CHAPTER

Construction Planning, Equipment, and Methods — Sixth Edition

EQUIPMENT FOR PUMPING WATER

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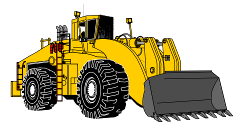

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ENCE 420 – Construction Equipment and Methods

Spring 2003

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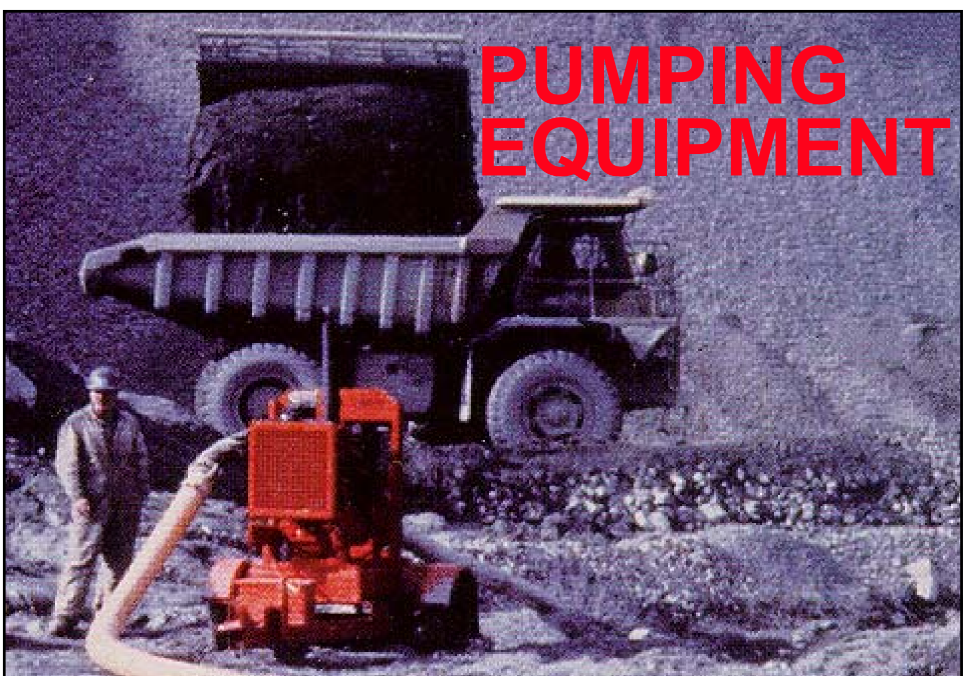


USES OF PUMPS

- Pumps are used extensively on construction projects for:
  1. Removing water from pits, tunnels. and other excavations.
  2. Dewatering cofferdams.
  3. Furnishing water for jetting and sluicing.
  4. Furnishing water for many types of utility services.
  5. Lowering the water table for excavations.
  6. Foundation grouting.

PUMP SELECTION

- The factors that should be considered in selecting pumps for construction applications include:
  1. Dependability.
  2. Availability of repair parts.
  3. Simplicity to permit easy repairs.
  4. Economical installation and operation.
  5. Operating power requirements.

CLASSIFICATION OF PUMPS

- The pumps commonly used on construction projects may be classified as:
  1. **Displacement**
     a. Reciprocating
     b. Diaphragm
  2. **Centrifugal**
     a. Conventional
     b. Self‐priming
     c. Air‐operated

RECIPROCATING PUMPS

- A **reciprocating pump** operates as the result of the movement of a piston inside a cylinder.
- **Double-acting pump**.
  When the piston is moved in one direction, the water ahead of the piston is forced out of the cylinder. At the same time additional water is drawn into the cylinder behind the piston. Regardless of the direction of movement of the piston, water is forced out of one end and drawn into the other end of the cylinder.

RECIPROCATING PUMPS

- **Single-acting pump.**

  If water is pumped during a piston movement in one direction only, the pump is classified as single-acting pump
- If a pump contains more than one cylinder, mounted side by side, it is classified as a **duplex** for two cylinders, **triplex** for three cylinders, etc. Thus, a pump might be classified as duplex double-acting, duplex single-acting.

RECIPROCATING PUMPS

- The volume of water pumped in one stroke will equal the *area of the cylinder times the length of the stroke*, less a small deduction for slippage through the valves or past piston, usually about 3 to 5%.
- If this volume is expressed in cubic inches (in^3), it may be converted to gallons by dividing by 231, which is the number of cubic inches in one gallon.

SIMPLEX DOUBLE-ACTING PUMP

- The volume pumped in gallons per minute (gpm) by a simplex double-acting pump will be

$$Q(\text{gpm}) = \frac{c(\text{area of cylinder} \times l \times n)}{231}$$

$$Q(\text{gpm}) = c\left[\left(\frac{\pi d^2}{4}\right) \times l \times n\right] \div 231 = c\frac{\pi d^2 l\, n}{924} \qquad (1)$$

where
Q = capacity of a pump, gpm
c = one-slip allowance; varies from 0.95 to 0.97
d = diameter of cylinder, in.
l = length of stroke, in.
n = number of strokes per min

SIMPLEX DOUBLE-ACTING PUMP

- The volume pumped in gallons per minute (gpm) by a multiplex double-acting pump is given by

$$Q(\text{gpm}) = N\frac{c(\text{area of cylinder} \times l \times n)}{231}$$

$$Q(\text{gpm}) = Nc\left[\left(\frac{\pi d^2}{4}\right) \times l \times n\right] \div 231$$

$$Q(\text{gpm}) = Nc\frac{\pi d^2 l\, n}{924} \qquad (2)$$

where
N = number of cylinders in a pump

ENERGY REQUIRED TO OPERATE A PUMP

- The energy (ft-lb/min) required to operate a pump is given by the following equation:

$$W = \frac{wQh}{e} \qquad (3)$$

where
W = energy, ft-lb per min
w = weight of one gallon of water, lb
h = total pumping head (ft), including friction loss in pipe
e = efficiency of the pump, expressed decimally

HORSEPOWER REQUIRED BY A PUMP

- The horsepower (hp) required by a pump is given by the following equation:

$$P = \frac{W}{33{,}000} = \frac{wQh}{33{,}000e} \qquad (4)$$

where
P = power, hp
W = energy, ft-lb per min
w = weight of one gallon of water, lb
h = total pumping head (ft), including friction loss in pipe
e = efficiency of the pump, expressed decimally
33,000 = ft-lb per minute for 1 hp

Example 1

How many gallons of freshwater will be pumped per minute by a duplex double acting pump, size 6 X 12 in, driven by crankshaft making 90 rpm? If the total head is 160 ft and the efficiency of the pump is 60%, what is the minimum horsepower required to operate the pump? The weight of water is 8.34 lb per gallon.

Assume a water slippage of 4%, therefore, $c = 1.0 - 0.04 = 0.96$

$$Q(\text{gpm}) = Nc\frac{\pi d^2 l\, n}{924} = (2)(0.96)\frac{\pi(6)^2(12)(2\times 90)}{924} = \underline{508\text{ gpm}}$$

$$\therefore P = \frac{wQh}{33{,}000e} = \frac{8.34(508)(160)}{33{,}000(0.6)} = \underline{34.2\text{ HP}}$$

RECIPROCATING PUMPS

- The capacity of a reciprocating pump depends essentially on the speed at which the pump is operated and is independent of the head.
- The maximum head at which a reciprocating pump will deliver water depends on the strength of the component parts of the pump and the power available to operate the pump.
- The capacity of reciprocating pumps may be varied considerably by varying the speed of the pump.

ADVANTAGES OF RECIPROCATING PUMPS

The advantages of reciprocating pumps are:

1. They are able to pump at a uniform rate against varying heads
2. Their capacity can be increased by increasing the speed
3. They have reasonably high efficiency regardless of the head and speed
4. They are usually self-priming

DISADVANTAGES OF RECIPROCATING PUMPS

The disadvantages of reciprocating pumps are summarized as follows:

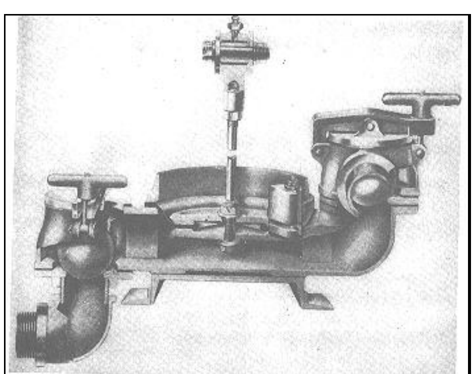
1. The heavy weight and large size for the given capacity.
2. The possibility of valve trouble, especially in pumping water containing abrasive solids
3. The pulsating flow of water.
4. The danger of damaging a pump when operating against a high head.

