EN 410
Energy Management

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Pump performance parameters

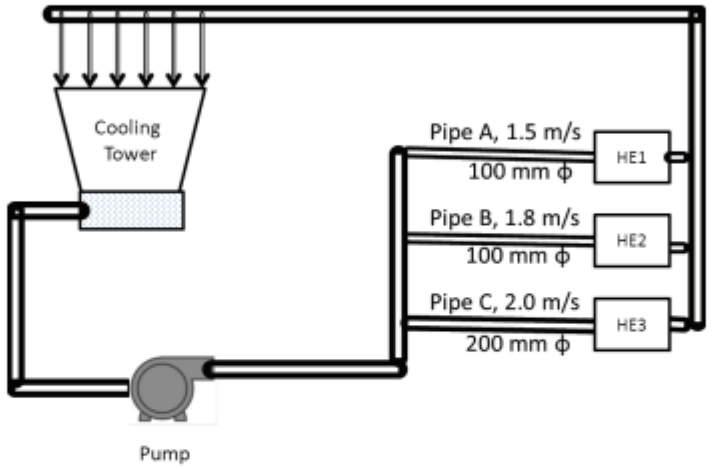
Hydraulic Power P_h = Q (m^3/s) x Total Differential head, $h_d - h_s$ (m) x ρ (kg/m^3) x g (m/s^2) / 1000

Where h_d - discharge head, h_s – suction head, ρ - density of the liquid, g – acceleration due to gravity

Pump Shaft Power P_s = Hydraulic power, P_h / Pump Efficiency, η_{Pump}

Motor Input Power = Pump shaft power P_s / Motor Efficiency, η_{Motor}

The cooling water circuit of a process industry is depicted in the figure below. Cooling water is pumped to three heat exchangers via pipes A, B and C where flow is throttled depending upon the requirement. The diameter of pipes and measured velocities with non-contact ultrasonic flow meter in each pipe are indicated in the figure.



The following are the other data:

Measured motor power	:	50.7 kW
Motor efficiency at operating load	:	90%
Pump discharge pressure	:	3.4 kg/cm^2
Suction head	:	2 meters

Determine the efficiency of the pump.

