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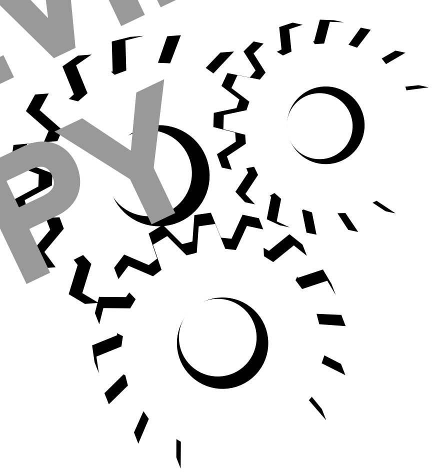
PUMP INSTALLATION AND MAINTENANCE

Lesson One

Basic Pumping Concepts



TPC Training Systems

34401

Lesson

1 Basic Pumping Concepts

TOPICS

Force
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Static Suction Lift
Pressure Losses
Available NPSH
Required NPSH
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Pumping Hot Water
Computing Pump Power Requirements
Effects of Operational Factors
Priming a Pump

OBJECTIVES

After studying this Lesson, you should be able to…

- Compute the amount of work done when giving values for force and distance.
- Name the two types of energy.
- Check a pump's capacity by determining the NPSHA of the system.
- Compute the brake horsepower required to drive a pump under given conditions.
- Explain how to prime a fluid-handling pump.

KEY TECHNICAL TERMS

Force 1.01 the influence on an object which causes it to accelerate

Work 1.05 the transference of energy that occurs when a force moves an object

Power 1.08 the rate of doing work

Horsepower 1.10 the amount of power needed to raise 33,000 lb 1 ft in 1 min

Energy 1.14 the capacity for doing work

Cavitation 1.33 the formation of vapor pockets within a liquid

Net positive suction head (NPSH) 1.33 the minimum suction head required for a pump to operate without cavitation

A piping system may convey liquids, gases, or other fluids. Many kinds of pumps propel fluids through a system. The two kinds of pumps generally used in industrial installations are the centrifugal pump and the rotary pump.

To select the right pump for a given application, you must know how much work a pump can do. The amount of work a pump is capable of doing is called its capacity. Pumping fluids through pipes, tubes, and ducts requires the use of force and power. In addition to defining such terms, this Lesson will discuss certain considerations that arise frequently in pump maintenance work.

Studying the ways in which piping systems, fittings, and connections affect the operating efficiency of a pump will improve your pump maintenance and troubleshooting skills. This Lesson will explain how to determine whether you are using a particular pump properly.

Force

1.01 In mechanical terms, *force* is that influence which causes a body at rest to be put into motion or which causes a body already in motion to accelerate. Every force has three distinct characteristics—direction, point of application, and size (magnitude). You must know all three characteristics of any force before you can make calculations involving that particular force.

1.02 Look at Fig. 1-1. A force of 200 lb is pushing at the side of a crate. The *direction* of the force is from left to right, as shown by the arrow. The *point of application* is that point where the force meets the object—where the arrowhead touches the side of the crate. The *size* of a force may be expressed in units of ounces, pounds, tons, and other measures of weight. In this case, the size of the force is 200 lb.

1.03 If the crate is heavy enough to resist the applied force of 200 lb, the crate will not move. It will move only when the applied force is greater than the resisting force. In Fig. 1-2 the crate is resisting the 200 lb applied force with a 200 lb opposing force of its own (equal to its weight), and thus will not move.

1.04 If the applied force were 205 lb, 5 lb greater than the 200 lb weight of the crate, then the resistance to movement would be overcome and the crate would move from left to right. (This example disregards the effects of friction, which will be discussed later in the Lesson.)

Work

1.05 *Work* takes place whenever an applied force moves a body through a given distance. The formula for work is:

$$W = F \times S$$

where W = work

F = applied force

S = distance.

Fig. 1-1. Characteristics of force

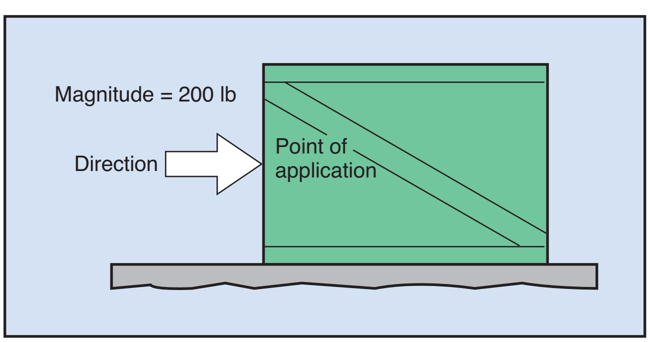
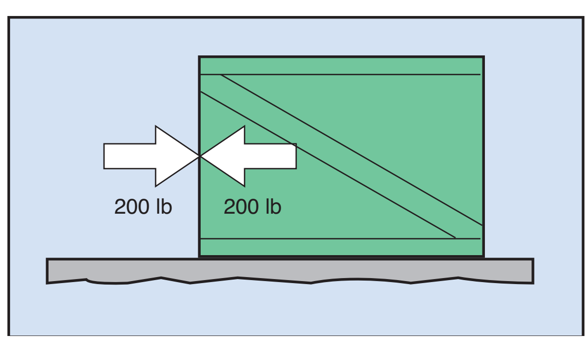


Fig. 1-2. Resisting force



1.06 Figure 1-3 shows a 200 lb weight being lifted a vertical distance of 25 ft. You can calculate the work needed for the pulley to raise the weight to the top by using the formula $W = F \times S$:

$$\text{work} = 200 \text{ lb} \times 25 \text{ ft}$$

$$= 5000 \text{ ft-lb.}$$

Foot-pounds is a common way to express work. It can also be calculated in inch-pounds, inch-ounces, foot-tons, and similar combinations.

