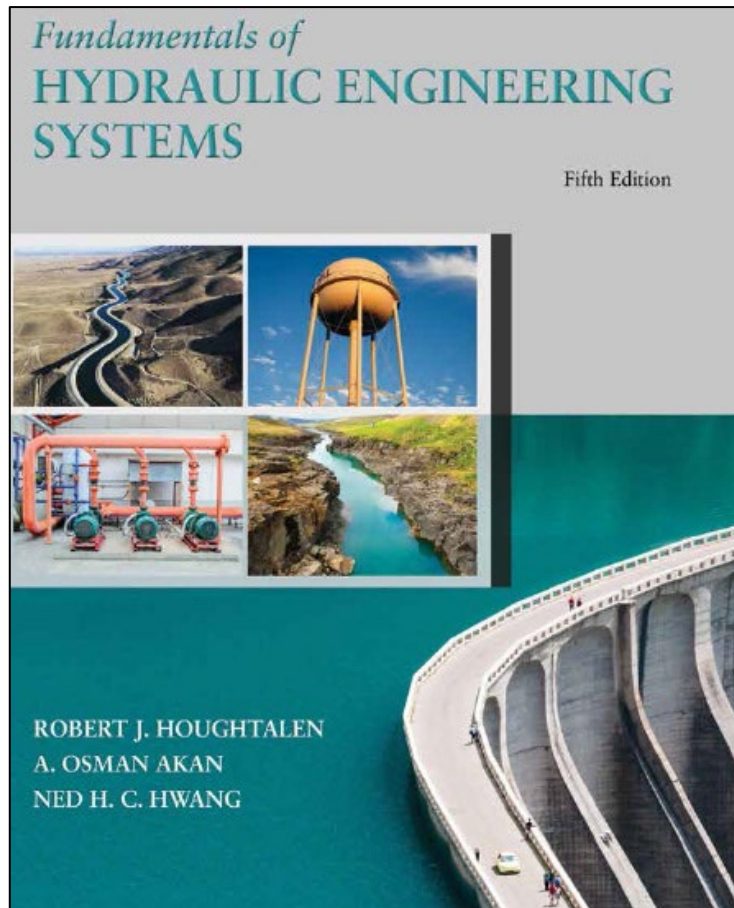


# Fundamentals of Hydraulic Engineering Systems

Fifth Edition



## Chapter 5b

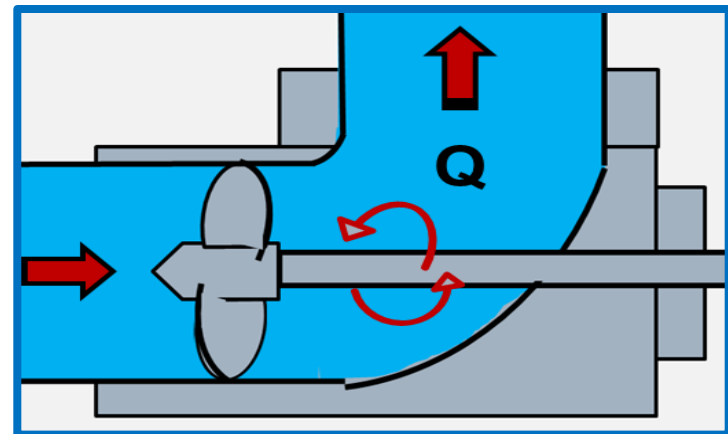
### Water Pumps

# Description of Pumps and Pump Types

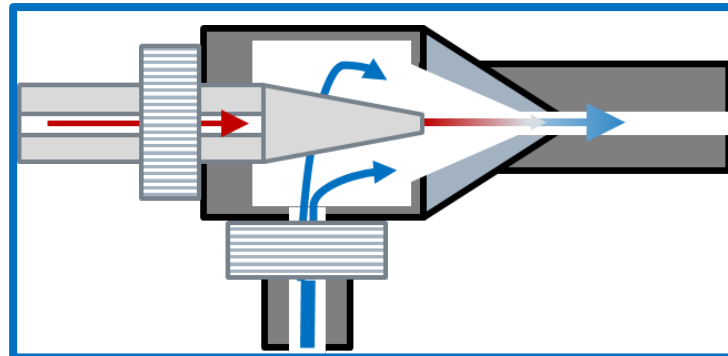
## Definitions and Visualization

**Pump:** a device that converts mechanical to hydraulic energy

**Propeller (axial flow) Pump:**  
pressure energy is imparted to the fluid by the mechanical rotation of blades.



