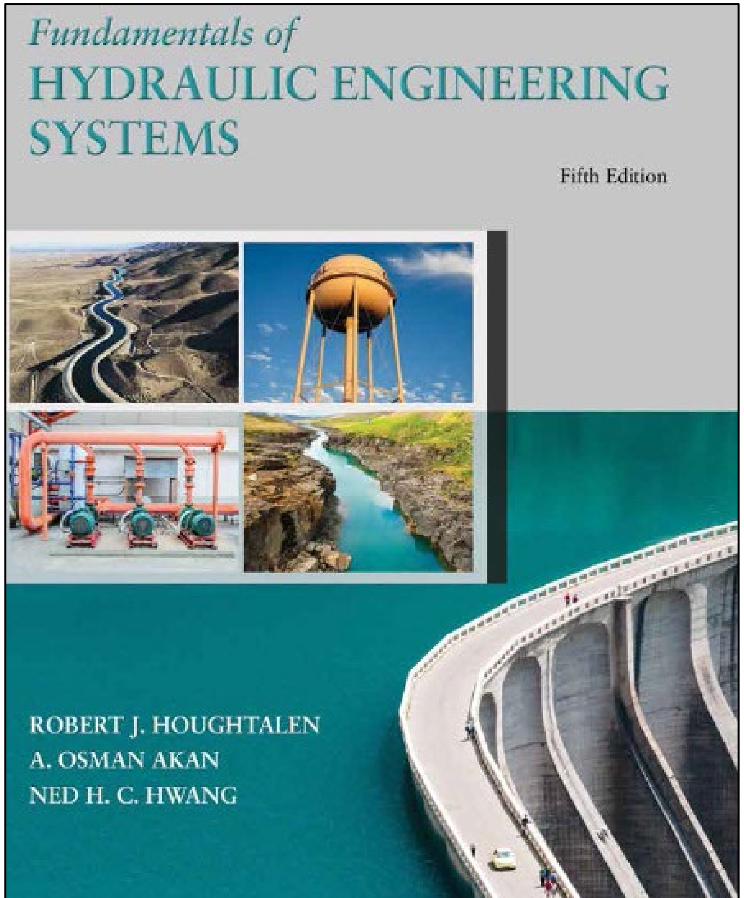
Fundamentals of Hydraulic Engineering Systems

Fifth Edition



Chapter 5b

Water Pumps

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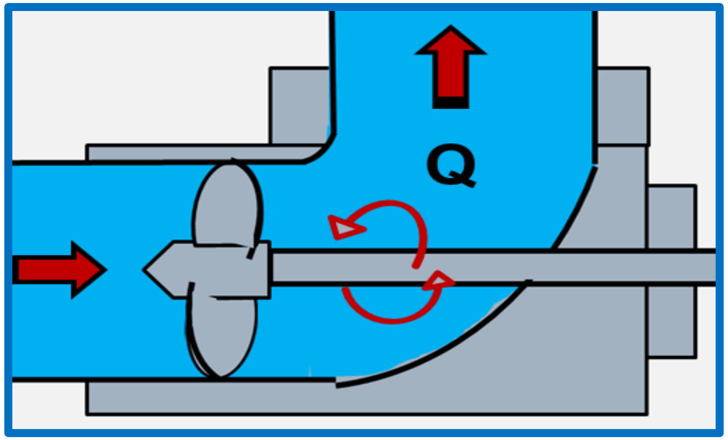
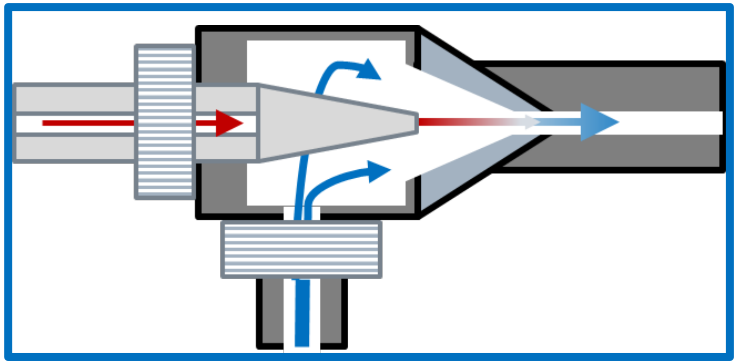
Description of Pumps and Pump Types

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: $P_o = \gamma Q H_p$

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.

