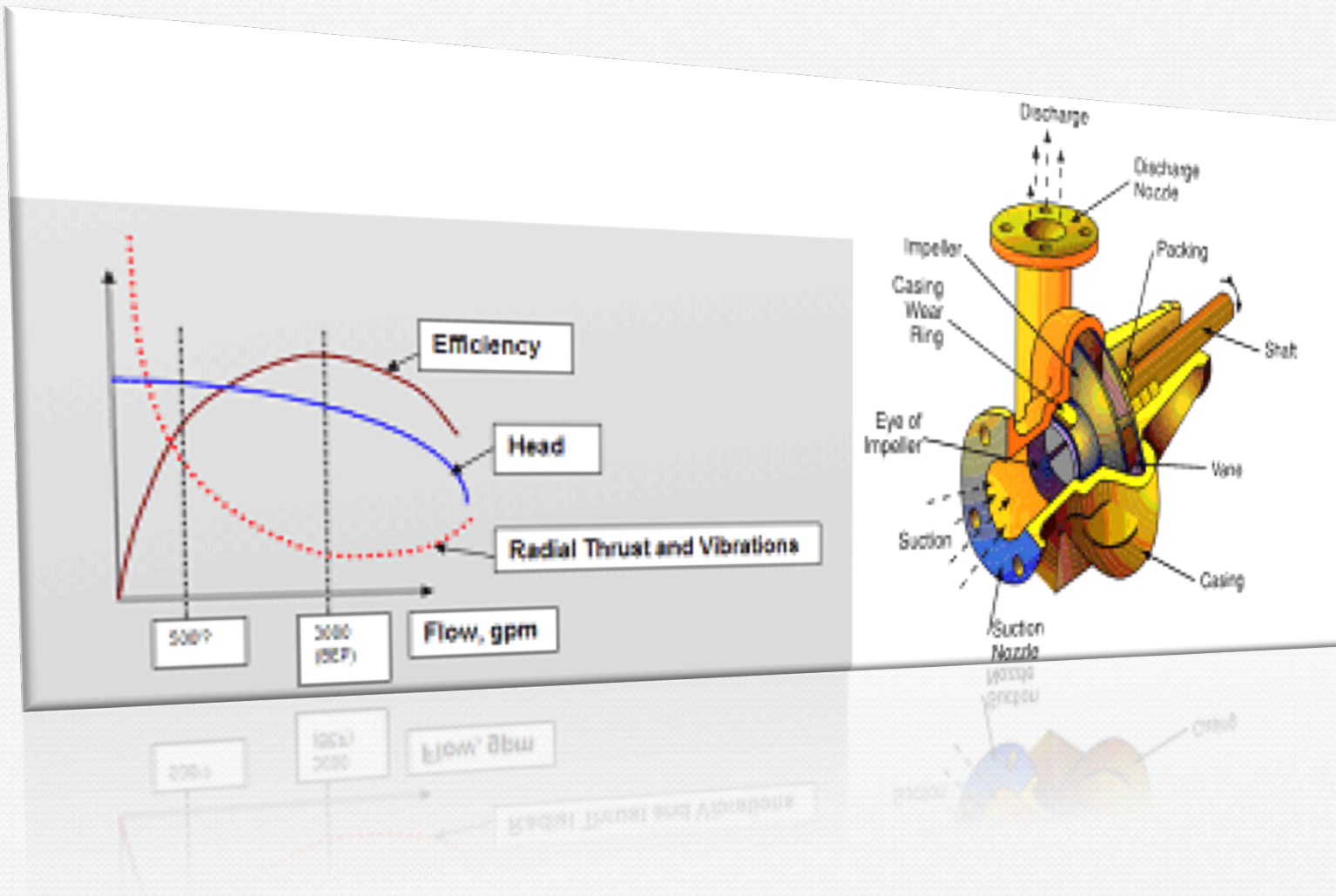
- The pump output (h_p) is measured in feet of head and referred to as the Total Dynamic Head (TDH)
 - Duty point is based on flow (Q) and TDH (ft)
- The electrical energy required to move water is a function of the flow and TDH

$$\text{Pump BHP} = \frac{Q(\text{gpm}) \times \text{TDH}(\text{ft}) \times 0.746}{3960 \times \text{pump efficiency}}$$

$$\text{Pump (kW)} = \frac{Q(\text{gpm}) \times \text{TDH}(\text{ft}) \times 0.746}{3960 \times \text{pump efficiency} \times \text{motor efficiency}}$$