**Jet (mixed flow) Pump:**  
nozzle spray is released into the throat of the main pipe and suction induces flow



# Centrifugal Pump Characteristic Curves

## Visualization and Flow vs. Head Principles

**Consider the aquarium pump flow in the figure.**

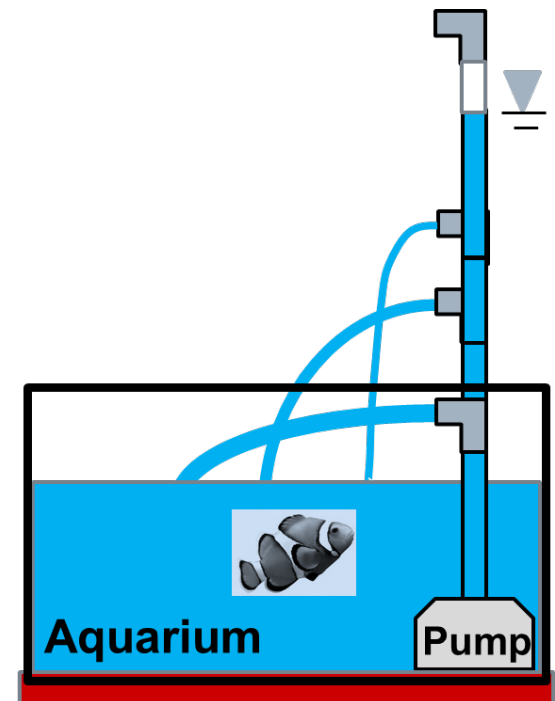
Every pump delivers a certain power:  $P_o = \gamma QH_p$

**Q:** Based on the equation, what happens to the flow if the delivery tube is raised?

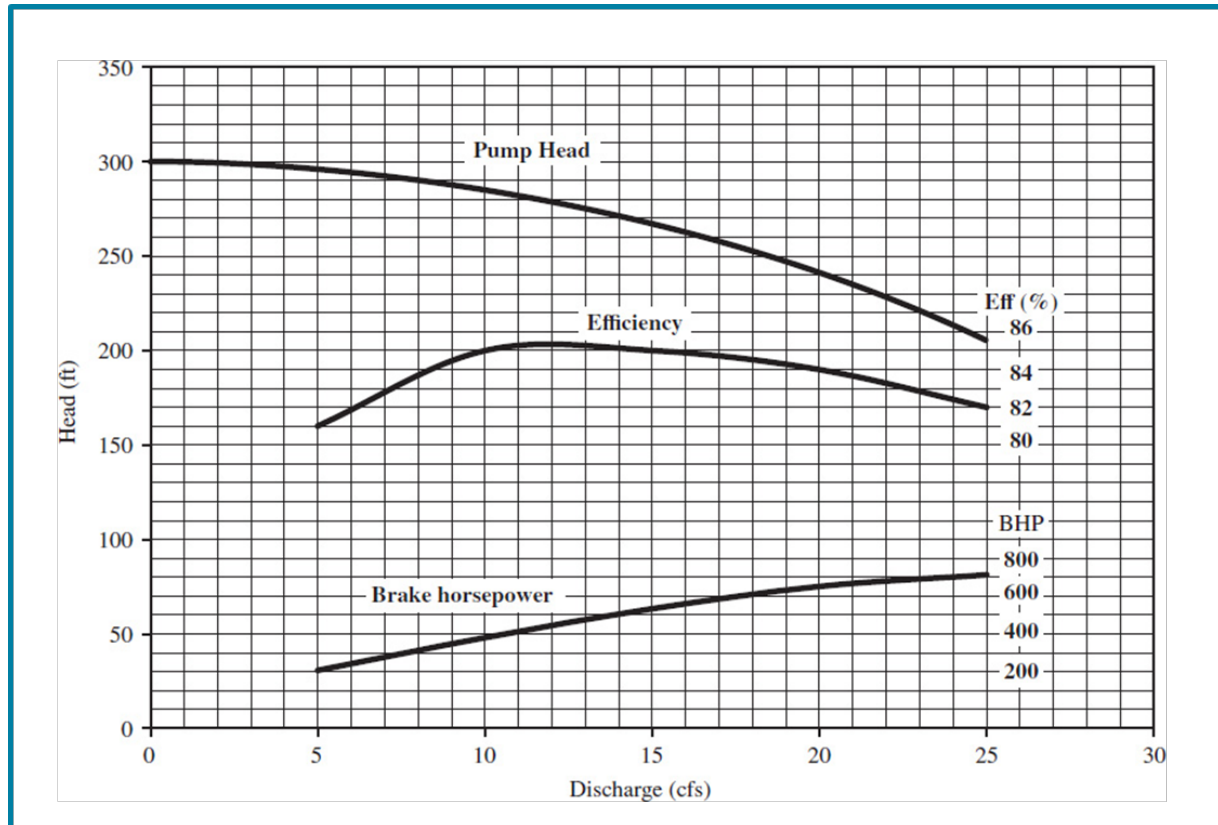
**A:** The Q is reduced since  $H_p$  is increased.  
(pump has to raise water to a higher level)