DIAPHRAGM PUMPS

- The principle under which a diaphragm pimp operates is shown in Figure 1 (Figure 20-3, Text).
- The central portion of the flexible diaphragm is alternately raised and lowered by the pump rod, which is connected to a walking beam.
- This action draws water into and discharges it from the pump.

DIAPHRAGM PUMPS

Figure 1. Section through a Diaphragm Pump (Fig 20-3, Text)



DIAPHRAGM PUMPS

- Because this type of pump will handle clear water or water containing large quantities of mud, sand, sludge, and trash, it is popular as a construction pump.
- It is perfect for use on jobs where the quantity of water varies considerably, as the loss of prime during low flow does not prevent the pump from automatically re-priming when the quantity of water increases.

DIAPHRAGM PUMPS

- The accessible diaphragm may be replaced easily.
- The Contractor's Pump Bureau specifies that diaphragm pumps shall be manufactured in the size and capacity ratings as given in Table 1 (Table 16-1, Text).

DIAPHRAGM PUMPS

Table 1. Minimum Capacities for Diaphragm Pumps at 10-ft Suction Lifts

Size	Capacity (gph)
Two-in, single	2,000
Three-in, single	3,000
Four-in, single	6,000
Four-in, double	9,000

CENTRIFUGAL PUMPS

- A centrifugal pump contains a rotation element, called an impeller, which imparts to water passing through the pump a velocity sufficiently great to cause it to flow from the pump, even against considerable pressure.
- A mass of water may possess energy due to either its height above a given datum or its velocity. The former is potential, whereas the latter is kinetic energy. One type of energy can be converted into the other under favorable conditions.

CENTRIFUGAL

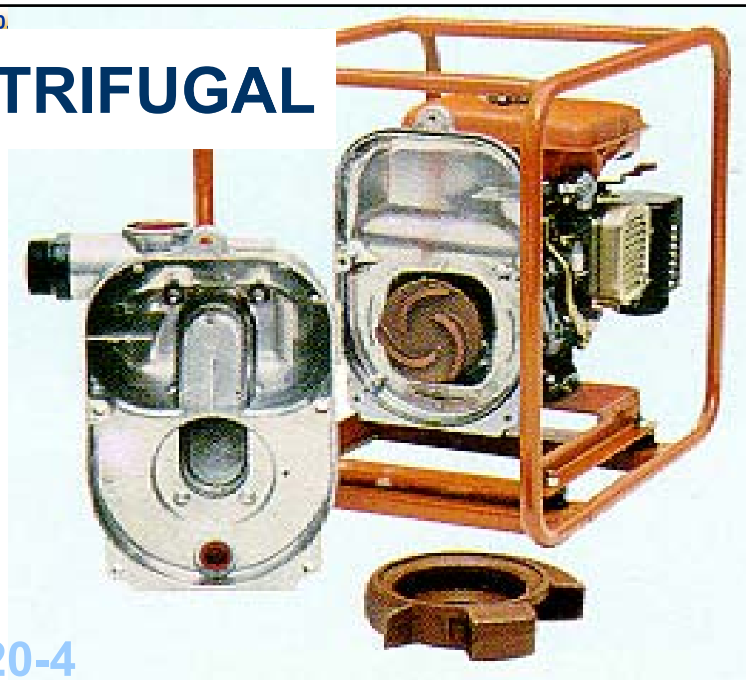
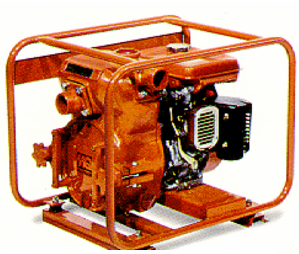
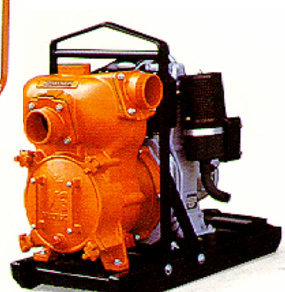


Fig. 20-4

CENTRIFUGAL



2” gas powered



4” diesel powered

6” diesel powered

CENTRIFUGAL PUMPS

The Bernoulli Equation:

$$z + \frac{v^2}{2g} + \frac{p}{\gamma} = \text{constant} \qquad (5)$$

- where

  z = elevation above datum

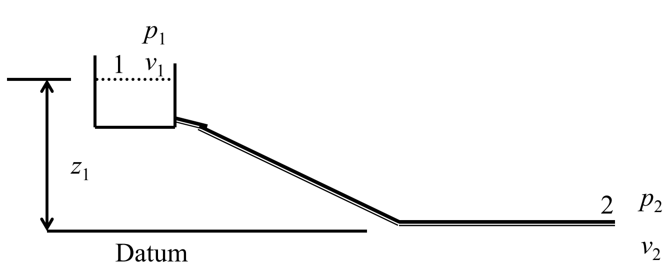
  v = velocity of the fluid

  p = pressure of the fluid

CENTRIFUGAL PUMPS

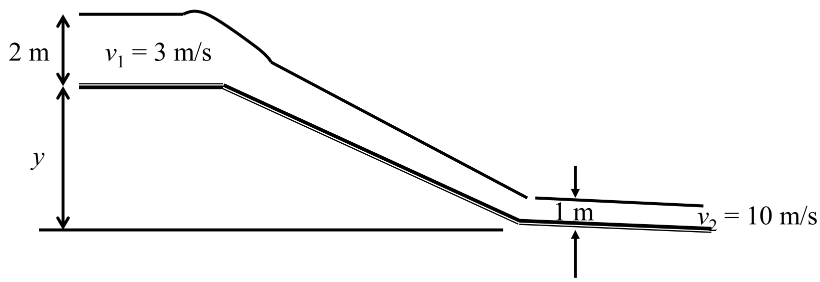
Application of Bernoulli Equation:

$$z_1 + \frac{v_1^2}{2g} + \frac{p_1}{\gamma} = z_2 + \frac{v_2^2}{2g} + \frac{p_2}{\gamma} + \text{Losses}_{1\text{-}2} \qquad (6)$$



Example 2

Water is flowing in an open channel (as shown) at a depth of 2 m an a velocity of 3 m/s. If then flows down a contracting chute into another channel where the depth is 1 m and the velocity is 10 m/s. Assuming frictionless flow, determine the difference in elevation of the channel floors.



Example 2 (continued)

$$z_1 + \frac{v_1^2}{2g} + \frac{p_1}{\gamma} = z_2 + \frac{v_2^2}{2g} + \frac{p_2}{\gamma} + \text{Losses}_{1\text{-}2}$$

$$z_1 = y + 2,\ z_2 = 1,\ v_1 = 3\ \text{m/s},\ v_2 = 10\ \text{m/s, and } p_1 = p_2 = 0$$

$$\text{Losses}_{1\text{-}2} = 0\ \text{(assumed)}$$

$$\therefore (y+2) + \frac{3^2}{2(9.806)} + 0 = 1 + \frac{10^2}{2(9.806)} + 0$$

$$\therefore y = 3.64\text{m}$$

CENTRIFUGAL PUMPS

- The principle of the centrifugal pump may be illustrated by considering a drop of water at rest at a height *h* above a surface. If the drop of water is permitted to fall freely, it will strike the surface with a velocity given by the equation

$$v = \sqrt{2gh} \qquad (7)$$

where v = velocity, fps
g = acceleration of gravity, equal to 32.2 ft per sec at sea level
h = height of fall, ft

CENTRIFUGAL PUMPS

- If the drop falls 100 ft, the velocity will be 80.2 fps.
- If the same drop is given an upward velocity of 80.2 fps, it will rise 100 ft.
- These values assume no loss in energy due to friction through air.
- It is the function of a centrifugal pump to give the water the necessary velocity as it leaves the impeller.

CENTRIFUGAL PUMPS

- If the speed of the pump is doubled, the velocity of the water will increase from 80.2 to 160.4 fps, neglecting any increase in friction losses
- With this velocity, the water can be pumped to height given by

$$h = \frac{v^2}{2g} = \frac{(160.4)^2}{2(32.4)} = 400 \text{ ft}$$

CENTRIFUGAL PUMPS

- This indicates that if a centrifugal pump is pumping water against a total head of 100 ft, the same quantity of water can be pumped against a total head of 400 ft simply by doubling the speed of the impeller.
- However, in actual practice, the maximum possible head for the increased speed will be less than 400 ft because of increases in losses in the pump due to friction.
- These results illustrate the effect which increasing the speed or the diameter of an impeller has on the performance of a centrifugal pump.