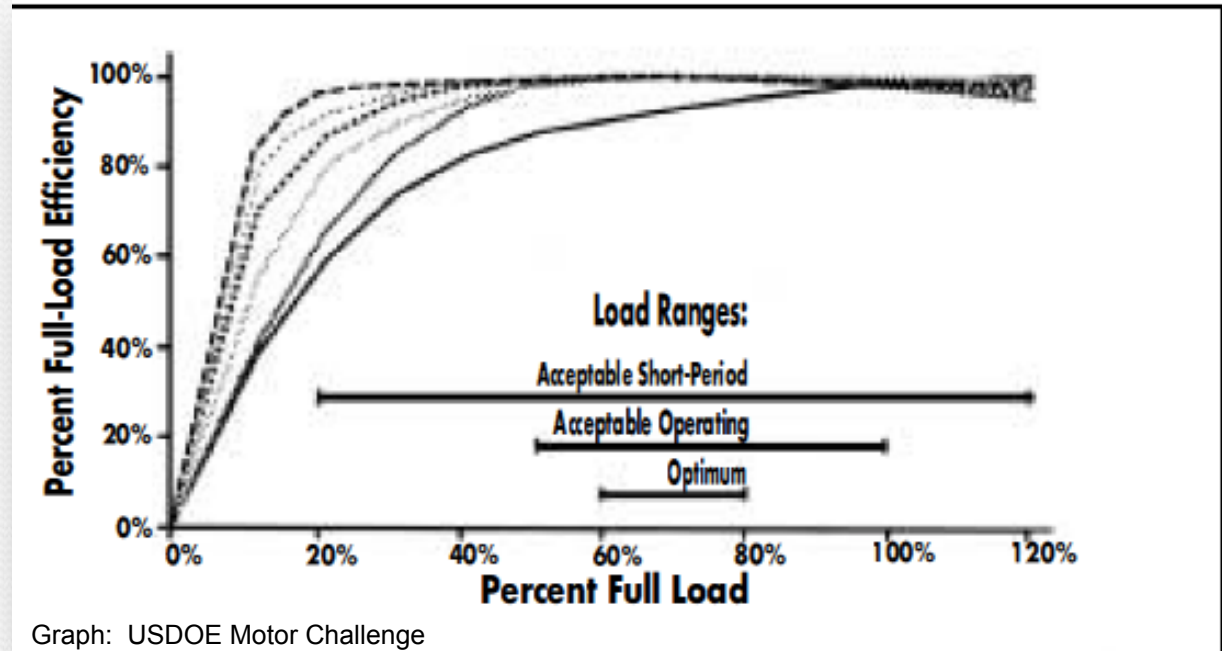
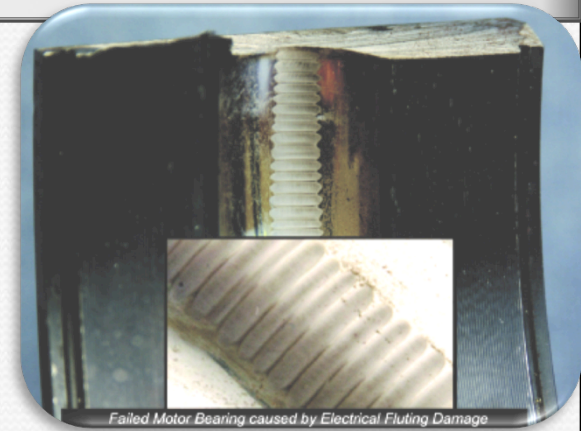
- **Total energy consumption (kWh) and costs are affected by flow, TDH, pump /motor efficiencies and pump run times**

Radial Thrust & Vibration

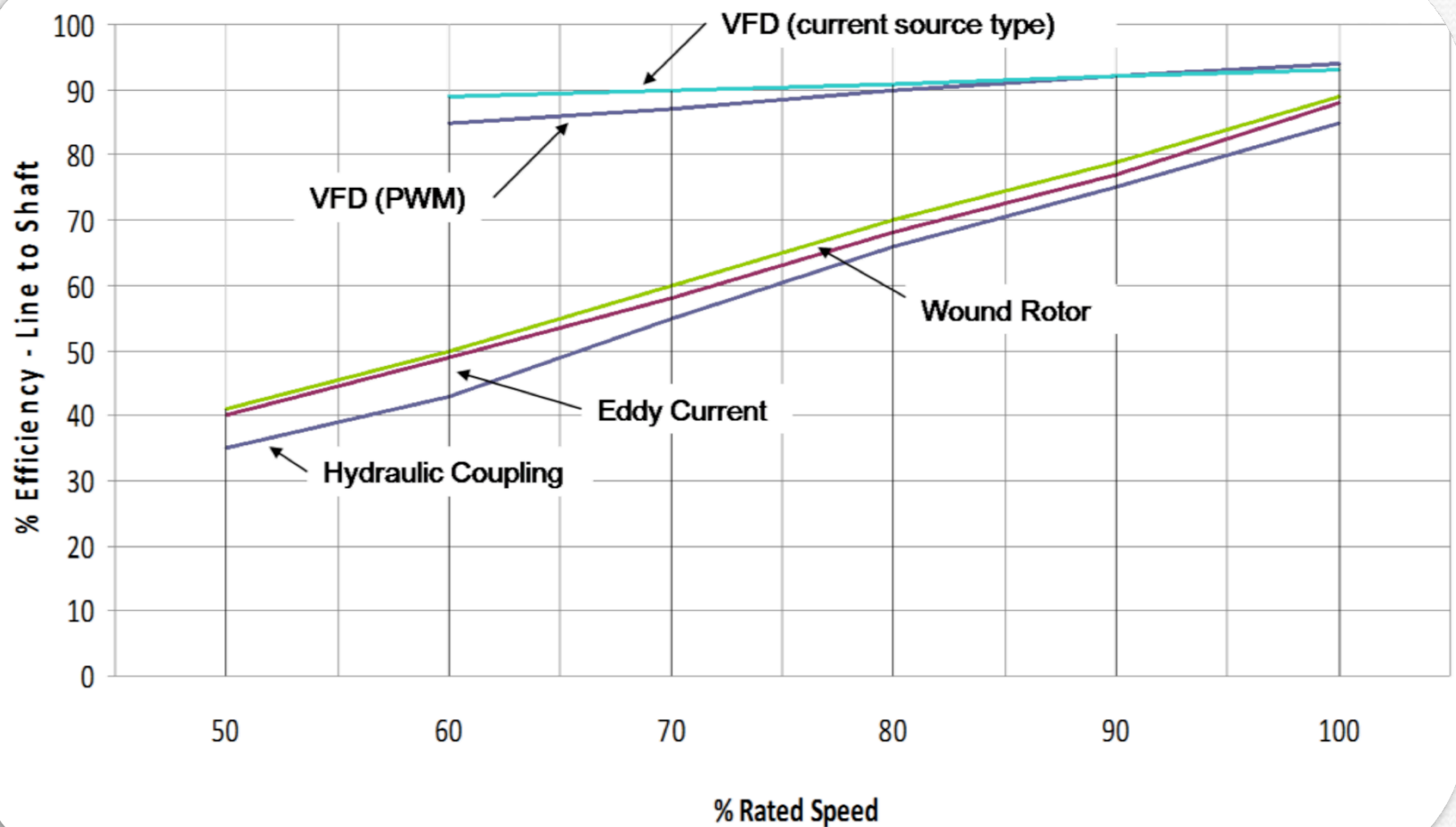


Motor Inefficiencies

- Loading
- Slip
- High temperature –VFD harmonics
- Bearing/shaft voltages
- Rewinding
- Speed
- Capacity



