

13TH EDITION

Water Systems Handbook

*A complete text on wells:
their design, operation, and maintenance*



Published by



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BOOK I

Well Fundamentals

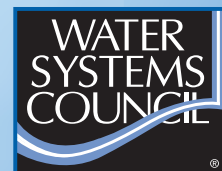


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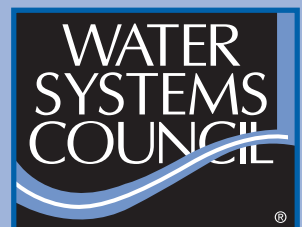
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A Word Of Caution



The products described in this Handbook, including all products using electrical current, can result in serious harm if not used with EXTREME CAUTION and in strict accordance with manufacturers' instructions. Professional assistance is recommended and should always be sought when utilizing unfamiliar equipment.

The products, materials, information, and instructions in this publication are provided for informational purposes only. This publication is not intended to provide instructions or recommendations relating to the selection, adoption, or use of equipment. All information is provided from sources believed to be reliable, accurate, and comprehensive. However, all information, including without limitation product descriptions and functionality is provided "as is" without any express or implied warranty of any kind, including warranties of title, merchantability, noninfringement of intellectual property, compatibility, or fitness for any purpose or use. In no event shall the Water Systems Council or its members, agents, employees, directors, or officers be liable for any damages or other claims whatsoever, including, without limitation, any direct, indirect, special, punitive, or consequential damages, whether from harm, loss of profits, business interruption, loss of information, or related expenses arising out of errors, omissions, or the use of or inability to use the materials, products, information, or services as provided in this Handbook, even if the Water Systems Council or its members have been advised of the possibility of such damages.

Introduction to Wells

Water is life's most vital resource. Through the centuries, people have searched for water, fought for it, and sometimes died for it. No living organism can exist without water.

Consequently, clean and plentiful groundwater is necessary for everyday life. As described in this handbook, groundwater is the reservoir of water that seeps downward through the soil to the water table below the earth's surface. About 98 percent of all fresh water available in the nation at any time is groundwater, which fills the porous beds of rock and sand that make up the earth's crust.

Groundwater is an ideal water supply, for it is pure and wholesome. Filtered by the underground formations through which it passes, groundwater has a degree of purity seldom attained by surface waters.

Natural groundwater reservoirs have many advantages. They have huge capacities, they are relatively inexpensive to tap by means of wells, and they lose little water by evaporation. Above all, they are dependable sources of water.

In the United States alone, more than 115 million people get their drinking water from groundwater every day. More than 23 million American households are supplied from individual, private wells.

A modern well is both flexible and functional. A variety of pumps is available to lift water from all types of wells, from the shallowest to the deepest. These systems are made automatic and dependable by many types of controls and accessories. Groundwater is there when needed. Additional equipment may be added to the system for treatment to ensure better quality of life.

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About this Handbook

The **WATER SYSTEMS HANDBOOK** provides basic information on well design, operation, and maintenance to boost the professional knowledge of well industry personnel.

Before you begin your studies, please take a few moments to familiarize yourself with the format of this handbook. The handbook is divided into eight books. Each includes several chapters that cover the most important aspects of wells. At the end of each chapter, you will find a **Quiz**. You can use this quiz as a learning tool to review the noteworthy points in each chapter. Answers to the quiz can be found at the end of each book. If you miss an answer, follow the directions to take you back to where the information is located in the chapter.

For quick reference, you will find that highlighted text is generally defined in a **Glossary** at the back of each book, where you will also find a topical **Index**. While illustrations appear in each chapter, you will also see tables and charts referenced in text and located in the **Appendix** at the back of each book. A handy metric system reference also appears in each appendix.

We hope that studying the information in this handbook will prepare you for your job as a well professional, charged with the important responsibility of helping to ensure access to pure, plentiful well water for families across America.

Water Systems Council

Dedication

This 13th Edition of Water Systems Handbook is dedicated to the millions of Americans who rely on private water systems to provide safe, sustainable water supply and to the water well professionals in the water well industry.

The 13th Edition is also dedicated in memory of Jeff Wellen for his many years of leadership and service to WSC and the water well industry.

Special thanks to the members of the Water Systems Council Technical Committee, who initiated and completed revisions to this 13th Edition.



The Water Systems Council (WSC) is a national nonprofit organization, dedicated to promoting the wider use of wells as safe, sustainable, and cost-effective drinking water systems; protecting groundwater resources and users of well water, and ensuring a safe drinking water supply for well owners. WSC members include major manufacturers of the integral components of wells and other drinking water systems, leading distributors of these components, and various drinking water professionals.

WSC is the only national nonprofit organization with programs solely focused on private water wells and small, shared wells.

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Chapter 1

Water Sources and Well Construction

- ✓ Sources of water for wells
- ✓ The water cycle
- ✓ Waterbearing formations and the water table
- ✓ Characteristics of the four basic types of water wells
- ✓ Well drilling methods
- ✓ Points for well drillers

A safe, adequate water system starts with a good well

It is true that impure water can sometimes be made safe by treating it with chlorine or other chemicals. And it may be possible to boost the output of a “weak” well. But in water systems work, it is really true that “an ounce of prevention is worth a pound of cure.” And the best way to prevent future water system problems is to base installations on sanitary wells that have plenty of capacity.

There are two typical sources for private water systems:

- **Surface water**, found on the surface of the earth in the form of ponds, lakes, streams, and other such sources.
- **Groundwater** (or underground water), found in saturated strata at various depths below the surface of the earth. 98 percent of all the fresh water in the world is found underground.

How the water cycle operates

The water supply for both aboveground and underground sources is rain or snow. As it falls to earth, some of this water collects to form lakes, rivers, and streams. A portion evaporates and returns directly to the atmosphere and is absorbed by growing plants. The rest seeps downward through the earth until it accumulates in porous material at some subsurface level and becomes groundwater.

This groundwater is not static. It is constantly moving slowly through subsurface strata.

Surface water is continuously evaporating into the air. It is this action that produces the clouds from which rain and snow fall. Thus, water is constantly changing from moisture in the air to rainfall, to surface water, to groundwater, back to surface water, and ultimately back to atmospheric moisture. This continuous process is known as the **water cycle** (Figure I.1.1).

Surface water poses problems for private systems

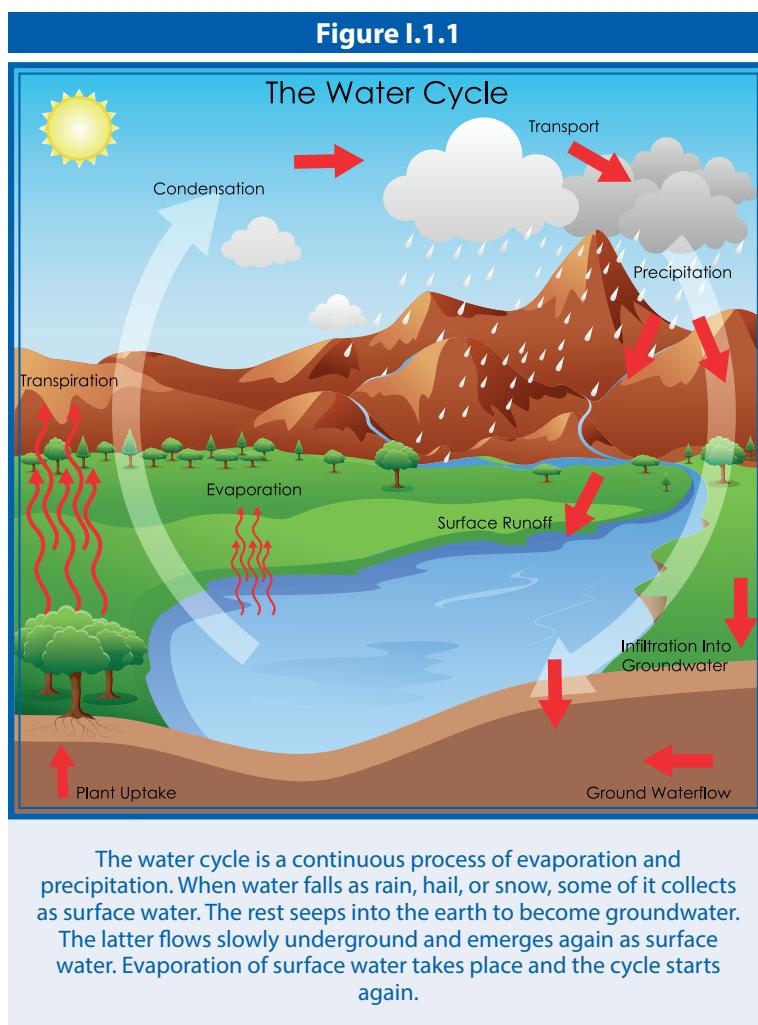
Surface water sources require consideration of additional factors not usually associated with groundwater. The risk of contamination of surface water by chemicals is greater due to its exposure to the atmosphere and to unfiltered surface runoff. Surface water should be used only when groundwater sources are not available. It should be used only for irrigation and similar uses — not for human or animal consumption. Obviously then, a private household system should rely on groundwater. This water is found in underground strata or layers known as **water-bearing formations**. The nature of these formations is shown in Figure I.1.2 (page 11).

The surface layer in most areas is top soil. Water passes through it easily. Next, there may be a layer of clay or hardpan. Either material is so tightly packed that it resists water flow. Beneath this stratum, or in place of it, there may be a more porous or permeable material. Finally comes the water-bearing formation, often called the groundwater reservoir.

Water-bearing formations and the water table

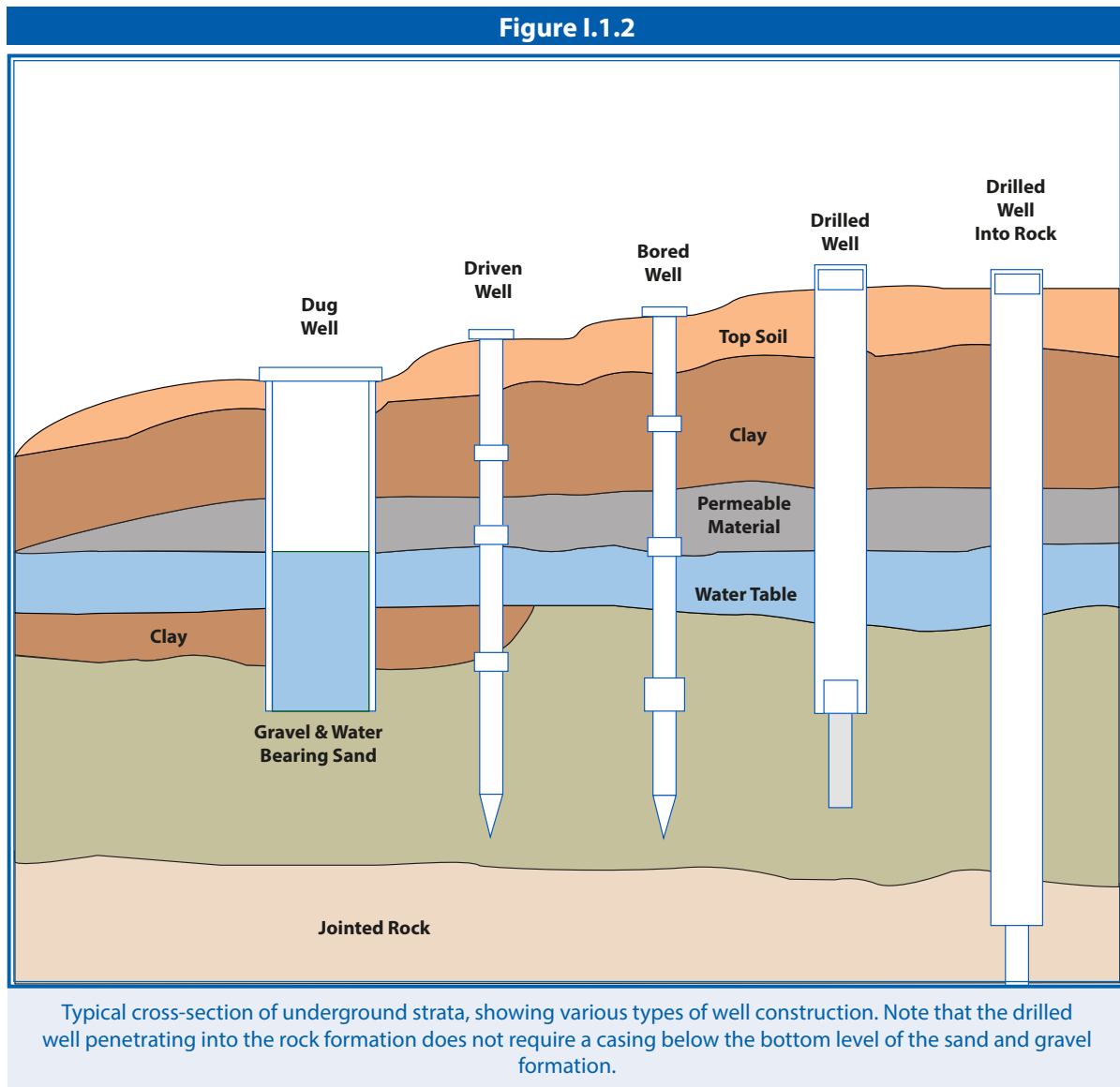
There are two basic types of water-bearing formations. One is sand, or a mixture of sand and gravel. The other is solid rock interlaced with crevices or fissures. In the case of a sand-and-gravel formation, the space between individual particles is filled with water. In a rock formation, the water is found in fissures or cracks.

The **water table** is a more or less continuous surface, below which the formation is saturated with water. Depending on the area, water table depth can vary from a few feet to hundreds of feet. It tends to follow the contours of the land, sloping downward from hilly areas to low points.



Water table and artesian wells

In some places, more than one water-bearing formation is found under the surface. There might, for example, be a sand-and-gravel formation directly above a rock formation, as shown in Figure I.1.2. When the well goes down only to the first such formation, where the water table is exposed to atmospheric pressure, it is known as a water table well or **shallow well**.



Sometimes, a well may be drilled to a lower formation where the water is under pressure because it is confined by an impermeable overlying layer at a higher elevation. This is known as an **artesian well**. In some cases, the atmospheric pressure is great enough to force water up to the surface when tapped by a well.

Basic types of wells

Water wells are classified according to the method used to build them. There are four common types — dug, bored, driven, and drilled. Dug, bored, and driven wells are rarely more than 50 feet deep. Drilled wells can be 1,000 feet or more in depth. The important facts about each type of well are discussed here.

Dug wells are simply made by excavating a hole several feet in diameter to a fairly shallow depth. The circular hole is then lined with rocks, brick, wood, or concrete pipe to prevent a cave-in. Since depth is limited to 25 to 30 feet, a dug well is practical only when the water table is near the surface of the earth. For this reason, there is a strong likelihood of contamination by surface drainage and/or subsurface seepage. Because a high percentage of such wells are polluted, the use of dug wells should be avoided, if at all possible. In many areas, dug wells are prohibited by state law.

Bored wells are constructed by means of an earth auger which bores a cylindrical hole into the earth. After water is reached, the well is cased with tile, steel pipe, or other suitable material. The lower part of the well should be covered with a screen, which keeps sand and other material from entering the water being pumped. Like dug wells, bored wells are subject to contamination unless the casing is sealed with grout to a depth of at least 15 feet below the ground surface.

Driven wells consist of a series of tightly coupled pipe lengths fitted with a well point at the lower end. The **well point** is forced through the ground by a series of blows on the pipe above it. When the point reaches the water table, water flows into the pipe through screened openings on the well point.

Driven wells are most practical when the water table is no deeper than 50 to 60 feet. Obviously, the underground strata must be porous and free from rocks in order to permit driving of the well point. When these conditions are present, the driven well may be the simplest and cheapest means of developing a groundwater supply. However, driven wells can be difficult to grout and may have small flows due to their small diameter.

Drilled wells are used when greater depth, volume, or diameter than a driven well can provide is needed. They are also necessary when the subsurface is too hard to permit a well point to be driven through it.

Drilling methods

Wells are commonly drilled by one of two methods. The first is known as the **cable tool method** or **percussion method** (Figure I.1.3a). A machine alternately lifts and drops a long chisel-shaped bit within the borehole. The hole is deepened as the bit cuts and breaks rock or other materials in the subsurface. In the second method, **rotary well drilling** (Figure I.1.3b), a rotating bit (Figure I.1.3c) is fixed to the lower end of a steel pipe, known as the drill pipe. The rotary action of this bit chews into the rock or other earth materials. Air or water is used to transport the cuttings or chips to the surface.

Figure I.1.3a



Percussion drill rig.

Figure I.1.3b



Rotary drill rig.

Figure I.1.3c



Rotary drill bit.

The drilled hole is lined with steel or plastic pipe called the **well casing**. The well casing keeps the well from caving in and protects the groundwater from contamination by preventing surface water from seeping.

Drilling uses a dual wall drill stem, compressed air, and a specialized down hole hammer (Figure I.1.4). Compressed air is passed down the hole to drive the down hole hammer. The formation being penetrated is cut or broken up by the hammer's percussion action. Cuttings or spoils are moved past the bit to the slotted crossover apparatus or adapter by air velocity exhausted from the hammer. These spoils enter the slots in the crossover apparatus and are directed to the inner tube of the dual wall pipe. The exhaust air velocity carries these spoils up the inner tube to the surface. This drilling method is cost-effective, rapid, and provides for a cleaner borehole, needing less development. This method is not suited for all types of formations. In some formation types, the borehole stability can be compromised or hard to maintain.

In the cable tool method, the casing is installed as the drilling proceeds. With rotary drilling, the hole is oversized and the pipe is set in the well after full depth has been reached. In the latter case, the space between the borehole and the outer walls of the well casing must be sealed with a cement or clay grout. Otherwise, surface water could seep down between the borehole and the casing, and could cause severe pollution.

If the water-bearing formation is loose sand and gravel, the casing must extend to the full depth of the well. The bottom end of the casing is fitted with a **well screen** to keep sand from entering the water supply. If the formation is hard rock, the casing needs to extend into the top of the rock stratum and be grouted in most cases. Screens are not usually needed in rock wells.

Good location is important to prevent pollution

Construction of a well has a great deal to do with preventing pollution of the water supply (Figure I.1.5). The same is true of location. Generally, wells should be located away from, and upstream of, sources of surface contamination such as barnyards, septic systems, and cesspools. If that is not possible, it is imperative to make sure that the well is drilled to a depth sufficient to ensure a pure groundwater supply and is properly constructed to prevent surface water contamination.

Construction of the well is the responsibility of a well-drilling contractor. Some pump dealers do their own drilling. Others subcontract this work or take over the job after the driller has finished building the well.

Figure I.1.4

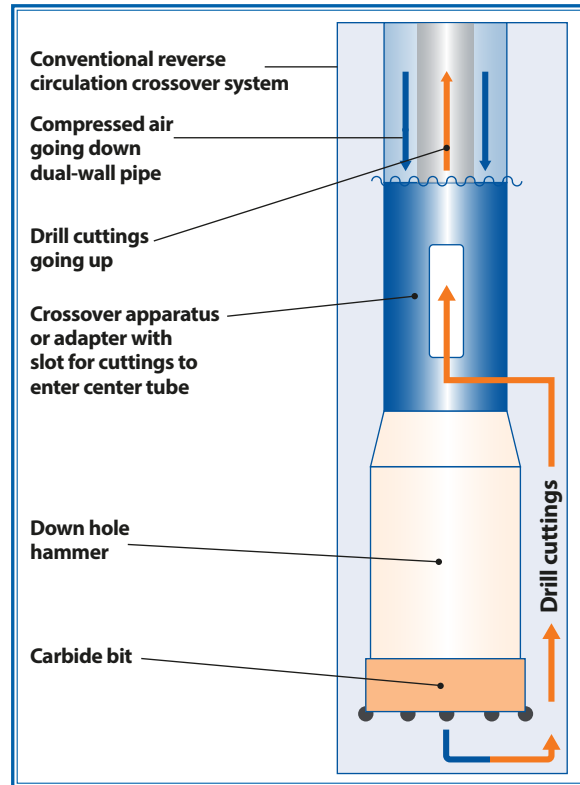
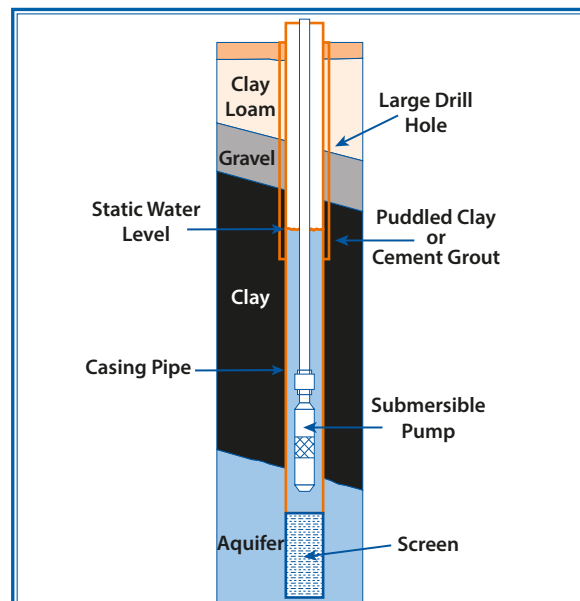


Figure I.1.5



When the borehole is drilled oversized (as in rotary drilling), the empty casing and borehole must be sealed with cement or clay grout. Otherwise, polluted surface or ground water may enter the water supply.

Points for Well Drillers

Here are some of the main points to check:

- ✓ Make sure your company carries full insurance coverage. In addition, local or state codes may require licensing and/or bonding. Be sure to check local requirements.
- ✓ Prepare a written contract that spells out the diameter of the well, the materials to be used, and the cost per foot for drilling the well.
- ✓ Make sure that the well is constructed and sealed according to sanitary practices and local or state codes. Be sure the casing is installed properly to prevent contamination from surface seepage.
- ✓ Upon completing the installation, see that the well is cleared of all loose materials and is pumped off so it is clean of sand to prevent possible damage to the pump and/or motor. The well should then be sterilized or disinfected by means of chlorination (Book V, Chapter 2).
- ✓ Furnish a **well log** to the customer. This is a drilling record, showing the depth of the well, the strata penetrated, and the depth at which water was found. This record, together with test data showing the pumping rate and pumping level, should be given to the owner. All of this information is needed to select and size the pump for efficient operation.
- ✓ Finally, remember that a private water system is only as good as the well.

A Word Of Caution

Always practice good rig safety when operating.

- ✓ Keep a safe distance from overhead and buried power lines.
- ✓ Observe personal safety while operating drilling equipment.
- ✓ Ensure rig stability.
- ✓ Know and observe all local and OSHA safety codes.
- ✓ Maintain safe distances from other obstructions and buildings.

Study Guide Questions - Chapter 1

Answers can be found on page 36

Q. Why should surface water not be used as a drinking water source?

Q. Name the four main types of wells.

Q. What are some factors to consider when deciding where to locate a well?

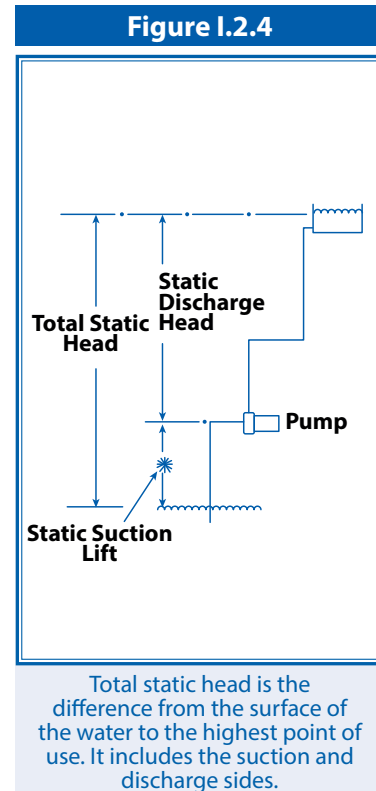
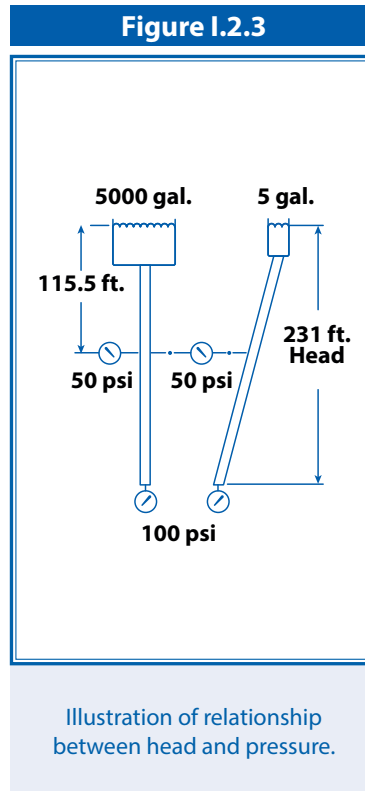
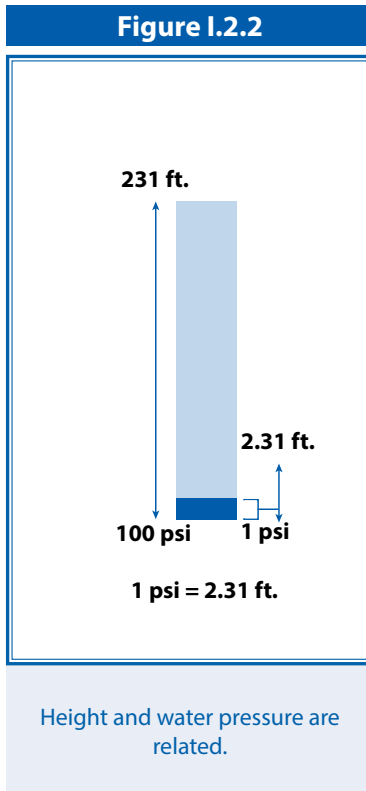
Q. What is a well log?

Notes

Chapter 2

Private Water System Fundamentals

- ✓ Components and operations of automatic water systems
- ✓ Relationship of head, pressure, and friction loss
- ✓ Flow rates and friction losses
- ✓ Operation of shallow well, deep well, and submersible pumps



Operating cycle of the automatic system

In an automatic water system, a **pressure tank** is used. Unlike air, water cannot be compressed or squeezed into a smaller volume. In a pressure tank, air that is compressed by the rising water level in the tank is a means of storing energy. The compressed air at the top of the tank acts like a coiled spring, pushing down on the water in the tank.

When a **valve** is opened in the system, air pressure in the upper part of the tank forces the water to flow out of the tank and into the system. The pressure falls as the water flows out of the tank. When it drops to the **cut-in setting** of the **pressure switch**, usually 20, 30, or 40 **pounds per square inch (psi)**, the pressure switch closes the circuit and the pump starts.

The pump again delivers water under pressure to the tank, and as the tank refills, the air over the water is compressed. If no water is being used, delivery to the tank continues until the pressure reaches the industry standard differential of 20 psi. The pressure switch then opens the electrical circuit to the motor and the pump stops. The **operating cycle** is thus completed.

Head is pressure (psi) expressed in terms of height in feet (One psi equals 2.31 feet of head)

Liquids have weight, so they exert pressure. Water has weight, so it requires power to move it. When water moves, friction's power also slows it, resulting in a loss of pressure. These characteristics are all related.

As shown in Figure I.2.2 (page 19), a column of water 231 feet high will exert 100 psi at ground level, because $1 \text{ psi} = 2.31 \text{ feet of head}$ ($231 \text{ ft.} / 2.31 \text{ ft.} = 100 \text{ psi}$). When the water in the column drops 2.31 feet, it creates 1 psi regardless of the diameter of the pipe. Conversely, it takes 100 psi to move the water up to the height of 231 feet.