CENTRIFUGAL PUMPS

- A centrifugal pump may be equipped with an open or enclosed impeller
- Although an enclosed impeller usually has higher efficiency, it will not handle water containing *trash* as well as an open impller
- The power required to operate centrifugal pump is given by Eq. 4
- The efficiencies of these pumps may be as high as 75%

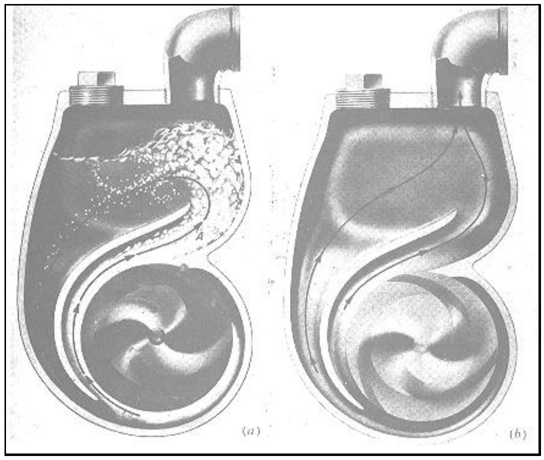
$$P = \frac{W}{33{,}000} = \frac{wQh}{33{,}000e} \qquad (4)$$

SELF-PRIMING CENTRIFUGAL PUMPS

- In construction projects, sometimes pumps must be set <u>above the surface of the water</u> which is to be pumped.
- This is why self-priming centrifugal pumps are more suitable than conventional types on construction projects.
- The operation of a centrifugal pump is illustrated in Figure 2 (Fig. 20-4, Text) .
- A check valve on the *suction side* of the pump permits the chamber to be filled with water prior to the starting the pump.

SELF-PRIMING CENTRIFUGAL PUMPS

Figure 2. Section through a Self-priming Pump. (a) Priming Action. (b) Pumping Action



SELF-PRIMING CENTRIFUGAL PUMPS

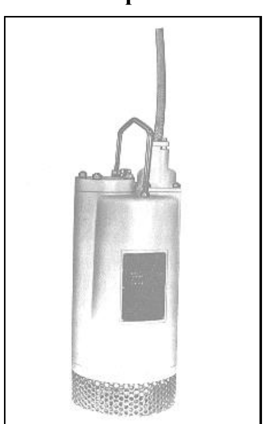
- When the pump is started, the water in the chambre produces a seal flow through channel A into the chamber, where air escapes through the discharge, and the water flows down through channel B to the impeller.
- This action continues until all the air is exhausted from the suction line and water enters the pump
- When the pump is stopped, it will retain its charge of priming water indefinitely.
- Such a pump is self-priming to heights in excess of 25 ft.

SUBMERSIBLE PUMPS

- Submersible pumps are very useful in dewatering
  - ✓ tunnels
  - ✓ foundation pits
  - ✓ trenches
  - ✓ others
- Figure 3 (Fig 20-7, Text) illustrates an electric-motor operated submersible pump.
- Figure 4 (Fig. 20-8, Text) is a performance curve for this pump when operated against varying heads of water. The figure includes pertinent information related to the pump. Other types and models have different performance characteristics.

SUBMERSIBLE PUMPS

Figure 3. Electric-motor Operated Submersible Pump (The Gorman-Rupp Co.)



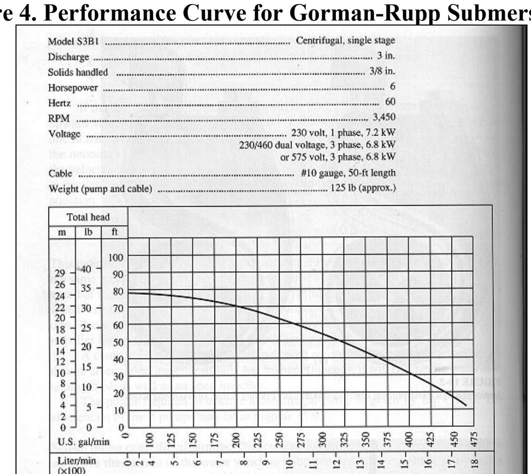
SUBMERSIBLE

Different sizes to fit specific needs.

Fig. 20-7

PERFORMANCE CURVE FOR A SUBMERSIBLE PUMP

Figure 4. Performance Curve for Gorman-Rupp Submersible Pump (G-R Co.)



Model S3B1	Centrifugal, single stage
Discharge	3 in.
Solids handled	3/8 in.
Horsepower	6
Hertz	60
RPM	3,450
Voltage	230 volt, 1 phase, 7.2 kW 230/460 dual voltage, 3 phase, 6.8 kW or 575 volt, 3 phase, 6.8 kW
Cable	#10 gauge, 50-ft length
Weight (pump and cable)	125 lb (approx.)

MULTISTAGE CENTRIFUGAL PUMPS

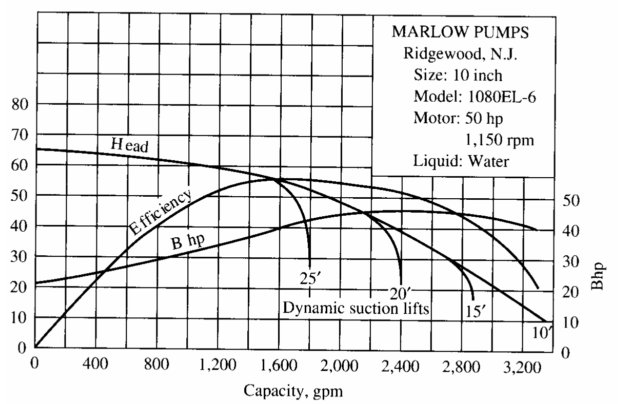
- If a centrifugal pump has a single impeller, it is described as a single-stage pump.
- If there are two or more impellers and the water discharge from one impeller flows into the suction of another, it is described as multistage pump
- These pumps are useful for pumping against high heads of pressure.
- Pumps of this type are used sometimes to supply water for jetting, where the pressure may run as high as several hundred pounds per square inch (psi).

PERFORMANCE OF CENTRIFUGAL PUMPS

- Pump manufacturers will furnish sets of curves showing the performance of their pumps under different operating conditions
- A set of curves for a given pump will show the variations in capacity, efficiency, and horsepower for different pumping heads

PERFORMANCE OF CENTRIFUGAL PUMPS

Figure 5 (Fig. 20-5, Text)
Performance Curves for Centrifugal Pump.



PERFORMANCE OF CENTRIFUGAL PUMPS

- Figure 5 illustrates a set of performance curves for a 10-in centrifugal pump.
- For a total head of 60 ft, the capacity will be 1,200 gpm, the efficiency 52%, and the required power 35 brake horsepower (bhp).

LOSS OF HEAD DUE TO FRICTION IN PIPE

- Table 2 (Table 20-4, Text) gives the nominal loss of head due to water flowing through clean iron or steel pipe.
- The actual losses of head may differ from the values given in Table 1 because of variations in the diameter of a pipe and in the condition of the inside surface.

Loss of Head due to Friction in Pipe

Table 2 (Table 20-5 Text)
Water Friction Loss in Feet Per 100 ft for Clean Iron Steel Pipe.

Flow in U.S. (gpm)	Nominal diameter of pipe (in.)												
	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4	5	6	8	10	12
5	26.5	6.8	2.11	0.55										
10	95.8	24.7	7.61	1.98	0.93	0.31	0.11							
15		52.0	16.3	4.22	1.95	0.70	0.23							
20		88.0	27.3	7.21	3.38	1.18	0.40							
25			41.6	10.8	5.07	1.75	0.60	0.25						
30			57.8	15.3	7.15	2.45	0.84	0.35						
40				26.0	12.2	4.29	1.4	0.59						
50				39.0	18.5	6.43	2.2	0.9	0.22					
75					39.0	13.6	4.6	2.0	0.48	0.16				
100					66.3	23.3	7.8	3.2	0.79	0.27	0.09			
125						35.1	11.8	4.9	1.2	0.42	0.18			
150						49.4	16.6	6.8	1.7	0.57	0.21			
175						66.3	22.0	9.1	2.2	0.77	0.31			
200							28.0	11.6	2.9	0.96	0.40			
225							35.3	14.5	3.5	1.2	0.48			
250							43.0	17.7	4.4	1.5	0.60	0.15		
275								21.2	5.2	1.8	0.75	0.18		
300								24.7	6.1	2.0	0.84	0.21		
350								33.8	8.0	2.7	0.91	0.27		
400									10.4	3.5	1.4	0.35		
500									15.6	5.3	2.2	0.53	0.18	0.08
600									22.4	6.2	3.1	0.74	0.25	0.10
700									30.4	9.9	4.1	1.0	0.34	0.14
800											5.2	1.3	0.44	0.18
900											6.6	1.6	0.54	0.22
1,000											7.8	2.0	0.65	0.27
1,100											9.3	2.3	0.78	0.32
1,200											10.8	2.7	0.95	0.37
1,300											12.7	3.1	1.1	0.42
1,400											14.7	3.6	1.2	0.48
1,500											16.8	4.1	1.4	0.55
2,000												7.0	2.4	0.93
3,000													5.1	2.1
4,000														3.5
5,000														5.5

† For old or rough pipes, add 50% to friction values.
Courtesy Contractors Pump Bureau.