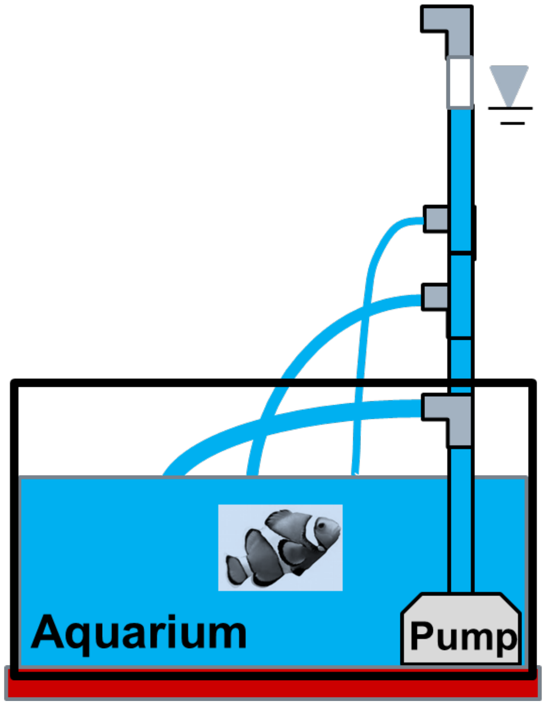
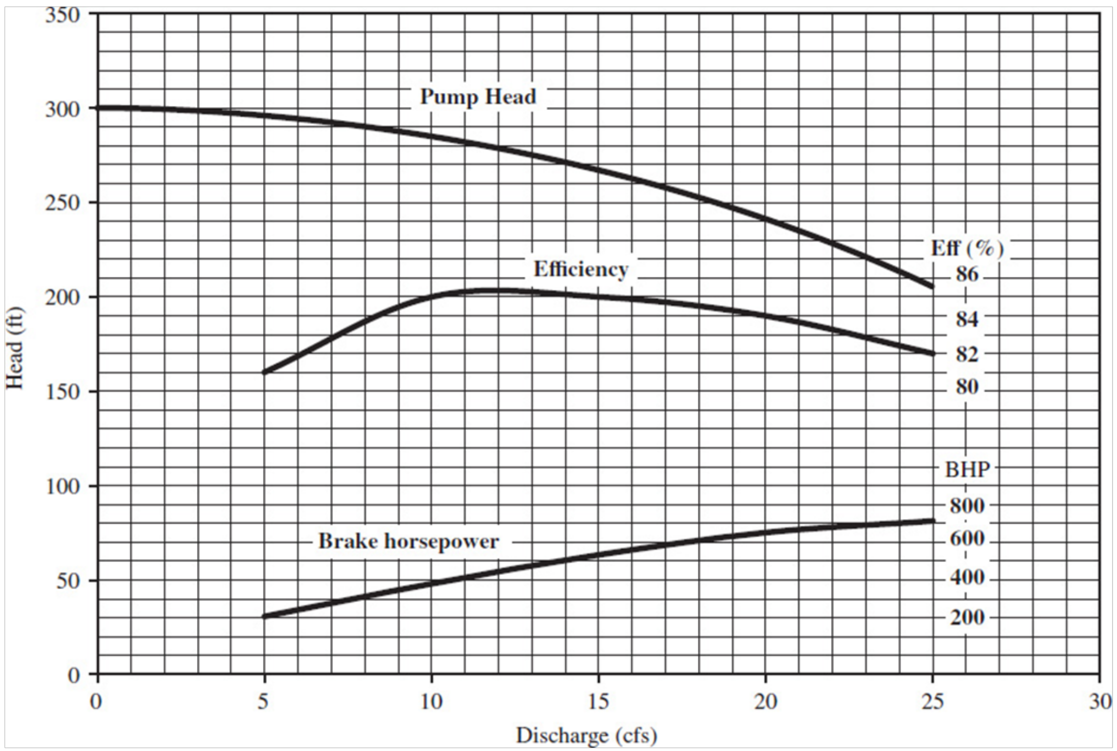


Figure 5.8 Typical Pump Characteristic Curves



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)