Pump selection curve

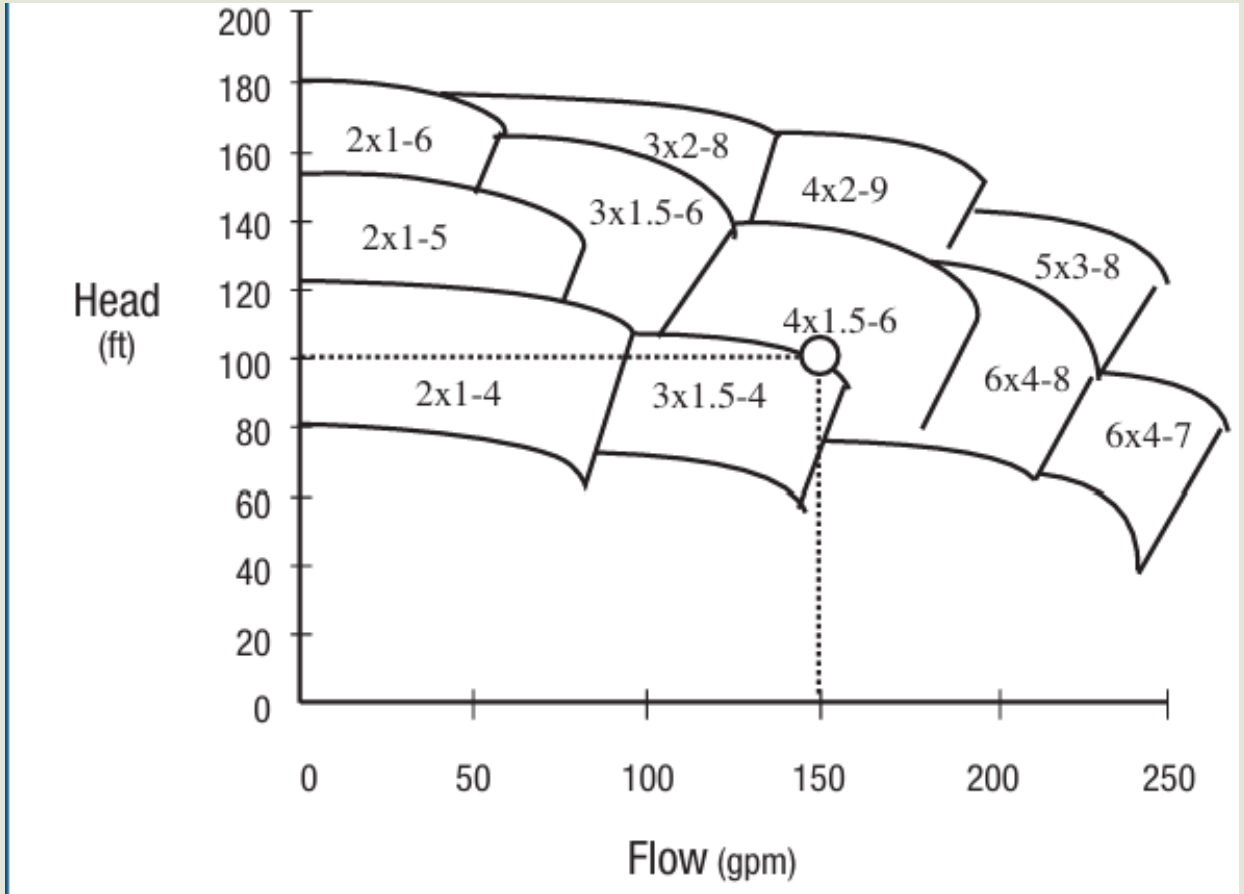


Figure 11. Family of Pump Performance Curves

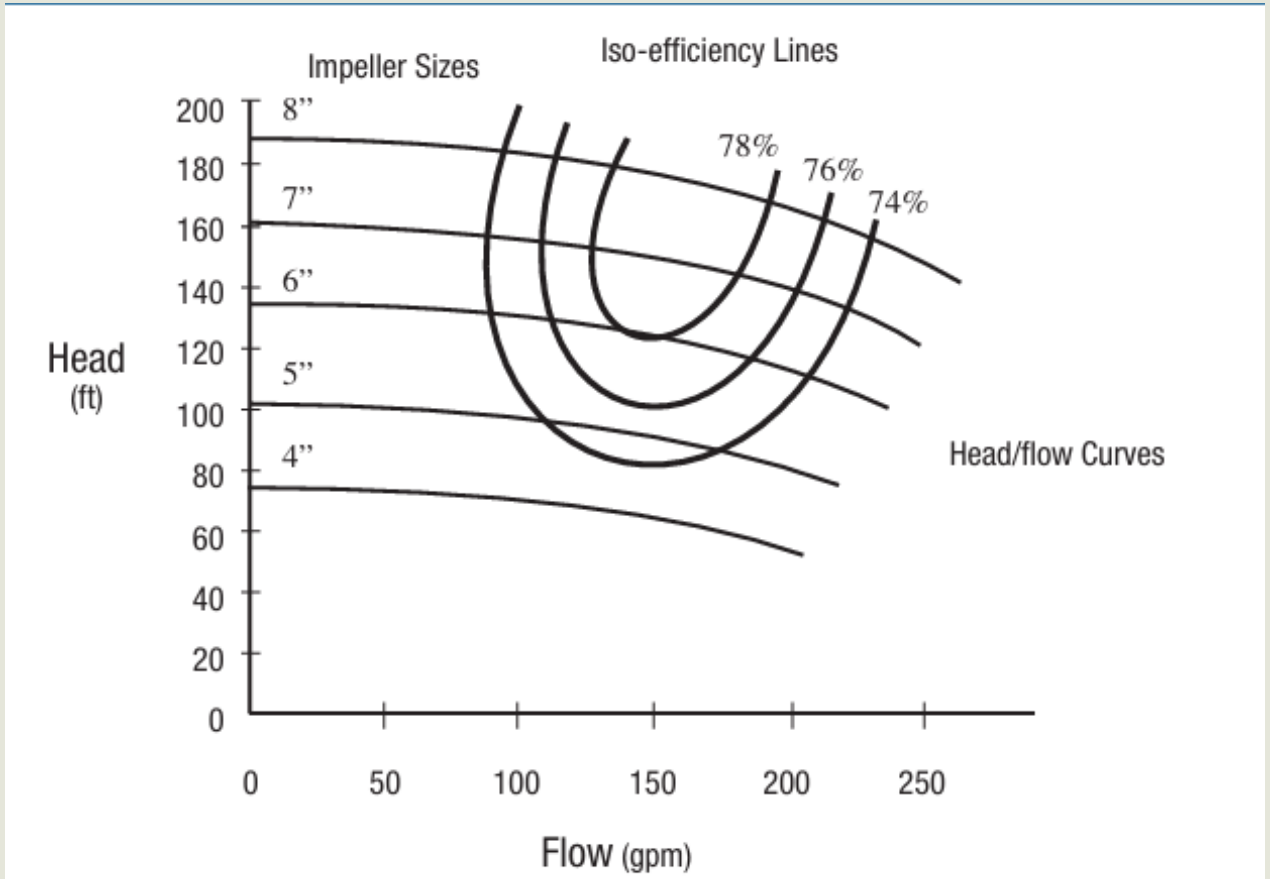
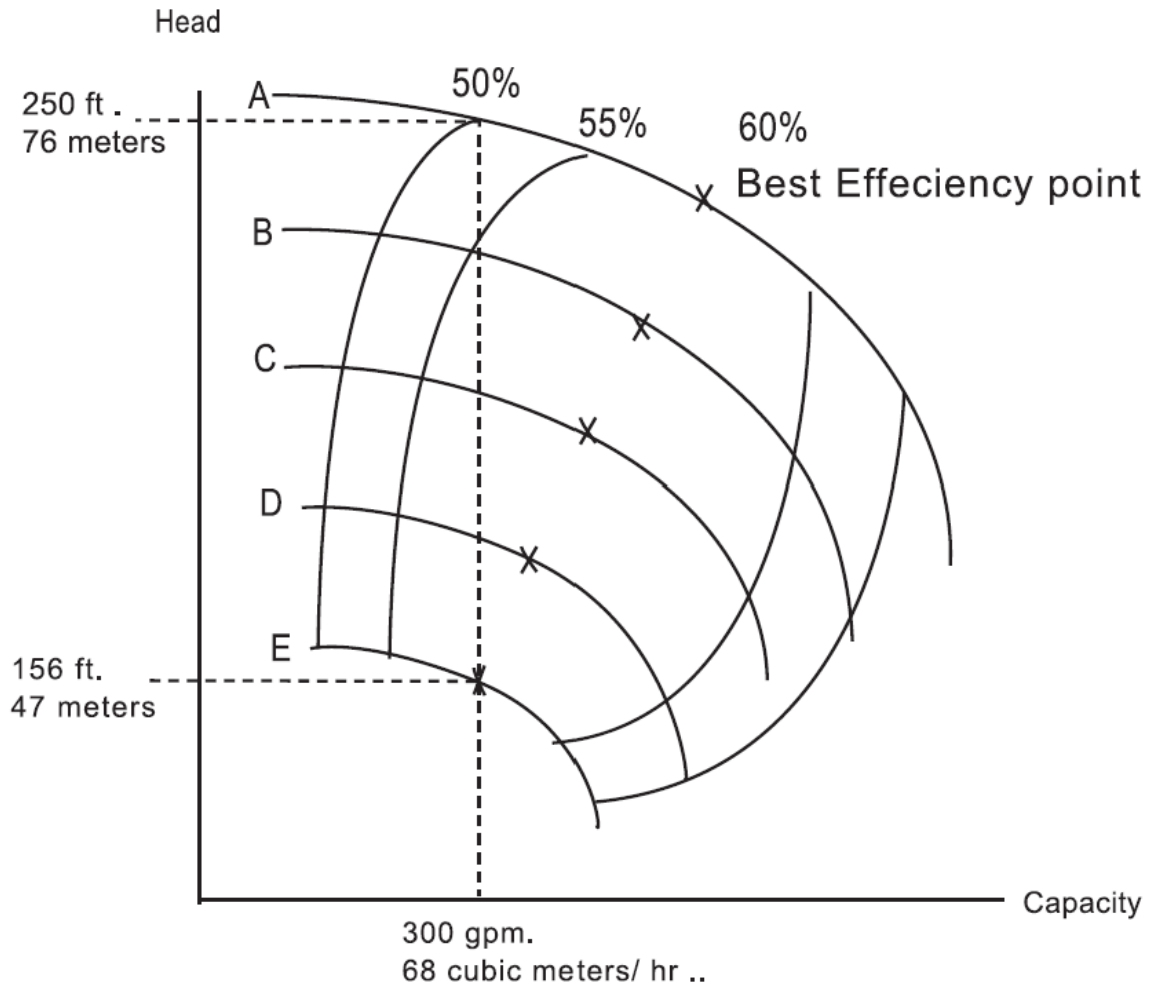


