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HYDRAULICS

LECTURE 2: PUMPS AND TURBINES



*PE REVIEW COURSE
PENN STATE BEAVER CONTINUING EDUCATION*

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1	Hydraulics – Fluid Statics & Flow
	Article on Preparing for PE Exam
2	Hydraulics – Pumps and Turbines
3	Hydraulics – Open Channel Flow
4	Hydraulics – Precipitation, Runoff & Flood Calculations

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HYDRAULICS
LECTURE 1: FLUID STATICS & FLOW

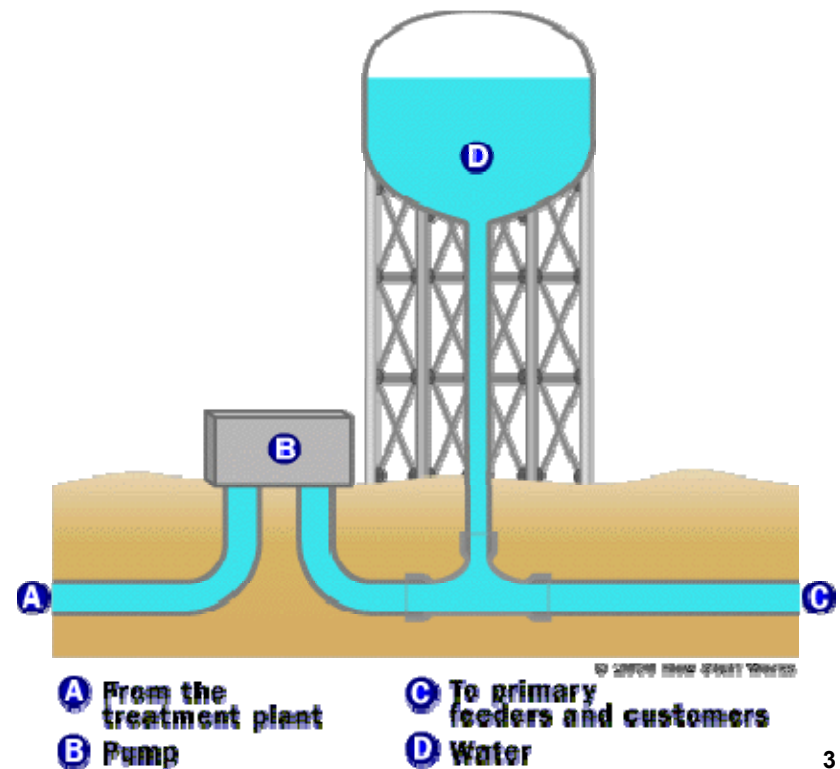
PE REVIEW COURSE
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OUTLINE

- General
 - Instructor Introduction
 - Signup sheet
 - Schedule
 - Textbook
 - Class monitor
 - How to prepare for PE Exam?
 - Useful resources
- Lecture 1: Fluid Statics And Flow
 - Chapter 14: Fluid Properties
 - Chapter 16: Fluid Statics
 - Chapter 18: Fluid Flow Parameters
 - Chapter 17: Fluid Dynamics

OUTLINE

- ◆ Chapter 18: Hydraulic Machines
 - ◆ Basics
 - ◆ Centrifugal pumps
 - ◆ Pumping power
 - ◆ Pump curve
 - ◆ Example problems
 - ◆ Practice problem



TYPES OF HYDRAULIC MACHINES

1. Pumps

- Covert mechanical energy into fluid energy
- Increase fluid energy

2. Turbines

- Covert fluid energy into mechanical energy
- Decrease (extract) fluid energy

TYPES OF PUMPS

1. Positive Displacement Pumps

- Two types:
 - Reciprocating pumps: use pistons
 - Rotary pumps: use screws
- Discharge a fixed volume for each stroke (of piston) or revolution (of screw)
- Energy is added intermittently to fluid
 - Discharge stream is “pulsing”

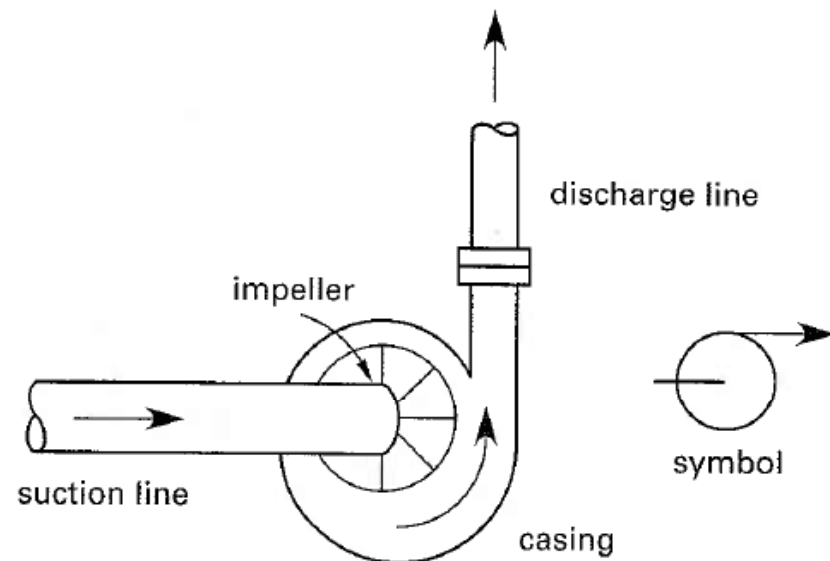
2. Kinetic Pumps

- Transform fluid kinetic energy into fluid static pressure energy using an impeller
- Examples:
 - Jet pumps
 - Ejector pumps
 - Centrifugal pumps
 - Most common; will be the focus of this lecture
- Table 18.1: Side-by-side comparison of positive displacement and kinetic pumps

CENTRIFUGAL PUMPS

- **Figure 18.3**
- **Suction line: inlet to the pump impeller**
 - Captures incoming flow
 - Adds velocity
 - Throws flow to outside casing
- **Casing: converts velocity into pressure energy**
- **Discharge Line: Exit from pump (approximately at 90° from the original flow direction)**

Figure 18.3 Centrifugal Pump and Symbol



TERMINOLOGY FOR PUMP EQUATIONS

- **Subscript**
 - **s**: suction side of pump
 - **d**: discharge side of pump
- Pump equations are based on “head” terms in units of height (ft or m) instead of pressure (in psi)
- You can convert pressure to head (or vice-versa) using

$$h = \frac{p}{\gamma} \quad \dots \quad 18.4$$

γ = specific weight = 62.4 lbf/ft³ for water at 68°F

$$\because \gamma = \rho \times \frac{g}{g_c} \quad \dots \quad 14.14b$$

$$h = \frac{p}{\rho} \times \frac{g_c}{g} \quad (U.S.) \quad \dots \quad 18.5b$$

VARIOUS HEADS

- **Friction Head (h_f):** head required to overcome resistance to flow in pipes, fittings, valves, entrances, and exists.

$$h_f = \frac{f L v^2}{2 D g} \quad \dots \quad 18.6 \text{ (same as Eq.17.22 - Darcy - Weisback Eq.)}$$

- **Velocity Head (h_v):** head due to kinetic energy.

$$h_v = \frac{v^2}{2 g_c} \quad \dots \quad 18.7 \text{ (same as Eq.16.3b)}$$

- **Atmospheric Head (h_a):** Atmospheric pressure converted to feet of fluid being pumped.