In Figure I.2.3 (page 19), if the pressure was measured 115.5 feet down from the top of pipe, the gauge would read 50 psi. Note also that in the slanted pipe, the reading would be the same. Therefore, measured pressure depends on the elevation placement of where the pressure is being measured, not the volume or the size of the column.

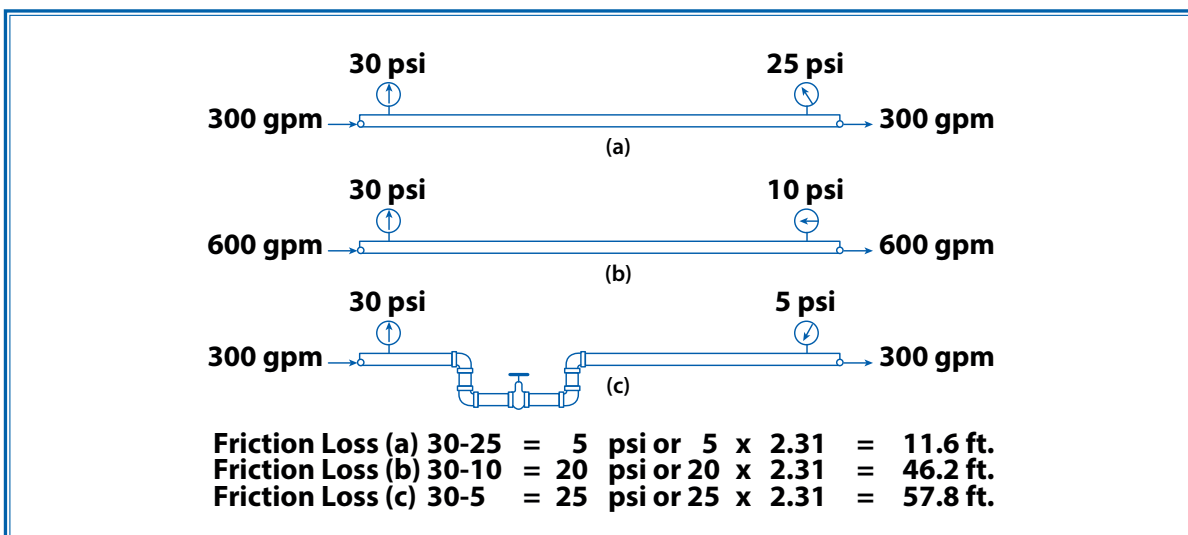
Pressure can be shown as the difference in elevation and is usually called **head**. For water, 231 feet of head is equivalent to 100 psi, and one foot of head is equivalent to .433 psi. When no water is flowing, the head is called **static head**. If the elevation is on the suction side of the pump, it is called **static suction lift** and is expressed in feet. On the discharge side it is called static discharge head, and may be expressed in feet or psi. The static suction lift and the static discharge head together make up the **total static head**. These terms are illustrated in Figure I.2.4 (page 19).

Flow is measured in volume moved in a given length of time, commonly **gallons per minute** (gpm) or **gallons per hour** (gph).

Friction caused by flow increases total head

When liquid moves through a pipe, it must overcome resistance caused by friction from sliding along the pipe walls and its own turbulence. For this reason, if pressures are recorded in a length of pipe such as that shown in Figure I.2.5, the gauge at the inlet will show a higher reading than at the outlet. Unfortunately, as the flow rate increases, the pressure drop increases rapidly. If the flow doubles, the pressure drop increases four times. Obviously, a smaller pipe has a higher friction loss at the same flow. Fittings, which introduce turbulence, also increase friction losses.

Figure I.2.5



As shown by these sketches, pressure loss from friction increases with either the flow rate (b) or fittings that increase the water's turbulence (c).

Power requirements increase with higher flow rates and greater friction losses

More flow equals more weight. More weight equals more horsepower.

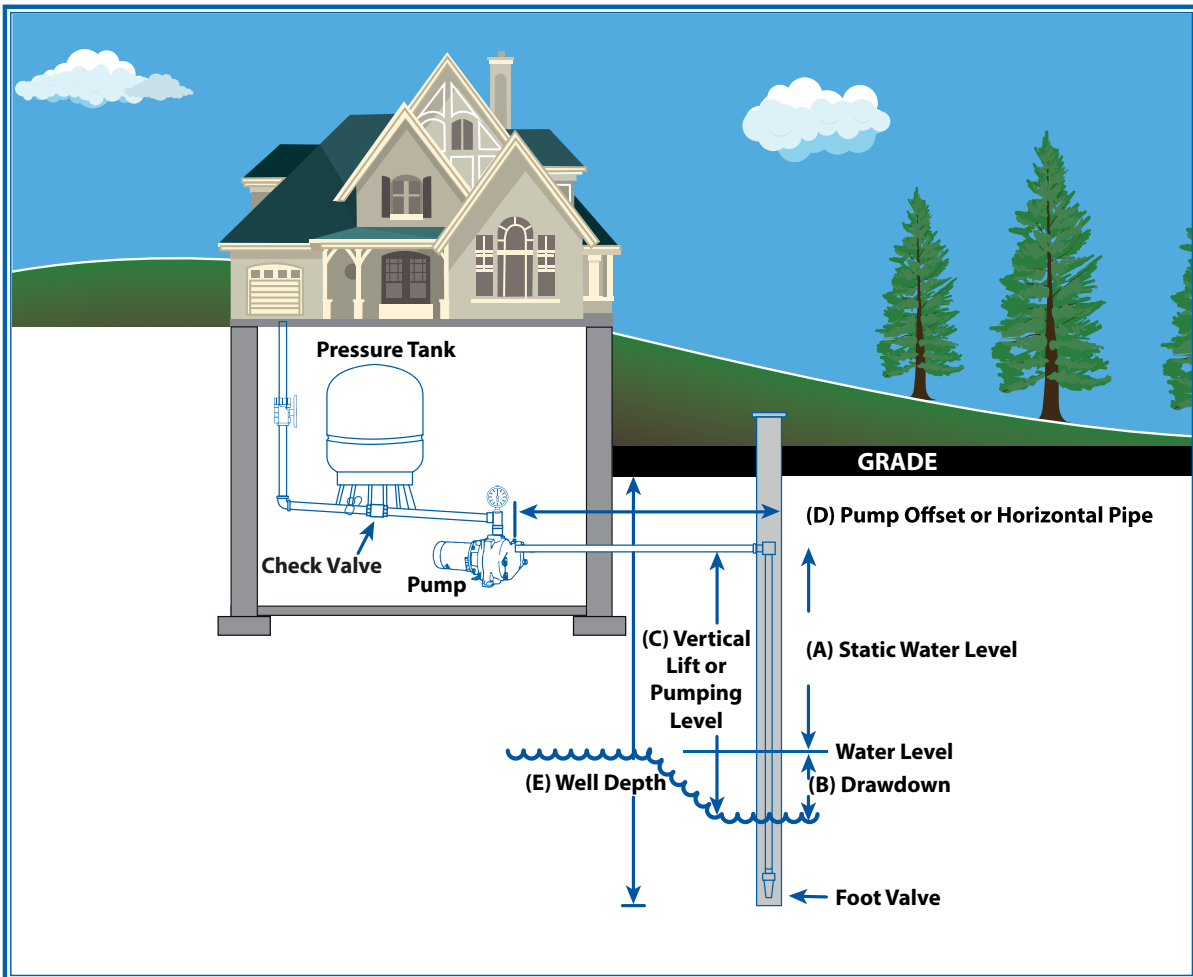
Whether a gallon of water is lifted to a higher level or pushed against friction, power is required. This power depends on the flow rate and the pressure or **head** the liquid moves against. Any power used to overcome pipe friction is not available to move more water or develop greater head.

Total head combines static and friction heads

As shown previously, when water flows, there is a loss of **pressure**. This loss is called **friction head**. This must be added to the **static head** to determine **total head**. For a pumping system, it is the total head that governs pump selection as far as pressure is concerned. In a pressure tank, the pressure in psi is converted to head in feet, which is the **discharge head**.

To convert feet of head to pressure in psi, multiply by .433.
To convert pressure in psi to feet of head, multiply by 2.31.

Figure I.2.6



Schematic layout of a pumping system for shallow wells using either a centrifugal pump or a shallow well jet pump.

A. STATIC WATER LEVEL (feet)...

Vertical distance from pump level of well to natural water level in the well.

B. DRAWDOWN (feet)...

Reduction in water level during pumping – varies with well yield and pump capacity.

C. VERTICAL LIFT or PUMPING LEVEL (feet)...

$C = A + B$.

D. PUMP OFFSET or HORIZONTAL PIPE (feet)...

Horizontal distance from well to pump.

E. WELL DEPTH (feet)...

Vertical distance from grade to bottom of well.

FRICTION LOSS =

Total Length of Pipe (D+E).

Loss of pressure and gallon per minute flow when water flows through a piping system factoring gallons per minute, pipe length, size, and fittings. Measure in feet of head.

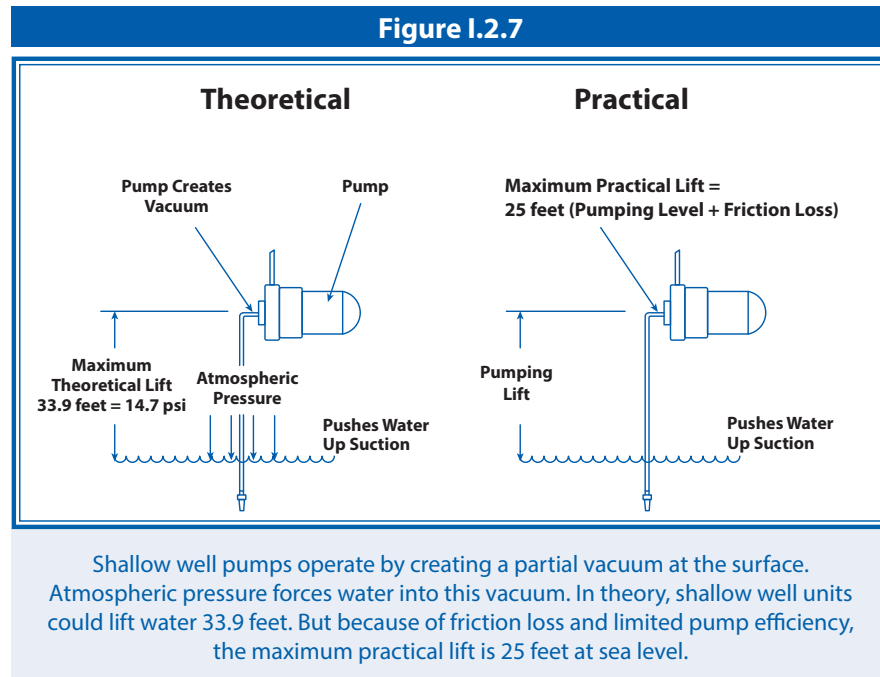
TOTAL SUCTION LIFT =

$C + \text{Friction Loss (Appendix)}$.

Shallow well pump

Figure I.2.6 (page 22) shows a typical shallow well jet pump or centrifugal pump installation and its various components.

A **shallow well pump** uses a jet assembly that includes a nozzle and **venturi** and produces a vacuum to lower the atmospheric pressure at its inlet. If the inlet is submerged in water in a well (Figure I.2.7), atmospheric pressure will force the water up the suction pipe.



Theoretically, if the pump could create a perfect vacuum at sea level, water could be drawn up 33.9 feet (14.7 x 2.31). Practically, this is not possible because the pump cannot create a perfect vacuum and there is friction loss in the suction pipe. The normal limit is 25 feet of **suction lift**; for example, the difference in elevation between the water in the well and the pump, plus any friction losses in the pipe. The two must be taken together as the pump has no way of knowing whether its suction lift comes from vertical lift or from friction and vertical lift.

Pump manufacturers indicate the capacities their pumps produce at a given suction. This lift is determined by adding vertical lift and friction.

NOTE: In mountainous areas where atmospheric pressure is lower, the suction lift must be lowered. This reduction is about one foot for each 1,000 feet of elevation above sea level (Book III, Chapter 1).

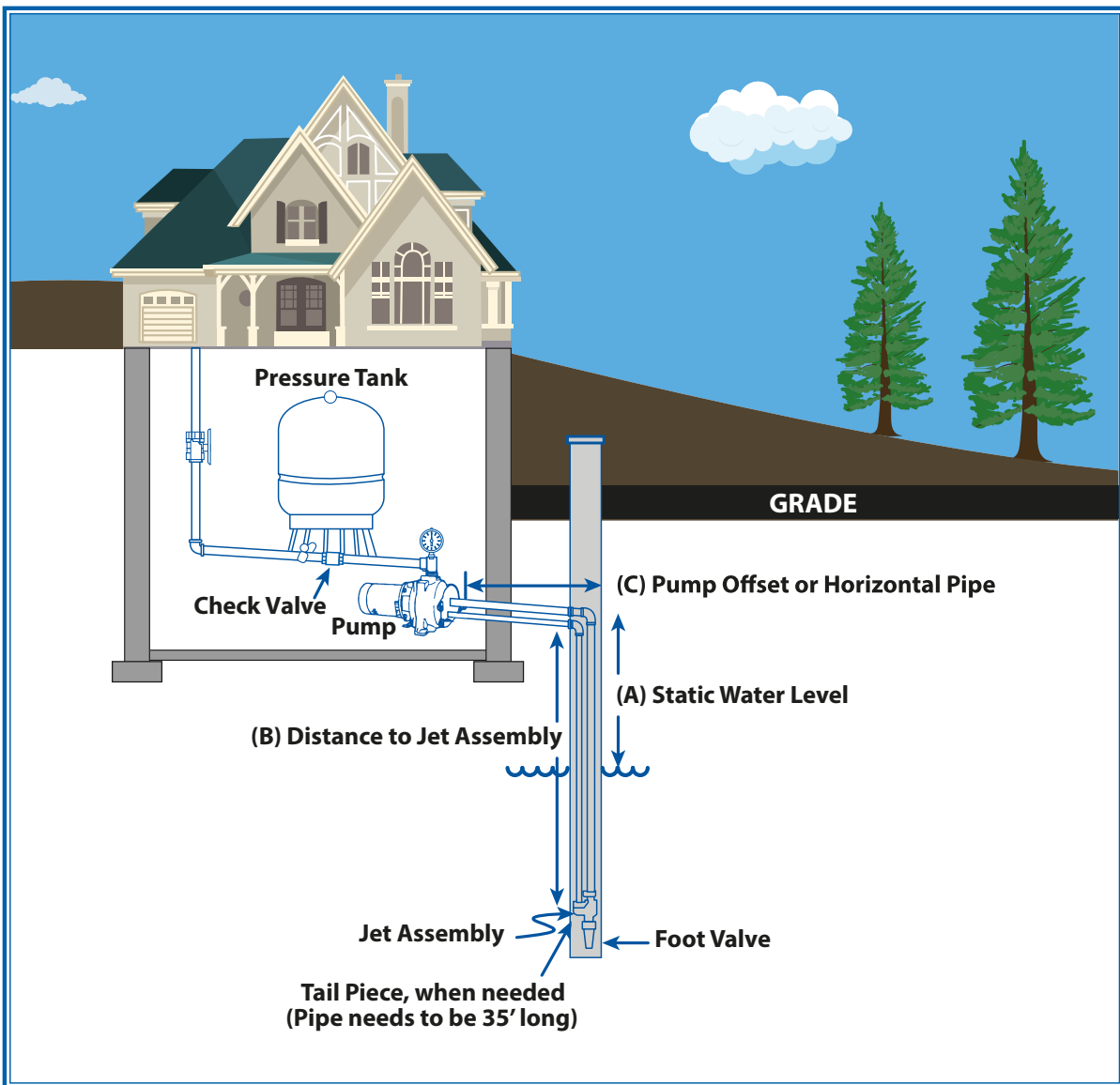
Deep well pump

For a **deep well pump**, as shown in Figure I.2.8 (page 24), a centrifugal pump at the surface sends water down to the **jet** or **ejector** submerged in the well water. This jet creates suction, which picks up well water and forces it to the surface. The combined flow passes through the pump. Part of the water then goes back to operate the jet and the rest flows to the tank or point of consumption (Book III, Chapter 1).

Submersible pump

The submersible pump is made of impeller, diffuser, and bowl assemblies in a long and slender stacked fashion. Such a pump is operated by a submersible motor. Figure I.2.9 (page 25) shows a layout of a pumping system using a multi-stage submersible pump (Book II, Chapter 2).

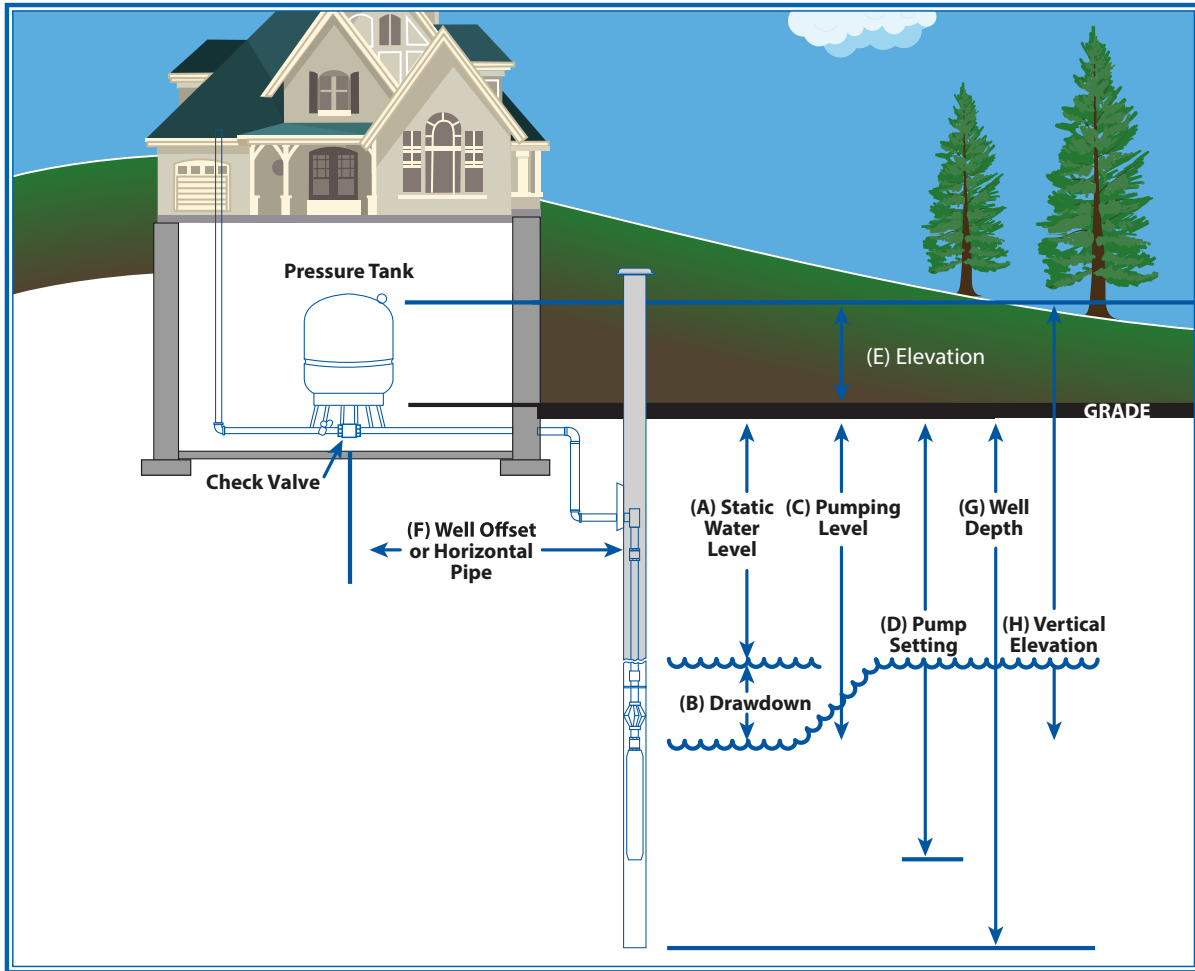
Figure I.2.8



Layout of a pumping system for deep wells using a deep well jet pump.

- A. STATIC WATER LEVEL (feet)...**
Vertical distance from pump level of well to natural water level in the well.
- B. DISTANCE TO JET ASSEMBLY (feet)...**
Vertical distance from pump level to bottom of well.
- C. PUMP OFFSET or HORIZONTAL PIPE...**
Horizontal distance from well to pump.

Figure I.2.9



Layout of a pumping system using a submersible pump.

A. STATIC WATER LEVEL (feet)...

Vertical distance from grade of well to natural water level in the well.

B. DRAWDOWN (feet)...

Reduction in water level during pumping – varies with well yield and pump capacity.

C. PUMPING LEVEL (feet)...

$C = A + B$.

D. PUMP SETTING (feet)...

Vertical distance from top of well to pump.

E. ELEVATION (feet)...

Vertical distance from E grade to the tank or highest fixture (shower head).

F. WELL OFFSET or HORIZONTAL PIPE (feet)...

Horizontal distance from well to tank.

G. WELL DEPTH (feet)...

Vertical distance from grade to bottom of well.

H. VERTICAL ELEVATION (feet)...

Vertical distance from the pumping level to the highest point... $H = C + E$.

FRICTION LOSS =

Total Length of Pipe ($D + E + F$)

Loss of pressure and gallon per minute flow when water flows through a piping system factoring gallons per minute, pipe length, size, and fittings. Measured in feet of head.

TOTAL DYNAMIC HEAD (TDH) =

$C + E + \text{Friction Loss} + \text{Discharge Pressure at Tank}$. Expressed in feet of head.

Study Guide Questions - Chapter 2

Answers can be found on pages 36-37

Q. How does a shallow well pump work?

Q. How does a deep well pump work?

Q. Define head.

Q. What are static head, suction lift, static discharge head, and total static head?

Study Guide Questions - Chapter 2

Answers can be found on pages 36-37

Q. How is flow measured?

Q. What is friction head and how does it help determine total head?

Q. What is a shallow well pump? A deep well pump? A submersible pump?

Notes

This image shows a full page of blank handwriting practice paper. It features a series of evenly spaced, horizontal orange lines that run across the entire width of the page. The background is a solid light gray color. There are no margins, text, or other markings on the page.

Appendix

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Length				
Inches	(in)	Millimeters	(mm)	25.400
Inches	(in)	Centimeters	(cm)	2.539
Feet	(ft)	Meters	(m)	0.305
Yards	(yd)	Meters	(m)	0.914
Miles (statute)	(mi)	Kilometers	(km)	1.609
Millimeters	(mm)	Inches	(in)	0.039
Meters	(m)	Feet	(ft)	3.281
Centimeters	(cm)	Inches	(in)	0.394
Meters	(m)	Yards	(yd)	1.094
Kilometers	(km)	Miles (statute)	(mi)	0.621
Area				
Square Inches	(in ²)	Square Centimeters	(cm ²)	6.452
Square Feet	(ft ²)	Square Meters	(m ²)	0.093
Square Yards	(yd ²)	Square Meters	(m ²)	0.836
Square Miles	(mi ²)	Square Kilometers	(km ²)	2.590
Acres	(ac)	Hectares	(ha)	0.405
Square Centimeters	(cm ²)	Square Inches	(in ²)	0.155
Square Meters	(m ²)	Square Feet	(ft ²)	10.764
Square Meters	(m ²)	Square Yards	(yd ²)	1.196
Square Kilometers	(km ²)	Square Miles	(mi ²)	0.386
Hectares	(ha)	Acres	(ac)	2.471
Liquid Volume				
Ounces	(oz)	Milliliters	(ml)	29.574
Pints	(pt)	Liters	(l)	0.473
Quarts	(qt)	Liters	(l)	0.946
Gallons	(gal)	Liters	(l)	3.785
Pounds per Cubic Foot	(lb/ft ³)	Kilograms per Cubic Meter	(kg/m ³)	16.018
Pounds per Gallon	(lb/gal)	Kilograms per Cubic Meter	(kg/m ³)	119.826
Milliliters	(ml)	Ounces	(oz)	0.034
Liters	(l)	Pints	(pt)	2.113
Liters	(l)	Quarts	(qt)	1.057
Liters	(l)	Gallons	(gal)	0.264
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Cubic Foot	(lb/ft ³)	0.062
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Gallon	(lb/gal)	0.008
Mass				
Ounces	(oz)	Grams	(g)	28.350
Pounds	(lb)	Kilograms	(kg)	0.454
Grams	(g)	Ounces	(oz)	0.035
Kilograms	(kg)	Pounds	(lb)	2.205
Flow				
Cubic Meters per Hour	(m ³ /h)	Gallons per Minute	(gpm)	4.400
Gallons per Minute	(gpm)	Cubic Meters per Hour	(m ³ /h)	0.227

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Force				
Foot Pound Force	(ft-lbf)	Joules	(J)	1.356
Newtons	(N)	Kilogram Force	(kgf)	0.102
Joules	(J)	Foot Pound Force	(ft-lbf)	0.738
Kilogram Force	(kgf)	Newtons	(N)	9.807
Power				
Horsepower	(hp)	Kilowatts	(kW)	0.746
Horsepower	(hp)	Watts	(W)	745.700
Kilowatts	(kW)	Horsepower	(hp)	1.341
Watts	(W)	Horsepower	(hp)	0.001
Pressure				
Bars	(b)	Pounds per Square Inch	(psi)	14.500
Kilograms per Square Centimeter	(kg/cm ²)	Pounds per Square Inch	(psi)	14.500
Pounds per Square Inch	(lb/in ²)	Kilograms per Square Meter	(kg/m ²)	703.070
Pounds per Square Inch	(lb/in ²)	Kilopascals	(kPa)	6.895
Pounds per Square Inch	(lb/in ²)	Meters of Water	(m)	0.704
Inches of Mercury	(inHg)	Kilograms per Square Meter	(kg/m ²)	345.300
Kilograms per Square Meter	(kg/m ²)	Pounds per Square Inch	(lb/in ²)	0.001
Kilopascal	(kPa)	Pounds per Square Inch	(lb/in ²)	0.145
Meters of Water	(m)	Pounds per Square Inch	(lb/in ²)	1.420
Kilograms per Square Meter	(kg/m ²)	Inches of Mercury	(inHg)	0.003
1 Atmosphere	14.7 lb/in ²	Kilograms per Square Centimeter	(kg/cm ²)	1.033
1 Atmosphere	14.7 lb/in ²	Kilograms per Square Meter	(kg/m ²)	10,335.000
1 Atmosphere	14.7 lb/in ²	Kilopascal	(kPa)	101.350
1 Atmosphere	14.7 lb/in ²	76.0 Centimeters Mercury	(cmHg)	5.170
1 Atmosphere	29.92 inHg	76.0 Centimeters Mercury	(cmHg)	2.540
Pascal	(Pa)	Newtons per Square Meter	(N/m ²)	1.000
Pascal	(Pa)	Kilograms per Square Meter	(kg/m ²)	0.102
Temperature				
Degrees Fahrenheit	(°F)	Degrees Celsius	(°C)	(°F-32) 0.556
Degrees Celsius	(°C)	Degrees Fahrenheit	(°F)	(1.8 x °C) + 32
Flow				
Feet per Second	(fps)	Meters per Second	(m/s)	0.305
Miles per Hour	(mph)	Kilometers per Hour	(km/h)	1.609
Gallons per Minute	(gpm)	Liters per Minute	(l/min)	3.785
Gallons per Minute	(gpm)	Cubic Meters per Minute	(m ³ /min)	0.004
Meters per Second	(m/s)	Feet per Second	(fps)	3.281
Kilometers per Hour	(km/h)	Miles per Hour	(mph)	0.621
Liters per Minute	(l/m)	Gallons per Minute	(gpm)	0.264
Cubic Meters per Minute	(m ³ /min)	Gallons per Minute	(gpm)	264.172