1.07 Now imagine that the weight consists of 200 lb of water rising in a 25 ft length of vertical pipe. In this example, a pump propels the water upward (see Fig. 1-4). The amount of work accomplished remains 5000 ft-lb.

Power

1.08 *Power* is the rate of doing work. Power measurements are expressed in units of work done per unit of time—inch-pounds per minute, inch-ounces per second, and the like. Foot-pounds per minute (ft-lb/min) is probably the most common term for expressing power.

1.09 Suppose you want to raise the 200 lb weight 25 ft in 1 min. You can calculate the amount of power required by using the following formula:

$$P = \frac{W}{t}$$

where P = power

W = work

t = time, or duration, of the work.

Therefore,

$$\text{Power} = \frac{5000 \text{ ft-lb}}{1 \text{ min}} = 5000 \text{ ft-lb/min}$$

To raise the same weight in 30 seconds, you need more power:

$$\text{Power} = \frac{5000 \text{ ft-lb}}{0.5 \text{ min}} = 10{,}000 \text{ ft-lb/min}$$

Horsepower

1.10 *Horsepower* is a unit of power in general use in industry. By definition, 1 hp is the amount of power required to raise a load of 33,000 lb a distance of 1 ft in 1 min:

$$1 \text{ hp} = \frac{33{,}000 \text{ lb} \times 1 \text{ ft}}{1 \text{ min.}}$$

Fig. 1-3. Calculating work

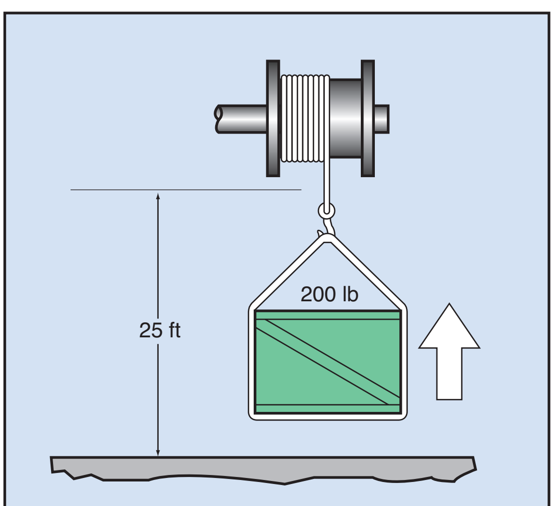
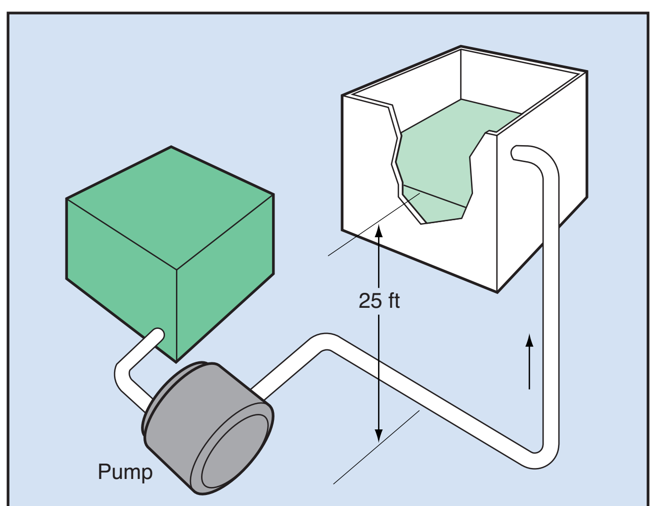


Fig. 1-4. Another example of work



1.11 Using the horsepower formula, you can express any value of power in terms of horsepower by dividing the power figure (in ft-lb/min) by 33,000. To return to the previous example, how much horsepower would be needed to raise the 200 lb weight 25 ft in 1 min? You have already computed the required power as 5000 ft-lb/min. Now convert that value to horsepower:

$$\text{required hp} = \frac{5000 \text{ ft-lb/min}}{33{,}000 \text{ ft-lb/min}}$$

1.12 An understanding of how to calculate horsepower can be helpful in troubleshooting. A pump problem, for instance, may involve an undersize driving motor that cannot handle the pumping power requirements. If you know how to calculate the actual loads involved, you can check the motor capacity against the power requirements. The same applies to pump capacity. These simple procedures can often save you the trouble of looking for broken or damaged parts in a system when the real problem lies with the pump or the motor capacity.

Energy

1.13 Whenever work is done on a body—that is, when it is moved through a given distance—the body then has the capacity to do an equal amount of work as it returns to its original position. For example, if the 200 lb weight being held 25 ft in the air were allowed to drop, it would accomplish 5000 ft-lb of work in the fall.

1.14 This ability to do work is called energy. There are two kinds of energy—potential and kinetic. It is important that you understand both when you work with pumps.

1.15 **Potential energy**. Potential energy is energy stored in a body or system. A tightly wound clock spring, for example, has a capacity for doing work. As the spring unwinds, it drives the gears that move the hands. The coiled spring converts its potential energy into work by moving the gears.