Figure 12. Performance Curves for Different Impeller Sizes

Effect of oversized pump



What happened if we select A instead of E?

- Pump cost of E is INR 300000
- Operating hours = 8000 hrs./year
- Utility rate = INR 5.5/kWh
- Motor efficiency = 90%
- Density of water = 1000 kg/m^3

Pump Control Strategies

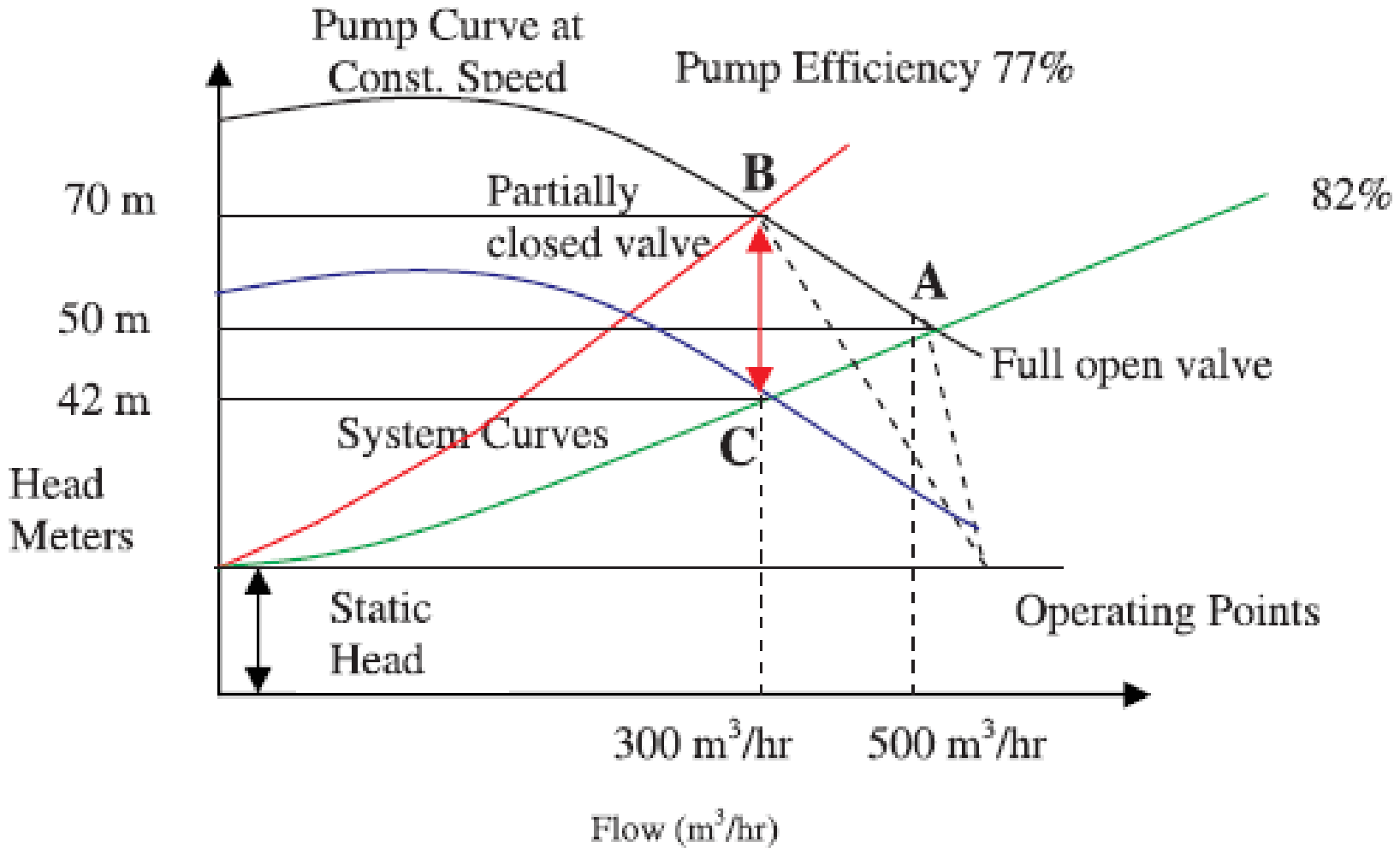
Often Oversizing – Does not operate at Design point