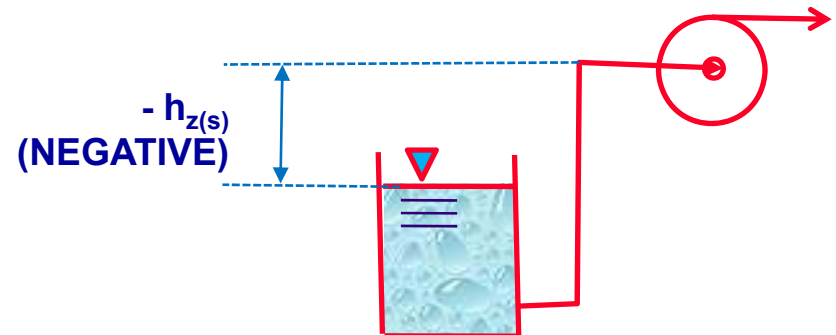
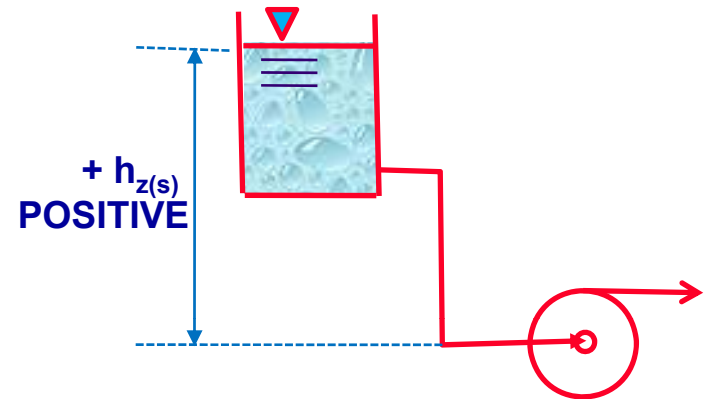
$$h_a = \frac{p_a}{\rho} \quad \rho = \text{density} = 62.4 \text{ lbm/ft}^3 \text{ for water at } 68^\circ \text{ F}$$

- **Pressure Head (h_p):** Pressure converted to feet of fluid being pumped.

$$h_p = \frac{p}{\rho} \quad \text{same as Eq.16.6}$$

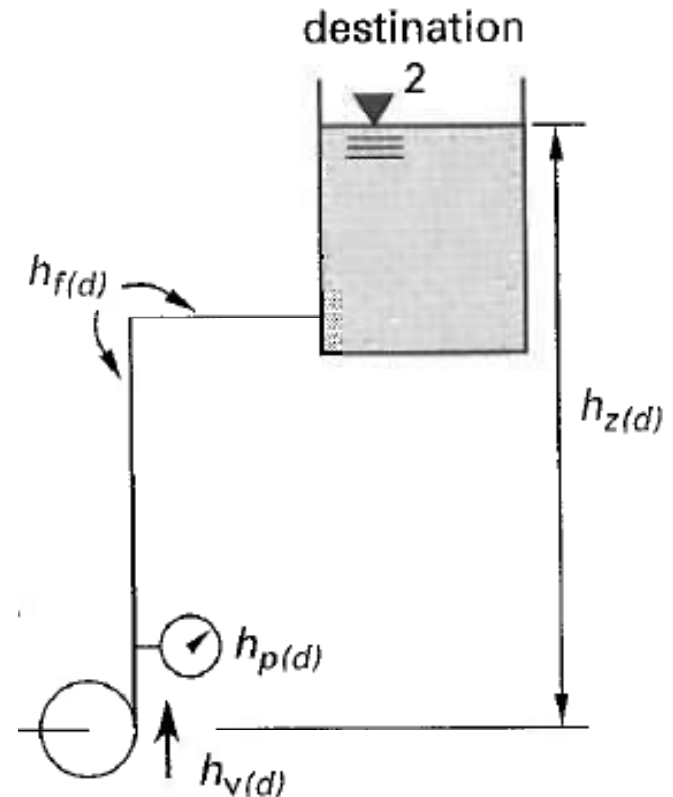
STATIC SUCTION HEAD

- $h_{z(s)}$: vertical distance above the center line of the inlet to the free level of fluid source
- If source level is above inlet:
 - h_z is positive
- If source level is below inlet:
 - h_z is negative and called static suction lift.



STATIC DISCHARGE HEAD

- $h_{z(D)}$: vertical distance above the center line of the inlet to the point of free discharge or surface level of discharge tank
- Total dynamic head (TDH) = discharge head – suction head





EXAMPLE 18.1: HEAD EQUATIONS

◆ (a): Total suction head

$$h_{t(s)} = h_{p(s)} + h_{z(s)} + h_{v(s)} - h_{f(s)}$$

◆ (b): Total discharge head

$$h_{t(d)} = h_{p(d)} + h_{z(d)} + h_{v(d)} + h_{f(d)}$$

◆ Note: h_f was -ve for suction head

◆ (c): Total (dynamic) head (TDH)

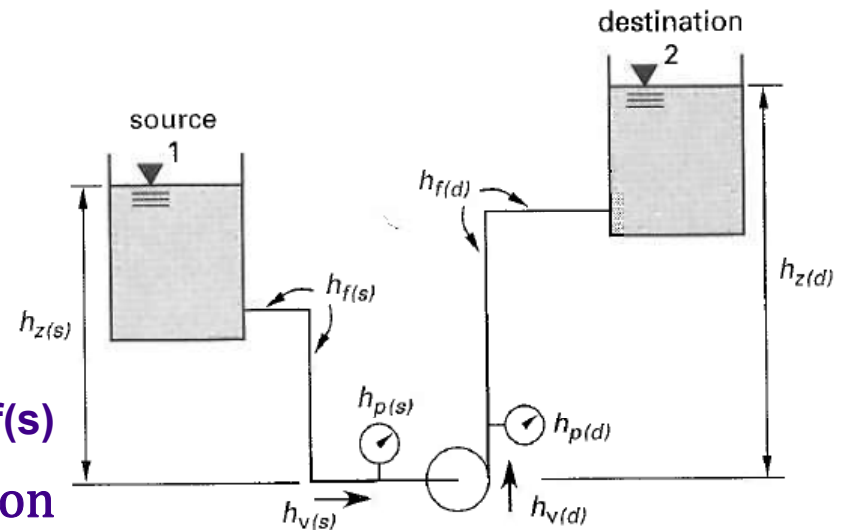
$$h_t = h_{t(d)} - h_{t(s)} \approx h_{z(d)} - h_{z(s)} + h_{f(d)} + h_{f(s)}$$

∴ $h_p = 0$ for open reservoirs (assume suction from and discharge to reservoir is exposed to atmosphere)

∴ $h_v = 0$ (assume negligible velocities in large reservoirs)

Example 18.1

Write the symbolic equations for the following terms:
 (a) total suction head, (b) total discharge head, and
 (c) total head.