Notes

[illegible]

Glossary

Artesian Well: A well descending to a lower formation where water is under pressure and creates an overflow at ground level. (I-1)

Bored Well: Cylindrical hole constructed with earth auger and lined with a sealed casing. (I-1)

Cable Tool Method (*Also called Percussion Method*): A drilling method that involves raising and dropping a heavy chisel-shaped bit to break up the soil in a borehole. (I-1)

Cut-in Setting: Set point at which water pressure causes a pump to turn on. (I-2)

Deep Well Pump: Any pump capable of producing water from deeper than 25 ft. (I-2)

Discharge Head: All the losses on the discharge side of the pump. These include pressure, elevation, and friction loss. (I-2)

Drilled Well: Well constructed by mechanical drilling means. (I-1)

Driven Well: Consists of a series of tightly coupled pipe lengths fitted with a well point at the lower end, forced into the ground by a series of blows. (I-1)

Dug Well: Made by excavating a hole several feet in diameter to a depth of 25 to 30 feet, then lined with material to prevent a cave-in. (I-1)

Ejector (*Also called a Jet*): A water pressure-making device with three parts: body, nozzle, and venturi tube. Atmospheric pressure forces water into a partial vacuum at the nozzle throat, then into the pumping system where the venturi tube slows water velocity and converts it into water pressure. (I-2)

Flow: Measure of water volume moved in a given length of time, typically measured as gpm. (I-1, I-2)

Friction Head/Loss: Loss of pressure when water flows through a piping system factoring gallons per minute, pipe length, size, and fittings. Measured in feet of head. (I-2)

Gallons Per Hour (gph): Unit of flow measurement, expressed in gallons per hour. (I-2)

Gallons Per Minute (gpm): Unit of flow measurement, expressed in gallons per minute. (I-2)

Groundwater: Water that flows or seeps downward and is filtered by underground formations to attain a high degree of purity; ideal drinking water supply. Utilized by wells. (I-1)

Head: Pressure expressed as height in feet. (I-2)

Jet: *See Ejector.* (I-2)

Jet Pump: A surface-mounted centrifugal pump that has an ejector (venturi) device to increase suction capacity. (I-2)

Operating Cycle: Cycle starts when a valve opens in the system and air pressure in the upper part of the tank forces the water to flow out of the tank and into the system. The pressure falls as the water flows out of the tank. When it drops to the cut-in setting of the pressure switch at the industry standard differential of 20 psi, the switch closes the circuit and the pump starts, completing the cycle. (I-2)

Percussion Method: *See Cable Tool Method.* (I-1)

Pressure: The force exerted in pounds over one square inch area. (I-1, I-2)

Pressure Switch: An electrical switch activated by system pressure to control starting and stopping of the pump. (I-2)

Pressure Tank: Vessel used to provide cycle control of the pump. (I-2)

Pounds Per Square Inch (PSI): A unit of pressure or force. (I-2)

Pump: A mechanical device that moves liquid or gas by pressure or suction; a device that converts mechanical torque and motion into hydraulic fluid power. (I-2)

Rotary Well Drilling: Method in which a rotating bit fixed to the lower end of a steel pipe chews into the rock or other earth materials. (I-1)

Shallow Well: Well that goes down only to the first water-bearing formation (less than 25 feet), where the water table is exposed to atmospheric pressure. (I-1, I-2)

Shallow Well Pump: A centrifugal pump with the ejector mounted to the housing that has a maximum total suction lift of 25 feet. (I-2)

Static Head: Water pressure under no flow conditions. (I-2)

Static Suction Lift: The measurement of distance from the water level to the inlet of the pump. Expressed in feet or inches of mercury. (I-2)

Submersible Pump: An adapted centrifugal pump and motor designed to be placed completely below the water surface. (I-2)

Surface Water: All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors which are directly influenced by surface water. (I-1)

Total Head: Determined by adding the friction head and static head; governs pump pressure selection. (I-2)

Total Static Head: Combination of static suction lift and static discharge head. (I-2)

Valve: Any device used to control flow in a water system. (I-2)

Venturi: A component that slows high velocity water due to its increasing orifice size, creating relatively high-water pressure. (I-2)

Water-Bearing Formations: Underground strata or layers in which water is located. (I-1)

Water Cycle: Water's continuous process of evaporation, condensation, and precipitation. (I-1)

Water Table: The upper limit of the portion of the ground wholly saturated with water. (I-1)

Well Casing: Steel or plastic lining permanently installed in drilled wells to prevent cave-ins or contamination by surface water. (I-1)

Well Log: A written form on which the driller lists well characteristics; required by many states. (I-1)

Well Point: A hollow, conically shaped, screened metal point used to make a driven well. (I-1)

Well Screen: Installed at bottom of a well casing to prevent sand and sediment from contaminating the well. (I-1)

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Study Guide Answers

Chapter 1

- Q. Why should surface water not be used as a drinking water source?
- A. The risk of contamination of surface water is great.

If you missed this question, go back to page 10 for information on surface water posing problems.

- Q. Name the four main types of wells.

- A. Dug, bored, driven, and drilled.

If you missed this question, go back to page 12 for information on basic types of wells.

- Q. What are some factors to consider when deciding where to locate a well?

- A. Wells should be located away from, and upstream, of sources of surface contamination such as barnyards, septic systems, and cesspools.

If you missed this question, go back to page 13 for information on good location is important to prevent pollution.

- Q. What is a well log?

- A. A drilling record that shows the depth of the well, the strata penetrated, and the depth at which water was found.

If you missed this question, go back to page 14 for information on points for well drillers.

Chapter 2

- Q. How does a shallow well pump work?

- A. A shallow well pump uses a jet assembly (comprised of a nozzle and venturi); this assembly creates a vacuum. When the suction pipe is submerged in the water, this vacuum creates a low-pressure zone. Atmospheric pressure causes the supply water to rush to this low-pressure zone. This forces the water up the suction pipe and into the pump. The impeller turning within the pump case delivers water under pressure to the discharge fitting. This type of pump has a lift limit of 25 feet at sea level. This limit is reduced if site elevation increases; higher elevation sites have less atmospheric pressure thus less lift.

If you missed this question, go back to page 23 for information on private water system fundamentals.

- Q. How does a deep well pump work?

- A. A centrifugal pump on the surface sends water down a submerged jet or ejector, creating suction that forces well water to the surface.

If you missed this question, go back to page 23 for information on deep well pump.

Q. Define head.

A. Water pressure expressed as height in feet.

If you missed this question, go back to page 20 for information on head.

Q. What are static head, suction lift, static discharge head, and total static head?

A. When no water is flowing, the head is called static head. If the elevation is on the suction side of the pump, it is called static suction lift and is expressed in feet. On the discharge side, it is called static discharge head, and may be expressed in feet or psi. The static suction lift and the static discharge head together make up the total static head.

If you missed this question, go back to page 20 for information on head.

Q. How is flow measured?

A. Flow is measured in volume moved over a given length of time, expressed as gallons per minute (gpm) or gallons per hour (gph).

If you missed this question, go back to page 20 for information on head.

Q. What is friction head and how does it help determine total head?

A. Friction head is the loss of pressure, expressed in pounds per square inch (psi) or feet, caused when water flows through the pipe. To determine total head, friction head is added to static head.

If you missed this question, go back to page 21 for information on total head.

Q. What is a shallow well pump? A deep well pump? A submersible pump?

A. A shallow well pump uses a jet assembly that includes a nozzle and venturi and produces a vacuum to lower the atmospheric pressure at its inlet.

A deep well jet pump is a centrifugal pump at the surface that sends water down to a submerged jet or ejector, creating suction that forces well water to the surface.

The submersible pump is made of impeller, diffuser, and bowl assemblies in a long and slender stacked fashion. Such a pump is operated by a submersible motor.

If you missed this question, go back to page 23 for information on various pumps.

Notes



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Pumps

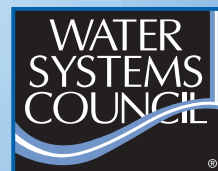


WATER SYSTEMS HANDBOOK

*A complete text on wells:
their design, operation, and maintenance*

13TH EDITION

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BOOK II

Pumps

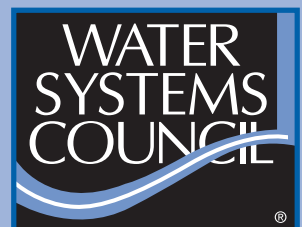
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A Word Of Caution



The products described in this Handbook, including all products using electrical current, can result in serious harm if not used with EXTREME CAUTION and in strict accordance with manufacturers' instructions. Professional assistance is recommended and should always be sought when utilizing unfamiliar equipment.

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Introduction to Wells

Water is life's most vital resource. Through the centuries, people have searched for water, fought for it, and sometimes died for it. No living organism can exist without water.

Consequently, clean and plentiful groundwater is necessary for everyday life. As described in this handbook, groundwater is the reservoir of water that seeps downward through the soil to the water table below the earth's surface. About 98 percent of all fresh water available in the nation at any time is groundwater, which fills the porous beds of rock and sand that make up the earth's crust.

Groundwater is an ideal water supply, for it is pure and wholesome. Filtered by the underground formations through which it passes, groundwater has a degree of purity seldom attained by surface waters.

Natural groundwater reservoirs have many advantages. They have huge capacities, they are relatively inexpensive to tap by means of wells, and they lose little water by evaporation. Above all, they are dependable sources of water.

In the United States alone, more than 115 million people get their drinking water from groundwater every day. More than 23 million American households are supplied from individual, private wells.

A modern well is both flexible and functional. A variety of pumps is available to lift water from all types of wells, from the shallowest to the deepest. These systems are made automatic and dependable by many types of controls and accessories. Groundwater is there when needed. Additional equipment may be added to the system for treatment to ensure better quality of life.

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About this Handbook

The **WATER SYSTEMS HANDBOOK** provides basic information on well design, operation, and maintenance to boost the professional knowledge of well industry personnel.

Before you begin your studies, please take a few moments to familiarize yourself with the format of this handbook. The handbook is divided into eight books. Each includes several chapters that cover the most important aspects of wells. At the end of each chapter, you will find a **Quiz**. You can use this quiz as a learning tool to review the noteworthy points in each chapter. Answers to the quiz can be found at the end of each book. If you miss an answer, follow the directions to take you back to where the information is located in the chapter..

For quick reference, you will find that highlighted text is generally defined in a **Glossary** at the back of each book, where you will also find a topical **Index**. While illustrations appear in each chapter, you will also see tables and charts referenced in text and located in the **Appendix** at the back of each book. A handy metric system reference also appears in each appendix.

We hope that studying the information in this handbook will prepare you for your job as a well professional, charged with the important responsibility of helping to ensure access to pure, plentiful well water for families across America.

Water Systems Council

Dedication

This 13th Edition of Water Systems Handbook is dedicated to the millions of Americans who rely on private water systems to provide safe, sustainable water supply and to the water well professionals in the water well industry.

The 13th Edition is also dedicated in memory of Jeff Wellen for his many years of leadership and service to WSC and the water well industry.

Special thanks to the members of the Water Systems Council Technical Committee, who initiated and completed revisions to this 13th Edition.



The Water Systems Council (WSC) is a national nonprofit organization, dedicated to promoting the wider use of wells as safe, sustainable, and cost-effective drinking water systems; protecting groundwater resources and users of well water; and ensuring a safe drinking water supply for well owners. WSC members include major manufacturers of the integral components of wells and other drinking water systems, leading distributors of these components, and various drinking water professionals.

WSC is the only national nonprofit organization with programs solely focused on private water wells and small, shared wells.

www.watersystemscouncil.org

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Chapter 1

Jet Pump Operation and Installation

- ✓ Classification
- ✓ How jet pumps operate
- ✓ Function of the ejector
- ✓ How shallow well and deep well jets work
- ✓ Two-pipe and packer installations
- ✓ Installing jet pumps
- ✓ Avoiding the overpumping of a low yield well
- ✓ The mechanical seal
- ✓ Seal life

The **jet pump**, a **centrifugal-type pump**, was, for many years, the most widely used type of equipment in domestic water systems because jet pumps feature simple design, low cost, and quiet operation. They also require little maintenance.

Jets are classified by both design and use as shallow well and deep well. The former are limited in use to water level depths of no more than 25 feet practical (33.9 feet theoretically).

Deep well jets are used on wells up to 300 feet deep. There is also a third type known as the **convertible jet**. This type is shipped from the factory without an ejector in the pump. It can be installed as a shallow unit with the ejector bolted onto the pump, or it can be conveniently converted to deep well use in the field by installing the proper jet in the well as specified by the pump manufacturer.

Another means of classifying jet pumps is as horizontal or vertical. This is determined by how the motor is mounted. Thus, a horizontal jet is one in which the motor shaft is horizontal.

Still another classification is as single-stage or multi-stage, depending on whether the pump has one or more impellers in the centrifugal pump portion of the unit.

How jet pumps operate

The modern jet pump combines two pumping principles — centrifugal operation and ejection.

A jet pump consists of two basic parts — an **impeller** and a **diffuser**. The impeller is mounted on the end of the motor shaft or on a coupling fastened to the motor shaft. As the motor shaft rotates, the impeller is turned at the same speed.

Water enters at the eye (center) or the opening of the impeller and is carried across the **vanes**, or the curved slots in the impeller. As the water moves from the center to the edge of the impeller, it moves at an increasing velocity. When it leaves the edge of the impeller, the high-speed water enters the diffuser, where the speed of the water is converted into **pressure**. The water leaving the eye of the impeller creates a partial vacuum, which causes more water to be drawn into the impeller.

The output of the centrifugal pump varies with changes in either the **suction lift** or **discharge pressure**. The output ranges from maximum pressure at no flow to maximum flow at no pressure, or open discharge. Increasing the suction lift has the same effect of increasing total dynamic **head** and will proportionately decrease the gallons per minute.

Ejector function and operation

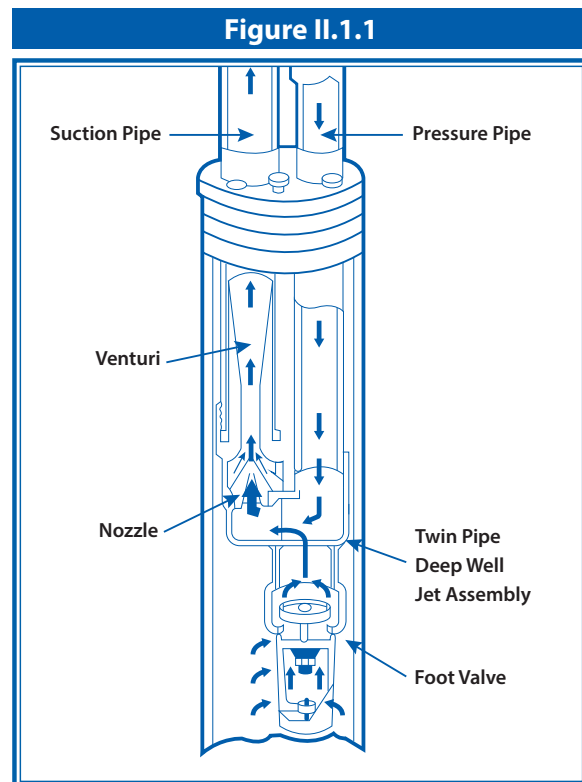
The principle of ejection allows the water to be forced through a device known as an **ejector** or jet. This unit consists of three parts — a body, a nozzle, and a **venturi** or throat. They are arranged in relation to each other as shown in Figure II.1.1.

The nozzle on a jet pump does the same work as the nozzle on a garden hose. Because of its decreasing orifice size, it increases the velocity of the water (shown here as drive water) flowing through it. This action creates a partial vacuum at the nozzle throat. Atmospheric pressure then forces the well water into the vacuum and into the pumping system. In other words, the vacuum created at the nozzle discharge pulls water from the well into the ejector.

The venturi, which gradually increases in orifice size, slows down this high-velocity water and converts the velocity of the water into pressure. As a result, a combination of drive water and pumped water emerges from the venturi at relatively high **pressure**.

Jet pump action, as described here, has these advantages:

1. The unit can pump limited amounts of air without difficulty.
2. There are no moving parts in the ejector. The only movement is the turning of the motor and pump impeller in the centrifugal pump.
3. The pumping action is smooth and uniform. There are no surges such as those that occur with **piston pumps** or **working head pumps**.



Operation of the ejector. High-velocity flow of drive water creates a partial vacuum at the nozzle discharge.

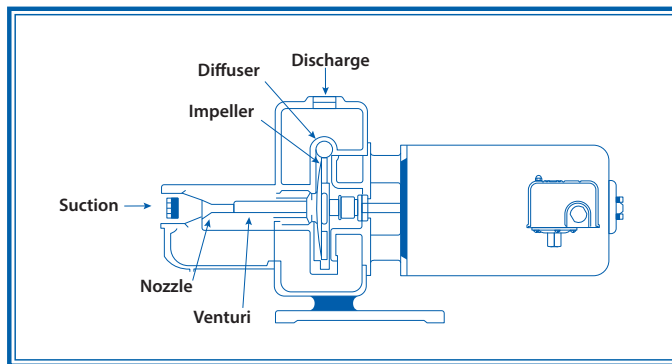
Atmospheric pressure forces the pumped water in the vacuum area nozzle. A combination of drive water and pumped water flows through the venturi, where the pressure increases as velocity decreases.

How a shallow well jet works

Different arrangements of ejector and jet pumps are used in shallow well and deep well jets. In shallow well units, the ejector is mounted in or attached to the pump housing, as shown in Figure II.1.2. Connected to the jet is a suction line that extends below the water level down in the well (Figure II.1.3).

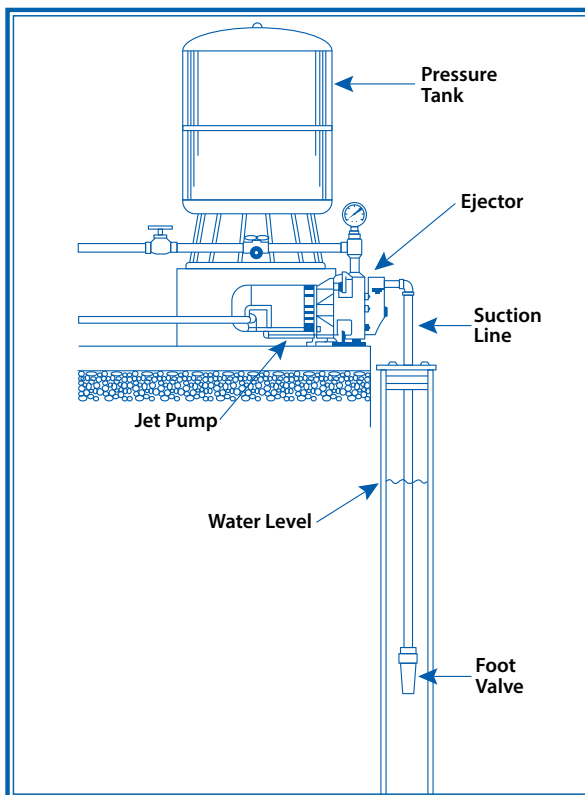
When the pump starts, the centrifugal impeller forces a stream of water through the ejector. The vacuum created at the nozzle discharge draws water from the well into the pump. As explained in Book I, Chapter 2, water can be drawn up a maximum of about 25 feet with this arrangement. The vacuum created reduces atmospheric pressure inside the system, resulting in higher pressure on the outside that pushes the well water up the suction pipe to the pump. Part of the water is sent out the discharge of the pump and a portion recirculates inside the pump through the nozzle and venturi to keep the vacuum developed (Figure II.1.4).

Figure II.1.2



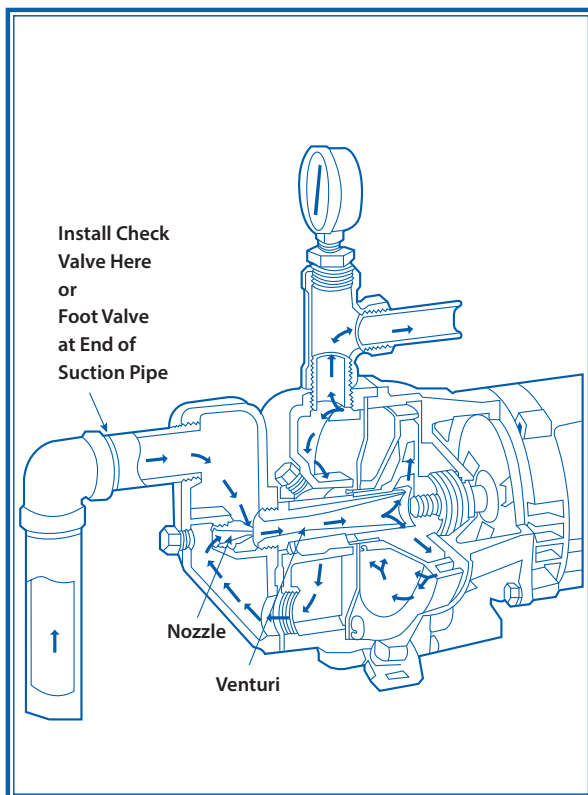
Shallow well jet pump. Note that the ejector is mounted on the pump body itself, rather than down in the well.

Figure II.1.3



Typical shallow well jet pump installation. Suction line from ejector can deliver water from a well depth of about 25 feet.

Figure II.1.4



Recirculation in a shallow well jet pump.

How a deep well jet works

Deep well jets have the ejector submerged down in the well as shown in Figure II.1.5. The jet pump (on the surface) forces water down in what is known as the **pressure pipe** or **drive pipe**. This pipe is connected to the pressure or nozzle side of the ejector body. As the drive water flows through the ejector, it creates a partial vacuum, which draws well water into the ejector body. This water, together with the drive water, flows up to the surface through a second pipe, known as the **suction pipe**. Part of the water is recirculated through the drive pipe. The rest is delivered to the **pressure tank**.

Two-pipe and packer installations

A **two-pipe system** has a pressure pipe and a suction pipe connecting the pump and the jet assembly. An alternative arrangement is shown in Figure II.1.6. This is the single-pipe **packer type**. In such an installation, the space between the suction pipe and the well **casing** itself serves as the pressure pipe. This requires the use of a well casing adapter, as shown in the diagram. A packer type ejector, which fits pressure tight against the side wall of the well casing, is also required.

Foot valves and check valves

Shallow well pumps installed with a **foot valve** will remain primed after initial priming. A **check valve** may be installed in the suction line or a foot valve may be attached to the end of the suction pipe in the well. (In driven shallow wells, a foot valve cannot be used. In such cases, a check valve is installed on the suction line to prevent loss of prime.)

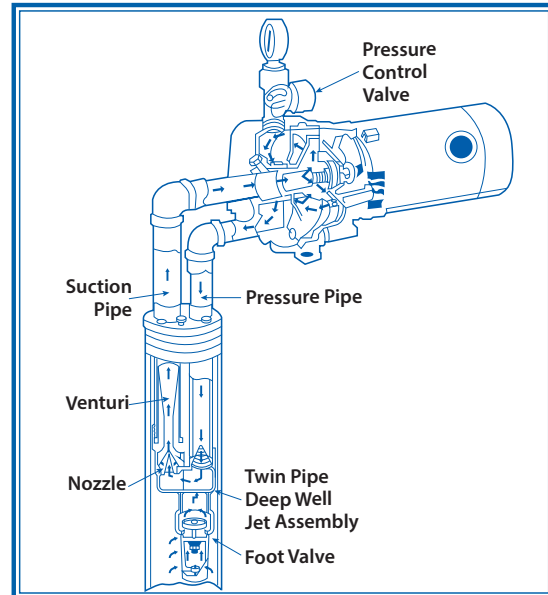
Deep well jet installations require a foot valve below the jet in the well. The purpose of these valves is to keep water from running out of the pipe(s) when the pump stops, and to maintain water in the pressure tank and pressure in the system. This is essential to prevent the centrifugal pump from losing its prime. The foot valve is simply a screened check valve that allows water to flow into the jet when the pump is running but closes tight when the pump shuts off.

Pressure control valves

Deep well jets must also have a **pressure control valve**, which may be an integral part of the pump or attached in the discharge line adjacent to it (Figure II.1.5).

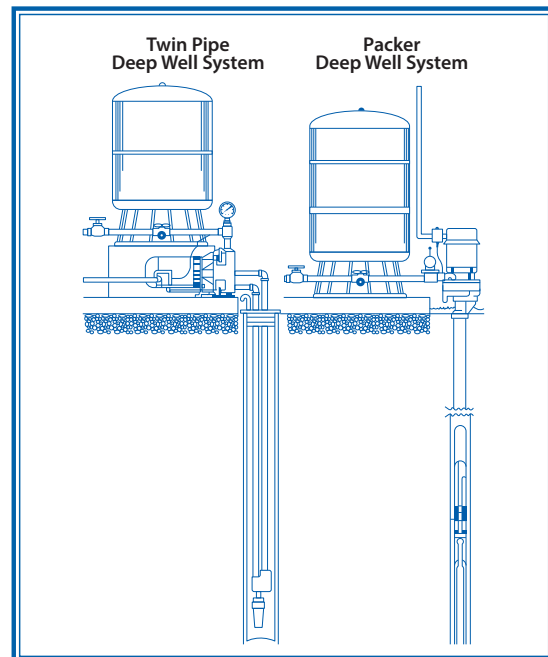
The purpose of this valve is to divert part of the pump output down to the ejector, ensuring adequate pressure to operate the ejector regardless of flow to the tank or service. This valve provides the proper back pressure necessary to carry the drive water down the pressure (drive) pipe to the ejector in the well. Proper adjustment of the valve during installation is basic to the operation of the deep well jet unit.

Figure II.1.5



Arrangement of components in a deep well jet system. The ejector, located down in the well, is connected to both a pressure pipe and a suction pipe.

Figure II.1.6



Alternate deep well jet installations: the two-pipe system (left) and the packer ejector (right). The latter requires a special well casing adapter and a special ejector that fits tightly against the casing. If possible, determine the actual drawdown.

Selecting a jet pump

Many factors affect the performance of a jet pump system. Among the most important are the distance to water, characteristics of the centrifugal pump, ejector design, and **friction losses** in the piping system. In selecting a pump for a given installation, first find out the well conditions and the pressure and **capacity** required. **Depth to water** should also be known, for both the **drawdown** and static water level depth. If possible, find the drawdown by actual test. If this cannot be done, the jet should be installed low enough for local well conditions. Recommended practice is to place it 5 to 10 feet below the maximum drawdown level.

Deep well jet pumps can be equipped with any one of a number of ejectors, depending on the distance to water and the capacity and pressure required. The system's performance is greatly affected by the ejector, so consult the pump manufacturer's performance tables when selecting components for a deep well jet system.

First steps in installing jet pumps

Pump manufacturers usually provide step-by-step installation guides, which should always be followed. In general, they involve the following four steps that apply to both shallow well and deep well jets. Separate installation directions for shallow well and deep well jets follow in separate sections.