- Bypass Control
- Throttling
- Variable Speed Drives
- Trimming Impeller (reducing Diameter)

Bypass control

- Pump runs continuously at the maximum process demand level, with a permanent bypass line attached to the outlet.
- When a lower flow is required, the surplus liquid is bypassed and returned to the supply source.

Valve control method



The Affinity Laws

$$Q_2 = \left[\frac{N_2}{N_1}\right] Q_1$$

$$H_2 = \left[\frac{N_2}{N_1}\right]^2 H_1$$

$$P_2 = \left[\frac{N_2}{N_1}\right]^3 P_1$$

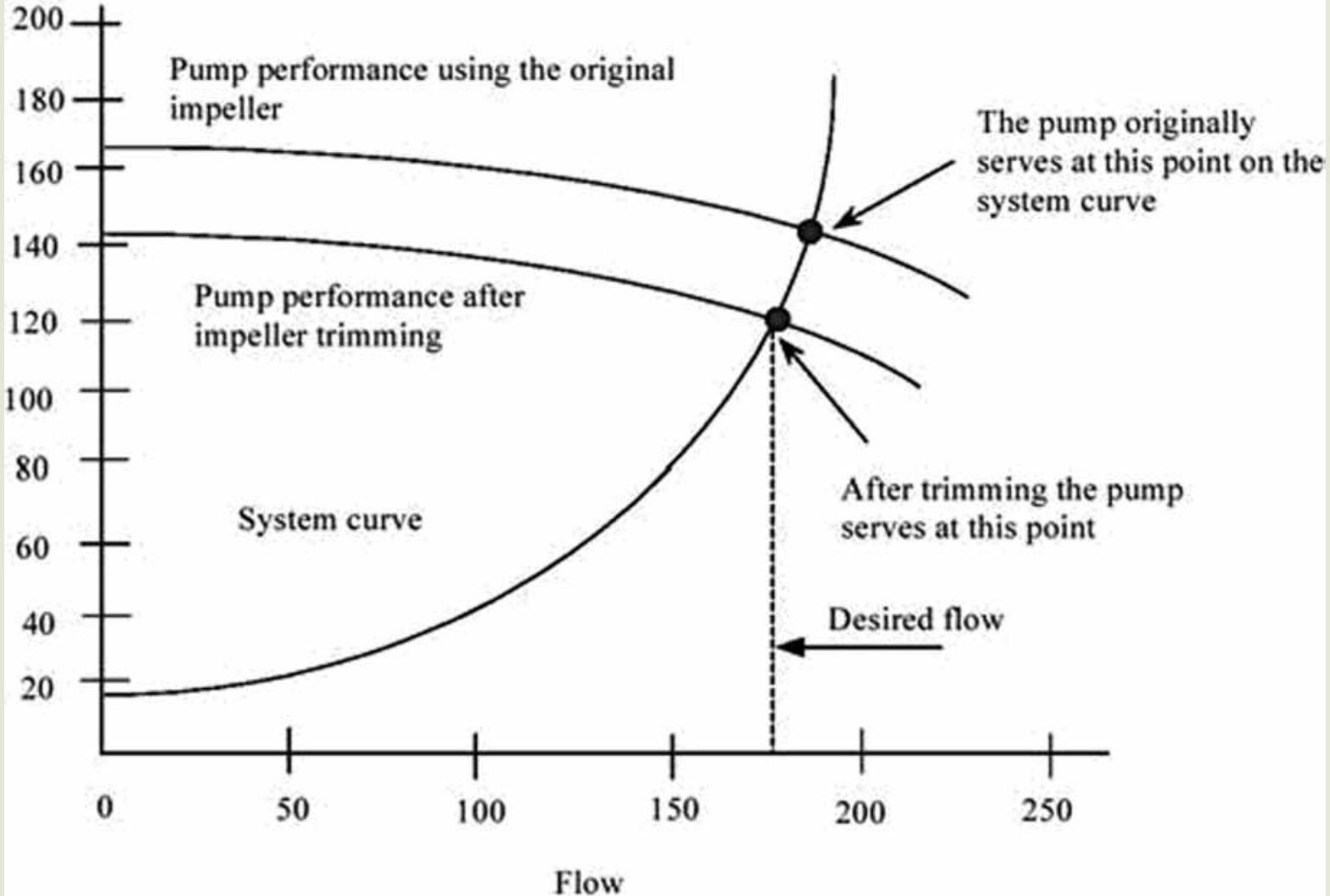
$$Q_2 = \left[\frac{D_2}{D_1}\right] Q_1 Q_2$$