1.16 **Kinetic energy**. Kinetic energy is active energy, energy that a body possesses because of its motion. Suppose the 200 lb of water contained in the tank at the top of the water column in Fig. 1-4 is allowed to flow back down through the pipe. The applied force in this case is gravity. The work done is equal to the work needed to raise the water—5000 ft-lb.

1.17 When the water is flowing through the pipe, it has the ability to do work because it is in motion. The 200 lb of water had a *potential* energy when it was stored in the reservoir at the top of the pipe. As it flows down through the pipe, that same energy is converted into active, or *kinetic*, energy. This is the principle involved in turning a waterwheel, as shown in Fig. 1-5.

Velocity and Acceleration

1.18 *Velocity* is another word for speed. When the water held in the reservoir in Fig. 1-4 is allowed to flow down through the pipe, it falls with a constant increase in velocity. Gravity causes any weight to fall at a constant rate of acceleration.

1.19 **Average velocity**. You can determine the average velocity of a body accelerating at a constant rate by using the following formula:

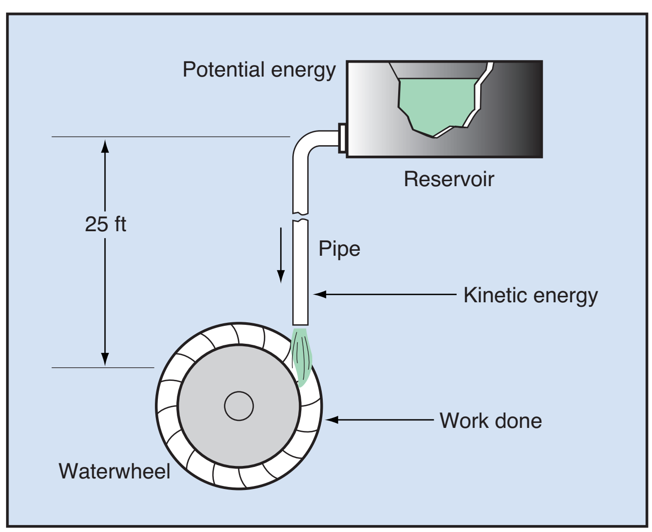
$$v_a = \frac{v_1 + v_2}{2}$$

where v_a = average velocity

v_1 = initial velocity

v_2 = final velocity.

Fig. 1-5. Energy converted into work



When the 200 lb of water drops from a state of rest in the reservoir, the initial velocity is zero. To compute the average velocity of the water during its fall, you need to determine the final velocity of the water as it reaches the bottom of the pipe. The equation for calculating final velocity is:

$$v_2 = gt$$

where g = acceleration due to gravity (32 ft/s/s)

t = time in seconds.

If the water takes 1.25 s to reach the bottom of the pipe, the final velocity is:

$$v_2 = gt$$

$$= 32 \text{ ft/s/s} \times 1.25 \text{ s}$$

$$= 40 \text{ ft/s}.$$

Thus, the average velocity of the falling water is:

$$v_a = \frac{v_1 + v_2}{2}$$

$$= \frac{0 + 40 \text{ ft/s}}{2}$$

$$= 20 \text{ ft/s}.$$

1.20 There is another way to compute final velocity when the height of the fall or lift is known:

$$v_2 = \sqrt{2gh}$$

where g = gravitational pull of 32 ft/s/s

h = height in feet.

Apply this formula to the example given above and see if you arrive at the same answer. Again, remember that these hypothetical situations do not take into account the effects of friction.

1.21 Feet per minute and miles per hour are two of many convenient ways of expressing velocity. However, when working with acceleration due to gravitational pull, express velocity in feet per second. The rate of acceleration due to gravity, 32 feet per second per second, can also be expressed as 32 ft/s^2.

1.22 In pump applications, the weight of the fluid (the load) and the distance it must be moved directly affect the horsepower required in the pump. For example, the work needed to raise 60 gallons of a fluid weighing 5 lb/gal to a height of 25 ft is:

$$W = (60 \text{ gal} \times 5 \text{ lb})\ 25 \text{ ft}$$

$$= 7500 \text{ ft-lb}.$$

To raise 60 gal of water (which weighs 8.33 lb/gal at the standard temperature of 62°F) the same distance, the amount of work needed is:

$$W = (60 \text{ gal} \times 8.33 \text{ lb})\ 25 \text{ ft}$$

$$= 12{,}495 \text{ ft-lb}.$$

Use the formula for calculating horsepower to determine the horsepower required to accomplish the work in 1 min:

for fluid #1,

$$\text{hp} = \frac{7500}{33{,}000} = 0.23 \text{ hp}$$

for water,

$$\text{hp} = \frac{12{,}495}{33{,}000} = 0.38 \text{ hp}.$$

Static Suction Lift

1.23 A column of water in a vertical pipe exerts a certain pressure on a horizontal surface at the bottom of the pipe. This pressure can be expressed in pounds per square inch (psi) or as the height of the water in feet, and is known as the *head*. The terms head and pressure are interchangeable, provided you express them in their correct units (1 psi = 2.31 ft of water). If you are working with a liquid other than water, use the following formula to convert pounds per square inch into feet of head:

Fig. 1-6. Atmospheric pressure acting on a body of water

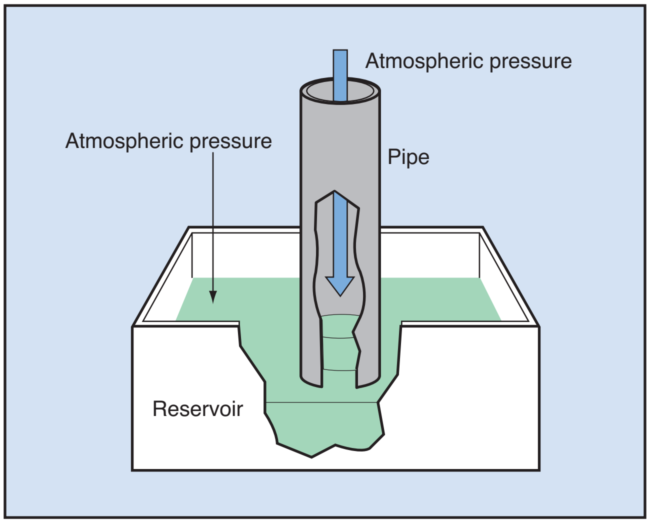
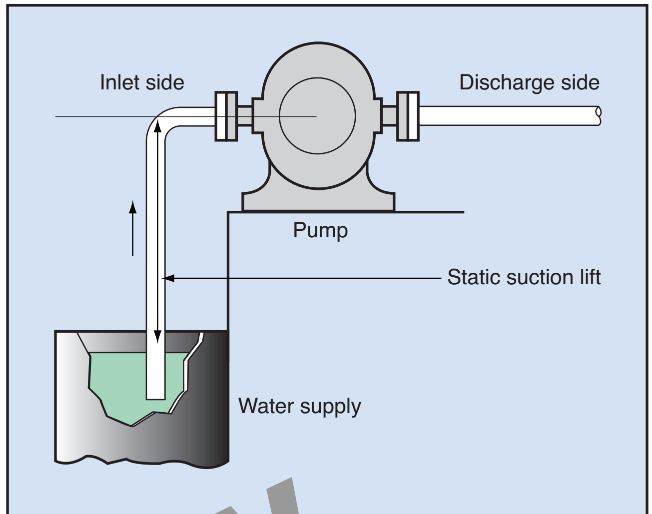


Fig. 1-7. Static suction lift



$$\frac{\text{psi} \times 2.31}{\text{S}} = \text{ft of head}$$

where S = the specific gravity of the liquid.

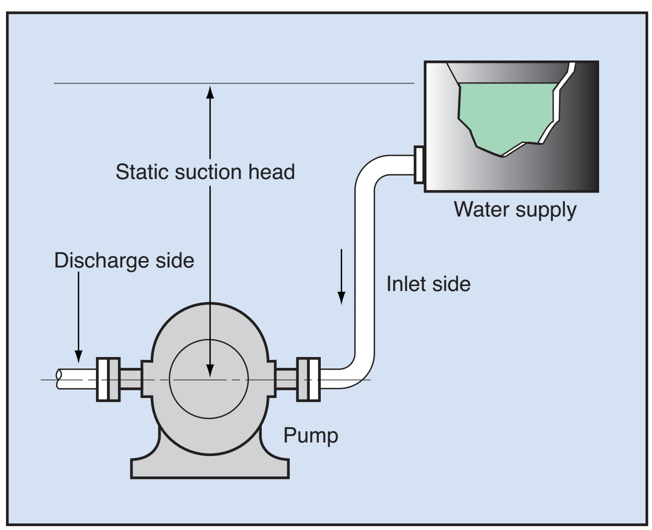
1.24 In Fig. 1-6 a body of water is at rest in an open reservoir. A pipe, open at the top and bottom, extends into the reservoir. Atmospheric pressure keeps the surface of the water at the same level inside and outside the pipe. The water will remain in this state of equilibrium as long as the applied atmospheric pressure stays the same inside and outside the pipe.

1.25 The atmospheric pressure outside the pipe can be put to work to raise the water level inside the pipe. Figure 1-7 shows the pipe with its top closed and connected to a pump. The pump removes the air from the pipe, thereby creating a vacuum. The atmospheric pressure on the surface of the water outside the pipe pushes the water up inside the pipe. This principle is called *static suction lift*, because the atmospheric pressure forces or "lifts" the water to a certain height above the elevation of its source of supply.

1.26 **Measuring static suction lift**. Static suction lift is the vertical distance, usually expressed in feet, from the surface of the water being pumped to the centerline of the pump shaft, when the pump is *above* the source of supply, as in Fig. 1-7. The actual intake of the pump—the bottom end of the pipe extending into the water—may be several feet below the surface of the water, but this is not included when determining the static suction lift. Horizontal runs of pipe are not considered part of the static suction lift either. When the pump is located *below* the source of supply, the corresponding vertical distance from the liquid supply level to the pump centerline is called the *static suction head* (see Fig. 1-8).

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the REVEAL KEY from the back of your Book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

Fig. 1-8. Static suction head



1-1. Name the three characteristics of force.	1-1. DIRECTION POINT OF APPLICATION SIZE Ref: 1.01
1-2. How much power is required to move a 150 lb weight through a distance of 20 ft in 2 min?	1-2. 1500 FT-LB/MIN Ref: 1.09
1-3. Convert your answer to the previous question to horsepower.	1-3. 0.045 HP Ref: 1.11
1-4. The ability to do work is called _________.	1-4. ENERGY Ref: 1.14
1-5. Name the two kinds of energy.	1-5. POTENTIAL; KINETIC Ref: 1.14
1-6. What is the final velocity of an object failing through a distance of 4 ft?	1-6. 16 FT/S Ref: 1.20
1-7. Name the two ways in which pressure, or head, can be expressed.	1-7. POUNDS PER SQUARE INCH (PSI) and FT OF HEAD Ref: 1.23
1-8. The vertical distance from the surface of a liquid being pumped to the center-line of the pump shaft, when the pump is above the source of supply, is called _________.	1-8. STATIC SUCTION LIFT Ref: 1.26

Pressure Losses

1.27 **Friction.** Friction occurs whenever fluids are pumped through a piping system. Friction is greatest at the inside walls of a pipe. The amount of friction present in a pipe depends on many factors, including the diameter and length of the pipe. The viscosity of a fluid and the number and kinds of fittings in a piping system can also contribute to friction.