1. Determine the well location. Jets can be located at the well or offset some distance from it. For best results, keep the pump as close as possible to the well, in a heated pump house, a basement, or some other suitable site. **Pitless adapters** may be used on offset installations, for either one-pipe or two-pipe installations. Well pits are not recommended due to health, safety, and flooding.
2. Make sure the well is clean. New wells should be pumped free from sand and grit by the well driller before the new pump is installed. Old wells may have to be cleaned to make sure they are free from sand and other materials that could damage pump parts.
3. Check well conditions. Examine the **well log** to determine **casing size, capacity, depth to water, drawdown**, and other factors. Make sure the well has enough capacity to supply the **demand** of the pump.
4. Check the piping. If a piping system already exists, make sure it is in good condition and free from dirt and scale build up. With new piping, ream all threaded joints to minimize restrictions. Use pipe dope on male threads only. Remember that the entire system must be completely leak proof. This means that all piping must be pulled up tight. Take extra care to keep dirt, pipe dope, thread cuttings, and other debris from getting into the system where they might clog the jet nozzle.

Any offset piping should slope upward from the well to the pump. Avoid dips or peaks in horizontal runs, as these may create air pockets. Connect the pump with unions or compression type couplings, so that it will be easy to service. And, most importantly, make sure that all piping is properly sized for the calculated **friction loss**. Minimum suction pipe size should be equal to pump suction size (inlet).

How to install shallow well jets

On shallow well jets, the following steps are taken next:

5. Install a foot valve on the bottom of the suction line. If the pump is going into a driven well, install a horizontal check valve close to the well.
6. Install the well seal at the top of the casing to prevent dirt or other foreign matter from contaminating the well.

7. Attach a tee to the top of the vertical suction pipe and plug the top opening of the tee. The tee facilitates priming, service, and removal of the pump.
8. Connect the suction tapping of the pump to the horizontal opening of the tee. Follow the manufacturer's recommendations for pipe size.
9. Connect the pump discharge tapping to the pressure tank. Install a **shutoff valve** and a union between the pump and the tank.
10. Connect the tank to the house service line.
11. Install the **air-volume control (AVC)**, if required. Diaphragm or bladder type captive air tanks do not need air-volume controls.



12. Complete the electrical connection. Do not operate the pump without properly grounding the motor and filling the pump with water. Wiring and grounding must conform to the National Electrical Code and any local requirements. The **National Electrical Code (NFPA 70)** paragraph 250.112 states: "... noncurrent carrying metal parts of the kind of equipment described in 250.112 (L) and (M) shall be grounded regardless of voltage..."

13. Prime the pump according to the manufacturer's directions. Priming means filling the pump and suction pipe with water. You must evacuate the air from the pump and all the suction lines. It may take several minutes to prime depending on depth to water, pipe size and length. It is easier to prime a pump if you allow all the air to escape from the pipe and pumps. The water cannot go in unless the air can escape.

How to install deep well jets

For deep well jets, the procedure continues as follows.

5. Attach the foot valve to the ejector.
6. Install the ejector on the bottom length of the **suction pipe** and **pressure pipe**. Attach each successive length of pipe until the ejector has reached the desired well depth. When using rigid lengths of pipe, fill the piping with water to check for leakage as each new length goes into the well.
7. Install the well seal.
8. Install a tee at the top of the upper length of the suction pipe and plug its top opening. The tee facilitates priming, service, and removal of the pump.
9. Connect suction and pressure pipes to the proper tappings on the pump.
10. Complete the installation, continuing with Step 9 of the Shallow Well section.

Tail pipe prevents overpumping

The risk of overpumping deep well jet installations can be completely eliminated by using a simple device known as a **tail pipe**. This is nothing more than a 35-foot length of pipe installed between the ejector assembly and the foot valve. Its use assures that the well will never be pumped down to within 5 feet above the foot valve.

To understand how a tail pipe works, remember the operating differences between shallow well and deep well jet pumps. The former works by suction, and in practical operation, the maximum lift is 25 feet. In contrast, the deep well jet operates by using suction to pull the water into the ejector, and pressure to force it to the surface, from depths as great as 300 feet.

Tail pipe should be 34 feet long

If a length of pipe is added to the bottom of the ejector assembly in a deep well installation (Figure II.1.7), the unit operates as a shallow well jet from the foot valve up to the ejector. From the ejector to the surface, it works like a deep well unit. If the tail pipe is 34 feet long, the well level can never be pulled down to the foot valve. The reason is that the shallow well portion of the system (below the ejector) has a theoretical drawdown of only 33.9 feet and a practical limit several feet less.

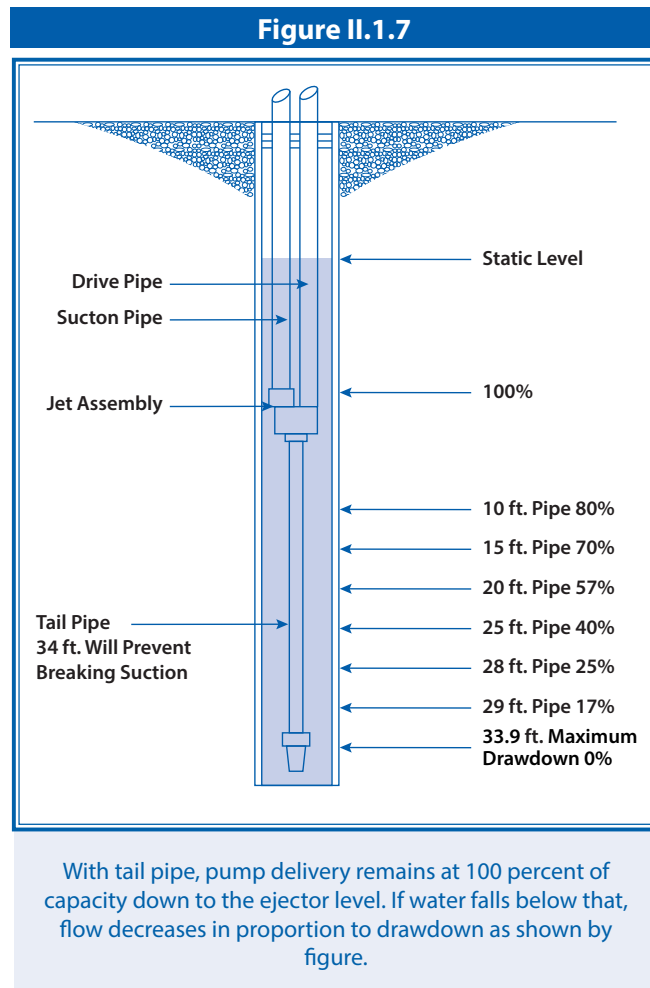
Consider how such a tail pipe would affect the drawdown in a weak well. Assuming that the well production rate is substantially less than the pump capacity, the water level quickly draws down from the standing level to the foot valve. At this point, if there were no tail pipe, air would start to enter the system, and result in a loss of prime.

Well cannot drawdown to 34 feet

With a tail pipe, however, the well continues to drawdown. As it does, the gpm flow decreases (This is an operating characteristic of all shallow well jets. As noted earlier in this chapter, a system equipped with a tail pipe functions as a shallow well jet below the ejector assembly). The numbers shown in Figure II.1.7 show the proportion of rated capacity that will be obtained at various depths below the ejector.

At some level below the ejector, the system's delivery will become equal to the rate at which water is flowing into the well. The pump will then continue to deliver this volume of water as long as it is operating. And when it is shut off, the well will gradually recover to the standing level.

Thus, a tail pipe functions as an automatic throttle to control the flow in weak wells. As long as the level remains above the ejector, full capacity is delivered. When the well is drawn down below that level, capacity is reduced in proportion.



Mechanical shaft seals

The great development of rural and suburban areas created a tremendous demand for packaged home water systems. Because it was more convenient to have the pumping unit inside the house, it was necessary that it be made watertight.

Fortunately, the mechanical seal had proven itself in home refrigerators for many years. It was only natural, then, that it be applied to jet pumps that were first developed for pumping groundwater out of a deep well. Mechanical seals usually prevented water from leaking out of the pump. However, silt and sand in the water soon wore out the seal faces in new wells. One or more seals had to be replaced until the water was free of these abrasive particles.

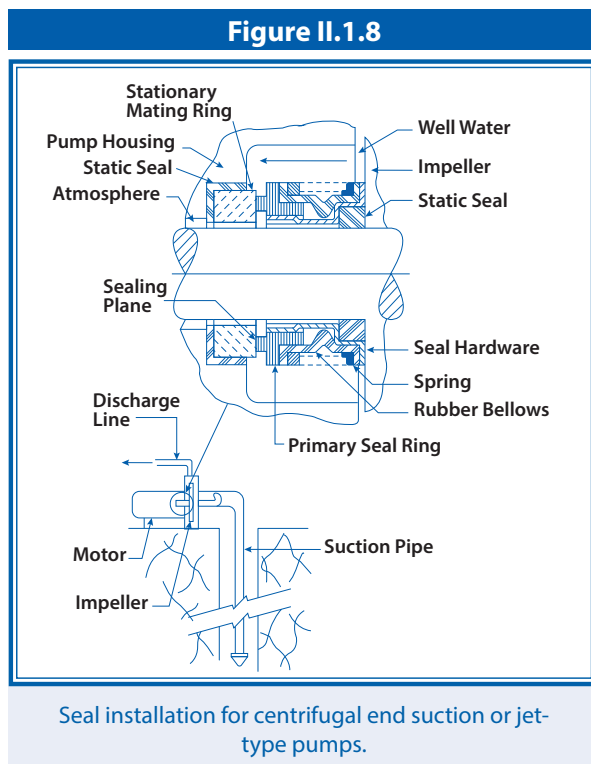
The first seals on jet pumps used a carbon rotating face and bronze for the stationary element. Ceramics also showed promise as better seals. Manufacturers eventually came up with ceramic seals, which are made from aluminum oxide, a substance that is almost as hard as a diamond. Changes in shape were made to take advantage of the most economical means of manufacturing the ceramic part. Today, ceramics are accepted as an economical and efficient material for the stationary element of a pump seal.

Description of mechanical seals

The terms axial mechanical seal or end face seal designate a sealing device that forms a running seal between flat precision-finished surfaces. Sealing is accomplished by a primary seal ring that rotates with the pump shaft and runs against a stationary mating ring as illustrated in Figure II.1.8. These parts form the sealing surfaces in a plane at right angles to the shaft.

The purpose of placing the sealing surface in this location is to provide the water systems industry with a seal that will not wear or score the shaft. All the sealing, relative motion and wear takes place at the seal faces. The mechanical load designed into the seal and hydraulic pressure from the water system are the two forces that hold the rubbing seal faces together.

All mechanical seals have the same basic components: primary and mating seal rings, a spring, hardware, and static seals. A static seal stops leakage of water past the primary and mating seal rings. This type of seal may take the form of a bellows or an o-ring. Flexibility, an important feature, is designed into all mechanical seals. This is accomplished through the proper use of component hardware and spring loading. Flexibility allows the primary seal ring to handle normal wear at the seal face, as well as mechanical motion and vibration of the equipment.



Life of mechanical seals

The life of a mechanical seal is usually governed by the degree of contamination in a system lubrication and cooling characteristics. Water pressure is somewhat of a factor in seal life, especially when the water contains abrasive particles. Modern face materials are available to extend the life of the mechanical seal and to handle abrasive particles.

Despite reduced life under extreme conditions, mechanical seals are used more extensively than any other type of seal. Successful performance in water systems has led to the use of these devices in many underwater applications.

Study Guide Questions - Chapter 1

Answers can be found on page 64

Q. What are two pumping principles of jet pump operation?

1. _____ 2. _____

Q. Name the parts of an ejector or jet.

Q. What are the advantages of jet pump operations?

Q. What does the pressure control valve do?

Q. List the first four (4) steps for installing jet pumps.

Study Guide Questions - Chapter 1

Answers can be found on page 64

Q. What is a tail pipe and what does it do?

Q. What materials are commonly used today to manufacture mechanical shaft seals?

Q. What factors govern the life of a mechanical seal?

Chapter 2

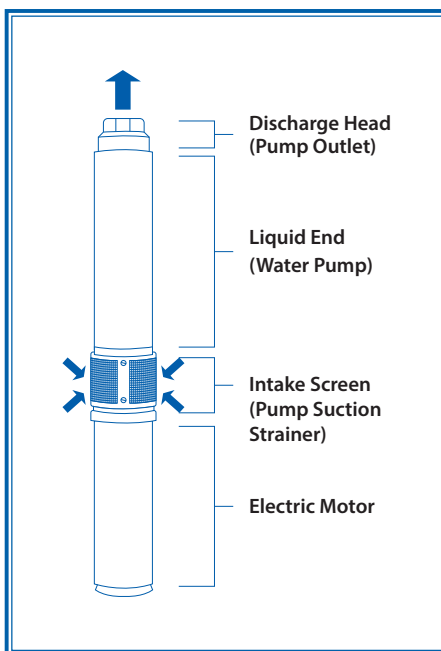
Submersible Pump Operation and Installation

- ✓ Principles of operation
- ✓ Type of motors
- ✓ Power requirements
- ✓ Installation techniques and procedures

Submersible pumps are currently the most widely used pumps for water systems. Its pump end consists of a **multi-stage centrifugal submersible pump** (Figure II.2.1). Its motor is of special construction, designed to operate while submerged under water.

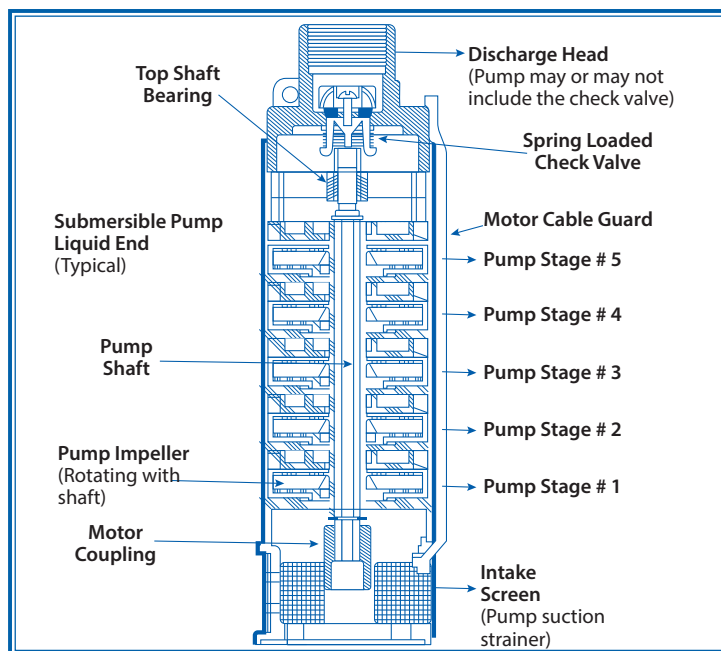
Submersible pumps (Figure II.2.2) have been a significant part of home and community water systems since the late 1940s. Technological advances involving both materials and production techniques permitted the relatively rapid growth of the submersible pump in water pumping. Before then, submersible pumping was primarily confined to mining and oil pumping applications.

Figure II.2.1



Typical multi-stage centrifugal submersible pump.

Figure II.2.2



Typical multi-stage centrifugal submersible pump.

The growth of the submersible pump can be attributed to several features unique to multi-stage pumps:

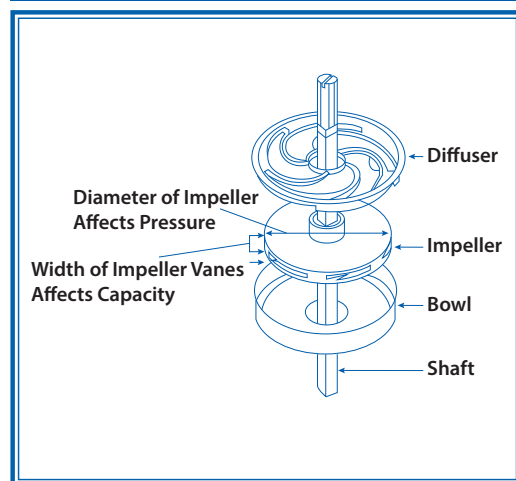
1. Higher system efficiencies are possible. All water pumped from the well is delivered to the service outlet. No water is recirculated, as in a jet pump application.
2. As capacity and pumping depth requirements increase, submersible pump installations and performance advantages increase.
3. Multi-staging of the centrifugal impellers and diffusers makes it possible to match the pump to system requirements.
4. Development of corrosion/abrasion resistant materials and improved manufacturing methods ensure a long life, even with the entire pumping unit operating submerged in the hostile environment of the water well.

Operation of impellers and diffusers

All of the impellers of the multi-stage submersible pump are mounted on a single shaft, and all rotate at the same speed. Each impeller passes the water to the eye of the next impeller through a diffuser. The impeller increases the velocity of the water and discharges it into the surrounding diffuser. The diffuser is shaped to slow down the flow of the water and convert velocity to pressure. Each impeller and matching diffuser is called a pump stage. As many stages are used as are necessary to lift the water out of the well at the required system pressure and capacity (Figure II.2.3).

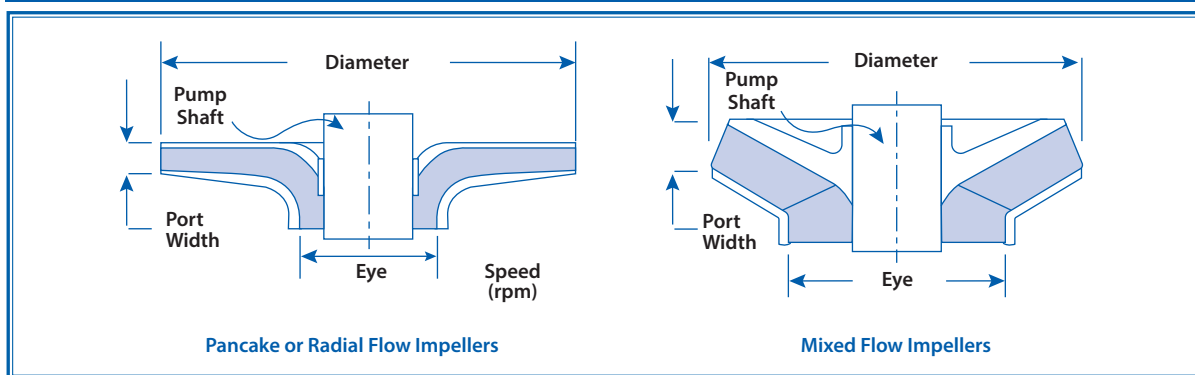
The capacity of a **multi-stage centrifugal pump** is largely determined by the design width of the impeller and diffuser, regardless of the number of stages (Figure II.2.3). The pressure is a function of the diameter of the impeller, the speed at which it rotates, and the number of impellers. The head (pressure) developed is proportional to the square of the speed and the square of the diameter. Diameter is greatly limited by the cost of well drilling. Therefore, most centrifugal submersibles are designed to fit in 4-inch or 6-inch wells (Figure II.2.4).

Figure II.2.3



Typical three-piece stage consisting of bowl, impeller, and diffuser.

Figure II.2.4



Multi-stage centrifugal impeller.

Power needed depends on pressure, capacity, and efficiency

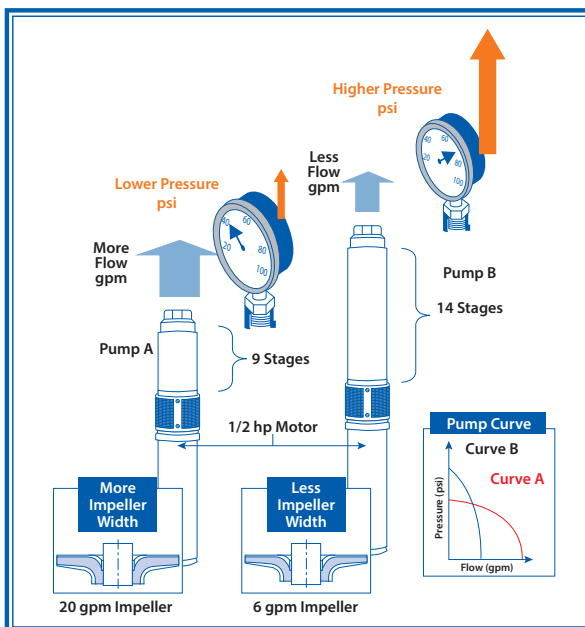
Motor rating, the power required to drive the pump, is a function of head, capacity, and the pumping unit efficiency. For this reason, submersible pumps cannot be compared on the basis of horsepower alone. While one might be designed for low head and high capacity, another could be designed for high head and low capacity. Thus, a 1/2-horsepower pump with nine impellers (designed mainly for capacity) would deliver more water at 80 feet than a 1/2-horsepower pump with 14 impellers (designed for pressure). But the latter pump would be able to raise water from a much greater depth (Figure II.2.5).

Types of submersible motors

The **submersible motor** is always submerged in well water, so the principal design goal is to make it waterproof. The motor's wet environment would cause it to ground or short out if water were to contact with the electrical circuits. Therefore, of the several motor designs in common use, all are aimed at keeping the motor winding isolated from the well water. The common motor design is potted (sometimes known as canned) windings and water-filled (Figure II.2.6), and is described in detail in Book II, Chapter 4.

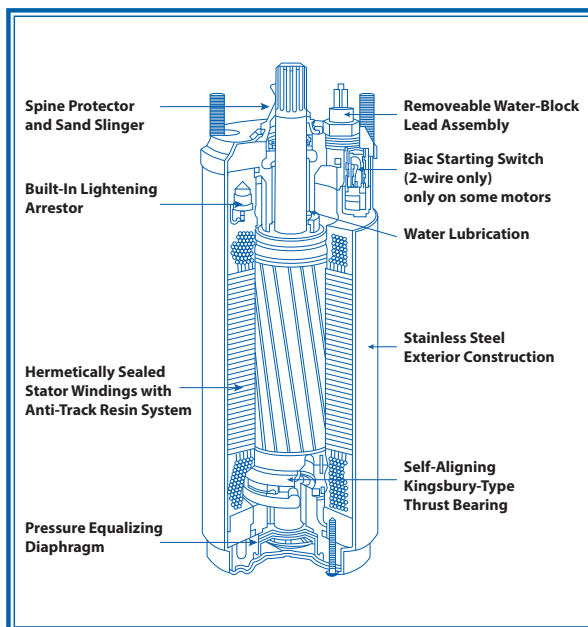
There are three common types of submersible motors: single-phase with three-wire cable plus ground, single-phase with two-wire cable plus ground, and three-phase with three-wire cable plus ground.

Figure II.2.5



Power needed depends on pressure, capacity, and efficiency.

Figure II.2.6



Potted (sometimes known as canned) water filled.

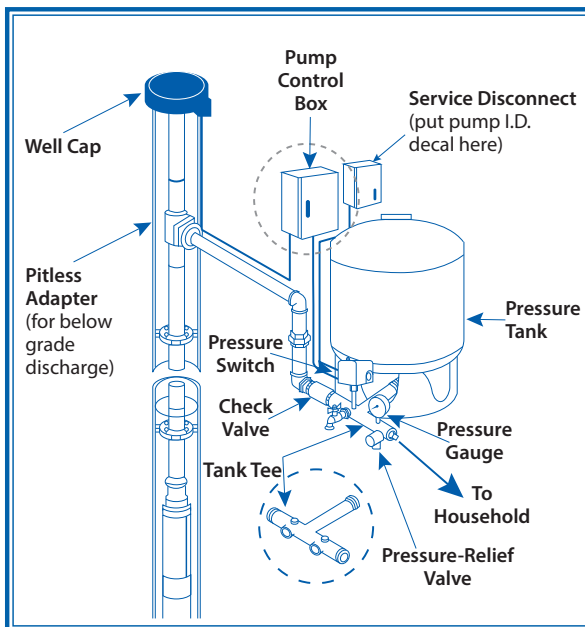
Single-phase three-wire motors with ground

Single-phase motors are not inherently self-starting the way three-phase motors are. Therefore, some auxiliary starting method is necessary. In submersible motors, a **starting capacitor** is usually connected to a **start winding** of the motor. The **capacitor** is used to get the motor started and almost up to running speed. Then a switch disconnects the capacitor and start winding, and the motor operates on its run windings.

The disconnecting switch is usually a relay, either voltage-operated or current-operated. This switch is placed in a control box together with the starting capacitor and, sometimes, an overload protector and a run capacitor. The control box is above ground. Hence, it requires a three-wire cable to connect it with the motor. The three wires referred to in this case include two power conductors and a starting-winding conductor, but do not count any grounding conductor that may be present in the cable. This should not be confused with a three-phase system or a 230-volt single-phase system with three wires. (Figure II.2.7 and Figure II.2.8).

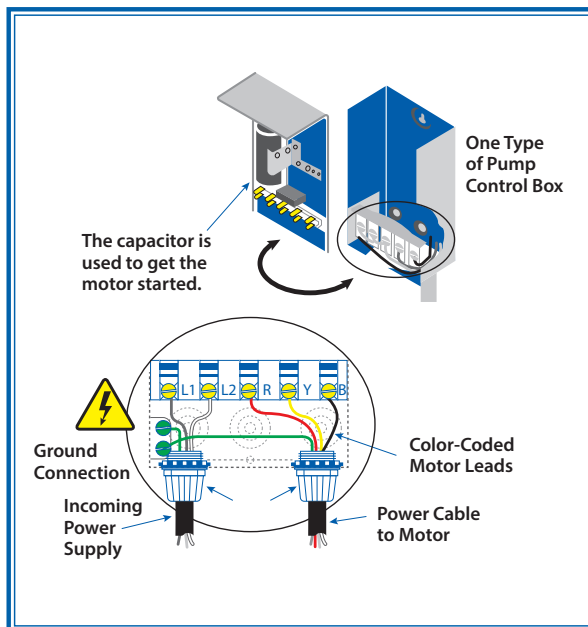
Control boxes are sized by the motor manufacturer to match the motor as to voltage, horsepower, and starting characteristics. The control box of one manufacturer may not be compatible with the motor of another manufacturer.

Figure II.2.7



Typical single-phase three-wire submersible pump installation.

Figure II.2.8



Typical installation of a three-wire control box.

Single-phase two-wire motors with ground

Two-wire motors are those that have starting capability within the motor and, therefore, only require two-wire cable with ground (Figure II.2.9). The overload protectors may be mounted in a box on the surface or imbedded in the motor windings. The two wires referred to are power conductors, and do not count any grounding conductor that may be present in the cable.

Three basic means of starting are in popular use today: **split-phase starting method**, **capacitor-start/induction-run starting method**, and **permanent split-capacitor starting method**. The first two methods require an internal switch, either mechanical or solid-state electronic, and the third has a run capacitor connected in series with the start winding at all times.

Three-phase motors

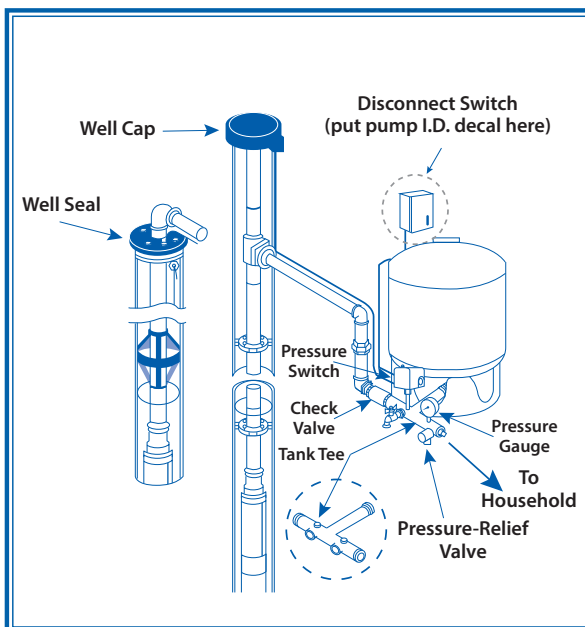
Three-phase motors are self-starting. Therefore, they do not require control boxes with capacitors or switches. (Figure II.2.10)

However, three-phase motors must be provided with starters containing three-leg overload protection. The starters may be of the conventional type, but the overload protection must be Class 10, quick trip type. Furthermore, starters must be the size recommended by the manufacturer in order to protect the motor under abnormal starting conditions and guard against single-phasing and voltage unbalance.