$$= \left[\frac{D_2}{D_1}\right] Q_1 Q_2$$

$$= \left[\frac{D_2}{D_1}\right] Q_1$$

Impeller trimming to reduce flow

- Permanent changes
- Impeller diameters are rarely reduced below 70% of their original size



Pump speed adjustments

- Multiple-speed pump motors and variable speed drives (VSDs)
- Multiple-speed motors: different set of windings for each motor speed
  - Expensive, less efficient, discrete speeds
- Mechanical VSDs: hydraulic clutches, fluid couplings, and adjustable belts and pulleys.
- Electrical VSDs: eddy current clutches, wound-rotor motor controllers, and variable frequency drives (VFDs)

Speed control

- A centrifugal pump, pumping water operates at 35 m^3/h and at 1440 RPM. The pump operating efficiency is 68% and motor efficiency is 90%. The discharge pressure gauge shows 4.4 kg/cm^2. The suction is 2 m below the pump centerline. If the speed of the pump is reduced by 50% estimate the new flow, head and power.

- **Original**
  - **flow:**
  - **head:**
  - **power:**

Modified

Speed control

- A centrifugal pump, pumping water operates at 35 m^3/h and at 1440 RPM. The pump operating efficiency is 68% and motor efficiency is 90%. The discharge pressure gauge shows 4.4 kg/cm^2. The suction is 2 m below the pump centerline. If the speed of the pump is reduced by 50% estimate the new flow, head and power.

Original	**Modified**
flow: 35 m^3/h	**17.5 m^3/h**
head: 46 m	**11.5 m**
power: 7.17 kW	**0.9 kW**