LOSS OF HEAD DUE TO FRICTION IN PIPE

- The relationship between the head of freshwater in feet and pressure in psi is given by the equation

$$h = 2.31p \tag{8}$$

$$p = 0.433h \tag{9}$$

where h = depth of water or head, ft
p = pressure at depth h, psi

LOSS OF HEAD DUE TO FRICTION IN PIPE

- Table 3 (Table 20-5, Text) gives the equivalent length of straight steel pipe having the same loss in head due to water friction as fittings and valves.

LOSS OF HEAD DUE TO FRICTION IN PIPE

Table 3. Length of Steel Pipe (ft) Equivalent to Fittings and Valves (Table 20-5, Text)

Length of steel pipe, in feet, equivalent to fittings and valves

	Nominal size (in.)											
Item	**1**	**1¼**	**1½**	**2**	**2½**	**3**	**4**	**5**	**6**	**8**	**10**	**12**
90° elbow	2.8	3.7	4.3	5.5	6.4	8.2	11.0	13.5	16.0	21.0	26.0	32.0
45° elbow	1.3	1.7	2.0	2.6	3.0	3.8	5.0	6.2	7.5	10.0	13.0	15.0
Tee, side outlet	5.6	7.5	9.1	12.0	13.5	17.0	22.0	27.5	33.0	43.5	55.0	66.0
Close return bend	6.3	8.4	10.2	13.0	15.0	18.5	24.0	31.0	37.0	49.0	62.0	73.0
Gate valve	0.6	0.8	0.9	1.2	1.4	1.7	2.5	3.0	3.5	4.5	5.7	6.8
Globe valve	27.0	37.0	43.0	55.0	66.0	82.0	115.0	135.0	165.0	215.0	280.0	335.0
Check valve	10.5	13.2	15.8	21.1	26.4	31.7	42.3	52.8	63.0	81.0	105.0	125.0
Foot valve	24.0	33.0	38.0	46.0	55.0	64.0	75.0	76.0	76.0	76.0	76.0	76.0

Courtesy The Gorman-Rupp Company.

LOSS OF HEAD DUE TO FRICTION RUBBER HOSE

- The flexibility of rubber hose makes it a desirable substitute for pipe for use with pumps on many construction projects.
- A hose may be used on the suction side of a pump if it is constructed with a wire insert to prevent collapse under partial vacuum.
- Rubber hose is available with end fittings corresponding with those for iron or steel pipe
- Table 4 (Table 20-6, Text) provides the loss in head in feet per 100 ft due to friction caused by water flowing through the hose.

LOSS OF HEAD DUE TO FRICTION RUBBER HOSE

Table 4 (Table 20-6, Text)
Water Friction Loss, in Feet Per 100 ft of Smooth Bore Hose.

Flow in U.S. (gpm)	Actual inside diameter of hose (in.)											
	5/8	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8
5	21.4	8.9	2.2	0.74	0.3							
10	76.8	31.8	7.8	2.64	1.0	0.2						
15		68.5	16.8	5.7	2.3	0.5						
20			28.7	9.6	3.9	0.9	0.32					
25			43.2	14.7	6.0	1.4	0.51					
30			61.2	20.7	8.5	2.0	0.70	0.3				
35			80.5	27.6	11.2	2.7	0.93	0.4				
40				35.0	14.3	3.5	1.2	0.5				
50				52.7	21.8	5.2	1.8	0.7				
60				73.5	30.2	7.3	2.5	1.0				
70					40.4	9.8	3.3	1.3				
80					52.0	12.6	4.3	1.7				
90					64.2	15.7	5.3	2.1	0.5			
100					77.4	18.9	6.5	2.6	0.6			
125						28.6	9.8	4.0	0.9			
150						40.7	13.8	5.6	1.3			
175						53.4	18.1	7.4	1.8			
200						68.5	23.4	9.6	2.3	0.8	0.32	
250							35.0	14.8	3.5	1.2	0.49	
300							49.0	20.3	4.9	1.7	0.69	
350								27.0	6.6	2.3	0.90	
400									8.4	2.9	1.1	0.28
450									10.5	3.6	1.4	0.35
500									12.7	4.3	1.7	0.43
1,000										15.6	6.4	1.6

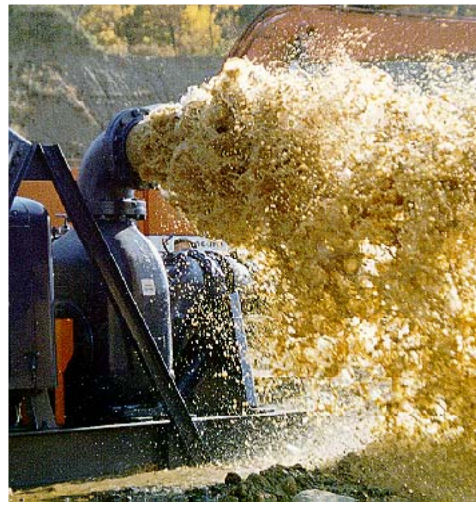
Courtesy Contractors Pump Bureau.

SELECTING A PUMP

- Before a pump for a given job is selected, it is necessary to analyze all information and conditions that will affect the selection.
- The most satisfactory pumping equipment will be the combination of pump and pipe that will provide the required service for the least total cost.

PUMP SELECTION

What size centrifugal pump is required to handle the 200 gpm from the previous example?



SELECTING A PUMP

- The total cost includes the installed and operating cost of the pump and pipe for the period that it will be used, with an appropriate allowance for salvage value at the completion of the project.
- In order to analyze the cost of pumping water, it is necessary to have certain information, such as:
  1. The rate at which the water is pumped.

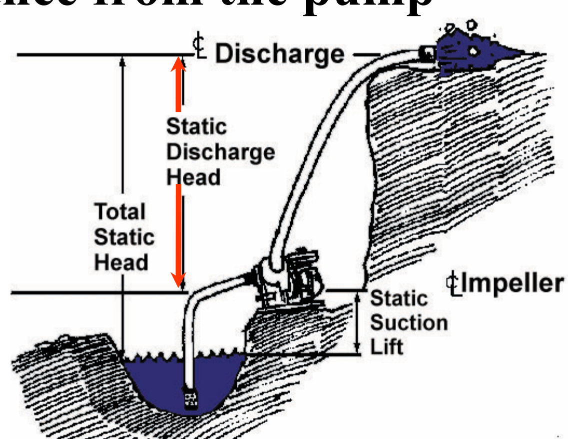
SELECTING A PUMP

2. The height of the lift from the existing water surface to the point of discharge.
3. The pressure head at discharge, if any.
4. The variations in water level at suction or discharge.
5. The altitude of the project.
6. The height of the pump above the surface of water to be pumped.
7. The size of pipe to be used, if already determined.
8. The number, sizes, and types of fittings and valves in the pipeline.

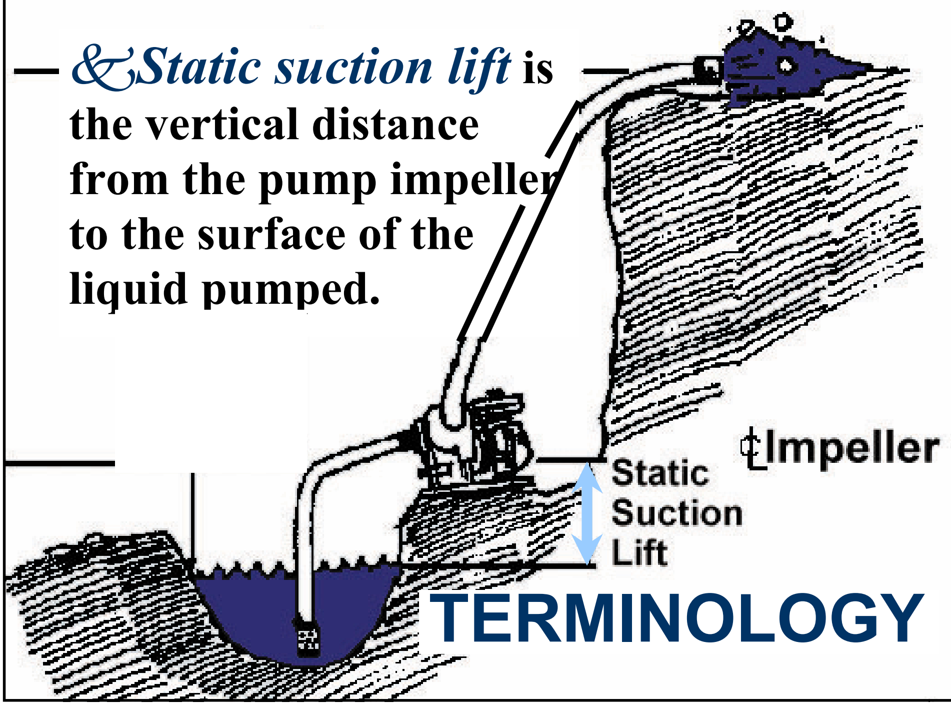
TERMINOLOGY

- ***Static discharge head*** **is the vertical distance from the pump impeller**

to the point of discharge.