Drive Efficiency

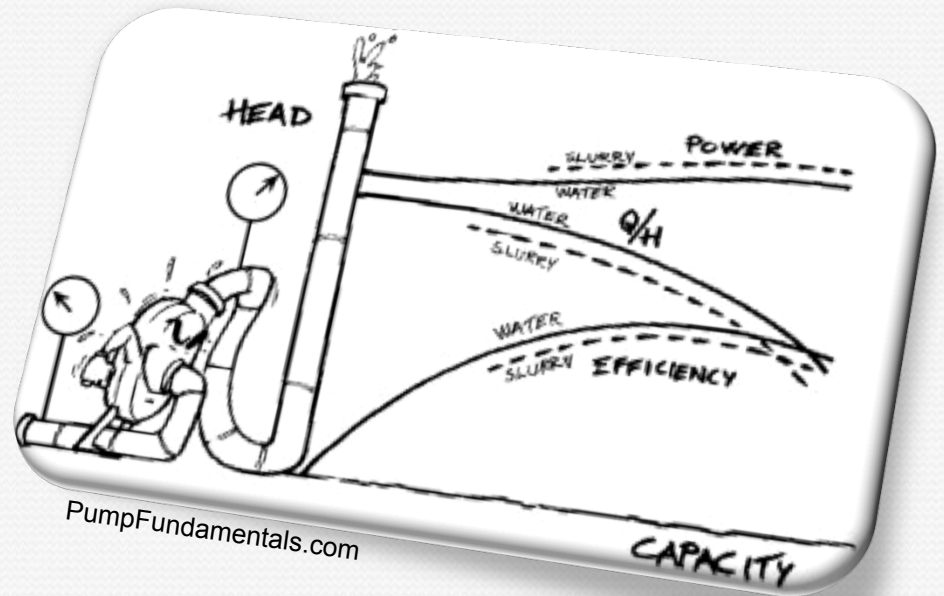


What is pump efficiency?

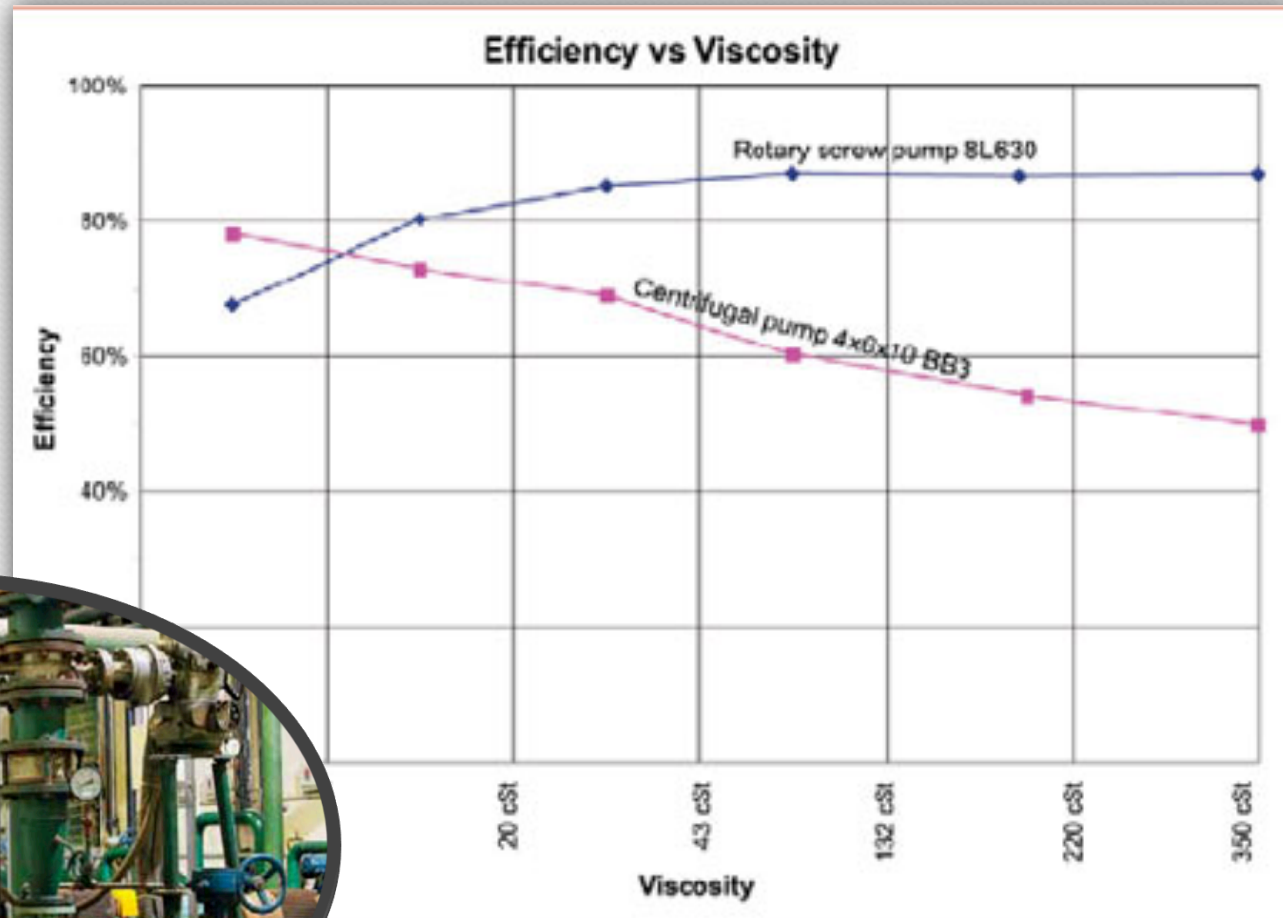
- Comparison between the amount of work (power) a pump gives versus the amount of power that it consumes.
- Pump efficiencies are specific to the unit itself and vary with flow and TDH.
- Design should be based around the best efficiency point of the pump.