Speed Control

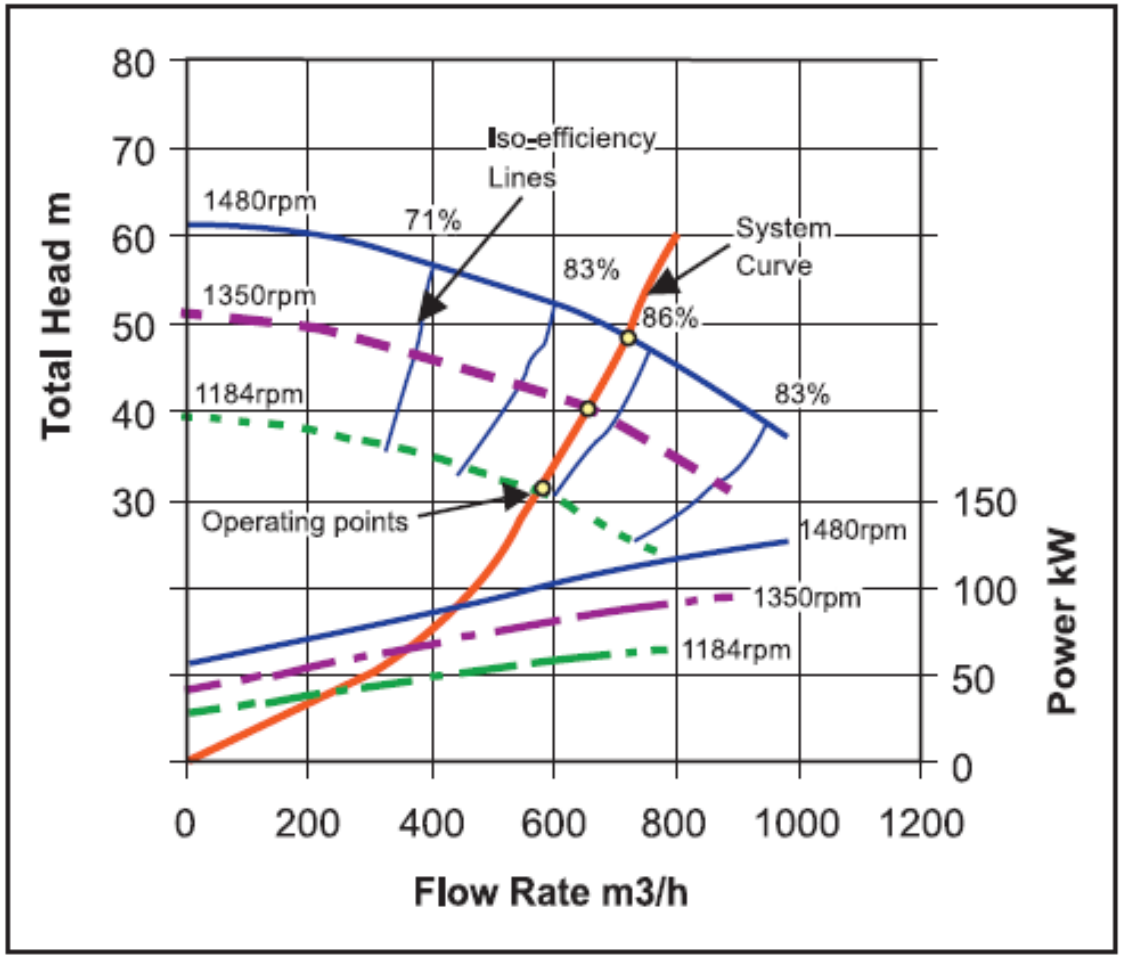


Figure 6.15 Example of the Effect of Pump Speed Change in a System with Only Friction Loss