**Q:** What happens if the delivery tube is raised even higher?

**A:** Eventually  $Q = 0$ , (shutoff head). The pump's energy is used to maintain a column of water.



# Figure 5.8 Typical Pump Characteristic Curves



Note: As the head the pump must overcome increases, the flow rate decreases.

# Description of Characteristic Curves

## Definitions and Pump Rating Concepts

**Characteristic (Performance) Curves:** produced and made available by pump manufacturers based on lab and field tests.

**Pump Head:** energy head added to the flow by the pump.

**Brake Horsepower:** power input required by the pump ( $P_i$ ).

**Efficiency (e):**  $\frac{P_o}{P_i}$     **Rated Capacity:** Q at max. efficiency

**Q:** For the pump on the previous slide, determine the rated capacity (max. “e” and BHP), shutoff head, and H at Q = 20.

**Affinity Laws:** Once the characteristics of a pump are known for one speed, they can be determined for any speed.

$$\frac{Q_2}{Q_1} = \frac{N_{r2}}{N_{r1}}; \quad \frac{H_{p2}}{H_{p1}} = \left( \frac{N_{r2}}{N_{r1}} \right)^2; \quad \frac{BHP_2}{BHP_1} = \left( \frac{N_{r2}}{N_{r1}} \right)^3$$

# Single Pump and Pipeline Analysis (1 of 4)

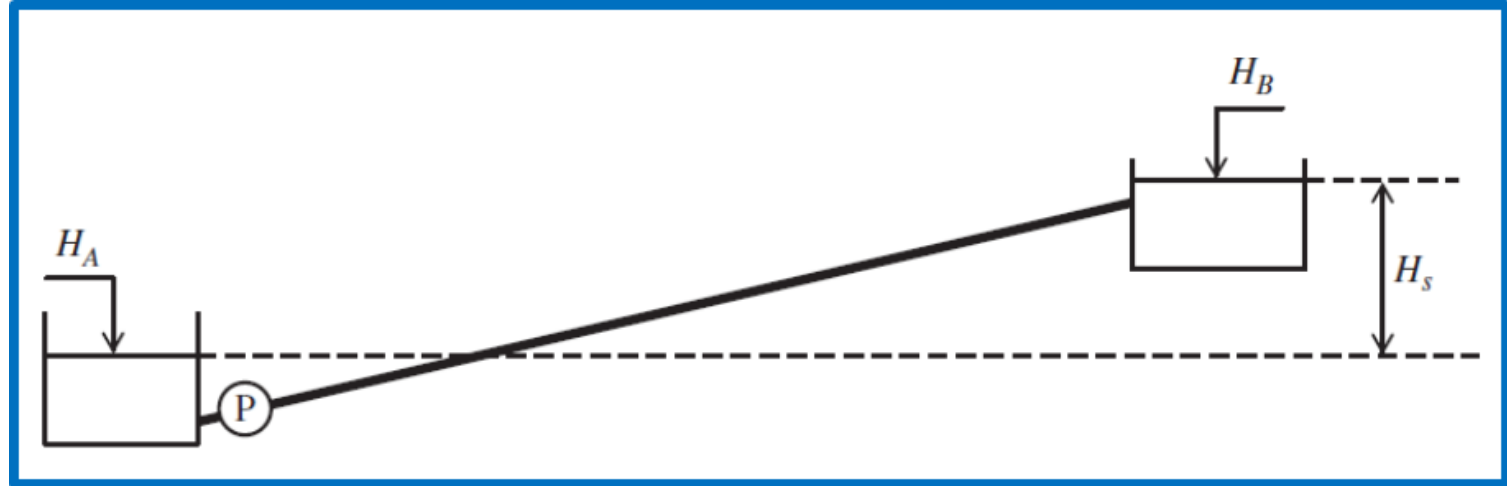
## Example Problem – Active Learning

For the pump-pipeline system shown;  $H_A = 100$  ft,  $H_B = 220$ , pump characteristics  $D = 2.0$  ft.,  $L = 12,800$  ft.,  $C_{HW} = 100$ , are known (columns 1 & 2; table on Slide 9). Find the Q.