Pump Efficiency Changes Over Time

- Hydraulic modifications
 - Valves
 - Piping
 - Elevations
- Wear
 - Bearings
 - Seals
 - Clearances
 - Surface roughness
 - Vibration/misalignment
- Impeller modifications
- Cavitation



Viscosity



Graph & Photo: Pump & Systems

Interior Coatings



- Monroe County NY
- All 100 pumps:
 - 35% below rated flow & head
 - 20-30% below specified efficiency

- 11.6% efficiency increase
 - 5.4% - refurbishment
 - 6.2% – interior coating



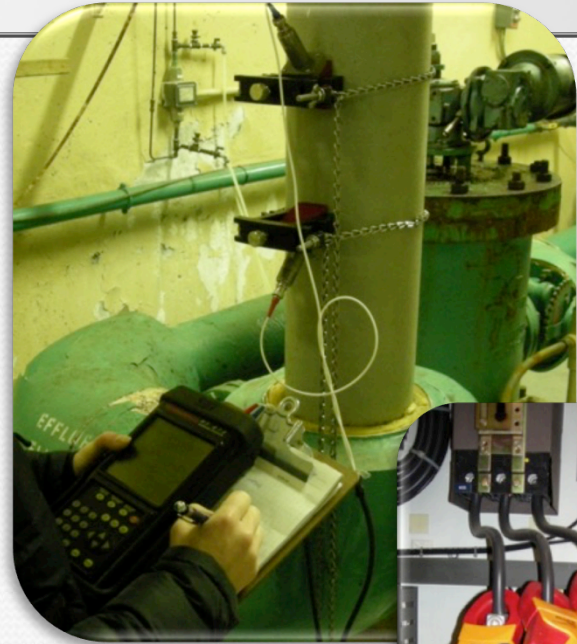
Photos: WE&T March 2010

Pump Efficiency Testing

Installed or portable instrumentation

Efficiency testing includes:

- Flow monitoring
- Power (kW) measurements
- Using pressure instrumentation to determine pump head
- Data loggers to evaluate energy use changes over a period of time



Compare to the original pump performance



Evaluate rebuild/replacement options.

Pump Efficiency Testing

Pump #1

Specified optimal eff (below) ▼

Achievable efficiency 85.0

Pump rpm 327

Drive Direct drive ▼

Units gpm, ft, hp ▼

Kinematic viscosity (cS) 1.00

Specific gravity 1.000

stages 1

Fixed specific speed? YES

Line freq. 60 Hz ▼

HP 800 ▼

Motor rpm 321

Eff. class Specified (below) ▼

FL efficiency, % 90.0

Voltage 2300

Estimate FLA

Full-load amps 215.0

Size margin, % 0

Operating fraction 0.500

\$/kwhr 0.0900

Flow rate, gpm 44444

Head, ft 39.0

Head tool

Load estim. method Current ▼

Motor amps 193.0

Voltage 2292

Pump #2

Specified optimal eff (below) ▼

Achievable efficiency 85.0

Pump rpm 327

Drive Direct drive ▼

Units gpm, ft, hp ▼

Kinematic viscosity (cS) 1.00

Specific gravity 1.000

stages 1

Fixed specific speed? YES

Line freq. 60 Hz ▼

HP 800 ▼

Motor rpm 321

Eff. class Specified (below) ▼

FL efficiency, % 90.0

Voltage 2300

Estimate FLA

Full-load amps 215.0

Size margin, % 0

Operating fraction 0.500

\$/kwhr 0.0900

Flow rate, gpm 40972

Head, ft 35.0

Head tool

Load estim. method Current ▼

Motor amps 174.0

Voltage 2288

Pump #1

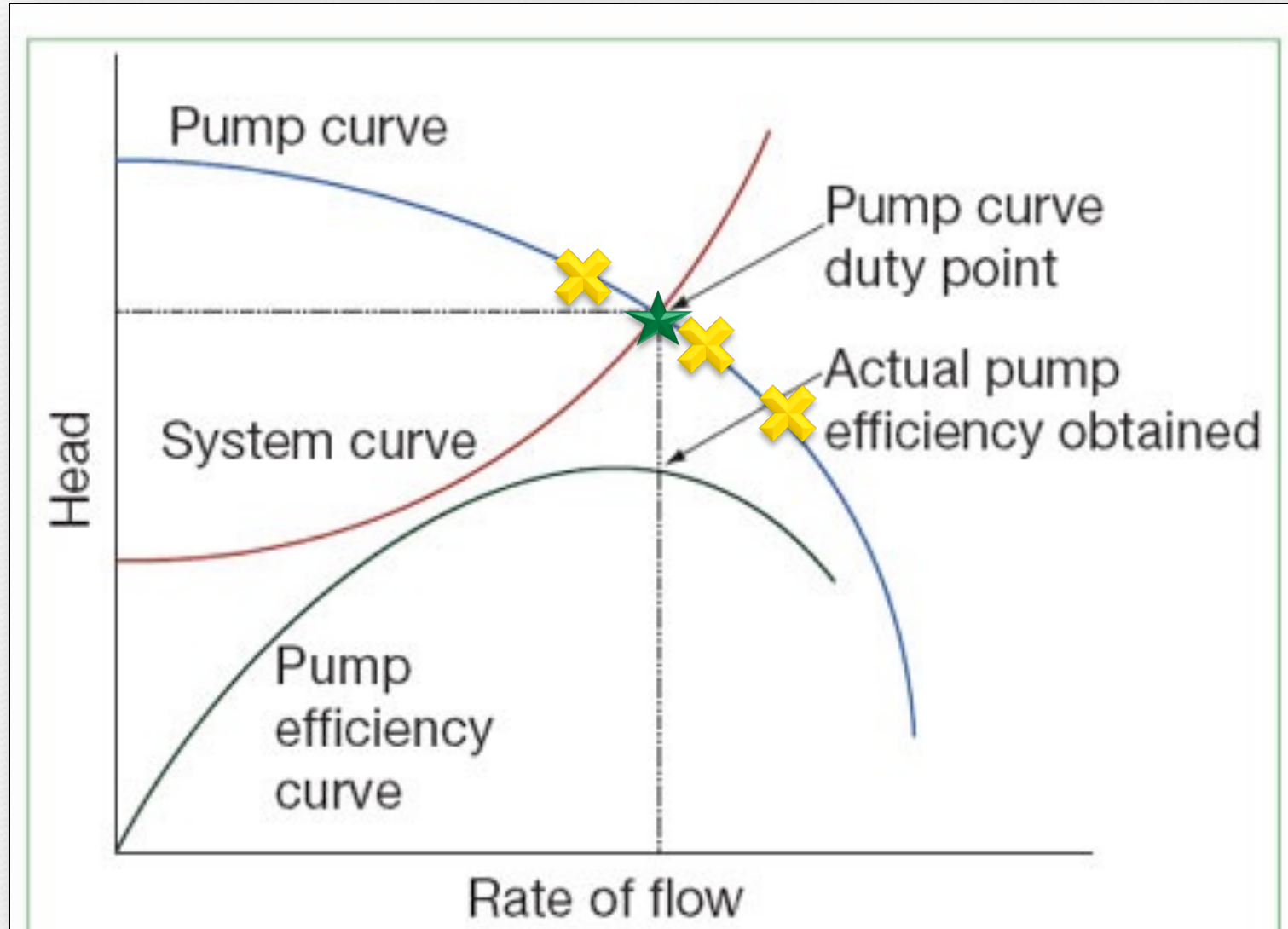
	Existing	Optimal	Units
Pump efficiency	63.1	85.0	%
Motor rated power	800	800	hp
Motor shaft power	693.5	514.8	hp
Pump shaft power	693.5	514.8	hp
Motor efficiency	90.5	94.8	%
Motor power factor	74.6	72.5	%
Motor current	193.0	140.6	amps
Motor power	571.6	405.0	kW
Annual energy	2503.5	1773.7	MWh
Annual cost	225.3	159.6	\$1000
Annual savings potential, \$1,000		65.7	
Optimization rating, %		70.9	