Keep in mind that three wires leading from a power supply do not necessarily indicate three-phase current because most 230-volt single-phase supplies carry a grounded neutral wire.

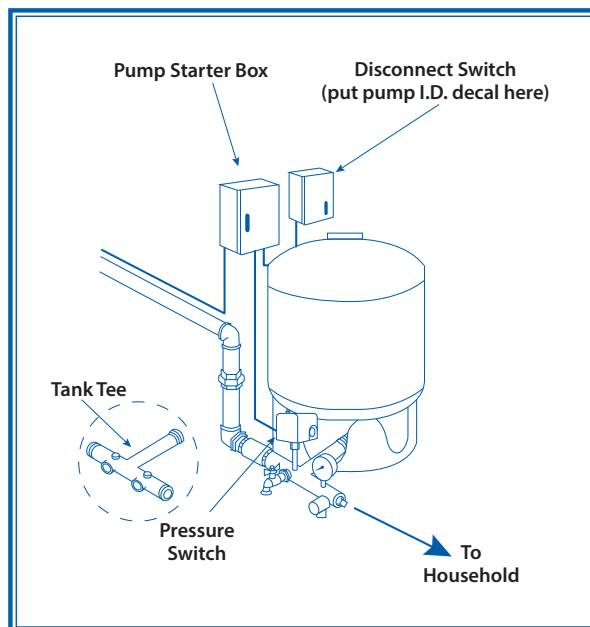
Temperature-compensated overload protection is recommended, especially where the starter is subjected to a wide variation in temperature. A starter should always be protected from direct sunlight and rain, and extremes of heat or cold.

Figure II.2.9



Typical single-phase two-wire submersible pump installation.

Figure II.2.10



Typical three-phase submersible pump installation.

Power supply must match motor

Most submersible pump problems are electrical. Hence it is most important to have an adequate power supply and to protect the motor from abnormal voltage and current conditions that sometimes occur on power supply lines.

As noted earlier, there are three common types of submersible motors:

- (a) single-phase with three-wire cable plus ground;
- (b) single-phase with two-wire cable plus ground; and
- (c) three-phase with three-wire cable.

The motor, control, cable, and power source must match. Before running a pump, check to make sure that all devices – motor, control, and power source – are of the same rated voltage, phase, and frequency, and that the power supply is adequate to handle the starting and running load of the motor. Overload protection required, refer to manufacturer.

How to connect power supply

When working with electrical circuits or connecting the pump motor, always make sure the electric power is turned off at the main disconnect switch or power meter. The circuit should be locked out, tagged, and tested using a **voltmeter** to verify that it is de-energized. Lock out and tagging prevents another person from accidentally re-energizing a circuit while you are working on it.

Single-phase three-wire and two-wire pumps are usually rated at either 115 or 230 volts. A 115-volt power source has only two power conductors: The neutral line is white and is always connected to ground in the main disconnect switch or service panel. The other line is called the hot line and may be any color other than white, green, or yellow with a green stripe. Connect the hot line to either a single pole disconnect switch or a circuit breaker or fuse in the service panel. Make sure that only the hot line is fused.

A 230-volt power source has two hot lines and usually a third line called neutral. In connecting a 230-volt submersible pump, only the two hot lines will be used. These should be connected to a disconnect, a double-pole breaker, or two fuses in the service panel. The color-coding of the motor cable is independent of the power source wire color-coding.

Three-phase motors are normally rated for 230 or 460 volts. The three lines should be connected to a three-pole fused disconnect switch and a starter with three-pole ambient Class 10, quick-trip overloads to trip the motor within 10 seconds of a fault to protect the motor windings.

Fixed heater overloads must be the ambient compensated Class 10, quick trip type to maintain protection at high and low air temperatures.



All electrical equipment and wiring must comply with national and local electrical codes, with grounding of all metal enclosures especially important for safety. The **National Electrical Code (NFPA 70)** paragraph 250.112 states: "... non-current carrying metal parts of the kinds of equipment described in 250.112 (L) and (M) shall be grounded regardless of voltage..."

- (L) Motor-Operated Water Pumps. "Motor-operated water pumps, including the submersible type."
- (M) Metal Well Casings. "Where a submersible pump is used in a metal well casing, the well casing shall be bonded to the pump circuit equipment grounding conductor."

Pre-installation tests must be made

To get satisfactory performance – and safety – from a submersible pump, install it according to the manufacturer's directions. Complete as many pre-installation checks as possible in the shop to save extra trips and added expense.

Here is the pre-installation routine:

1. Remove the pump from its shipping carton and check it for damage.
2. Check the nameplate against the intended specification for the well.
3. Examine the check valve to make certain it is free and will close of its own weight or by spring pressure.
4. Splice the cable. There are several ways to make a good splice, so follow the manufacturer's procedure. Make sure that the splice is kept clean and is made without flexing the wires unnecessarily. Otherwise, the wires may fatigue and break during later handling. Always put shrink wrap over one of the wire ends before crimping wires. Carefully observe the color-coding of wires with single-phase three-wire units.
5. Check the electrical supply. The power source should be checked for proper fusing, proper wire size, grounding, and transformer size, all as recommended by the manufacturer. Lightning protection, in the form of a secondary **lightning arrestor**, is strongly recommended, but these devices are of no value unless they are installed and grounded properly.



6. Warning: All submersible pumps must be grounded to prevent electrical shock hazards by connecting the motor frame to the power supply grounding terminal with a copper wire no smaller than the power cable wires. In any pump installation, all of the above-ground metal plumbing must be connected to the power supply ground as required by electrical code to prevent electrical shock hazard. A submersible pump should not be operated out of the well or out of water even for a few seconds. Doing so may result in damage to the pump and motor. Do not install in swimming areas.

7. Check rotation of three-phase units. Installers have used several methods to check for a proper rotation of three-phase units. The safest and most acceptable way is as follows: Briefly run the pump and note capacity and/or pressure. Switch any two leads at the starter and repeat the procedure. The combination resulting in higher flow is the correct one. Measure and record the following resistance values (in ohms) of the motor, line-to-line resistance, and line-to-ground resistance. Fixed heater overloads must be the ambient compensated Class 10, quick trip type to maintain protection at high and low air temperatures.

Equipment needed to install submersibles

To properly install a submersible pump, use pipe wrenches, pipe vises, or clamps, and equipment to support the weight of the pump, pipe, electrical cable, and **pitless adapter** as it is lowered into the well.

In addition to the control box for the pump, the installer must have enough pipe, electrical cable for the pump motor, **cable ties** to fasten the cable to the pipe from the pump, waterproof electrical splice kit, pitless adapter, **torque arrestor**, **cable guards**, and **check valves**. Refer to Book IV, Chapter 2 for more details.

Most pumps will require connection of a **pressure tank** (Book IV, Chapter 1) to the piping system with a **tank tee** fitting and other pipe fittings as required. The tank tee provides a convenient location to install the **pressure gauge** and **pressure switch**. (Book III, Chapter 1).

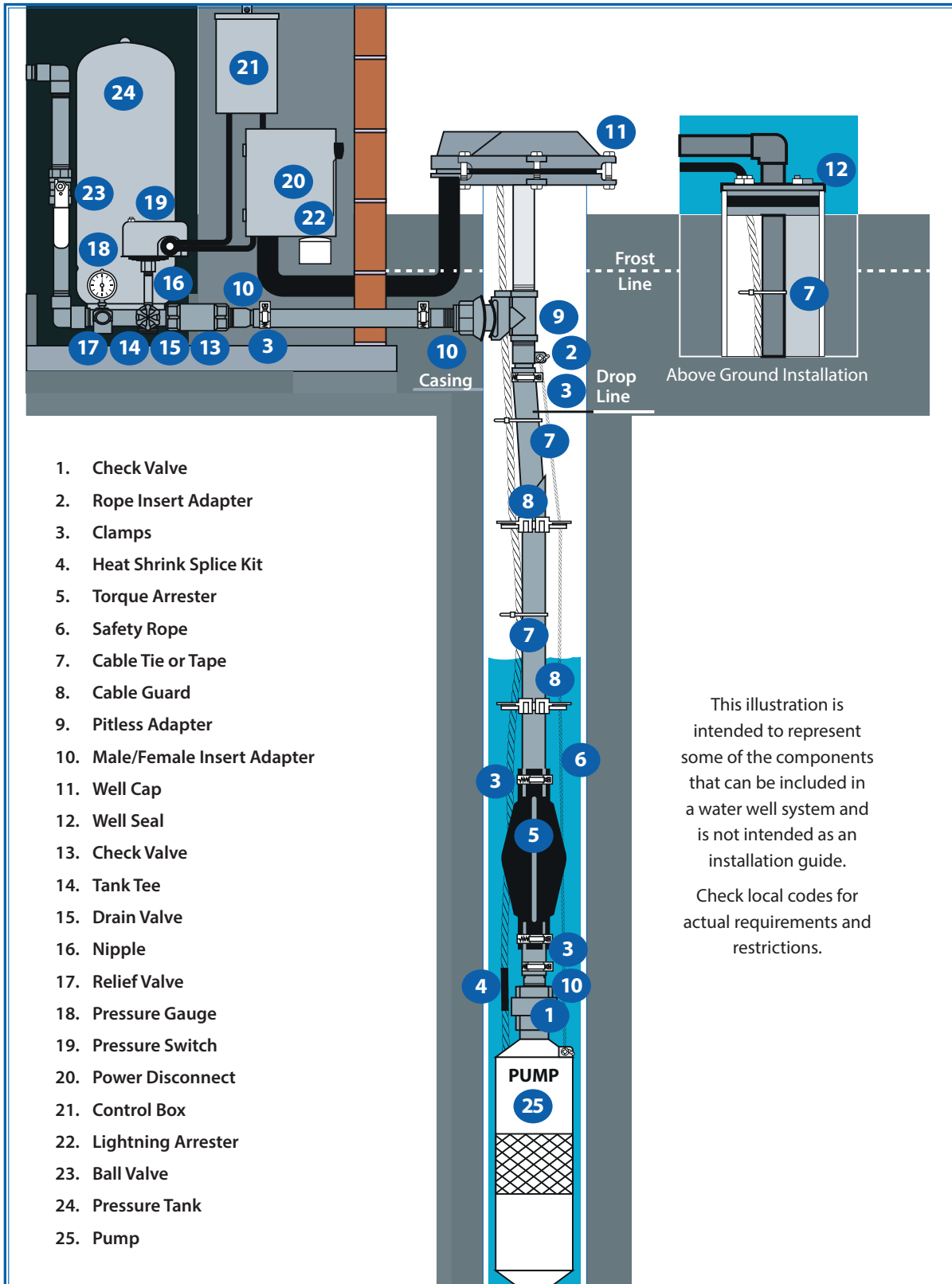
Follow the manufacturer's procedures to check the pump after it has been installed.

Step-by-step installation procedure

After the pre-installation procedure is finished, the pump is ready to be installed. Follow these steps (Figure II.2.11, page 28):

1. Chlorinate the well. **Chlorination** disinfects the well water, pressure system, and distribution system to inhibit the growth of iron bacteria that could later plug the well and pump. The chlorinated water will be pumped through the system during testing of the pump flow. This procedure is outlined in detail in Book V, Chapter 2.
2. Check the well casing. The upper edge of the casing should be smooth; jagged edges could cut or scrape the cable and cause it to fail in the well.
3. Attach the pump to the drop pipe. Attach safety rope to the top of the casing. Screw the pump onto the pipe and tighten. When using a pipe wrench on the pump, put it at or near the threads on the outlet casting – not on the pump body. In some areas, the use of an insulated or dielectric bushing between the pump and the first section of pipe is desirable. The purpose is to prevent electrolytic corrosion between the pump head and the galvanized steel pipe.
4. Lower the pump into the well. The drop pipe is usually threaded lengths of galvanized steel or plastic, or one continuous length of flexible plastic. Use a pump hoist or other method to lower the pump and drop the pipe into the well, making sure it is securely supported at all times to prevent injury and to avoid dropping the pump. Feed the cable into the well while the pump is lowered, being careful to prevent physical damage, and fasten it to the pipe with cable ties at least every 10 feet.

Figure II.2.11

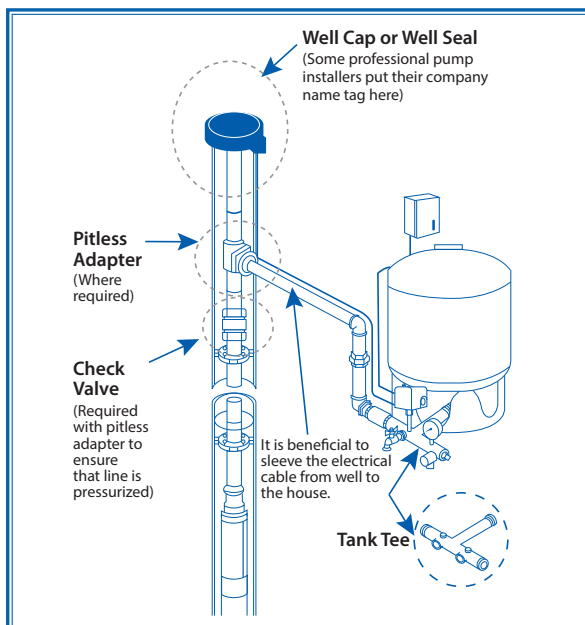


Typical installation of a submersible pump. Individual steps in making the hookup are described in the text. NOTE: Use only waterproof UL-approved electrical tape.

5. Air charger. Most modern water systems use factory air-charged pressure tanks, which require no recharging to maintain the correct air volume in the tank. If a system uses a plain pressure tank that requires air recharge, install the air recharge system in the pump delivery line in accordance with the manufacturer's instructions.
6.  Wellhead connections. (Figure II.2.12) Most submersible systems use underground discharge connectors, commonly called **pitless adapters**, below the freeze line to prevent freezing and minimize the potential for contamination. Underground wiring eliminates the possibility of physical damage or vandalism from above ground. Follow the manufacturer's instructions and applicable codes for installation. Finish or close the top of the well above ground with a **well cap** that meets state and local codes.
7.  Wire the pump. After the pump is set as described here, the electrical work should be completed carefully while observing all national and local codes. Particular attention should be given to proper grounding and other safety requirements. Connect all metal enclosures and plumbing together and connect them to the power supply ground with wire that is no smaller than motor wire. The National Electrical Code (NFPA 70) paragraph 250.112 states: "non-current carrying metal parts of the kinds of equipment described in 250.112 (L) and (M) shall be grounded regardless of voltage..."
 - (L) Motor-Operated Water Pumps. "Motor-operated water pumps, including the submersible type."
 - (M) Metal Well Casings. "Where a submersible pump is used in a metal well casing, the well casing shall be bonded to the pump circuit equipment grounding conductor."

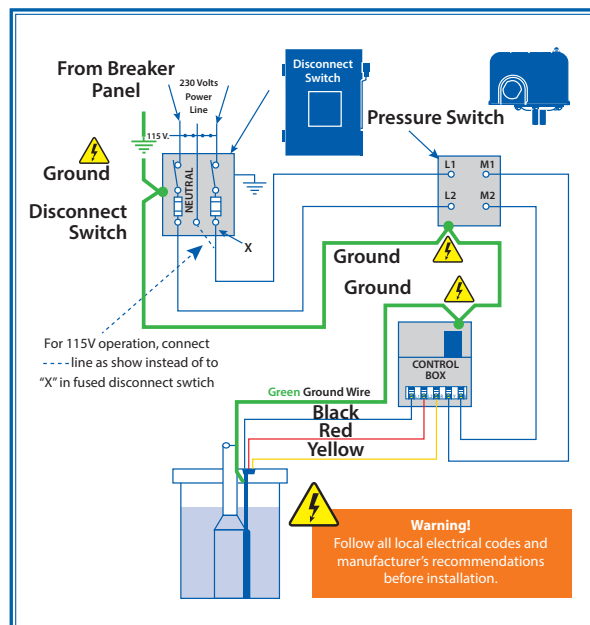
Install and connect all equipment and wiring as shown in the manufacturer's instructions and in compliance with national and local electrical codes. The following descriptions and diagrams show typical connections for single-phase and three-phase systems that can be used for general guidelines. All connections at the motor and splices at the pump must be absolutely watertight, and made as instructed by the manufacturer.

Figure II.2.12



Installation procedure showing wellhead connections.

Figure II.2.13

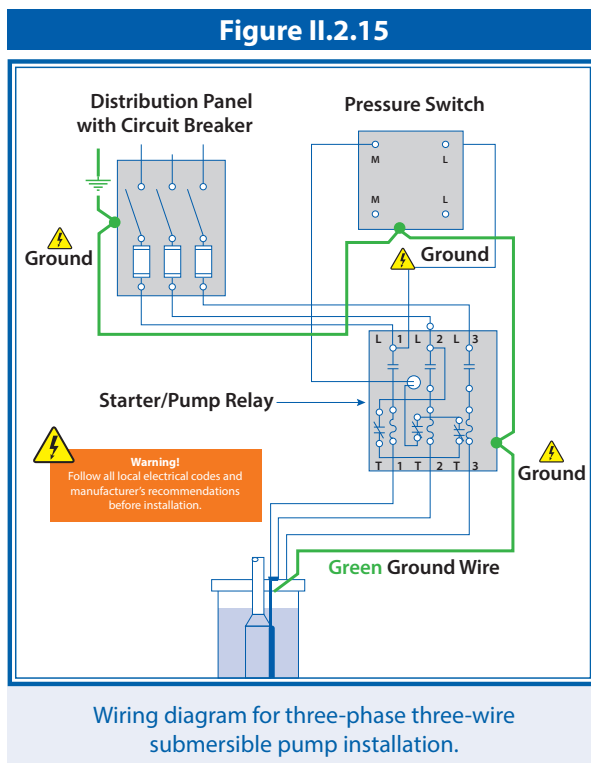
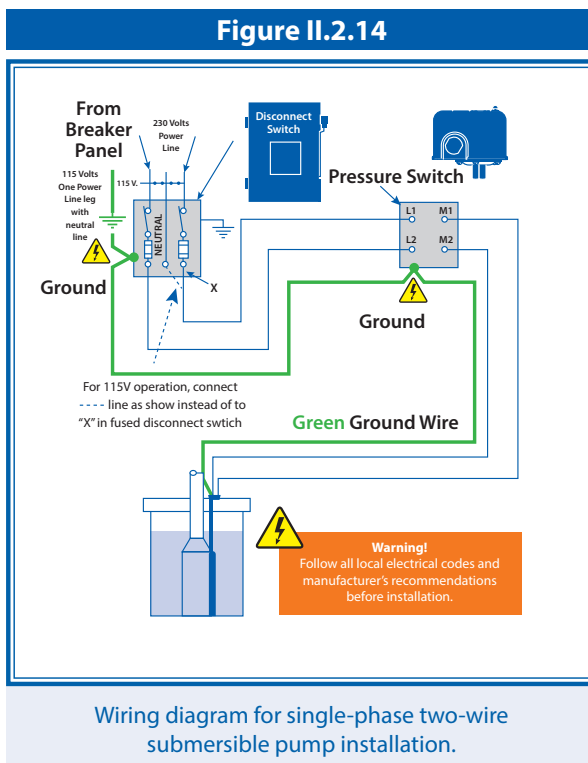


Wiring diagram for single-phase three-wire submersible pump installation.

Single-phase three-wire units: Make sure all power is off, that you have locked out and tagged the circuit, and measured for zero voltage on the conductors you want to work on. Figure II.2.13 (page 29) shows typical connections for a single-phase three-wire system. Connect grounding and power wiring as shown, making sure all connections are clean and tight, and that lead colors or other identification match the diagram.

Single-phase two-wire units: Make sure the power is off, that you have locked out and tagged the circuit, and measured for zero voltage on the conductors you want to work on. Refer to Figure II.2.14. Connect the two leads from the disconnect switch to the line terminals of the grounded pressure switch. Next, connect the leads of the motor cable to the load or motor terminals of the switch. The other end of the pump cable should be connected to the motor as described here for three-wire units.

Three-phase three-wire units: Make sure the power is off, that you have locked out and tagged the circuit, and measured for zero voltage on the conductors you want to work on. Refer to Figure II.2.15.



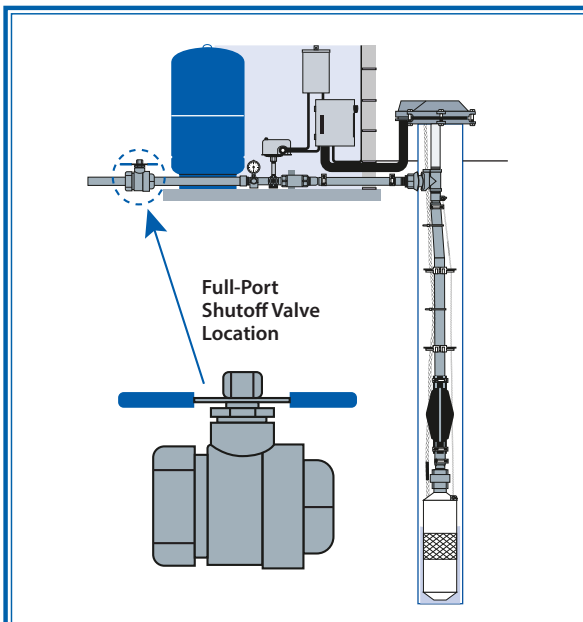
Connect the three leads from the disconnect switch to the line terminals of a three-pole starter. Next, connect the three wires of the motor cable to the load terminals of the starter. When power is applied, the motor may run either way, depending on phase rotation. If the rotation is incorrect, interchange any two of the motor leads on the load terminals of the magnetic starter. Do not operate a three-phase motor backward for more than 60 seconds.

8. Install a shutoff and union to facilitate installation and servicing (Figure II.2.16, page 31). This also makes it possible to throttle down a weak or low-yield well. A square-head stem valve between the **check valve** and the **pressure tank** is often used instead of a valve with a hand wheel because the square-head type is less likely to be tampered with. It also gives less friction loss. A flow control valve may also be used. They are designed to maintain a defined flow regardless of pressure variations.

9. Test the well water. After wiring the pump, test the well water for clearness by running the pump. This is best done before hooking up the tank. The pump discharge should be connected to a throttling valve. Open the valve partially and start the pump by closing the disconnect switch. In three-phase installations, if water does not flow within 60 seconds, the pump may be running backward. Reverse any two leads as described earlier.

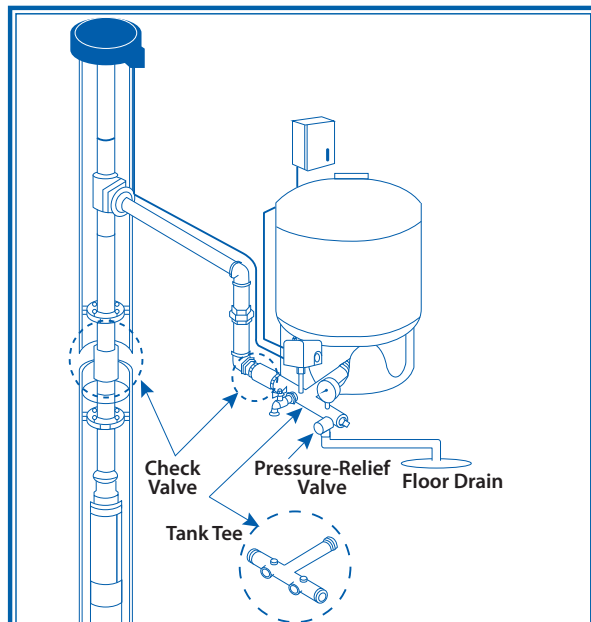
If the discharge is murky, or a glass jug filled with the water shows a sand deposit on the bottom, let the pump run until the water clears. Shutting it off at this time might cause it to sand lock. Continue pumping, gradually opening the throttling valve until it is fully open. If the water fails to clear up within the time specified by the manufacturer, the murkiness may be permanent. This would shorten the pump life, and the installer should consider pulling it before the pump is permanently damaged. See the manufacturer's warranty. When the well produces clear water, discontinue test pumping.

Figure II.2.16



Install a valve and union to facilitate installation and servicing, per local code.

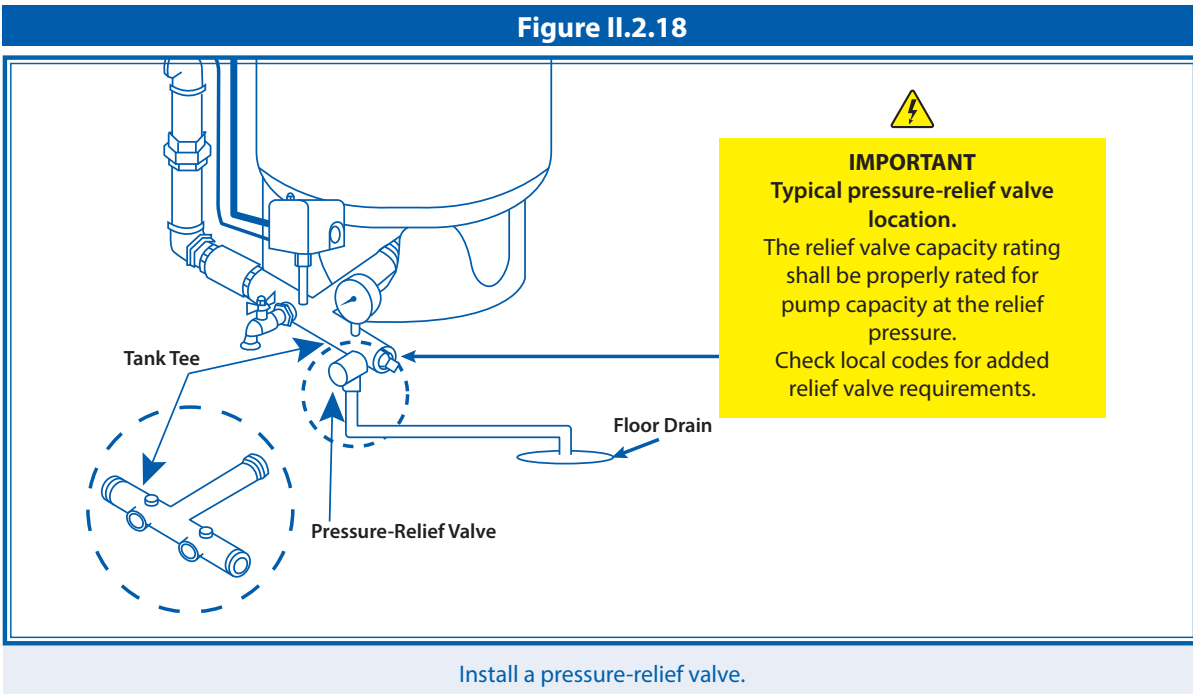
Figure II.2.17



Check valve.

10. Install the check valve. A check valve may be installed in the horizontal piping from the well top to the tank. Do not install with plain steel tanks. Follow the recommendation of the check valve manufacturer as to the proper spacing and placement of the check valve(s) in a system. The check valve holds water in the tank when the pump is idle. However, it should not be used in place of the valve just above the pump unless an air intake device is being used. If an air intake-type of bleeder is required, it should be on the pump side of the check valve (Figure II.2.17).
11. Install the tank with necessary controls. (Book IV, Chapter 1)
12. Install the pressure switch. The pressure switch is mounted on the tank or on the piping near the tank and wired between the disconnect switch and motor control box on single-phase motors up to a maximum of 2 horsepower, 230 volts. Larger single-phase motors require the use of a contactor. The pressure switch is used as a pilot device only with three-phase motors using magnetic starters, and single-phase motors using contactors.