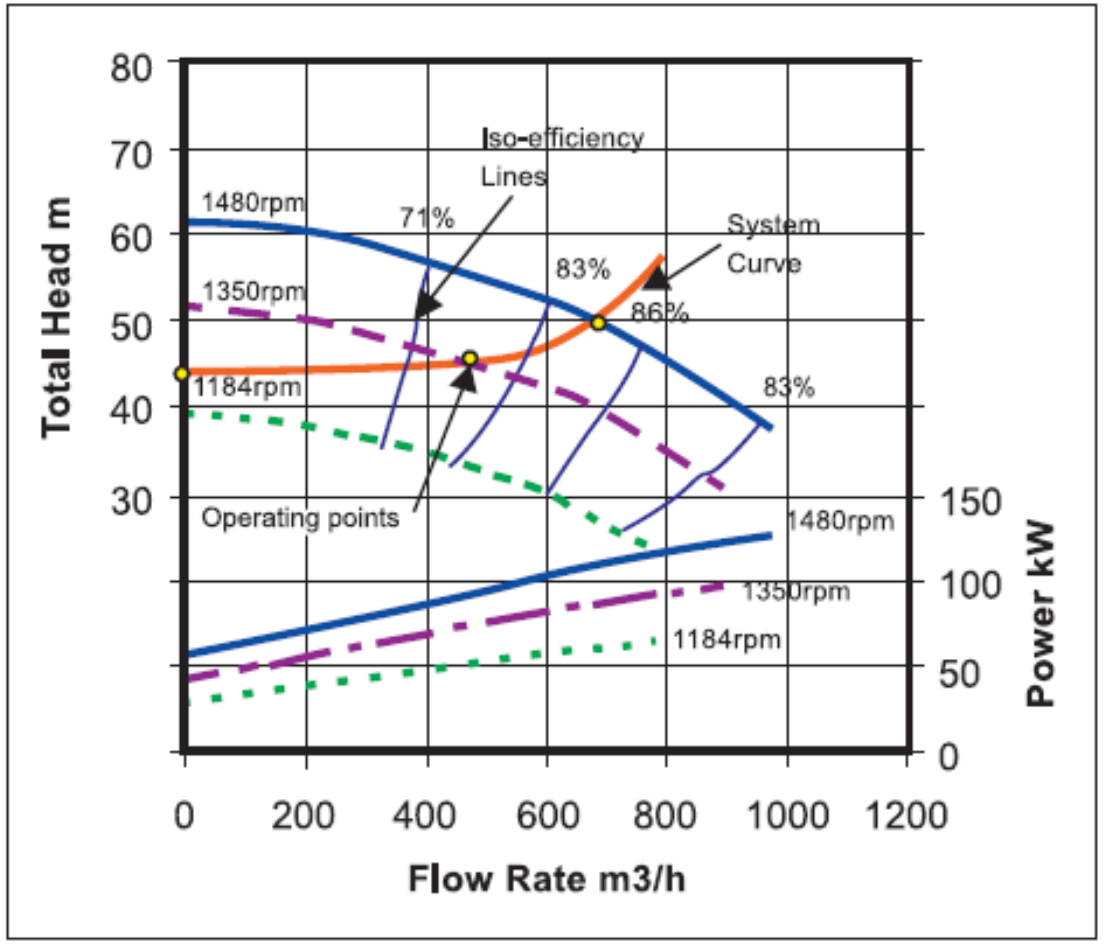
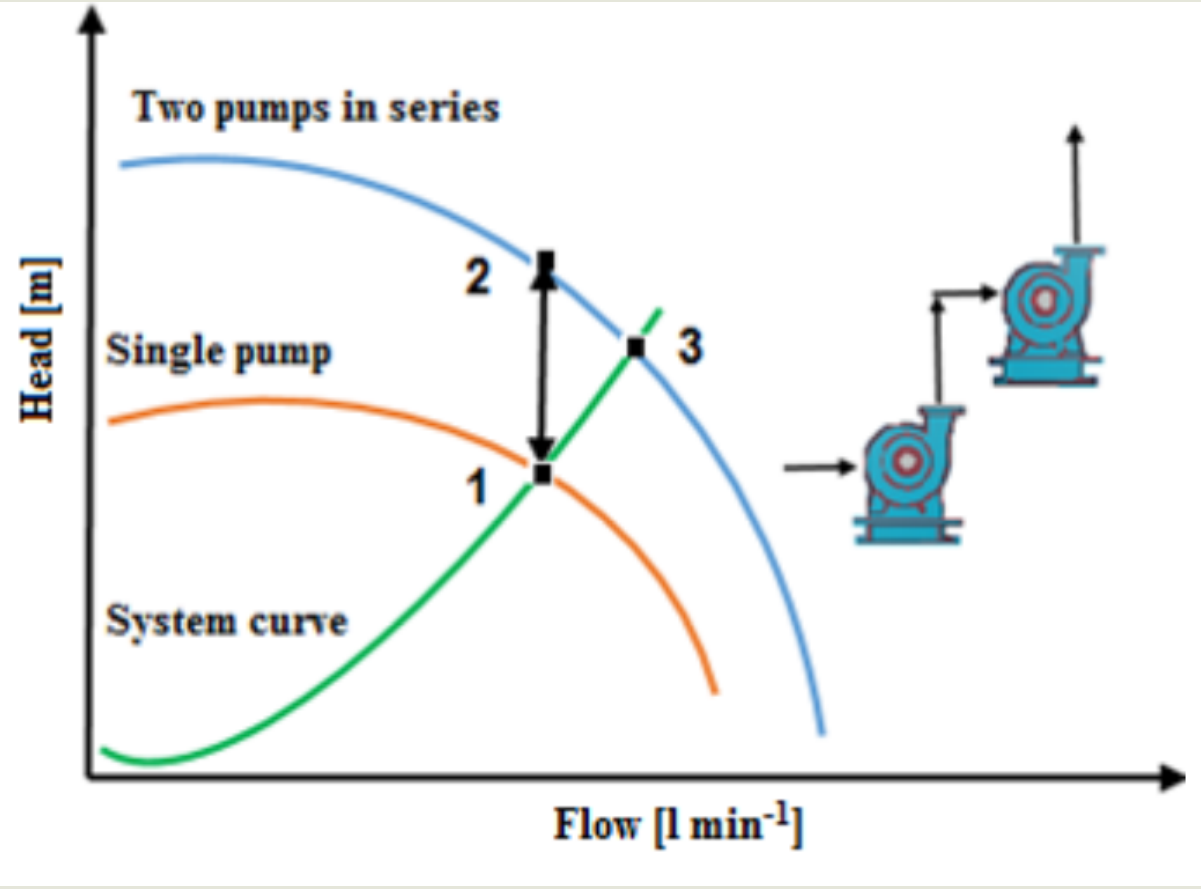
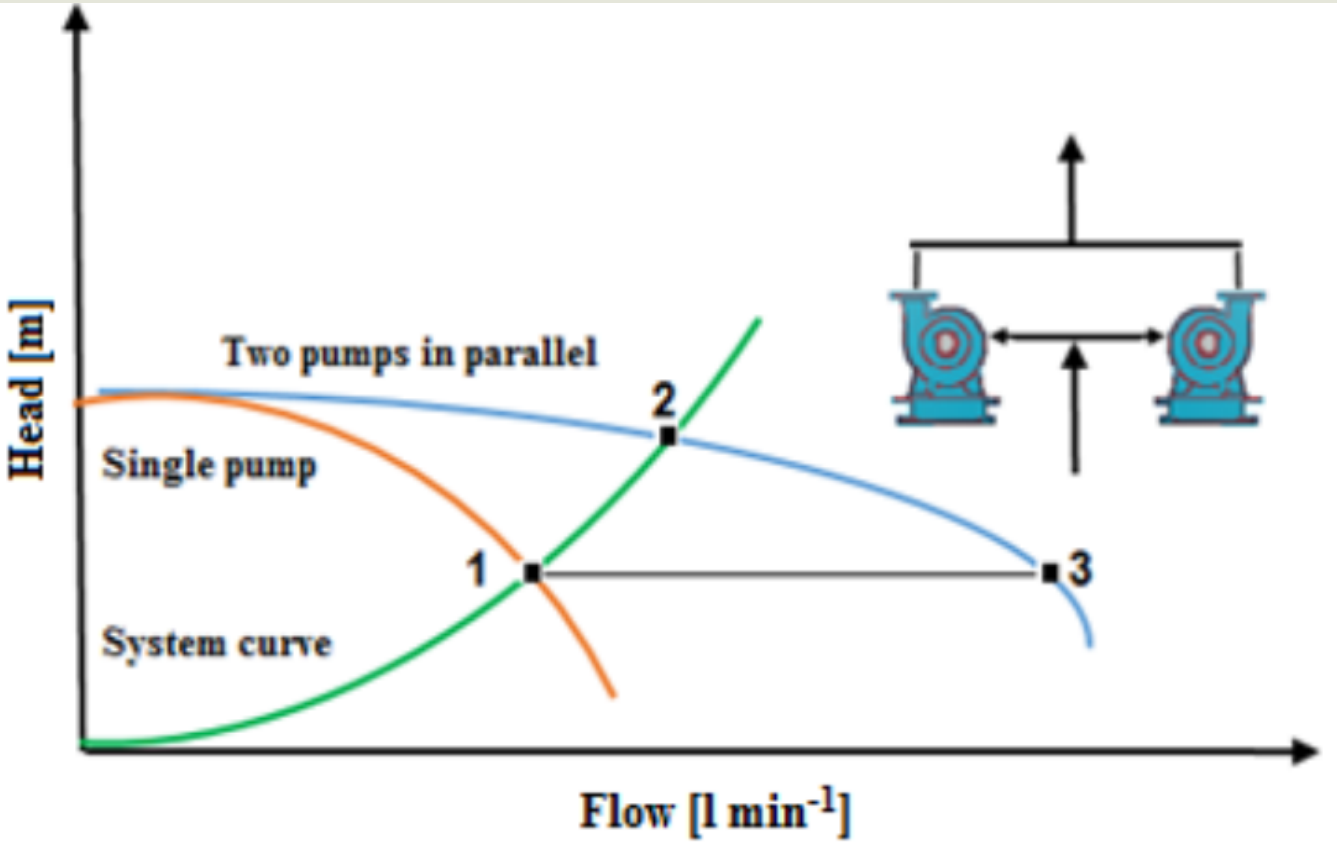