&*Static suction lift* is the vertical distance from the pump impeller to the surface of the liquid pumped.



TERMINOLOGY

TERMINOLOGY

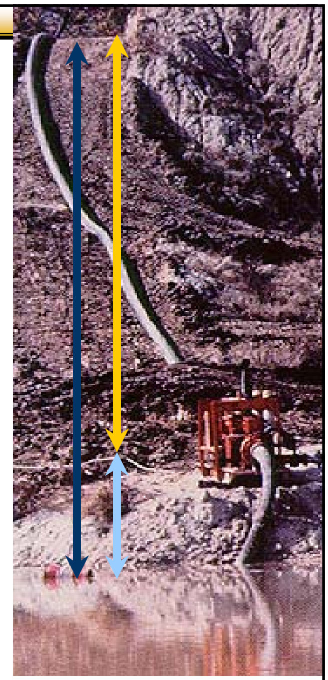
- ❖ Suction capability is limited by atmospheric pressure.

Maximum practical suction lift is 25 ft.

Decreasing suction lift will increase the volume that can be pumped.

TERMINOLOGY

- ***Total static head*** **is the static** ***suction lift*** **plus the static** ***discharge head*.**



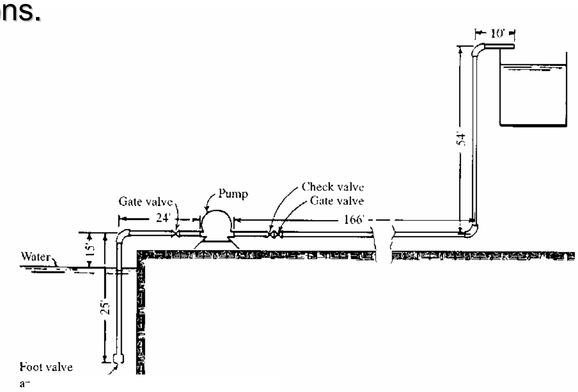
FRICTION LOSSES

The shearing stresses resist flow (friction losses), the overcoming of which requires that work be done. Concerned with losses in all components of the system:

- **Pipe**
- **Hose**
- **Fittings and valves**

Example 3

Select a self- priming centrifugal pump, with a capacity of 600 gpm, for the project illustrated as shown in the figure. All the pipe, fittings, and valves will be 6 in. with threaded connections.



Pump and pipe installation for Example 16-2.

Example 3 (continued)

From Table 3 (Table 20-5 Text):

Length of pipe: 25 + 24 + 166 + 54 + 10		= 279 ft
One foot valve and strainer		= 76 ft
3 90^0-elbows:	3 X 16	= 48 ft
2 gate valves:	2 X 3.5	= 7 ft
1 check valve:	1 X 63	= 63 ft
Total equivalent length		= 473 ft

From Table 2 (Table 20-4,Text) the friction loss per 100 ft of 6-in pipe will be 3.10 ft

$$\text{Total Head} = \text{Lift Head} + \text{Head lost in Friction} = (15 + 54) + \left(\frac{473}{100} \times 3.1\right) = 83.7\ \text{ft}$$

A model 90-M pump will deliver the required quantity of water (see Table 5 (Table 20-2c, Text)

Example 3 (continued)

Table 3. Length of Steel Pipe (ft) Equivalent to Fittings and Valves (Table 20-5, Text)

TABLE 16-5
Length of steel pipe, in feet, equivalent to fittings and valves

Item	Nominal size (in.) 1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4	5	6	8	10	12
90° elbow	2.8	3.7	4.3	5.5	6.4	8.2	11.0	13.5	16.0	21.0	26.0	32.0
45° elbow	1.3	1.7	2.0	2.6	3.0	3.8	5.0	6.2	7.5	10.0	13.0	15.0
Tee, side outlet	5.6	7.5	9.1	12.0	13.5	17.0	22.0	27.5	33.0	43.5	55.0	66.0
Close return bend	6.3	8.4	10.2	13.0	15.0	18.5	24.0	31.0	37.0	49.0	62.0	73.0
Gate valve	0.6	0.8	0.9	1.2	1.4	1.7	2.5	3.0	3.5	4.5	5.7	6.8
Globe valve	27.0	37.0	43.0	55.0	66.0	82.0	115.0	135.0	165.0	215.0	280.0	335.0
Check valve	10.5	13.2	15.8	21.1	26.4	31.7	42.3	52.8	63.0	81.0	105.0	125.0
Foot valve	24.0	33.0	38.0	46.0	55.0	64.0	75.0	76.0	76.0	76.0	76.0	76.0

Courtesy The Gorman-Rupp Company.

Example 3 (continued)

Table 2 (Table 20-5 Text)
Water Friction Loss in Feet Per 100 ft for Clean Iron Steel Pipe.

Flow in U.S. (gpm)	Nominal diameter of pipe (in.) $\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4	5	6	8	10	12
5	26.5	6.8	2.11	0.55										
10	95.8	24.7	7.61	1.98	0.93	0.31	0.11							
15		52.0	16.3	4.22	1.95	0.70	0.23							
20		88.0	27.3	7.21	3.38	1.18	0.40							
25			41.6	10.8	5.07	1.75	0.60	0.25						
30			57.8	15.3	7.15	2.45	0.84	0.35						
40				26.0	12.2	4.29	1.4	0.59						
50				39.0	18.5	6.43	2.2	0.9	0.22					
75					39.0	13.6	4.6	2.0	0.48	0.16				
100					66.3	23.3	7.8	3.2	0.79	0.27	0.09			
125						35.1	11.8	4.9	1.2	0.42	0.18			
150						49.4	16.6	6.8	1.7	0.57	0.21			
175						66.3	22.0	9.1	2.2	0.77	0.31			
200							28.0	11.6	2.9	0.96	0.40			
225							35.3	14.5	3.5	1.2	0.48			
250							43.0	17.7	4.4	1.5	0.60	0.15		
275								21.2	5.2	1.8	0.75	0.18		
300								24.7	6.1	2.0	0.84	0.21		
350								33.8	8.0	2.7	0.91	0.27		
400									10.4	3.5	1.4	0.35		
500									15.6	5.3	2.2	0.53	0.18	0.08
600									22.4	6.2	3.1	0.74	0.25	0.10
700									30.4	9.9	4.1	1.0	0.34	0.14
800											5.2	1.3	0.44	0.18
900											6.6	1.6	0.54	0.22
1,000											7.8	2.0	0.65	0.27
1,100											9.3	2.3	0.78	0.32
1,200											10.8	2.7	0.95	0.37
1,300											12.7	3.1	1.1	0.42
1,400											14.7	3.6	1.2	0.48
1,500											16.8	4.1	1.4	0.55
2,000												7.0	2.4	0.93
3,000													5.1	2.1
4,000														3.5
5,000														5.5

† For old or rough pipes, add 50% to friction values.
Courtesy Contractors Pump Bureau.

Example 3 (continued)

Table 5 (20-2c)

Minimum capacities for M-rated self-priming centrifugal pumps manufactured in accordance with standards of the Contractors Pump Bureau

Model 90-M (6-in.)