PUMPING POWER

- The net (output) power transferred to the fluid
- Also called hydraulic power or water power
- Units
 - horsepower (U.S.) or h.p.: Equations in Table 18.5
 - watt or kilowatt (S.I.)” Equations in Table 18.6
- For example, if head added by pump h_A is in ft and discharge Q in GPM

$$\text{Water horsepower} = \text{WHP} = \frac{h_A \times Q_{\text{GPM}} \times \text{SG}}{3956}$$

Table 18.5 Hydraulic Horsepower Equations^a

	Q (gal/min)	\dot{m} (lbm/sec)	\dot{V} (ft ³ /sec)
h_A in feet	$\frac{h_A Q(\text{SG})}{3956}$	$\left(\frac{h_A \dot{m}}{550}\right) \times \left(\frac{g}{g_c}\right)$	$\frac{h_A \dot{V}(\text{SG})}{8.814}$
Δp in psi ^b	$\frac{\Delta p Q}{1714}$	$\left(\frac{\Delta p \dot{m}}{(238.3)(\text{SG})}\right) \times \left(\frac{g}{g_c}\right)$	$\frac{\Delta p \dot{V}}{3.819}$
Δp in psi ^b	$\frac{\Delta p Q}{2.468 \times 10^5}$	$\left(\frac{\Delta p \dot{m}}{(34,320)(\text{SG})}\right) \times \left(\frac{g}{g_c}\right)$	$\frac{\Delta p \dot{V}}{550}$
W in $\frac{\text{ft-lbf}}{\text{lbm}}$	$\frac{W Q(\text{SG})}{3956}$	$\frac{W \dot{m}}{550}$	$\frac{W \dot{V}(\text{SG})}{8.814}$

(Multiply horsepower by 0.7457 to obtain kilowatts.)

^aTable 18.5 is based on $\rho_{\text{water}} = 62.4 \text{ lbm/ft}^3$ and $g = 32.2 \text{ ft/sec}^2$.

^bVelocity head changes must be included in Δp .

SG = specific gravity = 1.0 for water

PUMPING POWER

Brake horsepower = BHP = the input horsepower delivered to pump shaft

$$= \frac{WHP}{\eta_p} \quad \dots 18.12$$

η_p (eta) = pump efficiency

$$\text{Electric horsepower to motor} = EHP = \frac{BHP}{\eta_m} \quad \dots 18.14$$

η_m = motor efficiency

Overall efficiency of pump installation (η) = product of pump and motor efficiencies

$$\eta = \eta_p \times \eta_m = \frac{WHP}{BHP} \times \frac{BHP}{EHP} = \frac{WHP}{EHP} \quad \dots 18.16 \text{ (from Eqs. 18-12 and 18-14)}$$



EXAMPLE 18.2: PUMPING POWER (U.S. SOLUTION)

Example 18.2

A pump adds 550 ft of pressure head to 100 lbm/sec of water. (a) Complete the following table of performance data. (b) What is the hydraulic power in horsepower and kilowatts? (Assume $\rho = 62.4 \text{ lbm/ft}^3$ or 1000 kg/m^3 , and $g = 9.81 \text{ m/s}^2$.)

item	customary U.S.	SI
\dot{m}	100 lbm/sec	— kg/s
h	550 ft	— m
Δp	— lbf/ft ²	— kPa
\dot{V}	— ft ³ /sec	— m ³ /s
W	— ft-lbf/lbm	— J/kg
P	— hp	— kW

- **Given Data:**
 - $h_p = \text{pressure head} = 550 \text{ ft}$
 - $\dot{m} = \rho \times Q = \text{mass flow rate} = 100 \text{ lbm/sec}$

- **Calculate (?):**
 - $\Delta p = \text{pressure added in lbf/ft}^2$
 - $\dot{V} = Q = \text{discharge in ft}^3/\text{sec}$
 - $W = \text{work in ft-lbf/lbm}$
 - $P = \text{Power in h.p.}$



EXAMPLE 18.2: PUMPING POWER (U.S. SOLUTION)

➤ Solution:

From Eq.18.5b, $\Delta p = h_p \times \rho \times \frac{g}{g_c} = 550 \times 62.4 = \boxed{34,320 \text{ lbf/ft}^2}$ ANSWER 1

∴ most places, $g = g_c = 32.174 \text{ ft/sec}^2$

From Eq.17.2, $Q = \frac{\dot{m}}{\rho} = \frac{100}{62.4} = \boxed{1.603 \text{ ft}^3/\text{sec}}$ ANSWER 2

From Eq.16.6, $W = \text{pressure energy} = \frac{p}{\rho} = \frac{34,320}{62.4} = \boxed{550 \text{ ft} - \text{lbf/lbm}}$ ANSWER 3

or $W = h \times \frac{g}{g_c} = 550 \text{ ft} - \text{lbf/lbm}$

From Table 18.5, $P = \text{WHP} = \frac{h_A \times \dot{m}}{550} \times \frac{g}{g_c} = \frac{550 \times 100}{550} = \boxed{100 \text{ h.p.}}$ ANSWER 4

Or, From Table 18.5, $P = \text{WHP} = \frac{h_A \times Q}{8.818} = \frac{550 \times 1.603}{8.818} = 100 \text{ h.p.}$

SYSTEM CURVE

- A plot of TDH for different flow rates for only the configuration of the suction and discharge lines (Fig. 18.12)
- Fig. 18.9: system curves for different efficiencies
 - For the same discharge, a lower efficiency (65%) pump gives a lower head.

Figure 18.12 System Curve

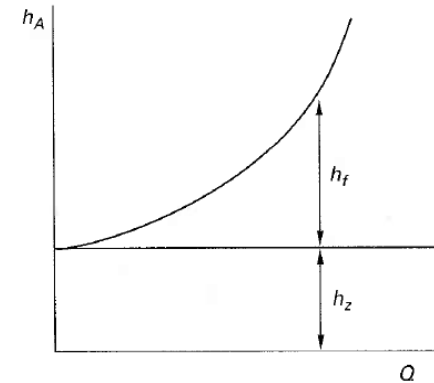
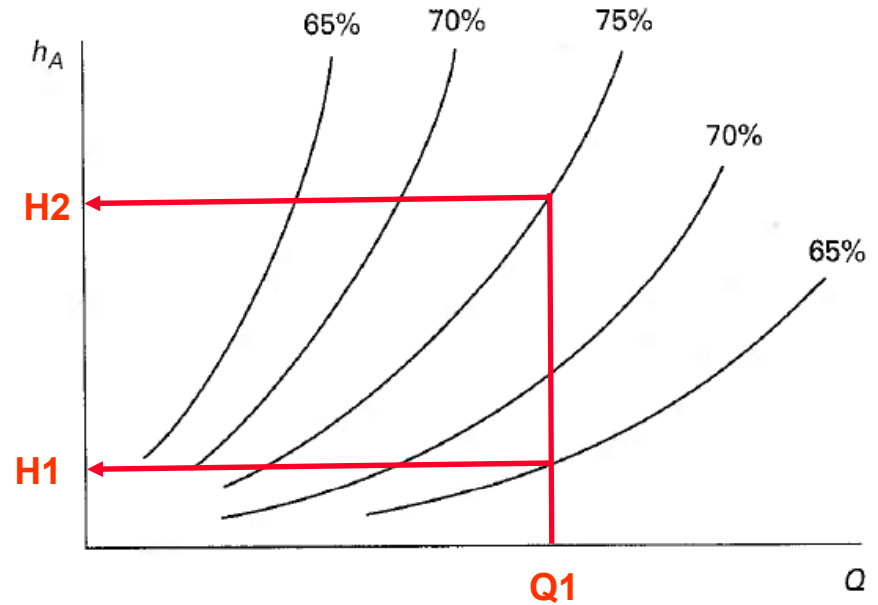