**Solution:** From an energy balance:  $H_A + H_P = H_B + h_f$   
or,  $H_p = H_B - H_A + h_f = H_S + h_f$ ; where  $H_S = H_B - H_A = 120$  ft

**Note:** The pump adds energy to overcome static lift or head ( $H_s$ ) and friction loss. For Hazen-Williams method  
**(Table 3.4 see slide 8)**

# Single Pump and Pipeline Analysis (2 of 4)



$$h_f = KQ^{1.85}, \text{ where}$$

$$K = \frac{4.73 \cdot L}{(D^{4.87} C^{1.85})}$$

$$\text{Thus, } K = 0.413$$

# Single Pump and Pipeline Analysis (3 of 4)

**Table 3.4** Friction Equations Expressed in the Form of  $h_f = KQ^m$

Equation	$m$	$K$ (BG System)	$K$ (SI System)
Darcy–Weisbach	2	$\frac{0.0252 fL}{D^5}$	$\frac{0.0826 fL}{D^5}$
Hazen–Williams	1.85	$\frac{4.73 L}{D^{4.87} C_{HW}^{1.85}}$	$\frac{10.7 L}{D^{4.87} C_{HW}^{1.85}}$
Manning	2	$\frac{4.64n^2L}{D^{5.33}}$	$\frac{10.3n^2L}{D^{5.33}}$



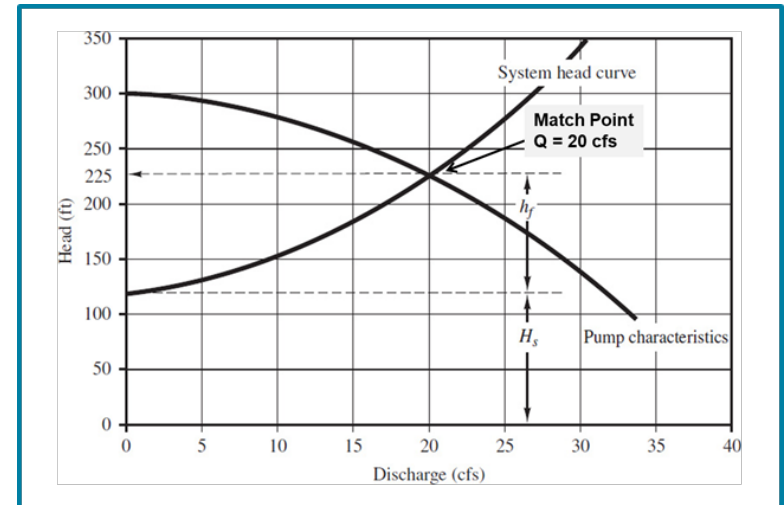
# Single Pump and Pipeline Analysis (4 of 4)

Fill in the solution table →

Q (cfs)	$H_p$ (ft)	$h_f$ (ft)	$H_s$ (ft)	$H_{SH}$ (ft)
0	300.0	0.0	120.0	120.0
5	295.5	8.1	120.0	128.1
10	282.0	29.2	120.0	149.2
15	259.5	61.9	120.0	181.9
20	225.5	105.4	120.0	225.4
25	187.5	159.3	120.0	279.3

**Homework Problems:**

Plot two curves. What is the **system head curve**? What is the Q for **this pump in this pipeline system**?



# Typical Centrifugal Pump

**Note:** Operating characteristics are often listed on an information plate. Do you understand them?

f	50	Hz	P2	0,950	kW
n	3240	min <sup>-1</sup>	H <sub>max</sub>	74.8	m
Q	3	m <sup>3</sup> /h	H	58.1	m
p <sub>max</sub> /t <sub>max</sub>	25/120		bar/°C	CCW	
Serial No.	0001		Made in Denmark		



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