1.28 The presence of friction, obviously, causes a loss of energy in a piping system. The *friction head* is the pressure, in terms of feet of liquid, required to overcome the resistance to flow in pipe and fittings. Table 1-1 (and other similar tables published in pump handbooks) provides you with a means of estimating the loss of head, or pressure, due to friction in various sizes of steel pipe. For example, a 200 gpm flow of water through a 4 in. pipe will produce a head loss of 2.27 ft per 100 ft of straight pipe. Friction losses can be reduced by using large-diameter pipe and keeping the number of fittings to a minimum.

1.29 **Vapor pressure**. Every liquid at any temperature above its freezing point exerts a pressure at its free surface. This *vapor pressure*, as it is called, is due to the formation of vapor by the process of evaporation. When water, for instance, is placed in a column under a vacuum, a portion of the water will flash into vapor. This vapor exerts pressure on the surface of the remaining water, reducing the available energy. Vapor pressure increases with an increase in water temperature, thus reducing the height to which atmospheric pressure can raise the water in the column. Table 1-2 on the following page indicates the vapor pressure of water at various temperatures. Similar tables can be found in most pump handbooks.

Available NPSH

1.30 The *suction head* is the distance, in feet, that a liquid must travel from the surface level of the supply well to the inlet of the pump. In a system such as the one shown in Fig. 1-7, the only energy available to push the liquid up to the pump is atmospheric pressure. When the energy losses due to friction and vapor pressure are subtracted, the result is called the *net positive suction head*, or NPSH.

Table 1-1. Head loss due to friction

Schedule 40 steel pipe — friction loss for water in feet per 100 feet

U.S. gallons per minute	2 in.		2½ in.		3 in.		4 in.		U.S. gallons per minute	1 in.		1¼ in.		1½ in.	
	V ft/s	h_f frict.	V ft/s	h_f frict.	V ft/s	h_f frict.	V ft/s	h_f frict.		V ft/s	h_f frict.	V ft/s	h_f frict.	V ft/s	h_f frict.
25	2.39	1.29							6	2.23	2.68				
30	2.87	1.82							8	2.97	4.54				
35	3.35	2.42	2.35	1.00					10	3.71	6.86				
40	3.82	3.10	2.68	1.28					12	4.45	9.62	2.57	2.48		
45	4.30	3.85	3.02	1.60					14	5.20	12.8	3.00	3.28		
50	4.78	4.67	3.35	1.94	2.17	0.662			16	5.94	16.5	3.43	4.20	2.52	1.96
60	5.74	6.59	4.02	2.72	2.60	0.924			18	6.68	20.6	3.86	5.22	2.84	2.42
70	6.69	8.86	4.69	3.63	3.04	1.22			20	7.42	25.1	4.29	6.34	3.15	2.94
80	7.65	11.4	5.36	4.66	3.47	1.57			22	8.17	30.2	4.72	7.58	3.47	3.52
90	8.60	14.2	6.03	5.82	3.91	1.96			24	8.91	35.6	5.15	8.92	3.78	4.14
100	9.56	17.4	6.70	7.11	4.34	2.39	2.52	0.624	26	9.65	41.6	5.58	10.37	4.10	4.81
120	11.5	24.7	8.04	10.0	5.21	3.37	3.02	0.877	28	10.39	47.9	6.01	11.9	4.41	5.51
140	13.4	33.2	9.38	13.5	6.08	4.51	3.53	1.17	30	11.1	54.6	6.44	13.6	4.73	6.26
160	15.3	43.0	10.7	17.4	6.94	5.81	4.03	1.49	35	13.0	73.3	7.51	18.2	5.51	8.37
180			12.1	21.9	7.81	7.28	4.54	1.86	40	14.8	95.0	8.58	23.5	6.30	10.79
200			13.4	26.7	8.68	8.90	5.04	2.27	45	16.7	119.0	9.65	29.4	7.04	13.45
220			14.7	32.2	9.55	10.7	5.54	2.72	50	18.6	146	10.7	36.0	7.88	16.4
240			16.1	38.1	10.4	12.6	6.05	3.21	55			11.8	43.2	8.67	19.7
260					11.3	14.7	6.55	3.74	60			12.9	51.0	9.46	23.2
280					12.2	16.9	7.06	4.30	65			13.9	59.6	10.24	27.1
300					13.0	19.2	7.56	4.89	70			15.0	68.8	11.03	31.3

Table 1-2. Vapor pressure of water at various temperatures

Temperature (°F)	Vapor pressure (psia)
40	0.1217
50	0.1781
60	0.2563
70	0.3631
80	0.5069
90	0.6982
100	0.9493

1.31 The *available* NPSH (sometimes noted as NPSHA) is a characteristic of the piping system in which a pump operates. It is the total head available at the eye of the impeller to move the fluid into the pump. The formula for calculating NPSHA is:

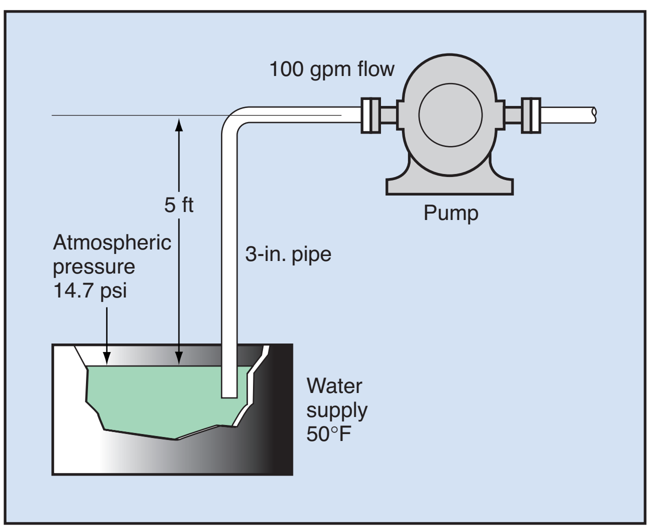
NPSHA = atmospheric pressure - static suction lift - friction loss - vapor pressure

or, if the pump is located below the source of supply:

NPSHA = atmospheric pressure + static suction head - friction loss - vapor pressure.

All of the terms in these equations are expressed in feet of liquid. The available NPSH in a system can sometimes be altered to suit the required NPSH of the pump.

Fig. 1-9. Computing available NPSH



Required NPSH

1.32 The *required* NPSH (NPSHR) is a function of the pump design and must be determined by test. The pump manufacturer does this by plotting the required NPSH characteristics for a given pump on a performance curve. Thus, just as each installation has its own NPSHA which can be calculated for a particular set of conditions, each pump has its own NPSHR which is obtained from the manufacturer.

1.33 The available NPSH of a system must be equal to or greater than the required NPSH of the pump if a condition called cavitation is to be prevented. *Cavitation* is the formation of vapor pockets, or bubbles, in a liquid (as when water boils). NPSHR, then, is the minimum suction head required for a pump to operate without bubbles of vapor forming in the liquid. NPSHR can vary widely, depending on the size and design of the pump, and on the conditions under which the pump operates.

Checking Pump Capacity

1.34 You can check a pump's capacity to see if it is capable of doing a job by determining the available NPSH in the system. In Fig. 1-9 the static suction lift is 5 ft. Water is flowing toward the pump through a 3-in. steel pipe at a rate of 100 gpm. The temperature of the water is 50°F, and the pressure "lifting" the water is atmospheric pressure, 14.7 psi. Compute the available NPSH. You will have to refer to Tables 1-1 and 1-2 to determine friction loss and vapor pressure.

NPSHA = atmospheric pressure - static suction lift - friction loss - vapor pressure

= 33.96 - 5 - 0.12 - 0.41

= 28.43 ft of head.

1.35 In order for the pump to operate satisfactorily, its NPSHR should be less than 28.43. Most pump manufacturers include performance curves with a pump's operating instructions and related literature. If you are not familiar with performance curves, ask your supervisor for assistance in plotting the pump's NPSHR. If the pump's NPSHR is greater than the system's NPSHA, then you must select a different pump or alter the NPSHA by reducing friction losses.

1.36 Remember that insufficient NPSHA usually results in cavitation. Vapor bubbles form when pressure in the suction line falls below vapor pressure. These "cavities" are carried along in the stream and collapse when they reach regions of higher pressure on their way through the pump. The most obvious effects of cavitation are noise and vibration. The bigger the pump, the greater the noise—cavitation sounds as if someone had thrown a handful of marbles into the pump. Over a period of time, cavitation will damage the pump and cause a drop in the pump's capacity.

Pumping Hot Water

1.37 Even though hot water under atmospheric pressure changes to steam at 212°F, water will flash into steam at much lower temperatures at a pump impeller because of the low pressure there. This condition (reduced NPSHA) limits the available lift. Very hot water cannot be lifted to any height—the pump cylinder fills with steam on the admission stroke.

1.38 For most hot water pumping applications, the pump should be placed well below the level of the hot water source so that the water will flow into the pump under pressure. To resolve any doubts about this kind of installation, consult the pump manufacturer for hot water pumping recommendations.

Computing Pump Power Requirements

1.39 The horsepower requirements of a pump are divided into three areas:

- **Water horsepower**, or hydraulic horsepower, is the horsepower that the pump transfers to the water.
- **Brake horsepower** (bhp) is the horsepower required to drive the pump.
- **Wire horsepower** is the electrical horsepower needed to run the motor—that is, to deliver the required brake horsepower (1 electrical hp = 746 watts).

The efficiency of the pump and the efficiency of the motor that drives the pump are expressed in percentages:

$$\text{pump efficiency} = \frac{\text{water hp}}{\text{brake hp}}$$

$$\text{motor efficiency} = \frac{\text{brake hp}}{\text{wire hp.}}$$

1.40 To calculate the actual power, in horsepower or kilowatts, needed to drive a pump, use the following formulas:

$$\text{brake hp} = \frac{\text{gpm} \times \text{h} \times \text{S}}{3960 \times \text{ pump efficiency}}$$

$$\text{kW} = \frac{\text{gpm} \times \text{h} \times \text{S}}{5308 \times \text{pump efficiency} \times \text{motor efficiency}}$$

where h = head in feet

S = specific gravity of the fluid being pumped

3960 and 5308 are constants.