13. Ensure surge protection. Groundwater is a true ground, especially if an electrical path such as a submersible pump motor and its cable are present. Lightning or other power surges can damage the pump and water system if protection is not provided. It is essential that control boxes for submersible motors and pressure switches be installed with lightning arrestors, and that they are properly grounded according to the manufacturer's recommendations.
14. Install the auxiliary equipment. Submersible pumps are capable of developing high-pressure heads. When the pump has the capability to develop pressures higher than the working pressure of the water system pressure tank, the tank must be protected from the possibility of excessive pressure if the



pressure switch fails to open properly.

A **pressure-relief valve** should be installed near the tank and be of sufficient capacity at relief to keep the system pressure below the working pressure of the tank (Figure II.2.18). Check local codes for added relief valve requirements and proper plumbing to a floor drain: sump pump, main sewer line, or outside.

15. Make a final check. When the installation is complete, check the running current with a clamp-on type **ammeter**. After turning off the power, check the installed resistance with an **ohmmeter**. Compare these results with those of the pre-installation tests. When checking the ohm resistance of the motor, be sure to add the ohm rating for the length and gauge of wire installed to the ohm rating specified by the motor manufacturer. The data will be useful if a service call is necessary. Refer to the manufacturer's installation manual for safe limits of current and resistance. Also check the line voltage at the control box or the magnetic starter during start and run conditions. Make sure this voltage is within the limits of the pump manufacturer's recommendations. The tolerance is typically plus or minus 10% of the nameplate voltage.

Study Guide Questions - Chapter 2

Answers can be found on pages 65

Q. How are a pump's capacity and pressure determined?

Q. Name the three types of submersible motors.

1.

2.

3.

Q. What is the recommended pre-installation routine for submersible pumps?

Q. What equipment is required to install a submersible pump?

Chapter 3

Positive-Displacement and Booster Pumps

- ✓ Installation
- ✓ Operation
- ✓ Control of positive-displacement and booster pumps

Positive-displacement water system pumps force or displace the water through a pumping mechanism. There are many types of positive-displacement pumps, although few are still in use for water system applications today, having been superseded by jet pumps and submersible pumps.

I. SHALLOW WELL RECIPROCATING PUMPS

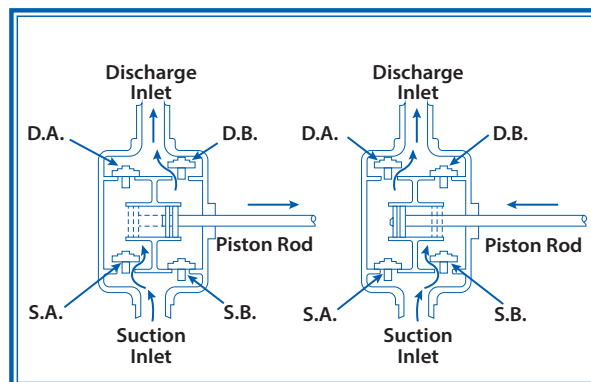
In a **piston pump**, a mechanical linkage moves a plunger (piston) back and forth in a closely fitted cylinder. The piston is driven by a power source through a crankshaft that converts a rotating action into a reciprocating motion. Do not use a piston pump with a **pressure tank** unless a relief valve is installed.

Double-acting piston pump

Figure II.3.1 illustrates the water end of a typical horizontal **double-acting piston pump**. The piston is shown at each end of its stroke. These are two separate water chambers with a suction and discharge valve in each. The piston operates through a cylinder in the center of both chambers. As the piston moves to the right, water is forced out of the discharge valve (D.B.). At the same time, a suction or vacuum is developed in the left chamber, permitting well water to enter through the suction valve (S.A.). On the reverse stroke (as the piston moves to the left), water is forced out through the discharge valve (D.A.) and well water enters the suction valve (S.B.) in the right chamber.

Because water is pumped when the piston travels in each direction, this is called a double-acting piston pump. All piston pumps are called reciprocating pumps because the piston reciprocates from one end of the cylinder to the other.

Figure II.3.1



Operation of a double-acting piston pump. In this sketch, the pump is drawing water into the left chamber and discharging it from the right one. When the piston moves to the position shown on the right, the action reverses.

Shallow well helical pump

Another type of shallow well positive-displacement pump is the **helical pump** or **spiral rotor pump** (Figure II.3.2). It consists of a molded rubber **stator** in helical form, in which a helical metal shaft rotates. As the helical shaft turns and rolls, it pockets or traps water between the rotor and stator, squeezing it ahead of the rolling action and forcing it out the pump discharge. Because the action of the rotor in the stator is continuous, the liquid flow is uniform.

Regenerative turbine pump

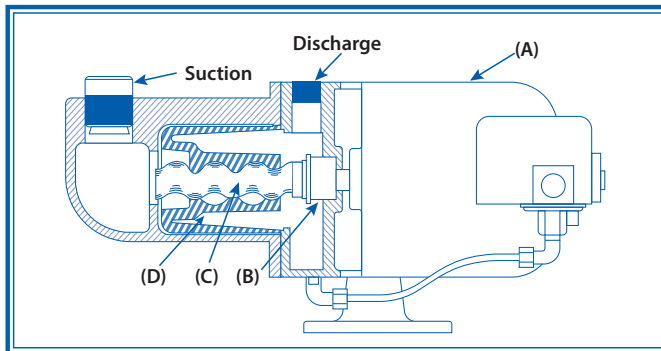
One other type of shallow well positive-displacement pump is the **regenerative turbine pump**. This pump uses a rotating wheel or impeller that has a series of **blades** or fins (sometimes called buckets) on its outer edge and a stationary enclosure called the casing or raceway (Figure II.3.3).

Water enters the suction opening in the casing or raceway near the outer edge of the impeller. Here it is picked up by the vanes or buckets on the impeller and drawn into the pump channel (Figure II.3.4). As the water is carried along the channel, it revolves, passing from one bucket to another in a spiral path. These pumps can develop pressures several times that of pumps relying solely on centrifugal force.

Shallow well pump characteristics

As **shallow well pumps**, these positive-displacement units will lift water from depths up to 25 feet. They are all self-priming after the pump case has been filled with water. Delivery characteristics of positive-displacement pumps remain about the same throughout their pressure range. Horsepower requirements increase as the pressure increases. These pumps should not be operated at pressures higher than those recommended by the manufacturer. Operation at excessive pressures will cause the motor to overload and could damage the pump.

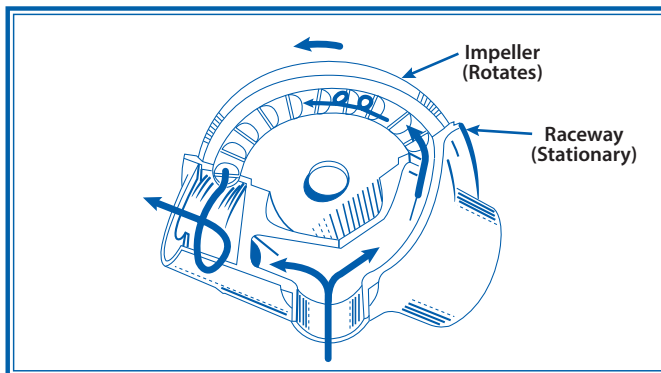
Figure II.3.2



Shallow well helical pump.

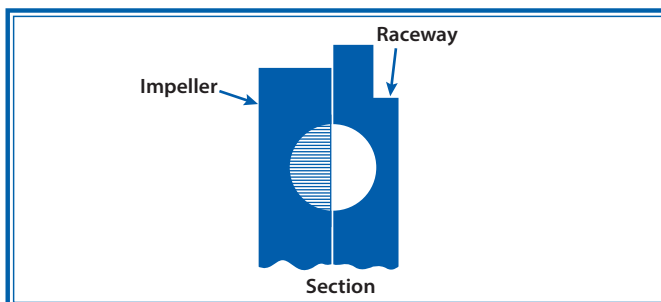
The helical metal shaft (C) rotates in a molded rubber stator (D), trapping water and forcing it toward the discharge end. (B) is the shaft linkage with the motor (A).

Figure II.3.3



Regenerative turbine pump action is illustrated in this cutaway view. Pressure is developed by the rotation of the finned impeller against the stationary raceway.

Figure II.3.4



Cross section of impeller and raceway in a regenerative turbine pump. Water travels in a spiral motion, which permits a much greater pressure buildup than is possible with conventional centrifugal pumps.

II. DEEP WELL RECIPROCATING PUMPS

The deep well **reciprocating pump**, better known as the **deep well working head pump**, but also known as working head, sucker rod pump, or stroke pump (Figure II.3.5), has a gear box that is the power end of the pump. The gear transmits power from an electric motor to a lever or walking beam that has one end projecting from the side of the working head. The outer end of the lever moves up and down, making a 4-inch, 5-inch, 6-inch, 8-inch, or 12-inch stroke, depending on construction. The stroke length, such as a 6-inch stroke, determines the size of the working head.

A rod is connected to the lever. It extends down in the well to a plunger in the cylinder, which is located below the pumping water level. A drop pipe connects the well head to the cylinder in the well.

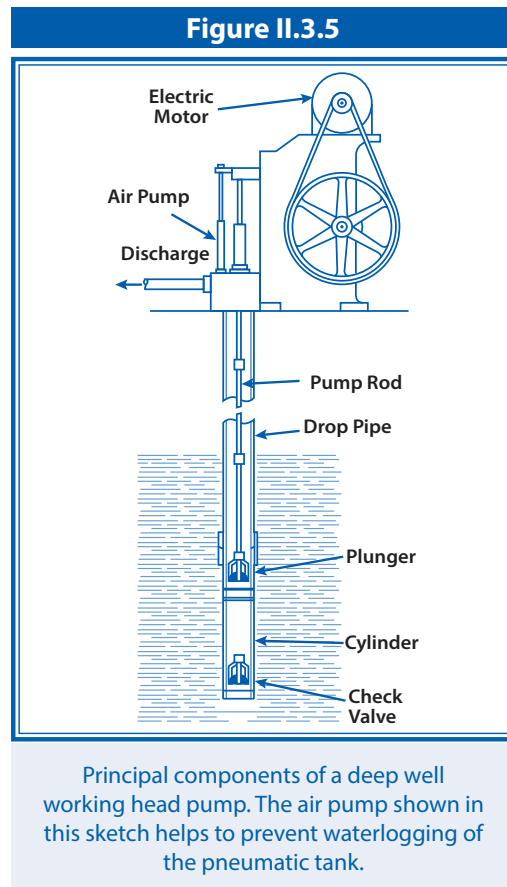
The cylinder may be a single-acting or double-acting type. In the single-acting cylinder, the plunger that moves up and down inside the cylinder does the pumping. Some deep well reciprocating pumps are equipped with a differential cylinder that eliminates pulsations, giving a steady flow of water and equalizing the power required. The double-acting cylinder provides a more even flow of water and, when used, a differential cylinder should not be used.

On each upstroke, the working head must overcome the resistance of the column of water extending from the plunger to the **pressure tank**, including the pressure in the tank. Because motors must start against pressure, those used for deep well working heads require a high starting **torque**. Pump **capacity** depends on the size of cylinder (displacement) and the number of strokes per minute. As with shallow well piston pumps, pressures are limited only by the strength of the pumping equipment and the motor horsepower.

Installation care saves callbacks

It is important to follow the manufacturer's installation instructions carefully. In addition, the following rules may save many hours of troubleshooting.

1. **General.** Observe local sanitary pump installation codes. The pump should be suitable for the well. Shallow well pumps are suitable for wells where the **suction lift**, including pipe **friction loss**, does not exceed 25 feet. Deep well pumps should be used where the water level is below 25 feet, as recommended by the pump manufacturer.
2. **Pump size.** Try to determine the capacity or delivery of the well in advance to avoid installing a pump that is too large for the available water. No pump can deliver more than the well or other water source will supply.
3. **Location.** Positive-displacement pumps should be located in dry, sheltered, accessible places that are not subject to freezing. Shallow well pumps should be placed as near to the well or source of water supply as possible to keep the suction lift at a minimum. Deep well working heads must be located directly over the well.



4. Installation. The suction pipe on all plumbing units should extend below the drawdown level of the well or other water source. All pipe joints must be tight to prevent any air or water leaks. Pipe threads should be sharp, clean, and of proper length. Pipe compound should be applied sparingly and to male threads only. The pipe should be new, clean, and of the size recommended by the pump manufacturer.
5.  Electrical connections. To ensure proper performance of the pump motor, ask a professional, competent electrician to connect it to the service line. Before wiring the motor, make certain the phase, voltage, and cycles of the supply circuit are the same as that stamped on the motor nameplate. A fused switch should be installed between the main line and the pump unit.

Do not energize the pump motor without properly grounding the motor and all metal parts. Connect the motor ground screw or ground wire to the power supply ground and make sure this grounding circuit is connected to all exposed metal parts. The electrical installation should conform to local and national electric codes.

The **National Electrical Code (NFPA 70)** paragraph 250.112 states: “non-current-carrying metal parts of the kinds of equipment described in 250.112 (L) and (M) shall be grounded regardless of voltage...”

(L) Motor-Operated Water Pumps. “Motor-operated water pumps, including the submersible type.”

(M) Metal Well Casings. “Where a submersible pump is used in a metal well casing, the well casing shall be bonded to the pump circuit equipment grounding conductor.”

III. BOOSTER PUMPS

The purpose of the **booster pump** is simple – to raise the pressure of the system, and, by doing so, improve the performance of the water system components (faucets, showers, toilets, water conditioners, and appliances). Nearly every type of pump could be and probably has been used as a booster pump. There is, of course, a best choice of pump for every application.

One pump most commonly used as a booster is the **centrifugal pump**, also known as an **end-suction centrifugal**, shown in Figure II.3.6. The great range of this pump makes it suitable for both high-pressure increases and high-flow rates. A positive-displacement pump (such as a gear or vane pump) is used when very high pressure but small flow rates are needed.

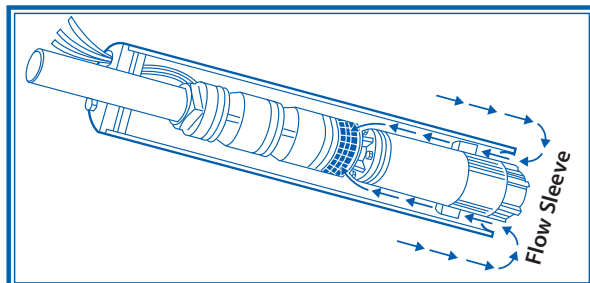
The emergence of the submersible pump has created a new type of booster as shown in Figure II.3.7. This pump is ideally suited to transmission lines because it does not disrupt the continuity of the line or require a pump house. It is recommended that the unit should be at a minimum 15-degree angle from horizontal to allow the thrust from the pump to be placed back on the motor thrust bearing. (Refer to the manufacturer’s owner’s manual). Also, there should be adequate flow past the motor to provide proper cooling to prevent damage.

Figure II.3.6



Centrifugal pump.

Figure II.3.7



Submersible pump.

Applications for booster pumps

Applications for booster pumps occur anywhere that higher pressure is needed. Even though there is direct control of the primary pressure source:

- such as a well and pump – a booster pump may still be needed. If high pressure is needed in limited areas
- such as a barn – a booster pump will provide a more economical and satisfactory operation than trying to maintain the whole water system at the higher pressure.

Booster pumps have a great many residential applications, particularly where the home is connected to a city water system:

- Residences located on the outskirts of a city or high on a hill that may experience very low water pressure during peak use periods.
- Older homes, where water lines, rusted or choked with scale, have been replaced with new properly sized pipe, but still experience low pressure.
- Homes with lawn-sprinkling systems.

Commercial applications of booster pumps are also common:

- Laundries and car washes that require large quantities of water at high pressure.
- Some industrial applications that use process water for washers.

Selection of a pump

Select a booster pump with care. Misapplication can be expensive because of poor efficiency and excess power costs. To make the proper selection, first decide on the pressure and flow rate desired (Figure II.3.8). The next step is to determine the pressure at which the desired flow rate can be delivered to the inlet of the booster pump. The difference between the desired pressure and the pressure at the booster pump inlet, plus any pressure losses between the booster pump discharge and high-pressure location, will indicate what pressure increase the booster pump must produce at the desired flow rate.

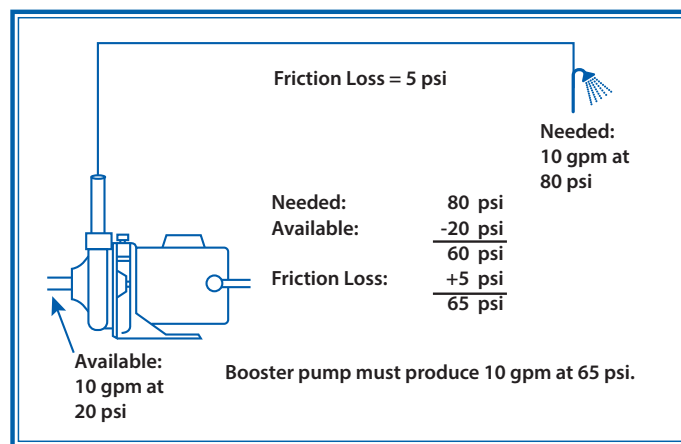
Knowing these facts, use a **pump curve** (Figure II.3.9) or a **pump chart** (Figure II.3.10, page 39). (Also see Book I, Appendix for Pump Sizing and Selection Guides – Sample Performance Curves and Selection Charts.)

Most pump curves and charts, however, show pump performance from 0 pressure and 0 flow. Fortunately, pumps are made so that an increase in inlet pump pressure produces a nearly equal increase in discharge pressure.

A characteristic of a centrifugal pump is that it will add its rated pressure (head) at the specified capacity to any incoming pressure (head). For example: incoming pressure and capacity to the pump suction is 20 psi @ 10 gpm, and the booster pump's rated performance is 30 psi @ 10 gpm. In this case, the pressure at the discharge of the pump will be a combination of both pressures or 50 psi @ 10 gpm. The important aspect is to know what the incoming capacity and pressure are by performing an incoming flow and pressure test, then select the proper pump accordingly.

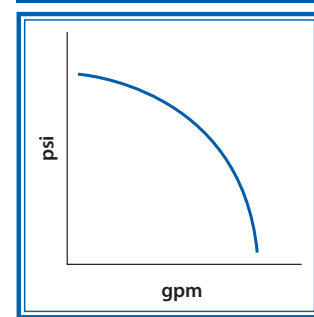
The desired pressure increase and flow rate will normally restrict the pump selection to one or two types and one or two sizes of each type. If there is a choice, maintenance, operating, and initial costs are among the final considerations.

Figure II.3.8



Differences between the desired pressure and the pressure at the booster pump inlet, plus any losses between the booster pump discharge and the high-pressure location, will indicate what pressure increase the booster pump must produce at the desired rate.

Figure II.3.9



Pump curve.

Control of booster pumps

The ideal condition for a booster pump is continuous operation at the pump's point of peak efficiency. Actual conditions, however, may be quite different. The following are types of controls and conditions under which pumps will perform best:

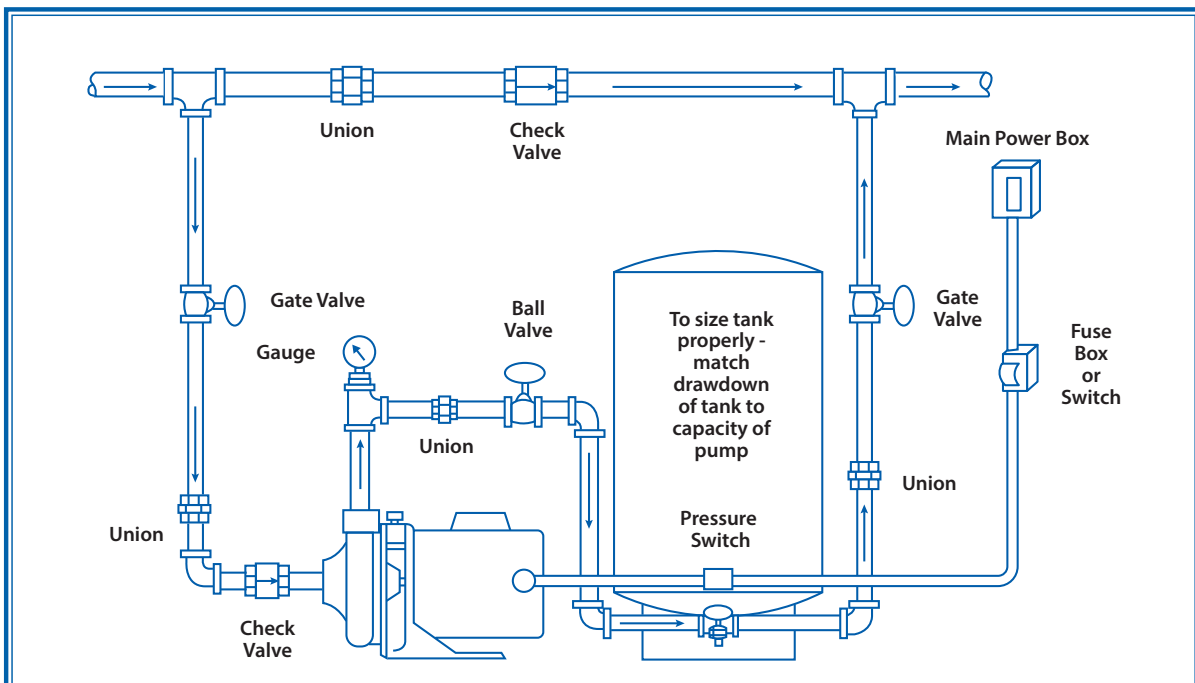
- **Manual switch**
Use when flow is occasional but continuous, or for continual use for long periods.
- **Flow-actuated switch**
Use at intervals great enough to avoid fast cycling of pump motor and when inlet pressure will produce enough flow to activate switch.
- **Pressure switch with tank**
Use when flow must be intermittent and off-on pump operation would harm the motor. Figure II.3.11 shows a typical installation of a residential booster pump.
- **VFD control with transducer** (pressure-sending device)
Use to produce constant pressure service.

Figure II.3.10

Total Suction Lift (feet)	Discharge Pressure - psi				Maximum Shutoff (psi)
	20	30	40	50	
5	17.5	16.5	10.2	5.0	63
10	15.7	14.4	9.2	4.3	61
15	13.7	12.5	8.0	3.6	59
20	11.5	10.4	7.1	2.3	57
25	8.7	8.6	6.2	1.3	54

Pump chart.

Figure II.3.11



Typical residential booster pump installation in automatic operation, showing a full-port throttling valve on the discharge pipe.

Study Guide Questions - Chapter 3

Answers can be found on page 65

Q. Name the three types of shallow well reciprocating pumps.

1. _____

2. _____

3. _____

Q. What is another name for a deep well reciprocating pump?

Q. What applications would be suitable for a positive-displacement pump?

Q. What is the purpose of a booster pump?

Q. What are the four types of controls used for pumps?

1. _____

2. _____

3. _____

4. _____

Chapter 4

Electric Motors

- ✓ Motor and pump types
- ✓ Mounting installation checklist

The electric motor is a practical, efficient, and useful way to convert energy to useful work, so the great majority of pumps are driven by electric motors. In fact, the motor is so much an integral part of the pump that it is important to understand the performance of both the pump and the driving motor.

Pumps are generally classed according to their mechanical construction, which determines their operating characteristics and, in turn, imposes certain requirements on their driving motors.

General types of pumps

Positive-displacement pump equipment includes **reciprocating** (shallow well) **pumps, deep well working head pumps**, pump jacks, rotary-gear pumps, roller pumps, and screw pumps. This pump group is characterized by high starting **torque** requirements, high pump shutoff head torque requirements, and usually a multiplicity of mechanical linkages and moving parts, which necessitate relatively low operating speeds.

Centrifugal pump types may be true centrifugal, mixed-flow, axial-flow, **jet pumps**, straight- and self-priming centrifugals, sump pumps, submersible and line-shaft deep well centrifugals (called vertical turbines), **regenerative turbine jet pumps**, or circulating pumps. The centrifugal pump group requires only sufficient starting torque to overcome the static friction of seals and bearings, has relatively low pump shutoff head torque requirements, and has basically one rotating part, which allows higher operating speeds than the positive-displacement group.

Induction motor: simple, rugged, producing constant speed

The **squirrel-cage induction motor** is the most commonly used AC motor. This motor runs on single-phase or three-phase currents and is equally popular for fractional horsepower and integral horsepower ratings. Its design is simple - the motor is rugged and reliable, and it has a relatively constant speed within its load limits. The squirrel-cage portion of the name comes from the fact that the rotor winding is made up of conductor bars with short-circuiting end rings that resemble a squirrel-cage. The bars and end rings are usually made of either aluminum cast under high pressure into the stack of punched rotor laminations, or of copper bars welded to rings.

The induction motor runs on current in the **stator** that is connected to the power lines and on current in the rotor that is induced from the stator, much like a common transformer. The two currents in this transformer, with the primary (stator) connected to the line and the secondary (rotor) short-circuited, result in a rotating magnetic field that compels the rotor and its shaft to follow. The speed of the rotating field is known as **synchronous speed**, which is determined by the number of pairs of poles (winding type) and the supply frequency. The motor's synchronous speed in revolutions per minute is given by: synchronous speed = 60 x power frequency in Hertz divided by pairs of motor poles.

Full-load speed of an induction motor is always less than synchronous speed. The difference between actual operating speed and synchronous speed is known as the **slip** of a motor, which is usually expressed as a percentage of synchronous speed. The average pump motor has a four percent slip. For example, a two-pole (1 pair of poles) motor operating on 60 Hertz has a synchronous speed of 60×60 , divided by 1 equals 3,600 rotations per minute (rpm). At a typical operating speed of 3,600 minus the slip (4 percent of 3,600), the actual speed is 3,456 rpm.

In order to begin rotating, all single-phase motors must employ a starting or phase-shifting winding in addition to the main running winding. The essential parts of a split-phase motor are represented in Figure II.4.1. There are two separate windings on the stator – a main (or run) winding and a start winding.

At standstill, both windings must be in the circuit to develop torque, and, as shown, they are connected in parallel across the line. After the motor accelerates to approximately 75 percent of synchronous speed, the **main winding** alone can develop adequate running torque and the starting switch opens, thus taking the starting winding out of the circuit.

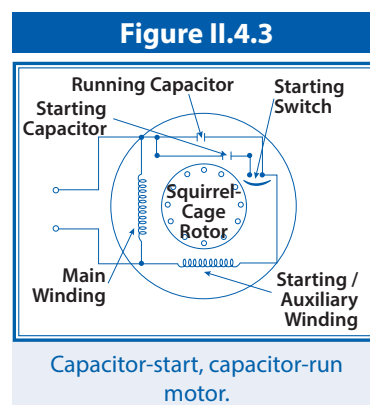
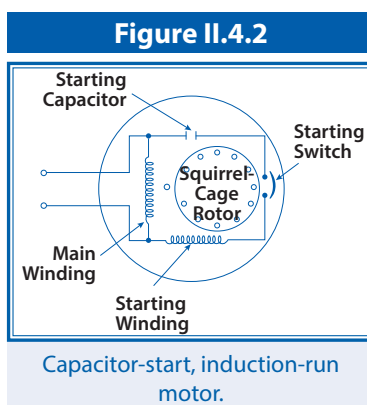
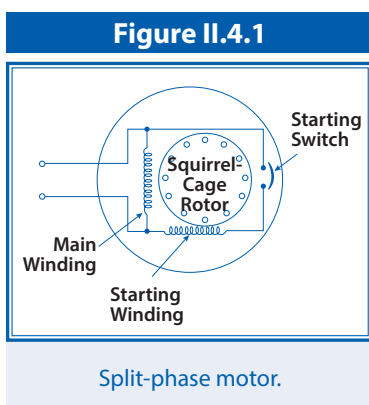
Capacitor-start motor for heavy-duty applications

For general purpose, heavy-duty applications requiring high starting and running torques, the capacitor-start motor is, by far, the most popular type. The capacitor stores electricity, a property called **capacitance**. In its simplest form, a **capacitor** is nothing more than two conductors separated by an insulator.