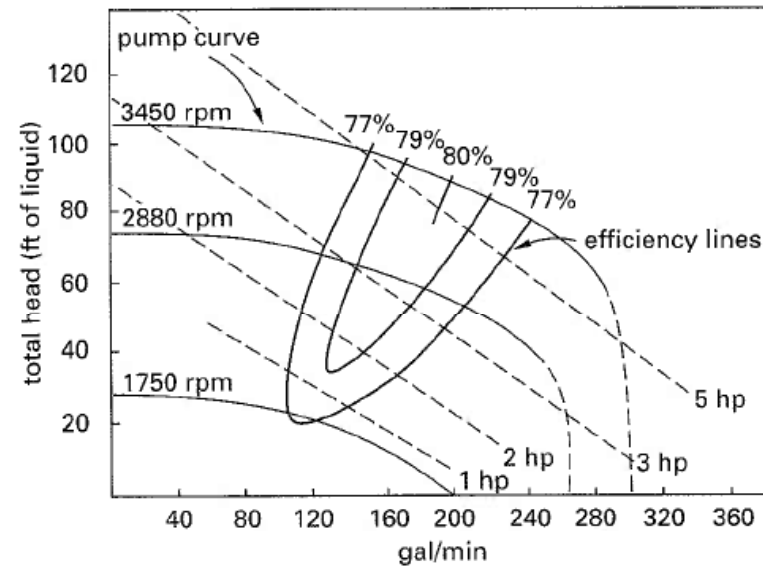
Figure 18.9 Typical Centrifugal Pump Efficiency Curves



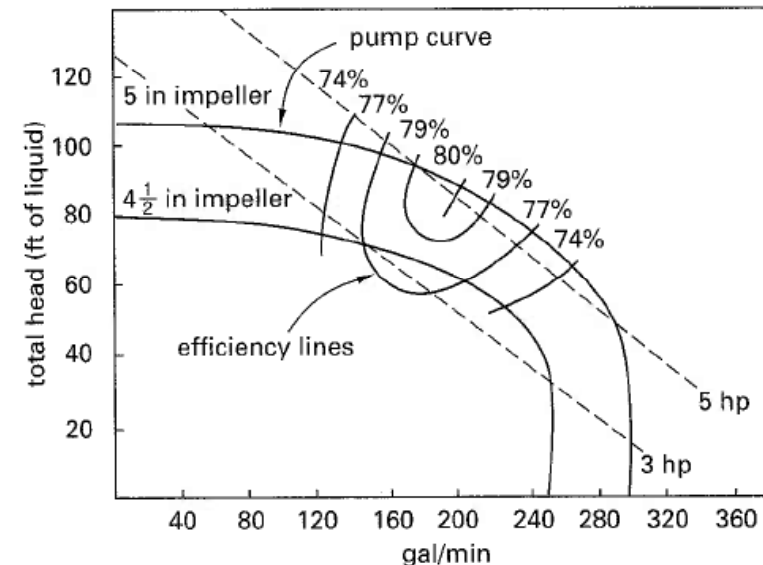
PUMP CURVE

- A plot of TDH and discharge (x-axis) for only the pump.
- Convex shape compared to system curve's concave shape
- Top: Three pump curves for three different speeds (rpm)
- Bottom: Two pump curves for two different impeller diameters

Figure 18.11 Centrifugal Pump Characteristics Curves



(a) variable speed

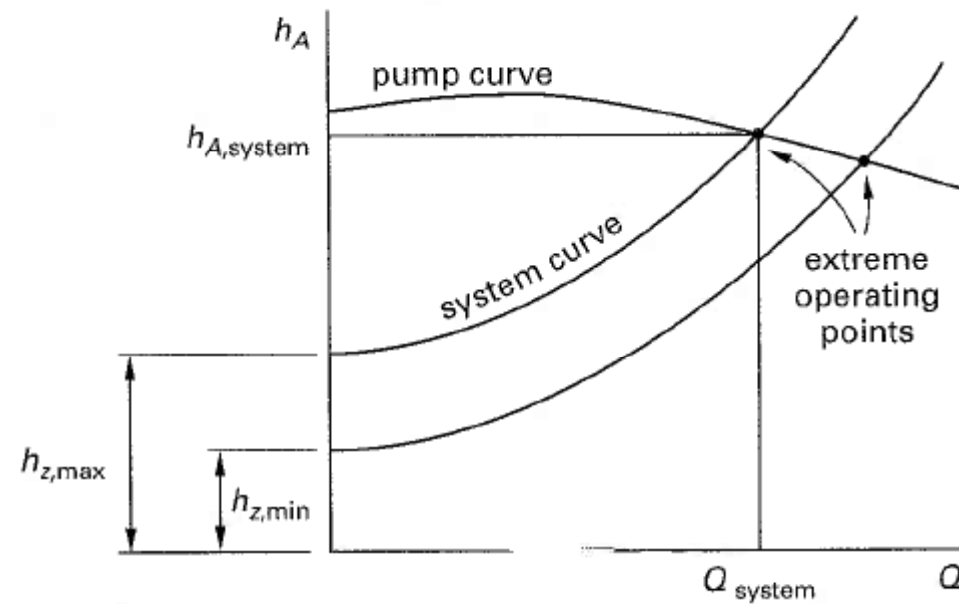


(b) variable impeller diameter

OPERATING POINT

- The intersection of the system and pump curves
- Defines system head and flow rate

Figure 18.13 Extreme Operating Points



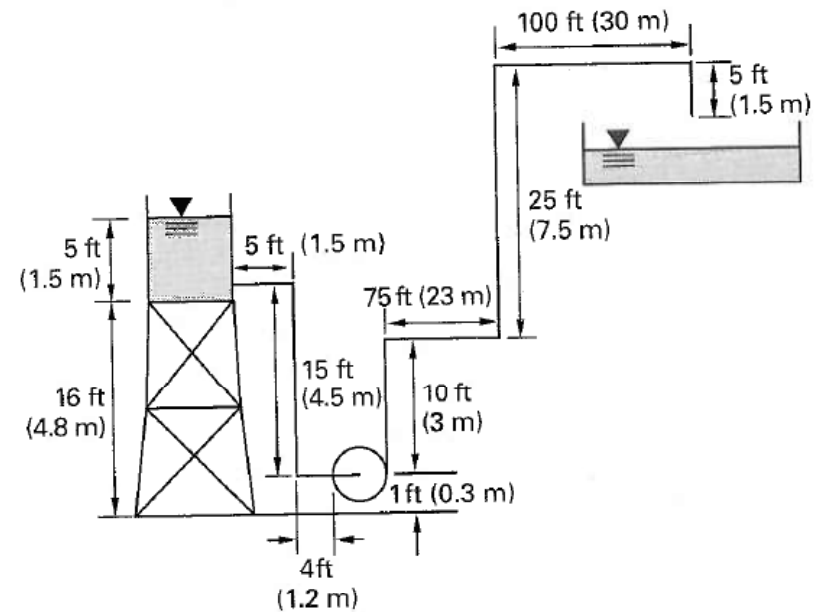
NET POSITIVE SUCTION HEAD (NPSH)

- Minimum fluid energy (or head) required at the inlet by the pump for satisfactory operation to avoid cavitation.
 - Cavitation: Small pockets of vapor trapped inside the pump that cause vibration and noise
- **NPSHR**: **NPSH Required**
 - Specified by the manufacturer
- **NPSHA**: **NPSH Available**
 - Actual energy (head) available at the inlet
- To avoid cavitation, **NPSHA > NPSHR**
- **$NPSHA = h_{atm} + h_{z(s)} - h_{f(s)} - h_{VP}$... 18.30a**
(VP = vapor pressure)



EXAMPLE 18.8: NPSHA

2.0 ft³/sec (56 L/s) of 60°F (16°C) water are pumped from an elevated feed tank to an open reservoir through 6 in (15.2 cm), schedule-40 steel pipe, as shown. The friction loss for the piping and fittings in the suction line is 2.6 ft (0.9 m). The friction loss for the piping and fittings in the discharge line is 13 ft (4.3 m). The atmospheric pressure is 14.7 psia (101 kPa). What is the NPSHA?