1.41 Assume you want to pump 300 gpm of a liquid having a specific gravity of 1.2 against a head of 50 ft. If the pump is 65% efficient, what size electric motor (bhp) is required? How much electricity (kW) is required if the motor is 80% efficient?

$$\text{bhp} = \frac{300 \times 50 \times 1.2}{3960 \times 0.65}$$

$$= \frac{18{,}000}{2574}$$

$$= 7 \text{ bhp}$$

$$\text{kW} = \frac{300 \times 50 \times 1.2}{5308 \times 0.65 \times 0.80}$$

$$= \frac{18{,}000}{2760}$$

$$= 6.52 \text{ kW.}$$

1.42 Another way to determine the required kilowatts is to convert the 7 bhp into electrical hp by inserting the correct values into the equation for motor efficiency:

$$0.80 = \frac{7}{\text{electrical hp}}, \text{ so}$$

$$\text{electrical hp } = \frac{7}{0.80} = 8.75 \text{ electrical hp.}$$

To find the power consumption:

8.75 electrical hp $\times$ 746 watts = 6527 watts or 6.52 kW.

Effects of Operational Factors

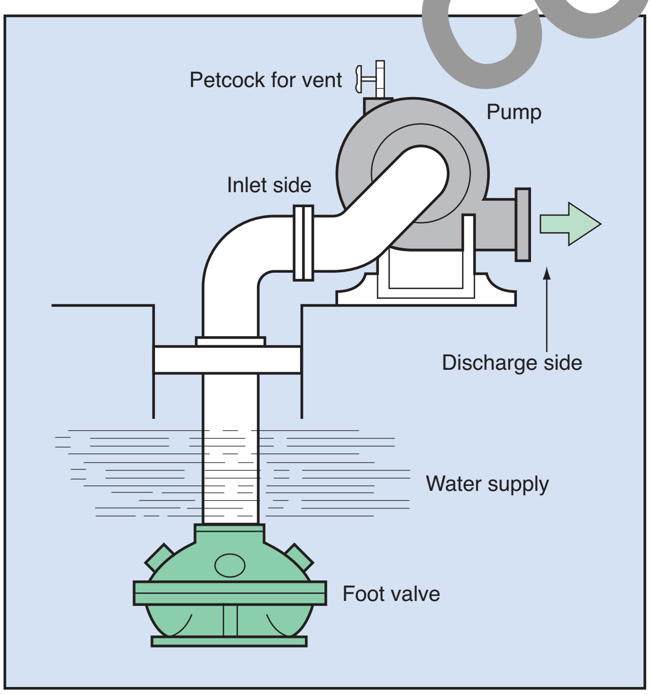
1.43 Many factors affect the operation of a pump. Pump-to-pipe connections, fittings within the system, and the flanges used to connect parts all play an important part in making an effective pumping system.

1.44 **Connections**. Install all connections properly and carefully. Select gaskets and other sealing elements on the basis of line pressure and the type of fluid to be pumped. Be sure that new parts are made of the same material and are the same size as the parts they replace. In order to help reduce leakage, threaded connections should be maintained in good condition. Replace any stripped parts with manufacturer-recommended components.

1.45 **Fittings**. Under normal operating conditions, most system leaks occur at flanges and fittings. Leaks cause head, lift, and pressure losses within a system. Select fittings that are right for the installation, and be sure they are correctly assembled. Fittings by their nature cause friction losses, so use as few as possible. Inspect fitted joints at regular time intervals. If you detect a leak, take the joint apart and replace defective parts.

1.46 **Flanges**. Excessive vibration from surrounding equipment often causes flange bolts to loosen. This condition allows air to enter a pipeline and diminishes a pump's lifting capacity. Establish an inspection log, or chart, to schedule periodic checks. Such regular maintenance helps ensure that the bolts are always tight and that the joints are secure. Both intake and discharge pipes should be supported independently near the pump so that no strain will be transmitted to the pump casing when you tighten the flange bolts.

Fig. 1-10. Installation using foot valve



Priming a Pump

1.47 Fluid-handling pumps must be primed before they can be put into full operation. Air trapped in a pump or in its inlet (suction) line can interfere with proper pumping and cause damage to the pump.

1.48 When the pump is lower than the fluid supply, as in Fig. 1-8, the pump will usually keep its prime after shutdown. This is due to the gravitational flow of fluid into the pump. When the pump is higher than the fluid supply, the system is not in a self-priming attitude. If no other means of priming are feasible in such cases, install a foot valve at the end of the suction pipe, as shown in Fig. 1-10.

1.49 When the pump is operating, the valve remains open, allowing a free flow of fluid into the pump. Upon shutdown, the foot valve closes, retaining fluid in the suction line and the pump. If such a system needs frequent priming before it will start, inspect the foot valve to make certain it is operating properly. Foot valves do not always seat tightly, and often result in high friction head loss. For these reasons, vacuum-priming devices are sometimes preferable.

1.50 To prime a pump that is located above the fluid supply, remove all vapor from the suction line. Be certain that all line connections are tight and that no air can enter. Most fluid-handling pumps have a priming connection in the pump housing.

1.51 With the discharge valve closed, fill the suction line and the pump with a supply of the fluid to be pumped. Be sure the petcock or other venting device is open during filling. Start the pump, open the discharge valve, and observe the flow of fluid through the system. Repeat the filling procedure until the pump picks up its prime.