Total head including friction [ft (m)]		Height of pump above water [ft (m)] 10	(3.0)	15	(4.6)	20	(6.1)	25	(7.6)
		Capacity [gpm (l/min)†]							
25	(7.6)	1,500	(5,678)						
30	(9.1)	1,480	(5,602)	1,280	(4,845)	1,050	(3,974)	790	(2,990)
40	(12.2)	1,430	(5,413)	1,230	(4,656)	1,020	(3,861)	780	(2,952)
50	(15.2)	1,350	(5,110)	1,160	(4,391)	970	(3,672)	735	(2,782)
60	(18.3)	1,225	(4,637)	1,050	(3,974)	900	(3,407)	690	(2,612)
70	(21.3)	1,050	(3,974)	900	(3,407)	775	(2,933)	610	(2,309)
80	(24.4)	800	(3,028)	680	(2,574)	600	(2,271)	490	(1,855)
90	(27.4)	450	(1,703)	400	(1,514)	365	(1,382)	300	(1,136)
100	(30.5)	100	(379)	100	(379)	100	(379)	100	(379)

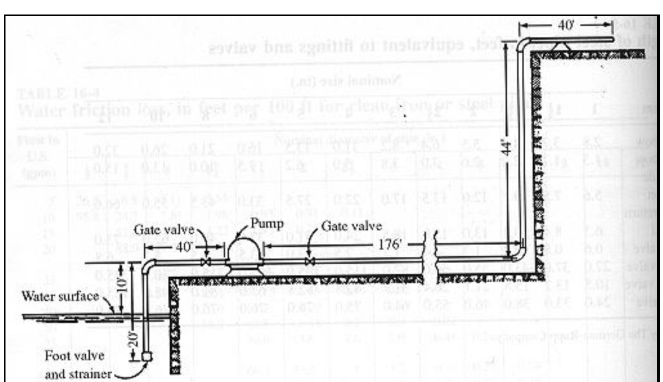
Model 125-M (8-in.)

Total head including friction [ft (m)]		Height of pump above water [ft (m)] 10	(3.0)	15	(4.6)	20	(6.1)	25	(7.6)
		Capacity [gpm (l/min)†]							
25	(7.6)	2,100	(7,949)	1,850	(7,002)	1,570	(5,943)		
30	(9.1)	2,060	(7,797)	1,820	(6,889)	1,560	(5,905)	1,200	(4,542)
40	(12.2)	1,960	(7,419)	1,740	(6,586)	1,520	(5,753)	1,170	(4,429)
50	(15.2)	1,800	(6,813)	1,620	(6,132)	1,450	(5,488)	1,140	(4,315)
60	(18.3)	1,640	(6,207)	1,500	(5,678)	1,360	(5,148)	1,090	(4,126)
70	(21.3)	1,460	(5,526)	1,340	(5,072)	1,250	(4,731)	1,015	(3,841)
80	(24.4)	1,250	(4,731)	1,170	(4,429)	1,110	(4,201)	950	(3,596)
90	(27.4)	1,020	(3,861)	980	(3,709)	940	(3,558)	840	(3,179)
100	(30.5)	800	(3,028)	760	(2,877)	710	(2,687)	680	(2,574)
110	(33.5)	570	(2,158)	540	(2,044)	500	(1,893)	470	(1,779)
120	(36.6)	275	(1,041)	245	(927)	240	(908)	240	(908)

† Liters per minute.
Courtesy Contractors Pump Bureau.

Example 4

In operating a rock quarry, it is necessary to pump 400 gpm of clear water. The pump and pipeline selected will be installed as shown. Based on 4 and 6 in steel pipes for the water line, select self-priming pumps for the job.



Example 4 (continued)

From Table 3 (Table 20-5 Text) for 4-in pipe:

Length of pipe: 20 + 40 + 176 + 44 + 40		= 320 ft
One foot valve and strainer		= 75 ft
3 90^0-elbows:	3 X 11	= 33 ft
2 gate valves:	2 X 2.5	= 5 ft
Total equivalent length		= 433 ft

From Table 2 (Table 20-4,Text) the friction loss per 100 ft of 4-in pipe will be 10.40 ft

$$\text{Total Head} = \text{Lift Head} + \text{Head lost in Friction} = (10+44) + \left(\frac{433}{100} \times 10.4\right) = 99.0 \text{ ft}$$

A model 125-M pump will deliver the required quantity of water (see Table 5 (Table 20-2d, Text)

Its capacity is 800 gpm

Example 4 (continued)

Table 3. Length of Steel Pipe (ft) Equivalent to Fittings and Valves (Table 20-5, Text)

Length of steel pipe, in feet, equivalent to fittings and valves

Item	Nominal size (in.)											
	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4	5	6	8	10	12
90° elbow	2.8	3.7	4.3	5.5	6.4	8.2	11.0	13.5	16.0	21.0	26.0	32.0
45° elbow	1.3	1.7	2.0	2.6	3.0	3.8	5.0	6.2	7.5	10.0	13.0	15.0
Tee, side outlet	5.6	7.5	9.1	12.0	13.5	17.0	22.0	27.5	33.0	43.5	55.0	66.0
Close return bend	6.3	8.4	10.2	13.0	15.0	18.5	24.0	31.0	37.0	49.0	62.0	73.0
Gate valve	0.6	0.8	0.9	1.2	1.4	1.7	2.5	3.0	3.5	4.5	5.7	6.8
Globe valve	27.0	37.0	43.0	55.0	66.0	82.0	115.0	135.0	165.0	215.0	280.0	335.0
Check valve	10.5	13.2	15.8	21.1	26.4	31.7	42.3	52.8	63.0	81.0	105.0	125.0
Foot valve	24.0	33.0	38.0	46.0	55.0	64.0	75.0	76.0	76.0	76.0	76.0	76.0

Courtesy The Gorman-Rupp Company.

Example 4 (continued)

Table 2 (Table 20-5 Text)
Water Friction Loss in Feet Per 100 ft for Clean Iron Steel Pipe.

Flow in U.S. (gpm)	Nominal diameter of pipe (in.)													
	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8	10	12
5	26.5	6.8	2.11	0.55										
10	95.8	24.7	7.61	1.98	0.93	0.31	0.11							
15		52.0	16.3	4.22	1.95	0.70	0.23							
20		88.0	27.3	7.21	3.38	1.18	0.40							
25			41.6	10.8	5.07	1.75	0.60	0.25						
30			57.8	15.3	7.15	2.45	0.84	0.35						
40				26.0	12.2	4.29	1.4	0.59						
50				39.0	18.5	6.43	2.2	0.9	0.22					
75					39.0	13.6	4.6	2.0	0.48	0.16				
100					66.3	23.3	7.8	3.2	0.79	0.27	0.09			
125						35.1	11.8	4.9	1.2	0.42	0.18			
150						49.4	16.6	6.8	1.7	0.57	0.21			
175						66.3	22.0	9.1	2.2	0.77	0.31			
200							28.0	11.6	2.9	0.96	0.40			
225							35.3	14.5	3.5	1.2	0.48			
250							43.0	17.7	4.4	1.5	0.60	0.15		
275								21.2	5.2	1.8	0.75	0.18		
300								24.7	6.1	2.0	0.84	0.21		
350								33.8	8.0	2.7	0.91	0.27		
400									10.4	3.5	1.4	0.35		
500									15.6	5.3	2.2	0.53	0.18	0.08
600									22.4	6.2	3.1	0.74	0.25	0.10
700									30.4	9.9	4.1	1.0	0.34	0.14
800											5.2	1.3	0.44	0.18
900											6.6	1.6	0.54	0.22
1,000											7.8	2.0	0.65	0.27
1,100											9.3	2.3	0.78	0.32
1,200											10.8	2.7	0.95	0.37
1,300											12.7	3.1	1.1	0.42
1,400											14.7	3.6	1.2	0.48
1,500											16.8	4.1	1.4	0.55
2,000												7.0	2.4	0.93
3,000													5.1	2.1
4,000														3.5
5,000														5.5

† For old or rough pipes, add 50% to friction values.
Courtesy Contractors Pump Bureau.

Example 4 (continued)

Table 5 (20-2c)

Minimum capacities for M-rated self-priming centrifugal pumps manufactured in accordance with standards of the Contractors Pump Bureau

Model 90-M (6-in.)

Total head including friction [ft (m)]		Height of pump above water [ft (m)] — Capacity [gpm (l/min)†]							
		10	(3.0)	15	(4.6)	20	(6.1)	25	(7.6)
25	(7.6)	1,500	(5,678)						
30	(9.1)	1,480	(5,602)	1,280	(4,845)	1,050	(3,974)	790	(2,990)
40	(12.2)	1,430	(5,413)	1,230	(4,656)	1,020	(3,861)	780	(2,952)
50	(15.2)	1,350	(5,110)	1,160	(4,391)	970	(3,672)	735	(2,782)
60	(18.3)	1,225	(4,637)	1,050	(3,974)	900	(3,407)	690	(2,612)
70	(21.3)	1,050	(3,974)	900	(3,407)	775	(2,933)	610	(2,309)
80	(24.4)	800	(3,028)	680	(2,574)	600	(2,271)	490	(1,855)
90	(27.4)	450	(1,703)	400	(1,514)	365	(1,382)	300	(1,136)
100	(30.5)	100	(379)	100	(379)	100	(379)	100	(379)

Model 125-M (8-in.)