➤ **Given Data:**

$$Q = 2.0 \text{ ft}^3/\text{sec}$$

$$T = 60^\circ\text{F}$$

$$\text{Pipe diameter} = 6 \text{ in} = 0.5 \text{ ft}$$

$$\text{Pipe type} = \text{schedule-40 steel}$$

$$h_{f(s)} = 2.6 \text{ ft}$$

$$h_{f(d)} = 13.0 \text{ ft}$$

$$p_{\text{atm}} = 14.7 \text{ psia (absolute pressure)}$$

$$\text{vapor pressure} = VP = 0.59 \text{ ft (From Appendix 14.A for } 60^\circ\text{F)}$$

➤ **Calculate (?):**

➤ **NPSHA**



EXAMPLE 18.8: NPSHA

➤ Solution:

$$\text{From Eq. 15.7b, } h_{atm} = \frac{p}{\gamma} = \frac{14.7 \times 144}{62.4} = 33.9 \text{ ft}$$

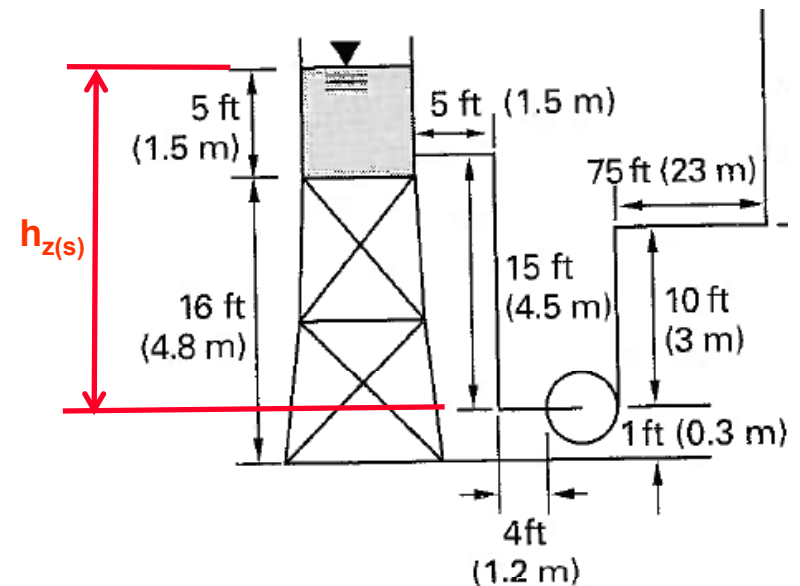
$$\text{➤ } h_{z(s)} = 5 + 16 - 1 = 20$$

➤ From Eq. 18.30a

$$\begin{aligned} \text{NPSHA} &= h_{atm} + h_{z(s)} - h_{f(s)} - h_{VP} \\ &= 33.9 + 20 - 2.6 - 0.59 \\ &= \boxed{50.7 \text{ ft}} \quad \text{ANSWER} \end{aligned}$$

➤ Distracters:

- Pipe type (not used)
- $h_{f(d)}$ (not used)
- Pipe lengths (in figure)



FOOD FOR THOUGHT

The new surface pump won't work because NPSHA is not adequate. They will need to replace the defective submersible pump with a new submersible pump.

Temporary solution: fill the suction line with water to remove the vacuum.

The Challenge



No Myth Is Safe — From everyday myths to urban legends, it's only a matter of time before the [MythBusters](#) take them all down. New episodes starting Wednesday, January 9th, 9:00 p.m. ET/PT. On the Discovery Channel.

Failing Pump...

Question:

While at your camp at the lake, walking with your daughter, you come across some neighbors working on the water system for one of the camps. It seems the original pump failed down in the well — the guys have pulled the pump and its wiring out of the well and replaced it with a surface mounted suction pump with a non-collapsible tube down to the water. They are baffled because even with the new pump, the water won't flow. During the ensuing discussion, your daughter wanders off. Within minutes she comes back and informs everyone, "There's nothing wrong with your pump. You could double the pump power and it's not going to matter. Even use 500 hp if you want. Won't work." How does she know?

Answer:

Your daughter walked off the old pump's wiring and measured 37 feet. Water pressure increases with depth by about 0.43 psi per foot, which means that the old pump was providing at least 15.9 psi (37×0.43) down in the hole when it was working. When using a vacuum to lift the water, however, it is atmospheric pressure that actually does the work, and standard pressure at sea level is 14.7 psi. There is simply not enough air pressure to push the water up the tube, even if a perfect vacuum could be created by the new pump. The maximum depth well that this suction arrangement could work for (self prime) would be $14.7/0.43 = 34$ ft. The guys have to use another submersible pump.



[back to top](#)

Link worked until 10/29/09

<http://material-handling.globalspec.com/Newsletter/ViewIssue?vol=Vol6Issue1B&pub=1&isPastIssue=1>

SUGGESTED READING: CHAPTER 18

◆ 29 to 34. Turbines

PRACTICE EXAM: FLUID STATICS AND FLOW (CHAPTERS 14-17) AND PUMPS (CHAPTER 18)



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A water supply system supplies water to a steel manufacturing plant (elevation = 1050 feet) at a normal pressure of 40 psi. The plant is located between a supply reservoir (elevation = 1000 feet) and a storage tank (ground elevation = 1100 feet, overflow elevation = 1200 feet). Discharge pressure of the reservoir is 75 psi. The piping data is given below:

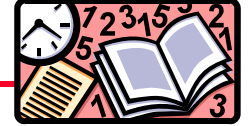
Between the reservoir and the plant: 2000 feet of 10-inch diameter cast iron pipe, two gate valves, two side outlet tees, and four 45° elbows. Equivalent length of fittings is 514 feet.

Between the plant and the storage tank: 4000 feet of 8-inch diameter cast iron pipe.

Assume $C = 140$ for all the pipes.

- Hydraulic head (feet) at the reservoir is most nearly:
 - 1000
 - 75
 - 173
 - 1170
 - 1100
- Hydraulic head (feet) at the storage tank is most nearly:
 - 1000
 - 1100
 - 1200
 - 100
 - 1170
- Hydraulic head (feet) at the plant is most nearly:
 - 1000
 - 1050
 - 92.4
 - 1092.4
 - 1140
- Equivalent length of pipe (feet) between the reservoir and the plant is most nearly:
 - 2000
 - 514
 - 2510
 - 2500
 - 500
- Head loss (feet) between the reservoir and the plant is most nearly:
 - 10
 - 20
 - 30
 - 40
 - 50
- Flow (gpm) from the reservoir to the plant is most nearly:
 - 1600
 - 1700
 - 1800
 - 1900
 - 2000
- Head loss (ft/ft) between the storage tank and the plant is most nearly:
 - 60
 - 0.01
 - 1140
 - 1200
 - 0.05
- Flow (cfs) from the storage tank to the plant is most nearly:
 - 1000
 - 900
 - 12
 - 2
 - 958
- The power consumption (horsepower) is most nearly, if the overall efficiency of the reservoir pump and motor is 72%:
 - 17
 - 27
 - 37
 - 12
 - 22
- If electric cost is $\$0.00$ mills per kilowatt hour, the cost of pumping one million gallons of water is most nearly:
 - \$10
 - \$50
 - \$100
 - \$1000
 - \$49.50

PRACTICE EXAM: FLUID STATICS AND FLOW (CHAPTERS 14-17) AND PUMPS (CHAPTER 18)



A water supply system supplies water to a steel manufacturing plant (elevation = 1050 feet) at a normal pressure of 40 psi. The plant is located between a supply reservoir (elevation = 1000 feet) and a storage tank (ground elevation = 1100 feet, overflow elevation = 1200 feet). Discharge pressure of the reservoir is 75 psi. The piping data is given below:

Between the reservoir and the plant: 2000 feet of 10-inch diameter cast iron pipe, two gate valves, two side outlet tees, and four 450 elbows. Equivalent length of fittings is 514 feet.