The term capacitor motor alone does not fully describe any type of motor. The definition must include the full name (1) capacitor-start, induction-run; (2) capacitor-start, capacitor-run or (3) permanent split-capacitor motor. The starting characteristics of the three types vary greatly.

Figure II.4.2 represents the internal circuits for the **capacitor-start, induction-run motor (CSIR)**. The capacitor and **phase winding** are in the circuit only during the starting period. This winding is opened at the correct speed by the starting switch. The motor develops much more torque per starting amp than the split-phase motor that it so closely resembles. After these motors are started, they may have identical characteristics.

Figure II.4.3 shows the circuit for a **capacitor-start, capacitor-run motor (CSCR)**. This motor has a high-value electrolytic capacitor and a lower value continuous-duty capacitor. Both capacitors are in the starting winding circuit during start. The starting switch or a relay removes only the electrolytic capacitor from the circuit when the motor comes up to speed. The starting winding is more accurately defined as an auxiliary or phase winding because this winding and the continuous-duty capacitor remain in parallel with the main winding at all times. The auxiliary winding and capacitor combination improves performance, power factor, and efficiency.



A **permanent split-capacitor motor** is represented in Figure II.4.4. This motor starts and runs with the auxiliary winding and continuous-duty capacitor in the circuit. It has no starting switch or relay, and as a result has lower starting torque than the CSIR and CSCR; however, the benefit is lower amperage.

Definite purpose motors

The pump manufacturer, in selecting the proper motor for the pump, must not only consider the basic characteristics required of the pump, as described above, but must also consider the general application of the pump and motor. Basically, motors used for water pumping applications are considered to be definite-purpose rather than general-purpose motors. **Jet pump motors**, for example, are designed to match not only the necessary speed torque characteristics, but also the application conditions to which a jet pump and its motor are subjected.

Jet pump motors can also be applied to other centrifugal-type pumps if operating conditions are similar. Within a given motor classification, however, there may be some differences in electrical or mechanical characteristics offered by various manufacturers tailored to their engineering and competitive sales preferences.

Most positive-displacement pumps offered in the water systems industry are belt-driven in order to reduce the pump's operating speed. Therefore, the motor design must take into account the basic speed torque characteristics of the pump as well as additional radial load and mounting considerations.

Shallow well pump characteristics

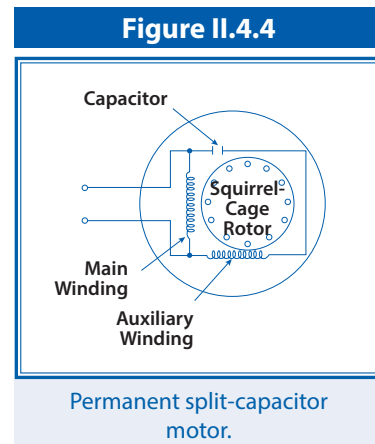
As shallow well pumps, these positive-displacement units will lift water from depths up to 25 feet. They are all self-priming after the pump case has been filled with water. Delivery characteristics of positive-displacement pumps remain about the same throughout their pressure range. Horsepower requirements increase as the pressure increases. These pumps should not be operated at pressures higher than those recommended by the manufacturer. Operation at excessive pressures will cause the motor to overload and could damage the pump.

Submersible pump motor applications and design variations

Submersible pump motor applications also require a special and definite purpose design. Both types of submersible pumps motors are subjected to special conditions of cooling and of insulation from the water environment in which they are submerged. The submersible pump must also fit into a well casing.

Motors with potted or canned windings are also wound with conventional wire, but after the windings are in place, the stator is potted. This means that the space around the stator windings, including the laminations, is filled with thermoplastic or thermosetting material that completely isolates the windings from any contact with the fluid in the motor.

One version of this type of motor adds a thin steel liner in the bore of the stator which hermetically seals off the potted stator windings to maintain a slightly higher pressure inside the motor than outside. Potted motors are filled at the factory with a lubricating fluid and require no further additions at the time of installation.



A third approach is the **open winding water-filled motor**. A special wire with highly flexible, water-resistant, heavier insulation is used. The heavy insulation on the wire is the only insulation between the motor windings and the water. The interior of the motor is filled with clean water, which is the cooling and lubricating fluid.

Motor capacitors

There are certain inherent limitations to the application of motor-starting and running capacitors. Temperature has a decided effect on all capacitors, especially the electrolytic types. The usual low-temperature limit is between -25°F (-31.7°C) and -40°F (-40°C). At these temperatures, the capacitance may be expected to fall off by about 12 percent at -25°F to 30 percent at -40°F.

These reductions in capacitance will lower instantaneous starting torque values from 15 to 40 percent. However, because the power factor at low temperatures increases sharply as the capacitance decreases, more heat is generated in the capacitor, causing the temperature of the capacitor to rise quickly to a temperature of normal capacitance. Therefore, the reduction in starting torque is minimal.

Extremely high ambient temperatures may result in a permanent decrease in capacity and short life, whether the capacitor is in use or only in storage.

Motor starting switches

An internal starting switch or a relay is necessary in split-phase motors and capacitor-start motors to disconnect the starting winding or starting capacitor, or both, as the motor comes up to speed. Starting windings and capacitors are typically designed for short-time use only during starting, and both may be damaged quickly if not disconnected during running. Split-phase and capacitor-start motors can never be more reliable than the switches or relays used to operate the starting circuit.

Torque pulsation

Three-phase induction motors supply a constant, smooth flow of power to the shaft. Torque developed by electromagnetic action of the winding is steady, not unlike the torque developed by a turbine.

Single-phase motors, however, supply the torque with electricity in a series of pulses, just like a reciprocating engine. These torque pulsations, inherent in any single-phase motor, are a major source of noise, particularly when the motor is mounted rigidly to any structure capable of emitting sound. The capacitor-start, capacitor-run-type motor has a marked reduction in the torque pulsations. The permanent split-capacitor motor also tends to have less torque pulsation than the split-phase or capacitor-start types.

Motor mounting

The motor and pump industries have cooperated to establish standards for mounting dimensions. One common method that is used has centrifugal or jet pumps designed to accept National Electrical Manufacturers Association (NEMA) C-flange mounted motors. Another popular variation used as a mounting configuration is referred to as a square flange. These motors may have a standard keyed shaft or a threaded shaft extension.

Almost all pumps in the smaller horsepower sizes in the centrifugal class are close-coupled.

A NEMA mounting standard is established for submersible motors.

Most positive-displacement pumps are belt-driven, and the motor manufacturers have standardized the mounting and shaft extensions for these motors. These motors usually operate at slower speeds and higher torques to match the pump's requirements.

Motor rating

Both the pump manufacturer and the installer must take into account the **motor rating**. The rating is summarized on the nameplate and provides all of the information necessary to properly install, apply, or replace the motor: nominal horsepower, maximum-load horsepower multiplier (called service factor), operating speed in rpm, DC or AC with frequency in Hertz, voltage, nominal current in amps, maximum load (service factor) amps, frame designation, motor type, maximum ambient temperature, class of insulation material, and operating time rating.

The nameplate also indicates if the motor is thermally protected and the locked rotor KVA code, which is important for larger motors in sizing power supplies. Some nameplates also give wiring or connection diagrams if the motor is dual voltage and can be altered in the field.

Improvements in motor design and materials now allow safe loading beyond nominal rated horsepower. This permissible loading of the motor at rated voltage and frequency is called **service factor (sf)**, a multiplier that can be applied to rated loading. Larger motors have a service factor of 1.15, which means they can be safely loaded up to 15 percent higher than nominal rated horsepower.

Many smaller pump motors, including jets and submersibles, have 60-Hertz service factors higher than 1.15, a factor that must be considered in the selection of controls, wire, fuses, and switches. Typical pump motor service factors higher than 1.15 are:

Horsepower (hp)	1/3	1/2	3/4	1	1-1/2	2
Service Factor (sf)	1.75	1.6	1.5	1.4	1.3	1.2

Installation conditions

Motors are designed to withstand the temperatures, moisture conditions, voltage variations, and, at times, pump overloads, as well as other short-term abnormalities of the installation. However, the pump installer has a responsibility to the owner to make certain that the installation conditions fall within the rating of the motor.

To ensure a safe and reliable installation, install all equipment in compliance with national and local codes, first and foremost. Also follow manufacturers' installation instructions and be vigilant of the following:

- Voltage rating and connection: Cross-check the power supply voltage with a voltmeter and the motor nameplate voltage. If the motor is a dual-voltage motor, make certain that the connection agrees with the connection diagram supplied with the motor.
- Overload and short-circuit protection: Most single-phase motors include overload (OL) protection. However, they should always have their own branch circuit protection. Dual-element (motor) fuses or circuit breakers sized to the service factor amps should always be used. Three-phase motors typically do not include overload protection. Always follow the manufacturer's recommendation for proper OL protection.
- Grounding: The **National Electrical Code (NFPA 70)** paragraph 250.112 states: "non-current-carrying metal parts of the kinds of equipment described in 250.112 (L) and (M) shall be grounded regardless of voltage..."

(L) Motor-Operated Water Pumps. "Motor-operated water pumps, including the submersible type."

(M) Metal Well Casings. "Where a submersible pump is used in a metal well casing, the well casing shall be bonded to the pump circuit equipment grounding conductor."

For safety and proper operation, make sure pumps, controls, and metal plumbing are bonded and connected to the power supply ground with copper wire at least as large as the supply cable wire (no smaller than 14 awg).

- Wiring: Always follow the manufacturer's wiring recommendations for the motor as to size and length from the load center. Always check for proper rotation.
- Mechanical freedom: With belt-driven pumps, turn the belt by hand before applying power to the motor to check that the belts are not loose or overly tight. Make sure the motor is mounted in such a way that no binding is possible.
- Recheck under load: After the pump motor has been started, recheck the voltage, the amps, and the direction of rotation.

Also refer to the Appendix for Dealing with Three-Phase Unbalance and procedures to ensure that a submersible water pump has the proper electrical installation to address current unbalance problems.

If these steps are followed carefully for each pump installation, there should be little chance of a callback for service because of improper installation.

Study Guide Questions - Chapter 4

Answers can be found on page 66

Q. What are some characteristics of positive-displacement pumps?

Q. What are some characteristics of centrifugal pumps?

Q. What is the motor rating and where is it located on a motor?

Appendix

THREE-PHASE UNBALANCE REQUIREMENTS

Dealing with Three-Phase Unbalance

The market for submersible water pumps is growing, but it may be limited if the pump and electrical industries cannot solve increasing current unbalance problems.

Current unbalance, particularly in rural areas with heavy single-phase loads, can result in nuisance tripping of the motor and damage to the motor windings. Power outages may cause current unbalance and the pump/motor rotation could change when power is restored. Current unbalance can lead to premature motor failure – a result of reduced starting and breakdown torque, excessive and uneven heating, and excessive vibration.

It is important that the electrical load to a submersible pump motor be reasonably balanced. It is also important that the installation be made properly. Here is how to make a proper electrical installation – and what to do if the installation cannot be made as specified by the manufacturer.

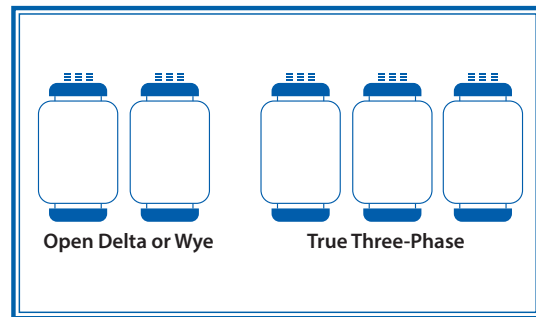
Step 1: Pre-Installation Checks

- Prior to installation, notify the power company about the motor data, plus other loads that are on the transformer bank.
- Find out if the service provided is a true three-phase, three-transformer system, or a two-transformer system. Count the transformers if the service is already installed, or ask the power company if service is yet to be installed. Figure 1 shows an open-delta or wye system (on the left), with a true three-phase, three-transformer system (on the right).
- Make sure that the transformer rating, in Kilovolt-Ampere (KVA), is adequate for the motor load by referring to Table I, which references the KVA requirement by horsepower. Note that the minimum KVA rating, at the right on the chart, refers to each transformer used. This table, incidentally, covers only the motor KVA requirements and does not make allowances for other loads.

Step 2: System Requirements

- Select the proper size magnetic starter or pump panel for the motor's horsepower rating.
- Use ambient compensated quick trip heaters on all three legs. The recommended heater size for the make of panel is provided with the motor.

Figure 1



Typical three-phase transformer systems.

Table 1

Submersible 3-Phase Motor HP Rating	Total Effective KVA Required	Smallest KVA Rating — Each Transformer	
		Open Wye or Delta 2 Transformers	Wye or Delta 3 Transformers
1 ½	3	2	1
2	4	2	1 ½
3	5	3	2
5	7 ½	5	3
7 ½	12	7 ½	5
10	15	10	5
15	20	15	7 ½
20	27	15	10
25	32	20	10
30	40	25	15
40	50	30	20
50	65	37 ½	25

KVA requirement by motor horsepower.

- Follow the manufacturer's recommended cable size from the transformer to the pump panel and from the panel to the motor based on horsepower and voltage rating. Make sure that the length of cable is no longer than the manufacturer's recommendation.
- If the pump is to operate properly on a system with two transformers, it is good practice to use both the next higher horsepower motor rating and the next larger cable size. Taking these steps gives a greater margin of safety and provides more tolerance to current unbalance.

Step 3: Start Up

- While the pump is still above ground, check the insulation resistance of the motor to make sure that it is at least 2 million or more ohms (2 megohms).
- After the drop cable has been spliced to the motor leads and the pump is installed in the well, check the insulation resistance again to determine if the splice and cable are good.
- If insulation resistance is still 2 million ohms or more, voltage can be applied to the motor.



Always remember, Safety First!
Before working inside the pump panel or magnetic starter,
always de-energizes the circuit, lock it out and tag it,
and verify it is de-energized with a meter.

- Check for correct rotation of the motor by running it first in one direction and then the other. Use a discharge valve and pressure gauge. The rotation that gives the highest pressure is always the correct one. Change rotation by switching any two of the three motor leads at the pump panel.
- After the correct rotation is established, calculate the amount of current unbalance between legs.

Current unbalance between legs should not exceed 5 percent of the average.

The percent of current unbalance is defined and calculated as follows:

$$\frac{\text{Percent current unbalance} = \frac{\text{Maximum current difference from average current}}{\text{average current}} \times 100$$

Current readings in amps should be checked on each leg using the three possible hookups shown in Figure 2. The best hookup is the one that has the lowest percentage of unbalance.

To prevent changing motor rotation when taking these readings, motor leads should be rolled across the starter terminals by always moving them in the same direction, as shown in the illustration calculating the amount of current unbalance between legs.

- By observing where the highest current reading is for each leg on the various hookups, determine if the unbalance is caused by the power source or the electric motor. This indicates that most of the unbalance was from the power source. If the high current was on a different leg each time the motor leads were changed, the motor or a poor connection caused most of the unbalance.
- Loads on a transformer bank may vary during the day, so readings should be taken at least twice – once during the day in what would be considered the normal load period and once in the evening during the usual peak load period. The installation should then be connected for the lowest percentage of current unbalance – again, not to exceed 5 percent.
- Should problems with balance continue or if overload trip problems are encountered, contact the power company for assistance. Keep a complete log of the pump installation so that the situation can be fully explained to the power company engineer or to the pump supplier.

The record should include:

- Date of installation
- Well location and owner
- Depth to water
- Horsepower
- Make of motor
- Size of control panel
- Heaters/Overloads used
- Cable sizes and lengths
- Current and voltage readings, by leg
- Unbalance percent reading

With this type of log, an installer is on solid ground when discussing the current unbalance problem with the power company.

Calculating the Amount of Current Unbalance Between Legs

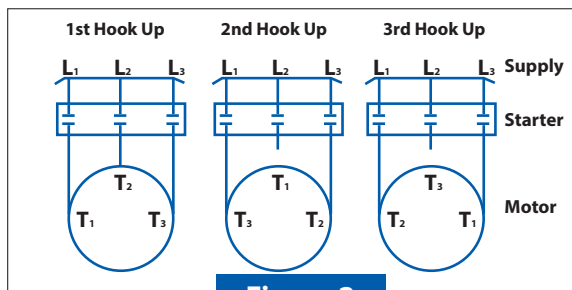


Figure 2

Three-phase motor hookup.

Totals for hookup number 1 are as follows:

$$\begin{aligned} T_1 &= 51 \text{ Amps} \\ T_2 &= 46 \text{ Amps} \\ T_3 &= 53 \text{ Amps} \end{aligned}$$

Total 150 Amps

Divide the total by three to obtain the average.

$$150 \text{ Amps} \div 3 = 50 \text{ Amps}$$

Calculate the greatest amp difference from the average.

$$\begin{aligned} 50 \text{ Amps} \\ - 46 \text{ Amps} \\ \hline 4 \text{ Amps} \end{aligned}$$

Divide this difference by the average to obtain the percentage of unbalance.

$$4 \text{ Amps} \div 50 = .08 \text{ Amps or } 8 \text{ percent}$$

In this case, the current unbalance for hookup number 1 is 8 percent.

Using the same method of calculation, the maximum current unbalance for hookup number 2 is 4 percent and for hookup number 3 is 2 percent.

Next, compare the percentage of unbalance for all three hookups. The first hookup exceeds 5 percent current unbalance and should not be used. The second and third hookups do not exceed 5 percent, so either would be satisfactory. However, the third hookup has the lowest percentage of current unbalance and it should be used, since the motor will then be operating at maximum efficiency and reliability.

Use simple arithmetic to calculate the perchange of current unbalance for all three hookups.

Table 2 is an example of current readings at maximum pump loads on each leg of a three wire hookup.

To start, add up all three reading for hookup number 1.

Table 2

1st Hook Up	2nd Hook Up	3rd Hook Up
$T_1 = 51 \text{ Amps}$	$T_3 = 50 \text{ Amps}$	$T_2 = 50 \text{ Amps}$
$T_2 = 46 \text{ Amps}$	$T_1 = 48 \text{ Amps}$	$T_3 = 49 \text{ Amps}$
$T_3 = 53 \text{ Amps}$	$T_2 = 52 \text{ Amps}$	$T_1 = 51 \text{ Amps}$

Current unbalance example.

Appendix

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Length				
Inches	(in)	Millimeters	(mm)	25.400
Inches	(in)	Centimeters	(cm)	2.539
Feet	(ft)	Meters	(m)	0.305
Yards	(yd)	Meters	(m)	0.914
Miles (statute)	(mi)	Kilometers	(km)	1.609
Millimeters	(mm)	Inches	(in)	0.039
Meters	(m)	Feet	(ft)	3.281
Centimeters	(cm)	Inches	(in)	0.394
Meters	(m)	Yards	(yd)	1.094
Kilometers	(km)	Miles (statute)	(mi)	0.621
Area				
Square Inches	(in ²)	Square Centimeters	(cm ²)	6.452
Square Feet	(ft ²)	Square Meters	(m ²)	0.093
Square Yards	(yd ²)	Square Meters	(m ²)	0.836
Square Miles	(mi ²)	Square Kilometers	(km ²)	2.590
Acres	(ac)	Hectares	(ha)	0.405
Square Centimeters	(cm ²)	Square Inches	(in ²)	0.155
Square Meters	(m ²)	Square Feet	(ft ²)	10.764
Square Meters	(m ²)	Square Yards	(yd ²)	1.196
Square Kilometers	(km ²)	Square Miles	(mi ²)	0.386
Hectares	(ha)	Acres	(ac)	2.471
Liquid Volume				
Ounces	(oz)	Milliliters	(ml)	29.574
Pints	(pt)	Liters	(l)	0.473
Quarts	(qt)	Liters	(l)	0.946
Gallons	(gal)	Liters	(l)	3.785
Pounds per Cubic Foot	(lb/ft ³)	Kilograms per Cubic Meter	(kg/m ³)	16.018
Pounds per Gallon	(lb/gal)	Kilograms per Cubic Meter	(kg/m ³)	119.826
Milliliters	(ml)	Ounces	(oz)	0.034
Liters	(l)	Pints	(pt)	2.113
Liters	(l)	Quarts	(qt)	1.057
Liters	(l)	Gallons	(gal)	0.264
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Cubic Foot	(lb/ft ³)	0.062
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Gallon	(lb/gal)	0.008
Mass				
Ounces	(oz)	Grams	(g)	28.350
Pounds	(lb)	Kilograms	(kg)	0.454
Grams	(g)	Ounces	(oz)	0.035
Kilograms	(kg)	Pounds	(lb)	2.205
Flow				
Cubic Meters per Hour	(m ³ /h)	Gallons per Minute	(gpm)	4.400
Gallons per Minute	(gpm)	Cubic Meters per Hour	(m ³ /h)	0.227

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Force				
Foot Pound Force	(ft-lbf)	Joules	(J)	1.356
Newtons	(N)	Kilogram Force	(kgf)	0.102
Joules	(J)	Foot Pound Force	(ft-lbf)	0.738
Kilogram Force	(kgf)	Newtons	(N)	9.807
Power				
Horsepower	(hp)	Kilowatts	(kW)	0.746
Horsepower	(hp)	Watts	(W)	745.700
Kilowatts	(kW)	Horsepower	(hp)	1.341
Watts	(W)	Horsepower	(hp)	0.001
Pressure				
Bars	(b)	Pounds per Square Inch	(psi)	14.500
Kilograms per Square Centimeter	(kg/cm²)	Pounds per Square Inch	(psi)	14.500
Pounds per Square Inch	(lb/in²)	Kilograms per Square Meter	(kg/m²)	703.070
Pounds per Square Inch	(lb/in²)	Kilopascals	(kPa)	6.895
Pounds per Square Inch	(lb/in²)	Meters of Water	(m)	0.704
Inches of Mercury	(inHg)	Kilograms per Square Meter	(kg/m²)	345.300
Kilograms per Square Meter	(kg/m²)	Pounds per Square Inch	(lb/in²)	0.001
Kilopascal	(kPa)	Pounds per Square Inch	(lb/in²)	0.145
Meters of Water	(m)	Pounds per Square Inch	(lb/in²)	1.420
Kilograms per Square Meter	(kg/m²)	Inches of Mercury	(inHg)	0.003
1 Atmosphere	14.7 lb/in²	Kilograms per Square Centimeter	(kg/cm²)	1.033
1 Atmosphere	14.7 lb/in²	Kilograms per Square Meter	(kg/m²)	10,335.000
1 Atmosphere	14.7 lb/in²	Kilopascal	(kPa)	101.350
1 Atmosphere	14.7 lb/in²	76.0 Centimeters Mercury	(cmHg)	5.170
1 Atmosphere	29.92 inHg	76.0 Centimeters Mercury	(cmHg)	2.540
Pascal	(Pa)	Newtons per Square Meter	(N/m²)	1.000
Pascal	(Pa)	Kilograms per Square Meter	(kg/m²)	0.102
Temperature				
Degrees Fahrenheit	(°F)	Degrees Celsius	(°C)	(°F-32) 0.556
Degrees Celsius	(°C)	Degrees Fahrenheit	(°F)	(1.8 x °C) + 32
Flow				
Feet per Second	(fps)	Meters per Second	(m/s)	0.305
Miles per Hour	(mph)	Kilometers per Hour	(km/h)	1.609
Gallons per Minute	(gpm)	Liters per Minute	(l/min)	3.785
Gallons per Minute	(gpm)	Cubic Meters per Minute	(m³/min)	0.004
Meters per Second	(m/s)	Feet per Second	(fps)	3.281
Kilometers per Hour	(km/h)	Miles per Hour	(mph)	0.621
Liters per Minute	(l/m)	Gallons per Minute	(gpm)	0.264
Cubic Meters per Minute	(m³/min)	Gallons per Minute	(gpm)	264.172

Glossary

Air-Volume Control (AVC): Ensures the proper balance of air to water in non-diaphragm, plain steel pressure tanks, by preventing waterlogging of the tank. (II-1)

Ammeter: Instrument to measure electrical current flow in amps. (II-2)

Blades (*Also called Buckets or Fins*): Located on rotating wheel or impeller to draw water into the pump channel. (II-3)

Booster Pump: Raises pressure of water. (II-3)

Cable Guard: Protects cable inside well by holding the pipe and cable in the center of the well. (II-2)

Cable Tie: Ties that fasten the cable to the pipe from a submersible pump. (II-2)

Capacitance: The ability of an electrical component such as a motor capacitor to store an electrical charge. (II-4)

Capacitor: A device designed to hold an electrical charge using two conductors separated by an insulator. (II-2, II-4)

Capacitor-Start, Capacitor-Run Motor (CSCR): A motor with a high-value electrolytic capacitor and a lower-value continuous-duty capacitor. (II-4)

Capacitor-Start, Induction-Run Motor (CSIR): Motor in which the capacitor and phase winding are in the circuit only during the starting period. This winding is opened at the correct speed by the starting switch. The motor develops much more torque per starting amp than the split-phase motor that it so closely resembles. (II-4)

Capacitor-Start, Induction-Run Starting Method: Starting method in which the capacitor and phase winding are in the circuit only during the starting period. (II-2)

Capacity: Amount of water moving past a given point in a given amount of time. (II-1, II-2, II-3, II-4)

Casing: A stationary enclosure. (II-1, II-2, II-3, II-4)

Casing Size: Size of the well casing; should be recorded in a well log. (II-1)

Centrifugal Pump: A pumping mechanism that spins water by means of an "impeller," pushing it out by centrifugal force. (II-1, II-2, II-3, II-4)

Check Valve: Prevents water from flowing backwards. (II-1, II-2)

Chlorination: Process of using chlorine to prevent contamination and growth of bacteria that could plug the well or pump. (II-2)

Control Box: Device that contains the start relay and capacitor(s). (II-2)

Current Unbalance (*Three-Phase*): A difference in the current read by the meter between any of the three phases. (II-4, App.)

Deep Well Jet Pump: Any pump capable of producing water from deeper than 25 feet. (II-1)

Deep Well Working Head Pump (*Also called a Deep Well Piston Pump or Pump Jack*): The piston and cylinder are submerged and actuated by a rod inside the drop pipe that is powered by a motor at the surface. (II-3, II-4)

Demand: The gallons of water needed within a specific timeframe. (II-1)

Depth to Water: Measurement of distance between static water level and ground level. (II-1, App.)