Total head including friction [ft (m)]		Height of pump above water [ft (m)] — Capacity [gpm (l/min)†]							
		10	(3.0)	15	(4.6)	20	(6.1)	25	(7.6)
25	(7.6)	2,100	(7,949)	1,850	(7,002)	1,570	(5,943)		
30	(9.1)	2,060	(7,797)	1,820	(6,889)	1,560	(5,905)	1,200	(4,542)
40	(12.2)	1,960	(7,419)	1,740	(6,586)	1,520	(5,753)	1,170	(4,429)
50	(15.2)	1,800	(6,813)	1,620	(6,132)	1,450	(5,488)	1,140	(4,315)
60	(18.3)	1,640	(6,207)	1,500	(5,678)	1,360	(5,148)	1,090	(4,126)
70	(21.3)	1,460	(5,526)	1,340	(5,072)	1,250	(4,731)	1,015	(3,841)
80	(24.4)	1,250	(4,731)	1,170	(4,429)	1,110	(4,201)	950	(3,596)
90	(27.4)	1,020	(3,861)	980	(3,709)	940	(3,558)	840	(3,179)
100	(30.5)	800	(3,028)	760	(2,877)	710	(2,687)	680	(2,574)
110	(33.5)	570	(2,158)	540	(2,044)	500	(1,893)	470	(1,779)
120	(36.6)	275	(1,041)	245	(927)	240	(908)	240	(908)

† Liters per minute.
Courtesy Contractors Pump Bureau.

Example 4 (continued)

From Table 3 (Table 20-5 Text) for 6-in pipe:

Length of pipe: 20 + 40 + 176 + 44 + 40		= 320 ft
One foot valve and strainer		= 76 ft
3 90^0-elbows:	3 X 16	= 48 ft
2 gate valves:	2 X 3.5	= 7 ft
Total equivalent length		= 451 ft

From Table 2 (Table 20-4,Text) the friction loss per 100 ft of 6-in pipe will be 1.40 ft

$$\text{Total Head} = \text{Lift Head} + \text{Head lost in Friction} = (10 + 44) + \left(\frac{451}{100} \times 1.4\right) = 60.3 \text{ ft}$$

A model 40-M pump will deliver the required quantity of water (see Table 6 (Table 20-2b, Text)

Its capacity is 585 gpm.

Example 4 (continued)

Table 6 (20-2b)

Minimum capacities for M-rated self-priming centrifugal pumps manufactured in accordance with standards of the Contractors Pump Bureau

Model 20-M (3-in.)

Total head including friction [ft (m)]		Height of pump above water [ft (m)] 10	(3.0)	15	(4.6)	20	(6.1)	25	(7.6)
		Capacity [gpm (l/min)†]							
30	(9.1)	333	(1,260)	280	(1,060)	235	(890)	165	(625)
40	(12.2)	315	(1,192)	270	(1,022)	230	(871)	162	(613)
50	(15.2)	290	(1,098)	255	(965)	220	(833)	154	(583)
60	(18.3)	255	(965)	235	(890)	205	(776)	143	(541)
70	(21.3)	212	(802)	209	(791)	184	(696)	130	(492)
80	(24.4)	165	(625)	165	(625)	157	(594)	114	(432)
90	(27.4)	116	(439)	116	(439)	116	(439)	94	(356)
100	(30.5)	60	(227)	60	(227)	60	(227)	60	(227)

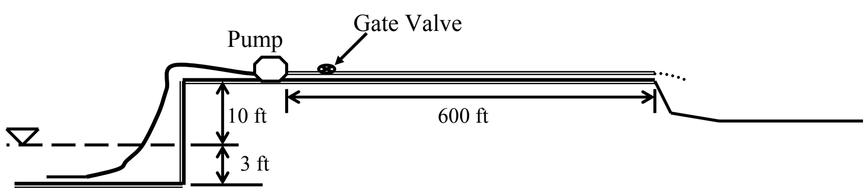
Model 40-M (4-in.)

Total head including friction [ft (m)]		Height of pump above water [ft (m)] 10	(3.0)	15	(4.6)	20	(6.1)	25	(7.6)
		Capacity [gpm (l/min)†]							
25	(7.6)	667	(2,525)						
30	(9.1)	660	(2,498)	575	(2,176)	475	(1,798)	355	(1,344)
40	(12.2)	645	(2,441)	565	(2,139)	465	(1,760)	350	(1,325)
50	(15.2)	620	(2,347)	545	(2,063)	455	(1,722)	345	(1,306)
60	(18.3)	585	(2,214)	510	(1,930)	435	(1,647)	335	(1,268)
70	(21.3)	535	(2,025)	475	(1,798)	410	(1,552)	315	(1,192)
80	(24.4)	465	(1,760)	410	(1,551)	365	(1,382)	280	(976)
90	(27.4)	375	(1,419)	325	(1,230)	300	(1,136)	220	(833)
100	(30.5)	250	(946)	215	(815)	195	(738)	145	(549)
110	(33.5)	65	(246)	60	(227)	50	(189)	40	(151)

† Liters per minute.
Courtesy Contractors Pump Bureau.

Example 5

In a highway project, it is required to pump 250 gpm of dirty water. For convenience, the contractor has decided to use a 6-in smooth rubber hose with expected maximum length of 300 ft. The hose will be used on the suction side of a proposed self-priming pump. A 4-in steel pipe will be used on the other side of the pump to remove the water as shown in the figure. What capacity pump should the contractor select?



Example 5 (continued)

From Table 3 (Table 20-5 Text) for 4-in pipe:

Length of pipe:		= 600 ft
1 gate valves:	1 X 2.5	= 2.5 ft
Total equivalent length of pipe		= 602.5 ft

From Table 2 (Table 20-4, Text) the friction loss per 100 ft of 4-in pipe will be 4.40 ft

From Table 4 (Table 20-6, Text) the friction loss per 100 ft of 6-in smooth rubber hose will be 0.49 ft

$$\text{Total Head} = \text{Lift Head} + \text{Head lost in Friction (Pipe)} + \text{Head lost in Friction (Hose)}$$

$$= (10) + \left(\frac{602.5}{100} \times 4.4\right) + \left(\frac{300}{100} \times 0.49\right) = 38 \text{ ft}$$

Example 5 (continued)

Table 4 (Table 20-6, Text)
Water Friction Loss, in Feet Per 100 ft of Smooth Bore Hose.

Flow in U.S. (gpm)	Actual inside diameter of hose (in.)											
	5/8	3/4	1	1¼	1½	2	2½	3	4	5	6	8
5	21.4	8.9	2.2	0.74	0.3							
10	76.8	31.8	7.8	2.64	1.0	0.2						
15		68.5	16.8	5.7	2.3	0.5						
20			28.7	9.6	3.9	0.9	0.32					
25			43.2	14.7	6.0	1.4	0.51					
30			61.2	20.7	8.5	2.0	0.70	0.3				
35			80.5	27.6	11.2	2.7	0.93	0.4				
40				35.0	14.3	3.5	1.2	0.5				
50				52.7	21.8	5.2	1.8	0.7				
60				73.5	30.2	7.3	2.5	1.0				
70					40.4	9.8	3.3	1.3				
80					52.0	12.6	4.3	1.7				
90					64.2	15.7	5.3	2.1	0.5			
100					77.4	18.9	6.5	2.6	0.6			
125						28.6	9.8	4.0	0.9			
150						40.7	13.8	5.6	1.3			
175						53.4	18.1	7.4	1.8			
200						68.5	23.4	9.6	2.3	0.8	0.32	
250							35.0	14.8	3.5	1.2	0.49	
300							49.0	20.3	4.9	1.7	0.69	
350								27.0	6.6	2.3	0.90	
400									8.4	2.9	1.1	0.28
450									10.5	3.6	1.4	0.35
500									12.7	4.3	1.7	0.43
1,000										15.6	6.4	1.6

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Example 5 (continued)

- A model 18-MT pump will deliver the required quantity of water
  (see Table 7 (Table 20-3a, Text)
- Its capacity is 300 gpm

Example 5 (continued)

Table 7 (Table 20-3a, Text)

Minimum capacities for MT-rated solids handling, self-priming centrifugal pumps manufactured in accordance with standards of the Contractors Pump Bureau

Model 18-MT (3-in.)

Total head including friction [ft (m)]		Height of pump above water [ft (m)] — Capacity [gpm (l/min)[†]]: 10	(3.0)	15	(4.6)	20	(6.1)	25	(7.6)
20	(6.1)	310	(1173)	265	(1003)				
30	(9.1)	305	(1154)	265	(1003)	200	(757)	115	(435)
40	(12.2)	300	(1136)	265	(1003)	200	(757)	110	(416)
50	(15.2)	275	(1041)	260	(984)	200	(757)	105	(397)
60	(18.3)	215	(814)	215	(814)	200	(757)	100	(379)
70	(21.3)	170	(644)	170	(644)	170	(644)	100	(379)
80	(24.4)	87	(329)	87	(329)	87	(329)	87	(329)
90	(27.4)	25	(95)	25	(95)	25	(95)	25	(95)

Model 33-MT (4-in.)