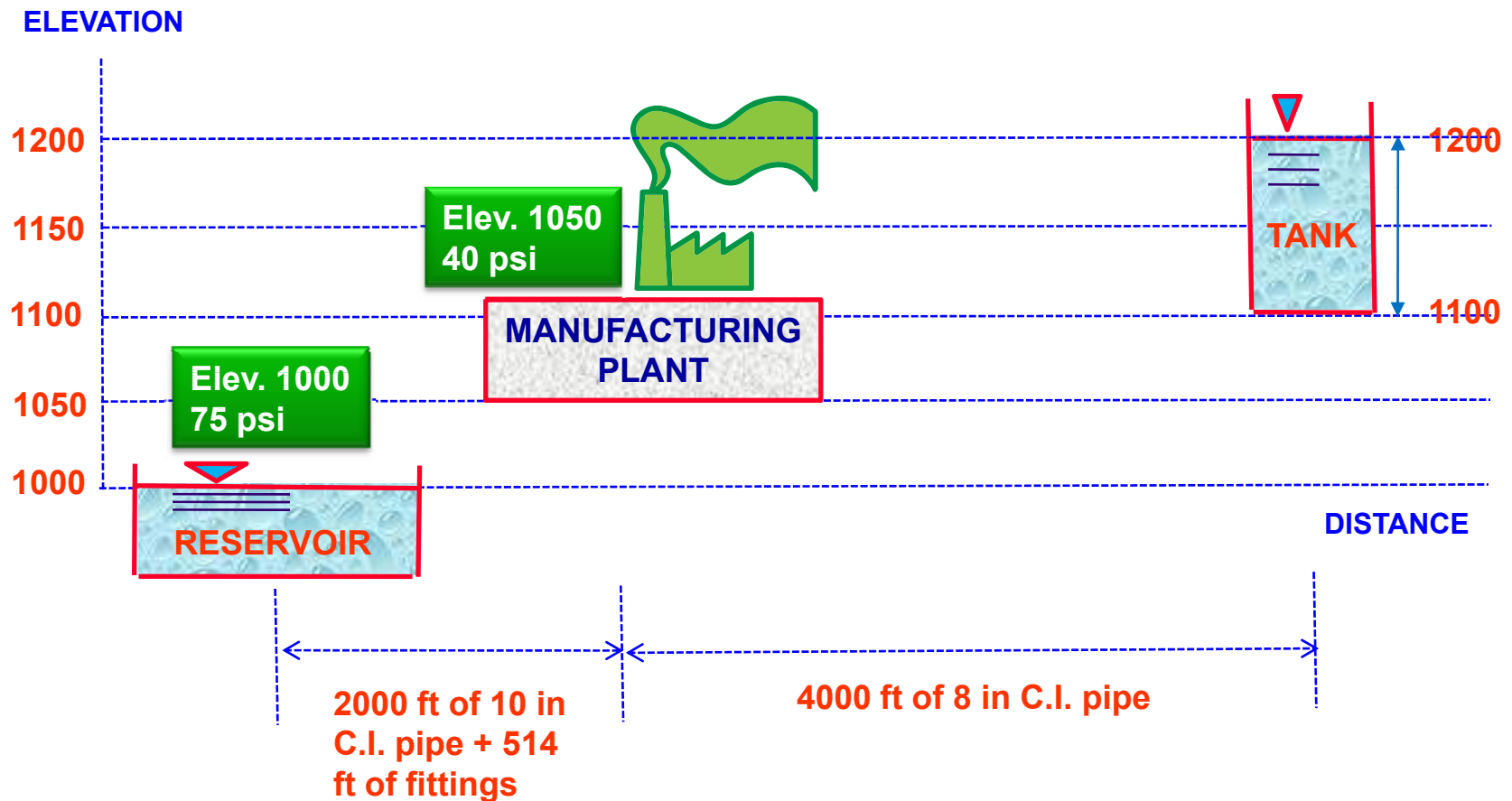
Between the plant and the storage tank: 4000 feet of 8-inch diameter cast iron pipe.

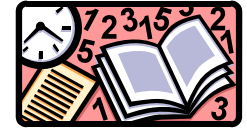
Assume $C = 140$ for all the pipes.



PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION

Step 1 (very important): Draw a sketch (profile plot)





PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION

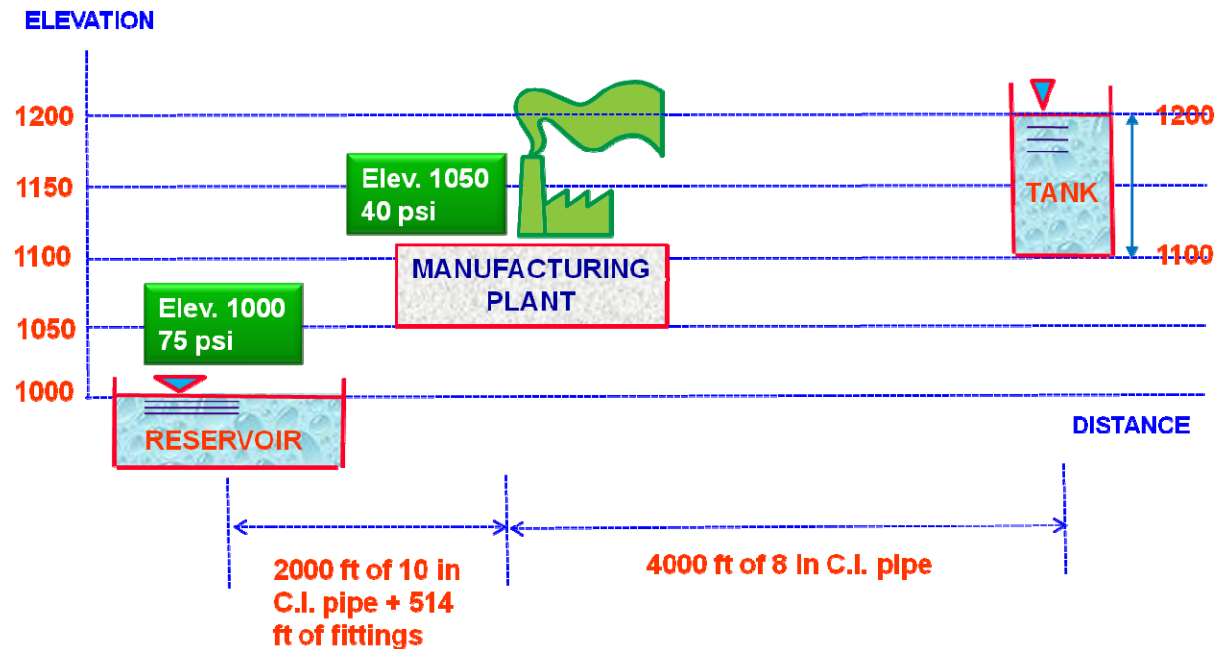
1. Hydraulic head (feet) at the reservoir is most nearly:

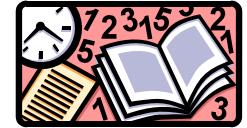
- A. 1000
- B. 75
- C. 173
- D. 1170
- E. 1100

Hydraulic head (feet) at the reservoir is:

$$= 1000 + (75 \text{ psi} \times 2.31 \text{ ft/psi}) = 1000 + 173.25 \text{ feet} = 1173.25 \approx 1170 \text{ feet}$$

Answer: Select D





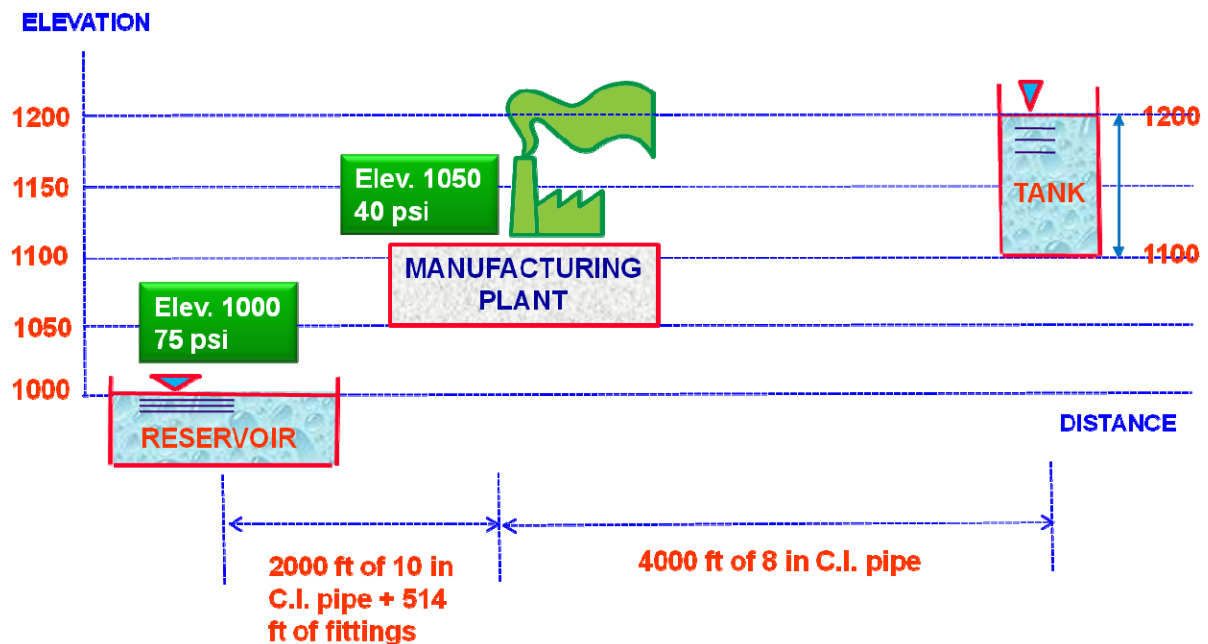
PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION

2. Assuming that the tank is full, hydraulic head (feet) at the storage tank is most nearly:

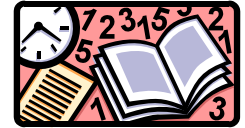
- A. 1000
- B. 1100
- C. 1200
- D. 100
- E. 1170

Hydraulic head (feet) at the storage tank is :
= Overflow elevation of the tank = 1200 feet

Answer: Select C



PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION



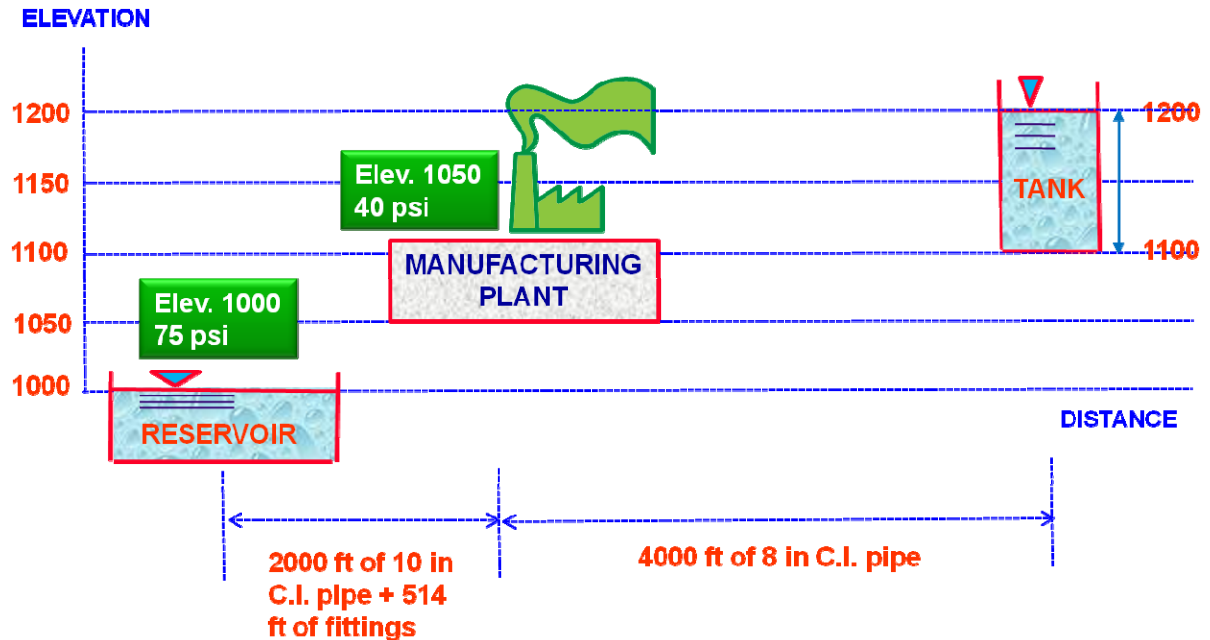
3. Hydraulic head (feet) at the plant is most nearly:

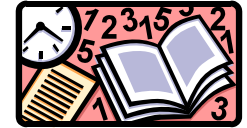
- A. 1000
- B. 1050
- C. 92.4
- D. 1092.4
- E. 1140

Hydraulic head (feet) at the plant is:

$$= 1050 + (40 \text{ psi} \times 2.31 \text{ ft/psi}) = 1050 + 92.4 \text{ feet} = 1142.4 \approx 1140 \text{ feet}$$