Pump #2

	Existing	Optimal	Units
Pump efficiency	60.7	85.0	%
Motor rated power	800	450	hp
Motor shaft power	596.7	425.9	hp
Pump shaft power	596.7	425.9	hp
Motor efficiency	90.8	94.6	%
Motor power factor	71.1	73.9	%
Motor current	174.0	114.7	amps
Motor power	490.1	335.9	kW
Annual energy	2146.7	1471.3	MWh
Annual cost	193.2	132.4	\$1000
Annual savings potential, \$1,000		60.8	
Optimization rating, %		68.5	

- Efficiencies pumps are 63% & 61%
- Restore pumps to 85% efficiency (originally 88%)
- Annual savings of \$126,490

Pump Efficiency Reduction



Pump Efficiency Improvement Options

- **Pump Rebuild**
- **VFD Installation**
- **Pump Replacement**
- **Operation or Control Changes**

Pump Efficiency Reduction – Example

SECTION 2340

END SUCTION PUMPS
Series C&F Type 820A Size 2 x 2½ x 8

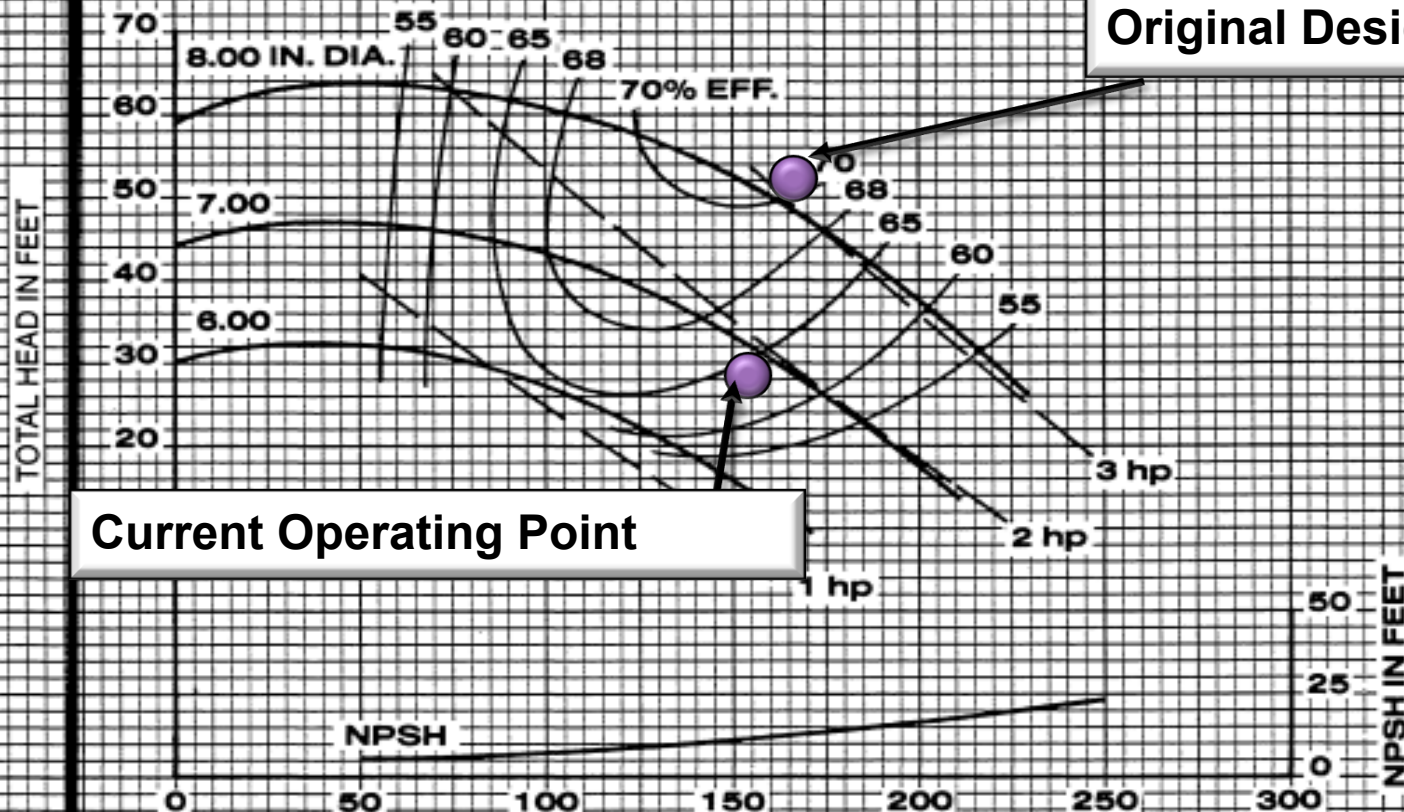


Peerless Pump Company
Indianapolis, IN 46207-7025

Pumps operating at reduced efficiencies

1750 RPM

Original Design



Current Operating Point

Pump Rebuild Savings

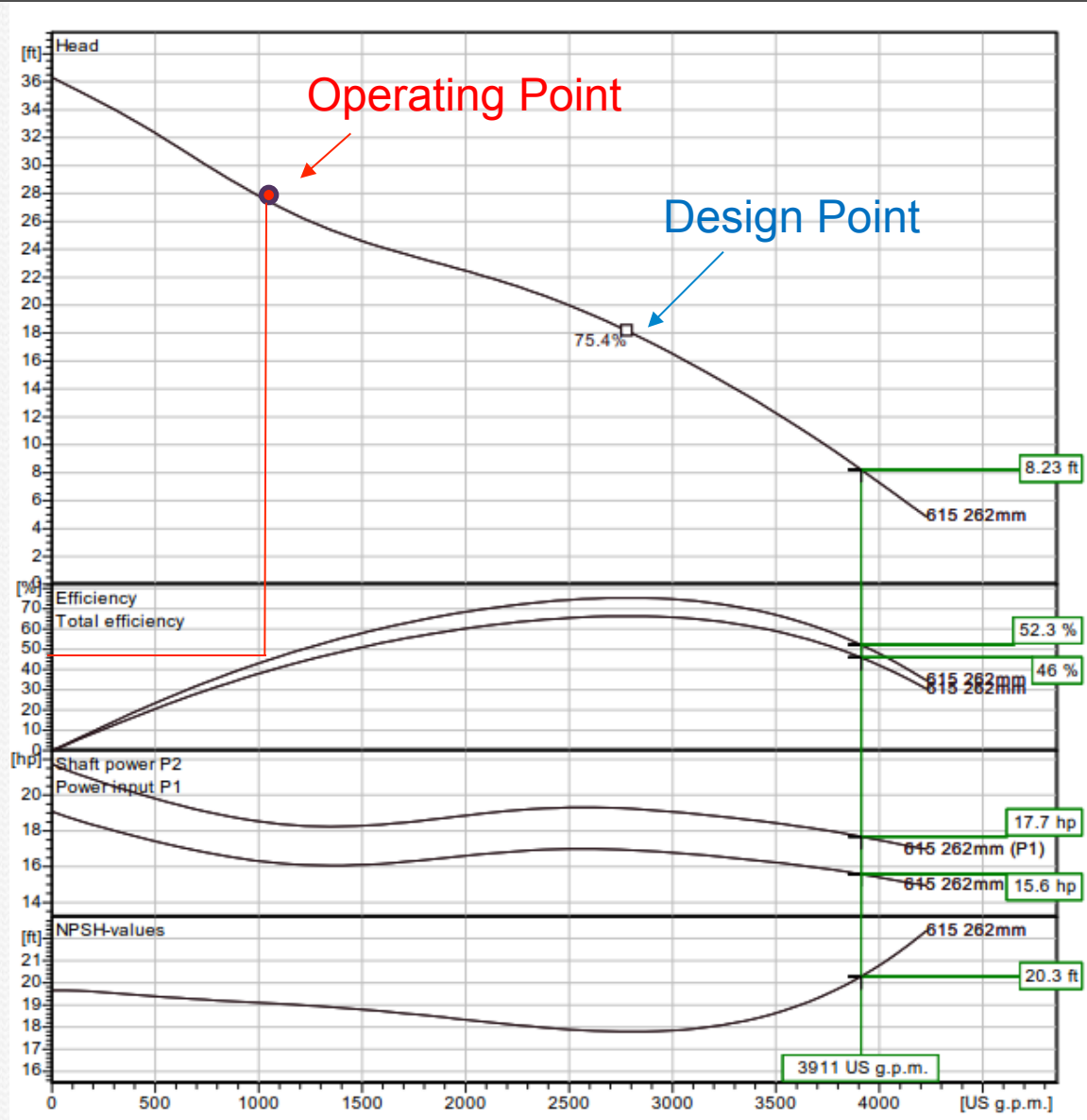
- **30 HP**

- Existing Conditions
 - Operating Efficiency **27%**
Annual kWh Usage **184,023**
 - Annual Cost **\$25,763**
- Rebuilt Conditions
 - Operating Efficiency **80%**
 - Annual kWh Usage **62,108**
 - Annual Cost **\$8,695**

- **250 HP**

- Existing Conditions
 - Operating Efficiency **39%**
 - Annual kWh Usage **937,320**
 - Annual Cost **\$103,105**
- Rebuilt Conditions
 - Operating Efficiency **80%**
 - Annual kWh Usage **435,840**
 - Annual Cost **\$47,942**