Total head including friction [ft (m)]		Height of pump above water [ft (m)] — Capacity [gpm (l/min)[†]]: 10	(3.0)	15	(4.6)	20	(6.1)	25	(7.6)
30	(9.1)	550	(2,082)	460	(1,741)	350	(1,325)	240	(908)
40	(12.2)	540	(2,044)	455	(1,722)	350	(1,325)	240	(908)
50	(15.2)	500	(1,893)	430	(1,628)	340	(1,287)	230	(871)
60	(18.3)	450	(1,703)	395	(1,495)	320	(1,211)	220	(833)
70	(21.3)	370	(1,401)	360	(1,363)	300	(1,136)	210	(795)
80	(24.4)	275	(1,041)	275	(1,041)	260	(984)	180	(681)
90	(27.4)	190	(719)	190	(719)	190	(719)	150	(568)
100	(30.5)	100	(379)	100	(379)	100	(379)	100	(379)

[†] Liters per minute.
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WELLPOINT SYSTEMS

- In excavating below the surface of the ground, the contractor may encounter groundwater prior to reaching the bottom of a pit.
- For pits excavated into sand and gravel, the flow of water will be large if some method is adopted to remove the water before it enters the pit.

WELLPOINT SYSTEMS

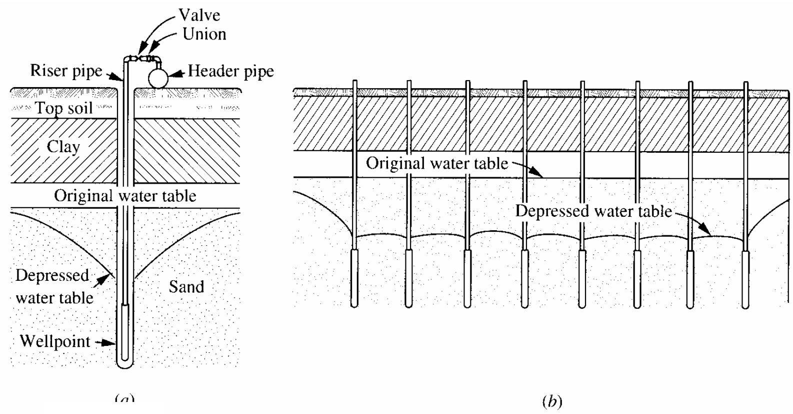
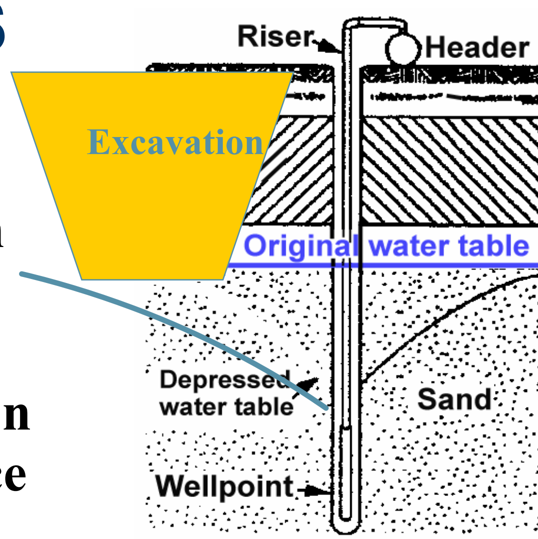


FIGURE 16-10
Lowering the water table adjacent to wellpoints.

PREDRAINING METHODS

Produce a cone of depression in the water table so that the excavation can take place in the dry.



DEEP WELLS

Large-diameter deep wells are suitable for lowering the water table when the soil becomes more pervious with depth or the excavation penetrates or is underlain by sand or coarse granular soils.

WELLPOINT SYSTEMS

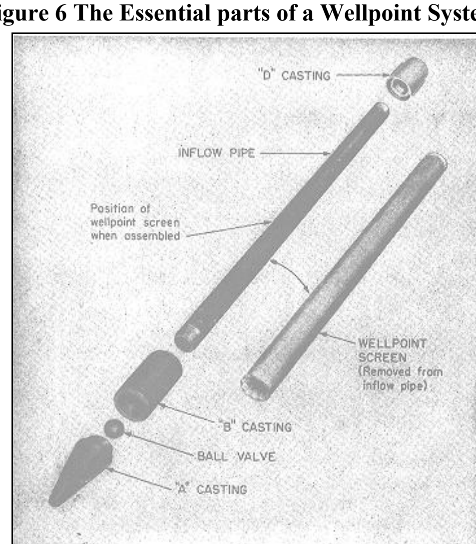
- While the water may be permitted to flow into sumps located in the pit and then removes by pumps, the presence of such water usually creates a nuisance and interferes with the construction operations.
- The installation of a wellpoint system along or around the pit may lower the water table below the bottom of the excavation, thus permitting the work to take place under relatively dry conditions.

WELLPOINT SYSTEMS

- *A wellpoint* is a perforated tube enclosed in a screen, which is installed below the surface of the ground in order to collect and remove water from the ground
- The essential parts of wellpoint system is shown in Figure 6
- The principle by which a wellpoint system work is illustrated in Figure 7 (Fig. 20-12, Text)

WELLPOINT SYSTEMS

Figure 6 The Essential parts of a Wellpoint System



WELLPOINT SYSTEMS

Figure 7. Lowering Water Table Adjacent to Wellpoints

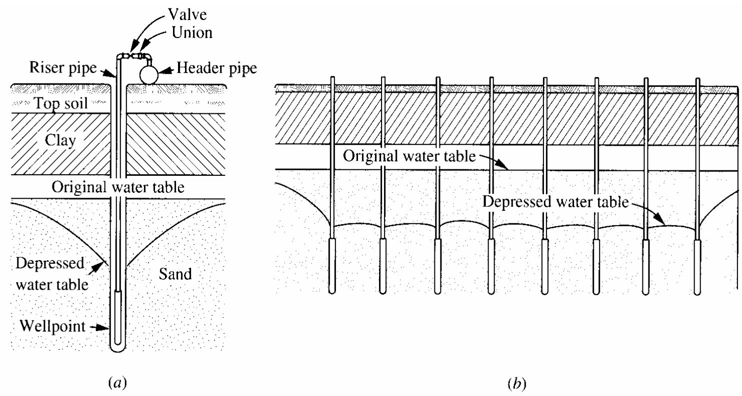


FIGURE 16-10
Lowering the water table adjacent to wellpoints.

WELLPOINT SYSTEMS

- Figure 7a shows a single point will lower the surface of water table in the soil adjacent to the point.
- Figure 7b shows several points, installed reasonably close together, lower the water table over extended area.
- A group of wellpoints properly installed along a trench or around a foundation pit can lower the water table below the depth of excavation.

WELLPOINT SYSTEMS

- The efficiency of a wellpoint systems depends on the type of soil.
- They operate satisfactory if they are installed in a permeable soil such as *sand* and *gravel*.
- If they are installed in less permeable soil, such as *silt*, it may be necessary first to sink a large pipe, say 6 to 10 in in diameter, for each point.

WELLPOINT SYSTEMS

- Then, remove the soil from inside the pipe, install a wellpoint, fill the space inside the pipe with sand or fine gravel, and then withdraw the pipe.
- This will leave a volume of sand around each wellpoint to act as a water collector and a filter to increase the rate of flow for each point.

INSTALLING A WELLPOINT SYSTEM

- A wellpoint is jetted into position by forcing water through an opening at the bottom of the point.
- After each point is jetted into position, it is connected through a pipe or a rubber hose to a header pipe
- Header pipe are usually 6 to 10 in. in diameter.
- A header is connected to a self-priming centrifugal pump.

CAPACITY OF A WELLPOINT SYSTEM

- The capacity of a wellpoint system depends on:
  - ✓number of point installed
  - ✓the permeability of soil
  - ✓the amount of water present
- The flow per wellpoint may vary from 3 or 4 gpm to as much as 30 or more gpm on some installations.

MORE INFORMATION

- *Selection Guidebook for Portable Dewatering Pumps*, Contractors Pump Bureau, P. O. Box 5858, Rockville, MD 20855
- *Construction Dewatering*, (1981) J. P. Powers, Wiley & Sons, NY

MORE INFORMATION

- *Foundation Engineering*, (1962) edited by G. A. Leonards, McGraw-Hill
- *Pump Handbook*, (1976) edited by Igor J. Karassik, William C. Krutzsch, Warren H. Fraser and Joseph P. Messina, McGraw-Hill