1.52 There are several ways to prime the various kinds of pumps. Later Lessons in this Unit will deal with specific types of pumps and discuss the methods of pump priming in greater detail.

1.53 When you start a primed pump with its discharge valve open, the pressure in the suction line normally drops. While this reduction must be great enough to permit the fluid to flow into the pump chamber, it must not be so great that it causes vaporization of the fluid. Excessive vaporization results in a loss of prime and stops fluid flow.

1-9. The pressure required to overcome the resistance to flow in the pipes and fittings of a piping system is called the __________.	1-9. FRICTION HEAD Ref: 1.28
1-10. The letters NPSH stand for __________.	1-10. NET POSITIVE SUCTION HEAD Ref: 1.30
1-11. The available NPSH of a system must be equal to or __________ than the required NPSH of a pump.	1-11. GREATER Ref: 1.33
1-12. The formation of vapor pockets in a liquid is called __________.	1-12. CAVITATION Ref: 1.33
1-13. For most hot water pumping applications, the pump should be placed __________ the level of the hot water source.	1-13. BELOW Ref: 1.38
1-14. The horsepower required to actually drive a pump is called the pump's __________ horsepower.	1-14. BRAKE Ref: 1.39
1-15. If 4.85 kW are required to run a 5 hp motor, what is the motor's efficiency?	1-15. 77% Ref: 1.39
1-16. When you start a primed pump with its discharge valve open, the pressure in the suction line normally __________.	1-16. DECREASES Ref: 1.53

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Which of the following is NOT a characteristic of force?

- ☐ a. Direction
- ☐ b. Point of application
- ☐ c. Velocity
- ☐ d. Size

1-2. Power is defined as the

- ☐ a. capacity for doing work
- ☐ b. rate of doing work
- ☐ c. transference of energy
- ☐ d. influence on an object which causes it to accelerate

1-3 How much power is required to move a 500 lb weight through a distance of 6 ft in 45 seconds?

- ☐ a. 66.7 ft-lb/min
- ☐ b. 2250 ft-lb/min
- ☐ c. 3750 ft-lb/min
- ☐ d. 4000 ft-lb/min

1-4. How much horsepower is needed to perform the task in the previous question?

- ☐ a. 0.002 hp
- ☐ b. 0.068 hp
- ☐ c. 0.114 hp
- ☐ d. 0.121 hp

1-5. What is the final velocity of a 100 lb object which falls 36 ft from a state of rest in 1.5 s?

- ☐ a. 21.3 ft/s
- ☐ b. 24 ft/s
- ☐ c. 48 ft/s
- ☐ d. 54 ft/s

1-6. What is the average velocity of the falling object in the previous question?

- ☐ a. 12 ft/s
- ☐ b. 24 ft/s
- ☐ c. 32 ft/s
- ☐ d. 40 ft/s

1-7. Convert 14 psi into ft of head for a liquid with a specific gravity of 1.4.

- ☐ a. 8.48 ft
- ☐ b. 10 ft
- ☐ c. 19.6 ft
- ☐ d. 23.1 ft

1-8. When a pump is located below the source of supply, the vertical distance from the liquid supply level to the centerline of the pump shaft is called the

- ☐ a. static suction head
- ☐ b. static suction lift
- ☐ c. NPSH
- ☐ d. friction head

1-9. For best results, the NPSHA of a system should be ________ ft of head if the NPSHR of the pump is 10 ft of head.

- ☐ a. less than 5
- ☐ b. between 5 and 10
- ☐ c. exactly equal to 10
- ☐ d. greater than 10

1-10. A pump which is 75% efficient must pump 250 gpm of water against a head of 38 ft. How much brake horsepower is required to drive the pump?

- ☐ a. 0.22 hp
- ☐ b. 1.8 hp
- ☐ c. 2.4 hp
- ☐ d. 3.2 hp

SUMMARY

Whenever an applied force moves an object through a distance, work is accomplished. Power is defined as the rate of doing work, and energy as the capacity for doing work. These are some of the basic concepts—velocity is another one—with which you must work when maintaining a pumping system. It is important that you learn how to calculate such properties as power and velocity, and that you are able to apply the necessary formulas to your everyday work.

When you measure the distance that water must travel to reach the impeller of a pump, you must remember to take into account the loss of pressure that occurs due to friction and vapor pressure. Pressure losses can be translated into distances—feet of head—and directly affect the selection of the proper pump for a particular application.

Calculating the pressure required for a pump to operate efficiently involves a complex concept called NPSH. Remember that the available NPSH is a characteristic of the system in which a pump operates, and required NPSH is a characteristic of the pump itself. Insufficient NPSHA generally results in cavitation, which in turn damages the pump and reduces its capacity.

You should also become familiar with the formulas for computing horsepower and kilowatts, the two most common units of power required to drive a pump. Power calculations are related to pump efficiency and motor efficiency, percentages which indicate how much energy is being lost to friction and heat. This Lesson ends with a brief discussion of pump priming methods.

Answers to Self-Check Quiz

1-1. c. Velocity. Ref: 1.01

1-2. b. Rate of doing work. Ref: 1.08

1-3. d. 4000 ft-lb/min. Ref: 1.09

1-4. d. 0.121 hp. Ref: 1.11

1-5. c. 48ft/s. Ref: 1.19

1-6. b. 24 ft/s. Ref: 1.19

1-7. d. 23.1 ft. Ref: 1.23

1-8. a. Static suction head. Ref: 1.26

1-9. d. Greater than 10. Ref: 1.33

1-10. d. 3.2 hp. Ref: 1.40