Oversized Pump – Example

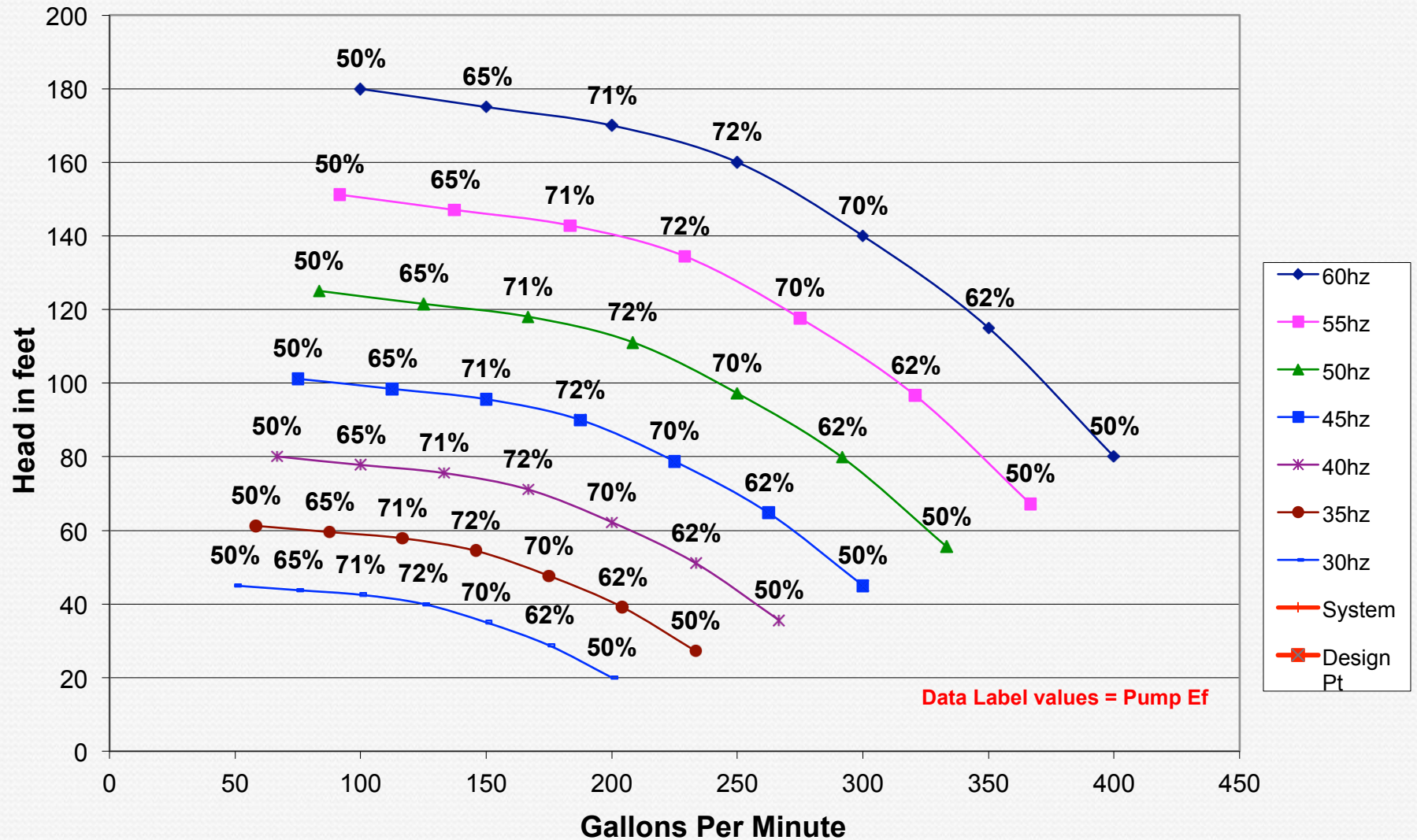


VFDs?

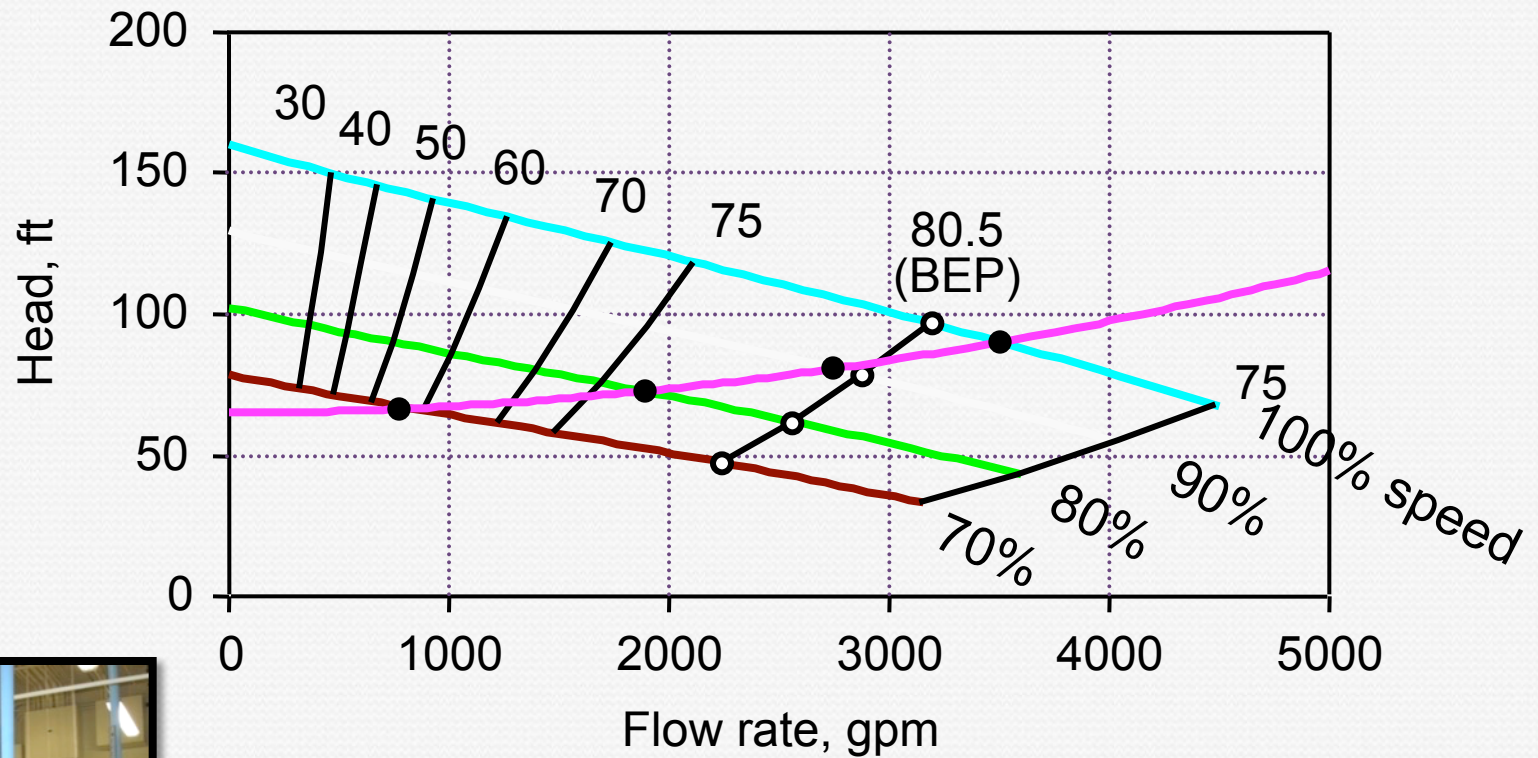
- **Constant Speed Operation** – pumping systems can operate by cycling on and off
- **VFD installation** – allow for continuous operation at varying speeds
- **Potentially provide energy savings**