Answer: Select E





PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION

4. Equivalent length of pipe (feet) between the reservoir and the plant is most nearly:

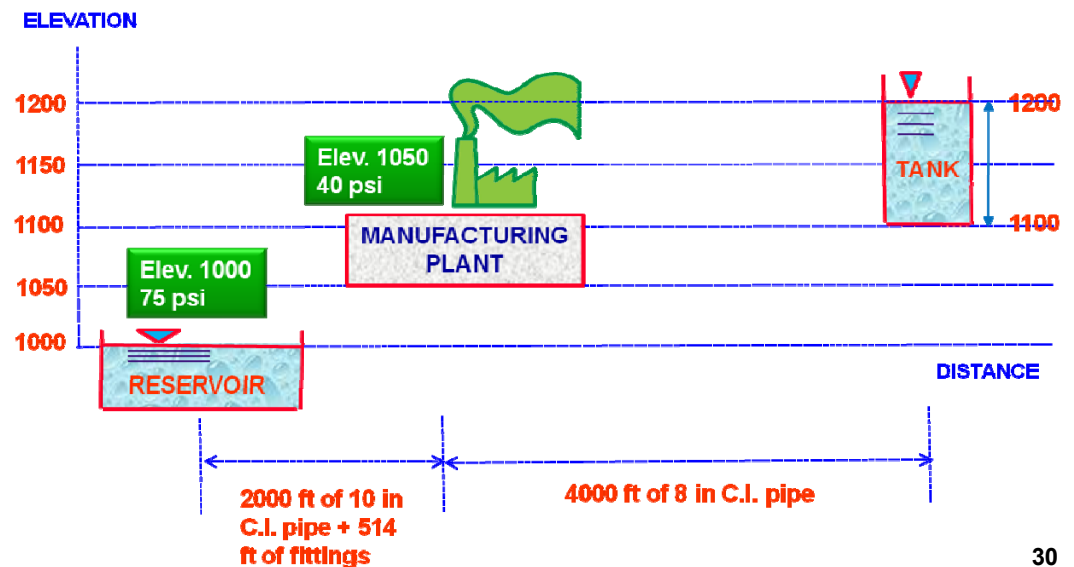
- A. 2000
- B. 514
- C. 2510
- D. 2500
- E. 500

Pipe length = 2000 ft

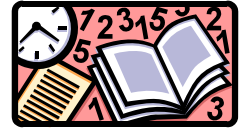
Equivalent length of fittings = 514 ft (given; ignore the distracter on description of fittings (valves, tees, elbows))

Total = 2000 + 514 = 2514 \approx 2510 ft

Answer: Select C



PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION



5. Head loss (ft) between the reservoir and the plant is most nearly:

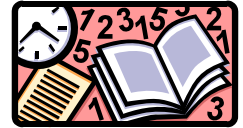
- A. 10
- B. 20
- C. 30
- D. 40
- E. 50

Head loss = hydraulic head at the reservoir - hydraulic head at the plant
= 1173.25 - 1142.4
= 30.85 ft \approx 30 feet

Answer: Select C

- *Hydraulic head at the reservoir = 1173.25 from Question 1*
- *Hydraulic head at the plant = 1142.4 from Question 3*
- *To be safe, use exact values (1173.25 and 1142.4) rather than the approximate values (1170 and 1140)*
- *Example of cascading question: If your answers for Q1 and Q3 were wrong, this answer will also be wrong.*

PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION



6. Flow (gpm) from the reservoir to the plant is most nearly:

- A. 1600
- B. 1700
- C. 1800
- D. 1900
- E. 2000

From Hazen-Williams Formula:

$$Q = 0.285 C d^{2.63} S^{0.54} \text{ (Derived from Eq. 19.14(b))}$$

where

Q = flow in gpm

C = roughness coefficient

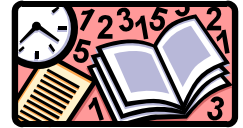
d = pipe diameter in inches

S = slope of hydraulic grade line in ft/ft = head loss / pipe length

$$\begin{aligned} \text{Flow} &= (0.285) (140) (10)^{2.63} (\underline{30.85/2514})^{0.54} \\ &= 1589 \text{ gpm} \approx 1600 \text{ gpm} \end{aligned}$$

Answer: Select A

PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION



7. Head loss (ft/ft) between the storage tank and the plant is most nearly:

- A. 60
- B. 0.01
- C. 1140
- D. 1200
- E. 0.05

Compare with Question 5: What's the difference?

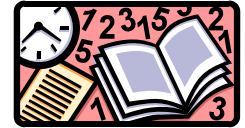
Q5 head loss units: ft

Q7 head loss units: ft/ft

$$\begin{aligned}\text{Head loss (ft/ft)} &= (\text{hydraulic head at the storage tank} - \text{hydraulic head} \\ &\quad \text{at the plant}) / (\text{pipe length}) \\ &= (1200 - 1142.4) / (4000) \\ &= 0.0144 \approx 0.01 \text{ ft/ft}\end{aligned}$$

Answer: Select B

PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION



8. Flow (cfs) from the storage tank to the plant is most nearly:

- A. 1000
- B. 900
- C. 12
- D. 2
- E. 958

- *Compare with Question 6: What's the difference?*
- *Q6 flow units: gpm*
- *Q8 flow units: cfs*

From Hazen-Williams Formula:

$$Q = 0.285 C d^{2.63} S^{0.54} \text{ (Derived from Eq. 19.14(b))}$$

$$= (0.285) (140) (8)^{2.63} (\underline{0.0144})^{0.54}$$

$$= 958 \text{ gpm}$$

$$= 958 / 448.831 \text{ cfs}$$

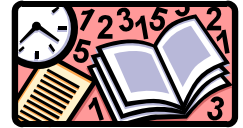
$$= 2.134 \text{ cfs}$$

$$\approx 2 \text{ cfs}$$

- *S = 0.0144 from Question 7*
- *Should use the exact value (0.0144) rather than the approximate value (0.01)*
- *Example of cascading question: If your answer for Q7 was wrong, this answer will also be wrong.*

Answer: Select D

PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION



9. The power consumption (horsepower) is most nearly, if the overall efficiency of the reservoir pump and motor is 72%:

- A. 17
- B. 27
- C. 37
- D. 12
- E. 22

From equation in Table 18.5

Horsepower = $(Q \times H) / (3960) (\text{efficiency})$

where

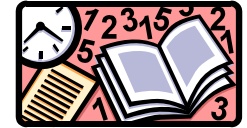
Q = flow in gpm

H = head added in ft

$$\begin{aligned} \text{H.P.} &= \frac{(1589) (1173.25 - 1142.4)}{(3960) (0.72)} \\ &= 17.2 \approx 17 \end{aligned}$$

Answer: Select A

- *Hydraulic head at the reservoir = 1173.25 from Question 1*
- *Hydraulic head at the plant = 1142.4 from Question 3*
- *Q = 1589 gpm from Question 6*
- *Must use exact values rather than the approximate values*
- *Example of cascading question: If your answers for Q1, Q3, and Q6 were wrong, this answer will also be wrong.*



PRACTICE EXAM: FLUID STATICS, FLOW AND PUMPS SOLUTION

10. If electric cost is 100 mills per kilowatt hour, the cost of pumping one million gallons of water is most nearly:

- A. \$10
- B. \$50
- C. \$100
- D. \$1000
- E. \$49.50

1 mill = 1/1000

Pumping cost = (Hours pumped) × (power consumption in kilowatts) × (cost in per kilowatt hour)

Hours pumped = (1,000,000 gallons) / (1589 gpm)

= 629.33 minutes

= 10.49 hours

Power consumption = 17.2 H.P. = (17.2) (0.745) = 12.8 kilowatts

Pumping cost = (10.49) (12.8) (100/1000)

= \$ 13.43

≈ \$ 10

Answer: Select A

- *Q = 1589 gpm from Question 6*
- *H.P. = 17.2 from Question 9*
- *Must use exact values rather than the approximate values*
- *Example of cascading question: If your answers for Q6 and Q9 were wrong, this answer will also be wrong.*