Figure 6.16 Example for the Effect of Pump Speed Change with a System with High Static Head

Pumps in Series/Parallel

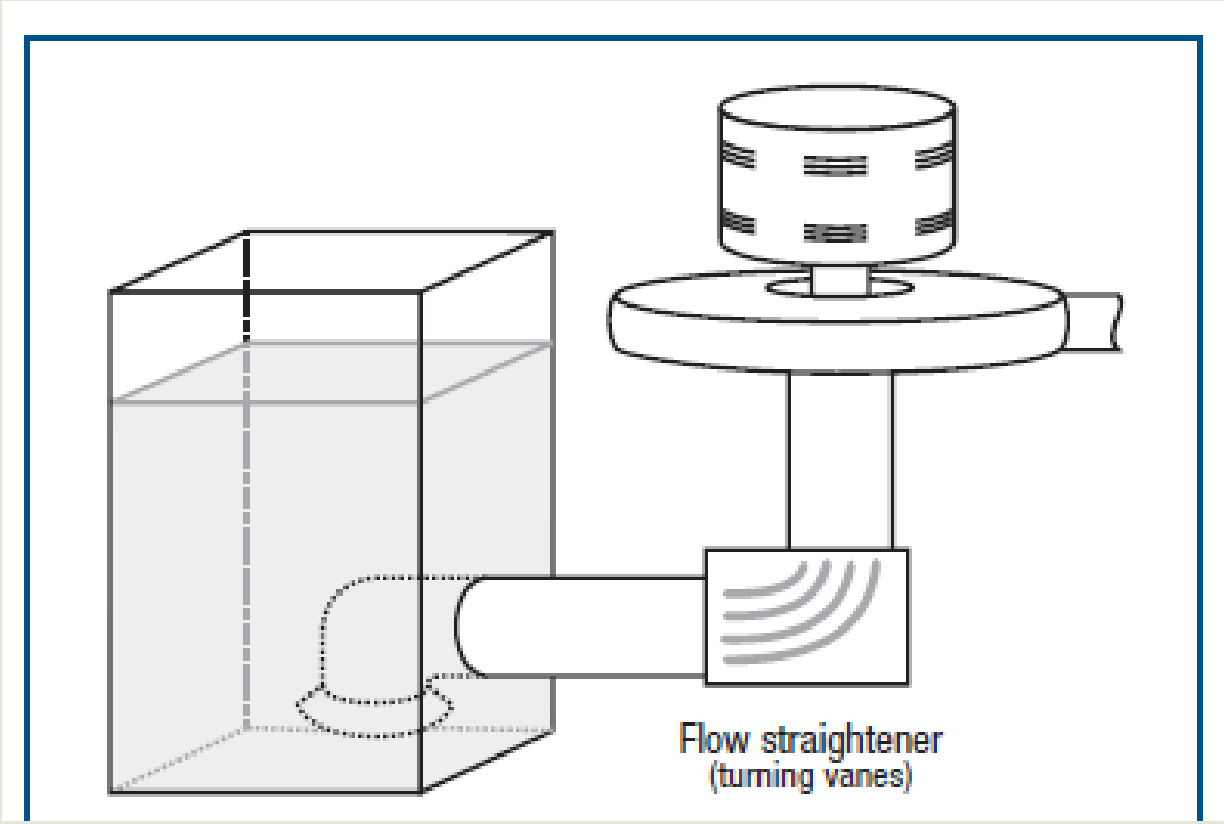




Symptoms for energy efficient operation

Symptom	Likely Reason	Best Solutions
Throttle valve-controlled systems	Oversized pump	Trim impeller, smaller impeller, variable speed drive, two speed drive, lower RPM
Bypass line (partially or completely) open	Oversized pump	Trim impeller, smaller impeller, variable speed drive, two speed drive, lower RPM
Multiple parallel pump system with the same number of pumps always operating	Pump use not monitored or controlled	Install controls
Constant pump operation in a batch environment	Wrong system design	On-off controls
High maintenance cost (seals, bearings)	Pump operated far away from BEP	Match pump capacity with system requirement

Piping arrangements



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