Variable Speed Analysis

Pump Hydraulic Efficiency vs System Head

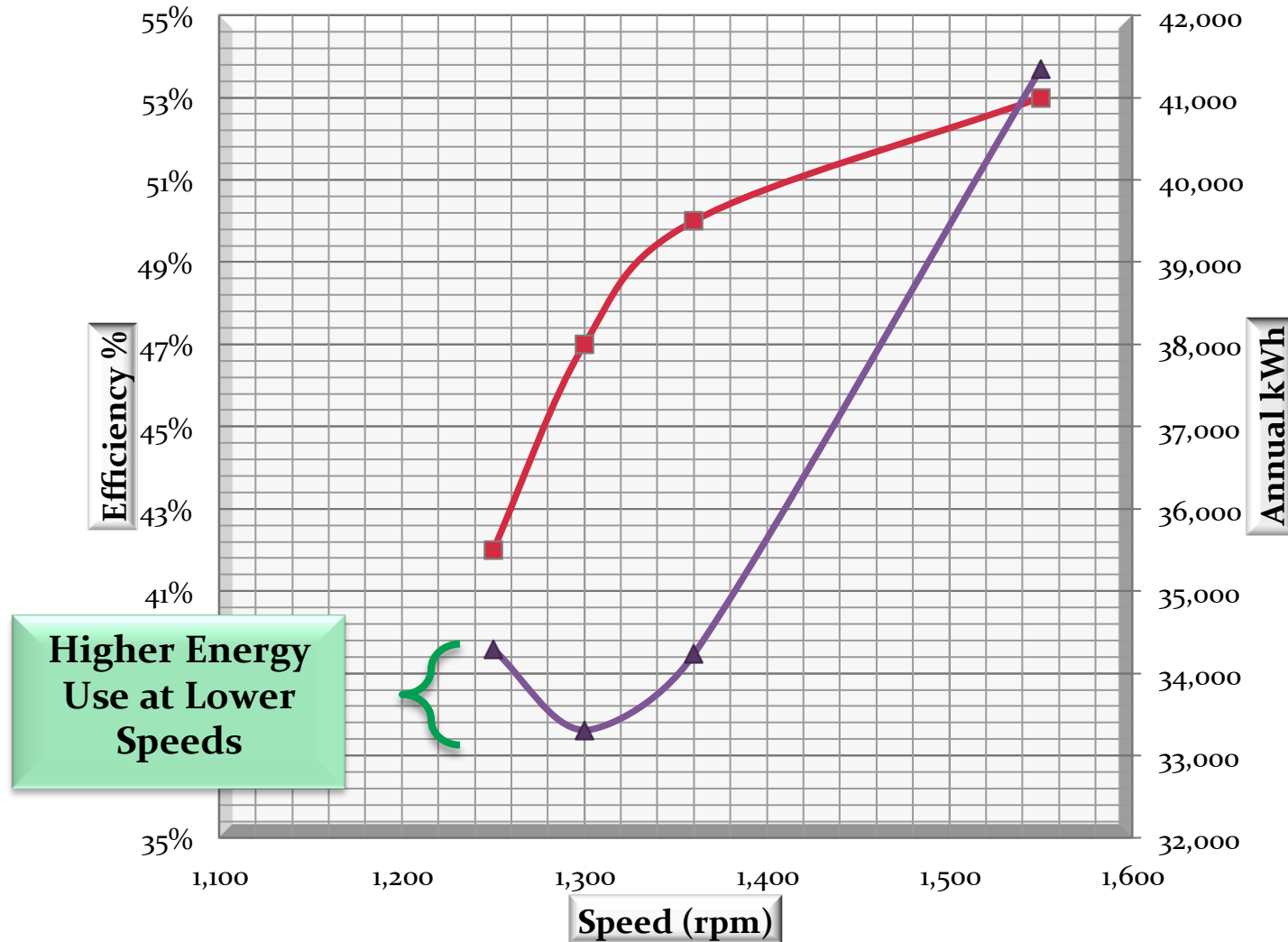


VFD Application – Example



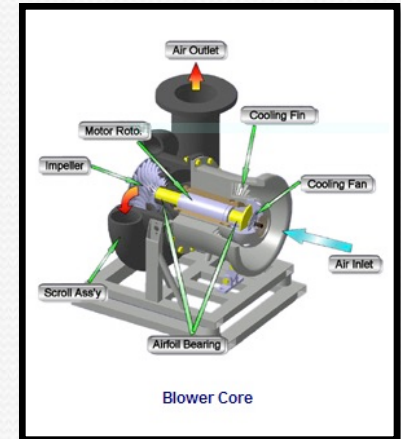
Graph Courtesy of Oak Ridge National Laboratory

VFD Set Points



Incentive Programs

- What's eligible
 - Prescriptive rebates (lighting/HVAC)
 - Custom projects
 - Pumps, mixing, aeration, VFDs, controls/automation
- Baseline data
- Calculating savings (kW & \$)
- Correspondence with utility



Jen Muir
Jessica Dzwonkoski
JKMuir, LLC
860-249-0989
JenMuir@jkmuir.com
www.jkmuir.com



Pump Efficiency Testing