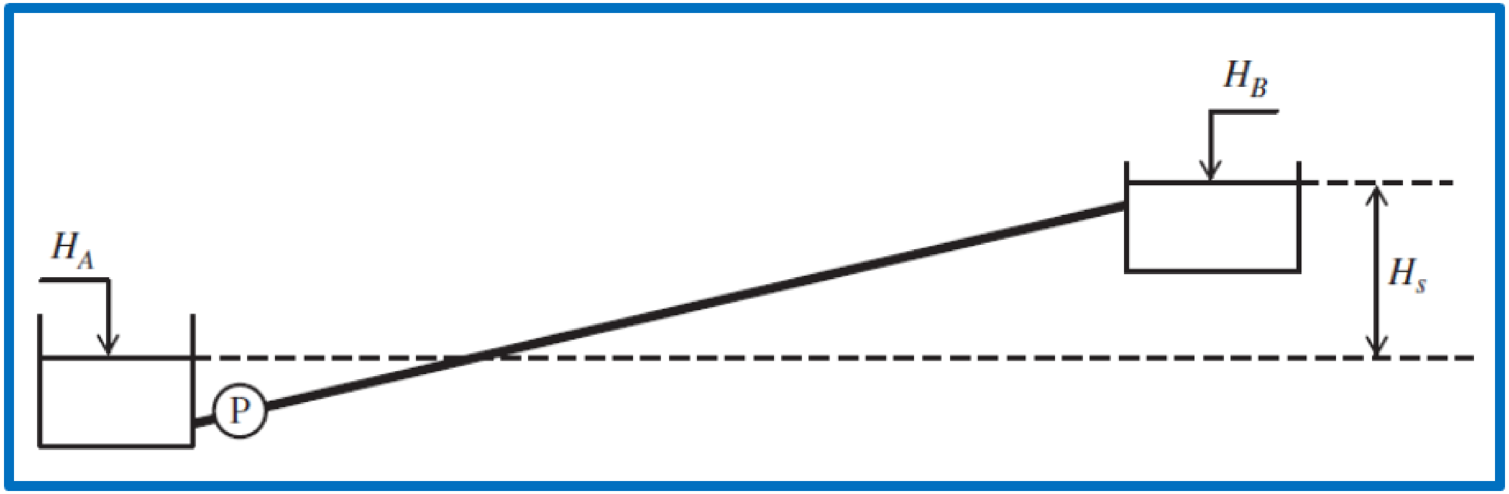
Example Problem – Active Learning

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

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

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

Single Pump and Pipeline Analysis (2 of 4)



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

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

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

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	$\frac{4.64 n^2 L}{D^{5.33}}$	$\frac{10.3 n^2 L}{D^{5.33}}$

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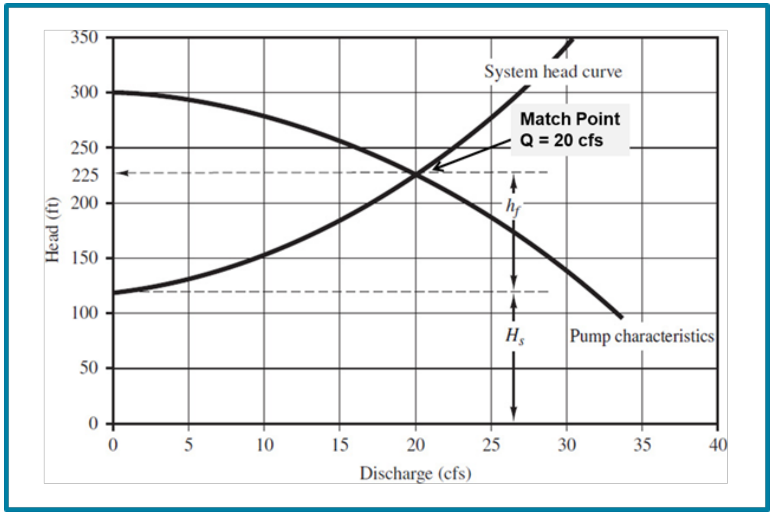
Single Pump and Pipeline Analysis (4 of 4)

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

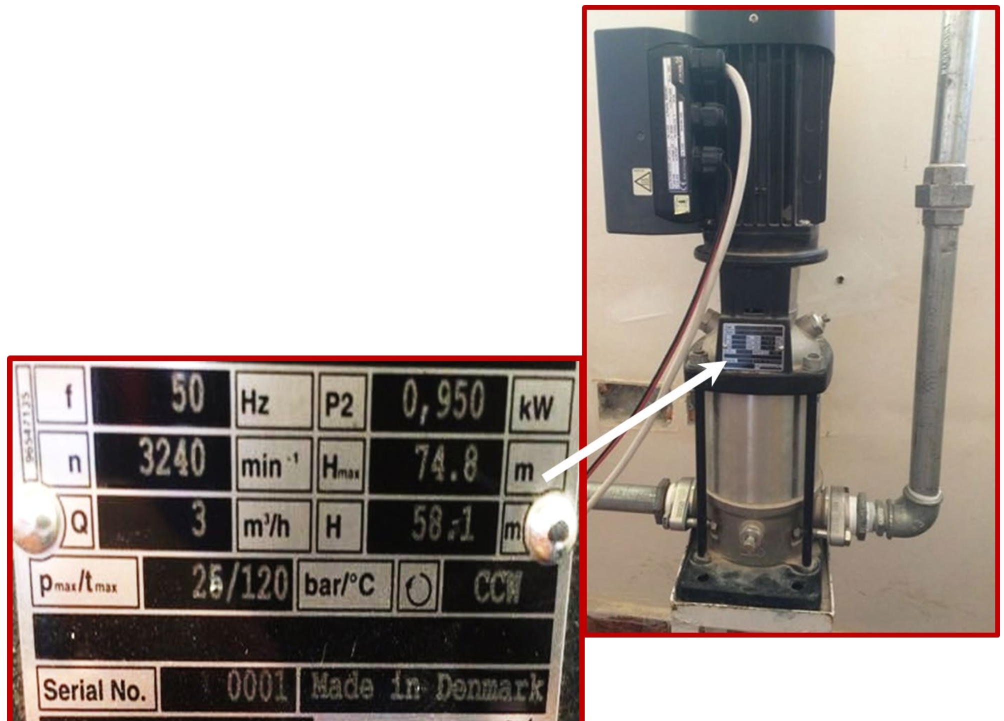
Plot two curves. What is the **system head** curve? What is the Q for **this pump in this pipeline system**?



Homework Problems:

Typical Centrifugal Pump

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



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