Diffuser: Pump component that converts water velocity to pressure. (II-1, II-2)

Discharge Pressure: Pressure available for the system after the pressure tank. (II-1, II-3)

Double-Acting Piston Pump: A type of piston pipe that pumps water in each direction that the piston travels. (II-3)

Drawdown: Reduction in water level during pumping (measured in feet); the amount of water delivered by the pressure tank between pump shutdown and pump precharge pressure. (II-1, II-3)

Drive Pipe:

- (a) A driven well component consisting of 1-1/4-inch to 2-inch pipe, equipped with a point and well screen, driven below the level of the water table.
- (b) *(Also called Pressure Pipe):* A pipe connected to the pressure or nozzle side of the ejector body in a deep well jet, through which a surface centrifugal pump forces water. (II-1)

Ejector *(Also called a Jet):* A water pressure-making device with three parts: body, nozzle, and venturi. Atmospheric pressure forces water into a partial vacuum at the nozzle throat, then into the pumping system where the venturi slows water velocity and converts it into water pressure. (II-1)

End-Suction Centrifugal: A pump used as a booster to raise water pressure and increase flow. (II-3)

Flow-Actuated Switch: A switch that starts the pump when water starts to flow; in booster systems. (II-3)

Foot Valve: A screened check valve allowing water to flow into a jet when a pump is running; closes when pump is shut off. Protects pump parts. Used on suction lift applications and located at the bottom of the suction assembly. Keeps the suction line full of liquid. (II-1)

Friction Loss: Loss of pressure when water flows through a piping system factoring gallons per minute, pipe length, size, and fittings. Measured in feet of head. (II-1, II-2, II-3)

Head: Pressure expressed as height in feet. (II-1, II-2, II-3, II-4)

Helical Pump *(Also called a Spiral Rotor Pump):* a shallow well positive-displacement pump with a helical molded rubber stator; provides uniform liquid flow. (II-3)

Impeller: A rotating disk containing vanes attached to the motor shaft; used in centrifugal pumps. (II-1, II-2, II-3)

Jet Pump: A surface-mounted centrifugal pump that has an ejector (venturi) device to increase suction capacity. (II-1, II-2, II-3, II-4)

Jet Pump Motor: A water pumping motor designed to match not only the necessary speed torque characteristics but also the application conditions to which a jet pump and its motor are subjected. (II-4)

Lightning Arrestor: A device for protecting electrical equipment from damage by lightning or other power surges. (II-2)

Main Winding: One of two windings on a stator; the main or running winding is the one that develops adequate running torque to open the starting switch. The second winding, a phase or starting winding, is then taken off the circuit. (II-4)

Manual Switch: A pump control device used when flow is occasional but continuous, or for continual use for long periods. (II-3)

Motor Rating: Information summarized on a motor nameplate that provides what is needed to properly install, apply or replace the motor: nominal horsepower, maximum load horsepower multiplier (called Service Factor), operating speed in rpm, DC or AC with frequency in Hertz, voltage, nominal current in amps, maximum load (service factor) amps, frame designation, motor type, maximum ambient temperature, class of insulation material, and operating time rating. (II-2, App.)

Multi-Stage Centrifugal Pump: A centrifugal pump with more than one impeller and chamber, arranged in a sequence to increase pressure. (II-2)

National Electrical Code (NFPA 70): Electrical standards code that requires the safe grounding of motor operated water pumps and metal well casings. (II-2, II-3, II-4)

Ohmmeter: Instrument to measure resistance in an electrical system. (II-2)

Open Winding Water-Filled Motor: Submersible pump motor containing a special wire with highly flexible, water-resistant, heavier insulation between the motor windings and the water. The interior of the motor is filled with clean water, which is the cooling and lubricating fluid. (II-4)

Packer: The space between a single pipe and the well casing serves as the pressure pipe. A deep well jet pump system that requires 2-inch or 3-inch well casing and has one pipe down in the well to the jet assembly. (II-1)

Permanent Split-Capacitor Motor: This motor starts and runs with the auxiliary winding and continuous-duty capacitor in the circuit. It has no starting switch or relay and as a result has lower starting torque than the CSIR and CSCR; however, the benefit is lower amperage. (II-4)

Permanent Split-Capacitor Starting Method: Method of starting single-phase two-wire submersible motors, in which a capacitor is connected in series with the start winding at all times. (II-2)

Phase Winding (*Also called an Auxiliary Winding*): Winding that, along with the continuous-duty capacitor, remains in parallel with the main winding at all times. The auxiliary winding and capacitor combination improves performance, power factor and efficiency. (II-4)

Pitless Adapter: An underground discharge connector that connects to a well casing; used in most submersible systems to prevent freezing and eliminates chances of contamination. (II-1, II-2)

Piston Pump: (*Also called a Reciprocating Pump*): A shallow well reciprocating pump. No longer used for domestic well systems. Shallow well pump in which the piston reciprocates from one end of the cylinder to the other.. (II-1, II-3)

Positive-Displacement Pump: This pump group is characterized by high starting torque requirements, high pump shutoff head torque requirements, and usually a multiplicity of mechanical linkages and moving parts, which necessitate relatively low operating speeds. (II-3, II-4)

Pressure: The force exerted in pounds over one square inch area. (II-1, II-2, II-3, II-4, App.)

Pressure Control Valve: The purpose of this valve is to divert part of the pump output down to the ejector, ensuring adequate pressure to operate the ejector regardless of flow to the tank or service. This valve provides the proper back pressure necessary to carry the drive water down the pressure (drive) pipe to the ejector in the well. Proper adjustment of the valve during installation is basic to operation of the deep well jet unit. (II-1)

Pressure Gauge: A device that measures pounds per square inch (psi) in a water system. (II-2)

Pressure Pipe: A pipe connected to the pressure or nozzle side of the ejector body in a deep well jet, through which a surface centrifugal pump forces water. (II-1)

Pressure-Relief Valve: Controls maximum pressure in the system. (II-2)

Pressure Switch: An electrical switch activated by system pressure to control starting and stopping of the pump. (II-2, II-3)

Pressure Tank: Vessel used to provide cycle control of the pump. (II-1, II-2, II-3)

Pump Chart: A chart that helps determine the correct pump size from the required water and head. (II-3)

Pump Curve: The pump curve describes the relation between flow rate and head for the actual pump. (II-3)

Pump Stage: Each impeller and diffuser in a multi-stage submersible pump. (II-2)

Reciprocating Pump: *See Piston Pump.*

Regenerative Turbine Pump: A pump that uses a rotating wheel or impeller with a series of blades or fins to develop high pressures. (II-3)

Service Factor (sf): Part of the information contained in a motor rating, the maximum-load horsepower multiplier. (II-4)

Shallow Well Pump: A centrifugal pump with the ejector mounted to the housing that has a maximum total suction lift of 25 feet. (II-1, II-3, II-4)

Shallow Well Reciprocating Pump: *See Piston Pump.* (II-3)

Shutoff Valve: Valve installed between the well and tank, making it possible to drain a portion of the system for repairs, instead of draining all of it. A device used to separate a component from the system, e.g., tank, pump. Valves can be of the ball, globe, or gate design. (II-1)

Single-Phase Motor: Type of submersible pump motor that is not inherently self-starting and requires an auxiliary starting method. (II-2)

Slip: The difference between actual operating speed and synchronous speed in a motor; usually expressed as a percentage of synchronous speed. (II-4)

Spiral Rotor Pump: *See Helical Pump.* (II-3)

Split-Phase Starting Method: Method of starting a submersible pump's motor in which a capacitor is connected in series with the start winding at all times. (II-2)

Squirrel-Cage Induction Motor: The most commonly used AC motor, it runs on single-phase or poly-phase currents and is equally popular for fractional horsepower and integral horse power ratings. Its design is simple, the motor is rugged and reliable, and it has a relatively constant speed within its load limits. The squirrel-cage portion of the name comes from the fact that the rotor winding is made up of conductor bars with short circuiting end rings that resemble a squirrel-cage. (II-4)

Starting Capacitor: Motor capacitor used for starting only. In submersible motors, a starting capacitor is usually connected to a start winding of the motor. The capacitor is used to get the motor started and almost up to running speed. Then a switch disconnects the capacitor and start winding, and the motor operates on its run windings. (II-2, II-4)

Start Winding: Motor winding used for starting only. In submersible motors, a starting capacitor is usually connected to a start winding of the motor. The capacitor is used to get the motor started and almost up to running speed. Then a switch disconnects the capacitor and start winding, and the motor operates on its run windings. (II-2, II-4)

Stator: The stationary part of a motor in or around which a rotor revolves. (II-3, II-4)

Submersible Motor: A motor subjected to special conditions of cooling and of insulation from the water environment in the well in which they are submerged. The submersible must also fit in the well casing. (II-2, II-4)

Submersible Pump: An adapted centrifugal pump and motor designed to be placed completely below the water surface. (II-2, II-3, II-4)

Suction Lift: The low pressure generated on the inlet in the suction of a pump that lifts water up into the pump. (II-1, II-3)

Suction Pipe: A pipe through which well water is drawn to the surface. (II-1, II-3)

Synchronous Speed: The speed of a rotating field created by the two currents in a transformer, determined by the number of pairs of poles (winding type) and the supply frequency. (II-4)

Tail Pipe: A 35-foot pipe section that prevents over pumping in weak wells. (II-1)

Tank Tee: Special pipe fittings that connect the water supply pipe from the well to the pressure tank. (II-2)

Tee: A fitting that allows another pipe to be joined at a 90-degree angle. (II-1)

Three-Phase Motor: A motor operating on three-phase power only. It has high starting and breakdown torque, high efficiency, medium starting current, and a long lifespan. (II-2, II-4, App.)

Torque: The rotary force transmitted by the driving shaft of the pump. (II-2, II-3, II-4)

Torque Arrestor: A rubber friction creation device designed to prevent damage to a pump and pump wire from startup torque/recoil that causes the pump to slap/rub the side of the casing. (II-2)

Two-Pipe System (*Also called Twin-Pipe System*): A type of deep well jet pump system requiring a 4-inch or larger well casing and two pipes (pressure pipe and suction pipe) running from the pump to the jet assembly in the well. (II-1)

Two-Wire Motor: Motors that have starting capability within the motor and, therefore, only require two-wire cable. (II-2)

Vanes: Curved slots in the impeller of a centrifugal pump. (II-1, II-3)

Venturi: A component that slows high velocity water due to its increasing orifice size, creating relatively high-water pressure. (II-1)

Voltmeter: Device used for measuring electrical voltage. (II-2, II-4)

Well Cap: Protective cover, usually made of aluminium or thermoplastic, that seals the upper end of a well to keep out the elements, contaminants, and vermin. (II-2)

Well Log: A written form on which the driller lists well characteristics; required in many states. (II-1)

Working Head Pump: *See Deep Well Working Head Pump.* (II-1, II-3, II-4)

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Study Guide Answers

Chapter 1

Q. What are two pumping principles of jet pump operation?

A. Centrifugal operation and ejection.

If you missed this question, go back to page 10 for information on how jet pumps operate.

Q. Name the parts of an ejector or jet.

A. The body, nozzle and venturi or throat.

If you missed this question, go back to page 10 for information on ejector function and operation.

Q. What are the advantages of jet pump operations?

A. The unit can pump limited amounts of air without difficulty; there are no moving parts in the ejector; and the pumping action is smooth and uniform.

If you missed this question, go back to page 10 for information on ejector function and operation.

Q. What does the pressure control valve do?

A. This valve diverts part of the pump output down to the ejector, ensuring adequate pressure to operate the ejector regardless of flow to the tank or service.

If you missed this question, go back to page 12 for information on pressure control valves.

Q. List the first steps for installing jet pumps.

A. Determine the well location, make sure the well is clean, check well conditions, and check the piping.

If you missed this question, go back to page 13 for information on first steps in installing jet pumps.

Q. What is a tail pipe and what does it do?

A. A tail pipe is a 35-foot length of pipe installed between the ejector assembly and the foot valve. It prevents overpumping by assuring that the well will never be pumped down to within 5 feet above the foot valve.

If you missed this question, go back to page 15 for information on tail pipes.

Q. What materials are commonly used today to manufacture mechanical shaft seals?

A. Ceramics.

If you missed this question, go back to page 16 for information on mechanical shaft seals.

Q. What factors govern the life of a mechanical seal?

A. A. The degree of contamination in a system. Water pressure is somewhat of a factor in seal life, especially when the water contains abrasive particles.

If you missed this question, go back to page 16 for information on life of mechanical seals.

Chapter 2

- Q. How are a pump's capacity and pressure determined?
- A. The capacity of a multi-stage centrifugal pump is largely determined by the design width of the impeller and diffuser, regardless of the number of stages. The pressure is a function of the diameter of the impeller, the speed at which it rotates, and the number of impellers.

If you missed this question, go back to page 21 for information on operation of impellers and diffusers.

- Q. Name the three types of submersible motors.

- A. (1) Single-phase with three-wire cable with ground; (2) single-phase with two-wire cable with ground; (3) three-phase with three-wire cable with ground.

If you missed this question, go back to page 22 for information on types of submersible motors.

- Q. What is the recommended pre-installation routine for submersible pumps?

- A. Remove the pump from its shipping carton and check it for damage; check the nameplate against the intended specification for the well; examine the check valve to make certain it is free and will close of its own weight or by spring pressure; splice the cable; check the electrical supply; make sure the unit is properly grounded; and check rotation of three-phase units.

If you missed this question, go back to pages 26-27 for information on pre-installation tests must be made..

- Q. What equipment is required to install a submersible pump?

- A. Pipe wrenches, pipe vises, or clamps and equipment to support the weight of the pump, pipe, electrical cable, and pitless adapter as it is lowered into the well. Also enough pipe, electrical cable for the pump motor, cable ties to fasten the cable to the pipe from the pump and/or cable guards, waterproof electrical splice kit, pitless unit or adapter, torque arrestor, cable guards, and check valves. Most pumps will require a pressure and a tank tee fitting and other pipe fittings as needed.

If you missed this question, go back to page 27 for information on equipment needed to install submersibles.

Chapter 3

- Q. Name the three types of shallow well reciprocating pumps.

- A. Piston pump, helical rotor pump, and regenerative turbine pump.

If you missed this question, go back to page 34-35 for information on positive-displacement and booster pumps.

- Q. What is another name for a deep well reciprocating pump?

- A. A deep well working head pump.

If you missed this question, go back to page 36 for information on positive-displacement and booster pumps.

- Q. What applications would be suitable for a positive-displacement pump?

- A. Uniform flow and higher pressure than that of a centrifugal pump.

If you missed this question, go back to page 35 for information on installation care.

- Q. What is the purpose of a booster pump?

- A. To raise the pressure of the system, and, by doing so, improve the performance of the water system components.

If you missed this question, go back to page 37 for information on booster pumps.

- Q. What are the four types of controls used for pumps?

- A. Manual switches, flow-actuated switches, pressure switches with tanks, and VFD control with transducer.

If you missed this question, go back to page 39 for information on control of booster pumps.

Chapter 4

- Q. What are some characteristics of positive-displacement pumps?
- A. They have high starting torque requirements, high pump shutoff head torque requirements, and usually a multiplicity of mechanical linkages and moving parts, which necessitate relatively low operating speeds.

If you missed this question, go back to page 42 for information on general types of pumps.

- Q. What are some characteristics of centrifugal pumps?
- A. They require only sufficient starting torque to overcome the static friction of seals and bearings, have relatively low pump shutoff head torque requirements, and have basically one rotating part, which allows higher operating speeds than the positive-displacement group.

If you missed this question, go back to page 42 for information on general types of pumps.

- Q. What is the motor rating and where is it located on a motor?
- A. The rating is on the nameplate. It includes information necessary to properly install, apply, or replace the motor: nominal horsepower, maximum-load horsepower multiplier (called service factor), operating speed in rpm, DC or AC with frequency in Hertz, voltage, nominal current in amps, maximum load (service factor) amps, frame designation, motor type, maximum ambient temperature, class of insulation material, and operating time rating.

If you missed this question, go back to page 46 for information on motor rating.



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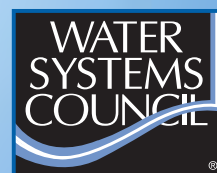


WATER SYSTEMS HANDBOOK

*A complete text on wells:
their design, operation, and maintenance*

13TH EDITION

Published by



WATER SYSTEMS HANDBOOK

BOOK III

Service

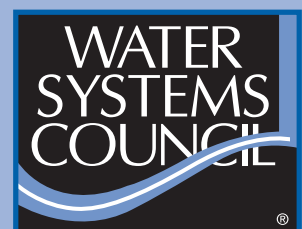
13TH EDITION



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A Word Of Caution



The products described in this Handbook, including all products using electrical current, can result in serious harm if not used with EXTREME CAUTION and in strict accordance with manufacturers' instructions. Professional assistance is recommended and should always be sought when utilizing unfamiliar equipment.

The products, materials, information, and instructions in this publication are provided for informational purposes only. This publication is not intended to provide instructions or recommendations relating to the selection, adoption, or use of equipment. All information is provided from sources believed to be reliable, accurate, and comprehensive. However, all information, including without limitation product descriptions and functionality is provided "as is" without any express or implied warranty of any kind, including warranties of title, merchantability, noninfringement of intellectual property, compatibility, or fitness for any purpose or use. In no event shall the Water Systems Council or its members, agents, employees, directors, or officers be liable for any damages or other claims whatsoever, including, without limitation, any direct, indirect, special, punitive, or consequential damages, whether from harm, loss of profits, business interruption, loss of information, or related expenses arising out of errors, omissions, or the use of or inability to use the materials, products, information, or services as provided in this Handbook, even if the Water Systems Council or its members have been advised of the possibility of such damages.

Introduction to Wells

Water is life's most vital resource. Through the centuries, people have searched for water, fought for it, and sometimes died for it. No living organism can exist without water.

Consequently, clean and plentiful groundwater is necessary for everyday life. As described in this handbook, groundwater is the reservoir of water that seeps downward through the soil to the water table below the earth's surface. About 98 percent of all fresh water available in the nation at any time is groundwater, which fills the porous beds of rock and sand that make up the earth's crust.

Groundwater is an ideal water supply, for it is pure and wholesome. Filtered by the underground formations through which it passes, groundwater has a degree of purity seldom attained by surface waters.

Natural groundwater reservoirs have many advantages. They have huge capacities, they are relatively inexpensive to tap by means of wells, and they lose little water by evaporation. Above all, they are dependable sources of water.

In the United States alone, more than 115 million people get their drinking water from groundwater every day. More than 23 million American households are supplied from individual, private wells.

A modern well is both flexible and functional. A variety of pumps is available to lift water from all types of wells, from the shallowest to the deepest. These systems are made automatic and dependable by many types of controls and accessories. Groundwater is there when needed. Additional equipment may be added to the system for treatment to ensure better quality of life.

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About this Handbook

The **WATER SYSTEMS HANDBOOK** provides basic information on well design, operation, and maintenance to boost the professional knowledge of well industry personnel.

Before you begin your studies, please take a few moments to familiarize yourself with the format of this handbook. The handbook is divided into eight books. Each includes several chapters that cover the most important aspects of wells. At the end of each chapter, you will find a **Quiz**. You can use this quiz as a learning tool to review the noteworthy points in each chapter. Answers to the quiz can be found at the end of each book. If you miss an answer, follow the directions to take you back to where the information is located in the chapter.

For quick reference, you will find that highlighted text is generally defined in a **Glossary** at the back of each book, where you will also find a topical **Index**. While illustrations appear in each chapter, you will also see tables and charts referenced in text and located in the **Appendix** at the back of each book. A handy metric system reference also appears in each appendix.

We hope that studying the information in this handbook will prepare you for your job as a well professional, charged with the important responsibility of helping to ensure access to pure, plentiful well water for families across America.

Water Systems Council

Dedication

This 13th Edition of Water Systems Handbook is dedicated to the millions of Americans who rely on private water systems to provide safe, sustainable water supply and to the water well professionals in the water well industry.

The 13th Edition is also dedicated in memory of Jeff Wellen for his many years of leadership and service to WSC and the water well industry.

Special thanks to the members of the Water Systems Council Technical Committee, who initiated and completed revisions to this 13th Edition.



The Water Systems Council (WSC) is a national nonprofit organization, dedicated to promoting the wider use of wells as safe, sustainable, and cost-effective drinking water systems; protecting groundwater resources and users of well water, and ensuring a safe drinking water supply for well owners. WSC members include major manufacturers of the integral components of wells and other drinking water systems, leading distributors of these components, and various drinking water professionals.

WSC is the only national nonprofit organization with programs solely focused on private water wells and small, shared wells.

www.watersystemscouncil.org

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Chapter 1

Servicing Instruments

- ✓ Basic servicing instruments for pump installers and services
- ✓ Operating principles of electrical instruments
- ✓ Test procedures

Warning

DISCONNECT POWER BEFORE SERVICING. Lock out and tag out circuits and use a meter to verify it is off before proceeding. When working with electrical circuits, use caution to avoid electrical shock and make sure metal control boxes, motors, and all metal parts are connected to power supply ground in compliance with local and **national electrical codes** before doing any servicing. Do not touch live parts when checking voltage and current. Lock out and tag the circuits and use a meter to verify it is off when making all other checks.

Also when working with electrical circuits, wear only electrically rated and regularly tested rubber gloves and boots, which can be trusted to provide electrical protection. ORDINARY RUBBER WORK GLOVES AND BOOTS ARE NOT RECOMMENDED. They may encourage a false sense of security when working on electrical components. WORSE, they may contain pinholes, rendering them dangerous to use.

Instruments for testing electrical characteristics

Every pump installer and servicer should have reliable electrical measuring instruments: a clamp-on **ammeter** to measure current, a voltmeter to measure the potential difference (voltage) between two points, and an **ohmmeter** to measure resistance – or a **multimeter**. A digital multimeter combines the functions of the other three devices – and some additional ones as well – into a single instrument. Carry these to all jobs.

High-grade, delicate instruments intended for laboratory use are unnecessary. While the digital multimeter is gaining popularity for field work, a versatile and convenient instrument is the clamp-on or tong-type combination ammeter-voltmeter. This device permits quick measurement of current in all lines without the need to break connections. Voltage between lines can also be measured at any uninsulated point without breaking connections.

Make sure your meter has a maximum voltage rating high enough for the circuit on which you are working. Use only the test leads that the manufacturer supplied with the voltmeter to make measurements. A common source of electrical injury is the use of improper test leads that can slip and cause electrical arcing. Never use uninsulated alligator clips to make voltage measurements.

An ohmmeter with a self-contained battery is also a must. It should have several scales capable of measuring relatively low winding resistance.



Resistance must never be measured with the power on — the meter may explode if you do this.

The circuit being measured must be disconnected from the power source to prevent damage to the ohmmeter and possible electric shock or burns to the user.

The modern water system is driven by an electric motor, so the pump installer must understand some basic principles of the electrical circuit and know how to use the three basic electrical instruments or multimeter, and interpret their readings.

Electrical instruments are not only for troubleshooting. Use these instruments on every installation to reduce call backs. Practice in the use of these instruments will help installers recognize a problem when one arises.

Operating principles of basic electrical instruments

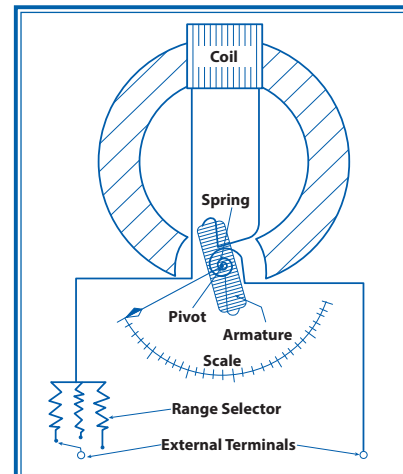
Each instrument is designed for a specific purpose and each is used in a slightly different way. However, knowledge of the basic operating principles for digital and analog meters can be helpful in using and understanding these devices.

Digital multimeters are becoming very popular. As with other field instruments, a good quality meter is essential. Accurate, repeatable readings are necessary for making good decisions. Some digital meters require the user to select a range to measure while others are self-scaling. Take the time to understand your meter.

Analog electrical instruments are electromechanical, which means that they operate on the principle of an electromagnet. Figure III.1.1 represents basic analog meter construction. The dial is calibrated in the divisions of the electrical quantity it is to indicate — either volts, amps, or ohms. An indicating needle is attached to a magnet, called an armature, suspended between two pivot points and held in a normal zero position by a spring. A stationary magnet is mounted so that its magnetic field passes through that of the armature. As current from the electrical circuit flows through the coils, the magnetic field set up tends to deflect the armature and needle generally in proportion to the amount of current flowing.

In order to obtain a range of scale readings, various amounts of resistance can be switched in or out of the meter circuit. The ohmmeter has a small internal source of voltage (a battery) that is necessary to measure resistances with line power disconnected.

Figure III.1.1



Arrangement of components in a typical analog electrical servicing instrument. Current flowing in the armature causes it to deflect in the magnetic field of a permanent magnet. The deflection shows up as movement of the needle across the scale.

Voltage, current, and resistance — how they are related

Understanding an electrical circuit will also help the installer understand the instruments and what they indicate. An electrical circuit may be compared with a hydraulic or water system circuit. **Voltage** is electrical “**pressure**.” It is measured between any two wires or between one wire and ground in the same manner that pressure in a **pipe** is measured between two places in a **piping** system or from inside the pipe to outside the pipe. This electrical pressure, or voltage, causes current to flow.

Water

Pressure...**psi**

Flow...gpm

Pipe friction...feet of head

Hole in pipe...leak

Electricity

Voltage...volts

Current...amps

Resistance...ohms

Hole in insulation...ground fault

Electrical current, which may be likened to water flowing in a piping system, is measured in amps. An **amp** is a quantity of electricity that flows past a given point in a given period of time just as **gallons per minute** represents the amount of water flowing through a piping system in a given period of time.

The **resistance** of an electrical system is measured in **ohms**, and it may be compared to the **friction loss** in a pipe of a given size.

The relationship of voltage (pressure), current (electrical flow), and resistance (friction) is expressed in what is called **Ohm’s Law**. This is expressed mathematically as $E = I \times R$ where E is the electrical pressure in volts, I is the current flow in **amps**, and R is the resistance in ohms.

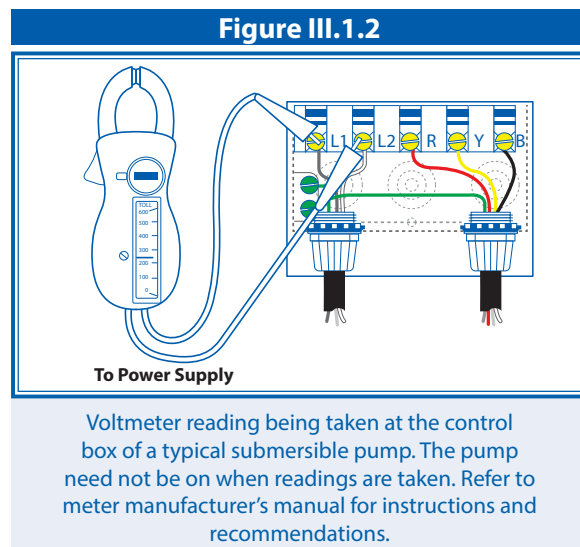
Other forms of this same formula are:

$$I = \frac{E}{R} \quad \text{and} \quad R = \frac{E}{I}$$

Voltmeter tests should be made with current off and on

As stated previously, the **voltmeter** is a device to measure electrical pressure between wires, or from wire to ground. Figure III.1.2 shows a reading being taken at the terminals of a typical submersible motor **control box**.

Note that it is not necessary to have the motor connected or running in order to obtain a voltmeter reading. In fact, readings should be made both with the motor off and with the motor running. A significant voltage difference would indicate an undersized power supply transformer or undersized input wiring.



In making voltage tests, if your meter does not set the range automatically, always start with the highest scale setting and work down to a scale that will give a reading between mid-scale and full-scale for best accuracy.



Nameplate voltage should +/- 10% from motor nameplate.

Example: Common Single-Phase Voltages

230V nameplate = 207 – 253V

115V nameplate = 103 – 127V

Measured line to line.

Procedure for making ammeter tests

Because an ammeter measures current flow, the motor must be running in order to get a meter reading. Figure III.1.3 shows a typical use of a tong-type ammeter. For maximum accuracy, follow these steps:

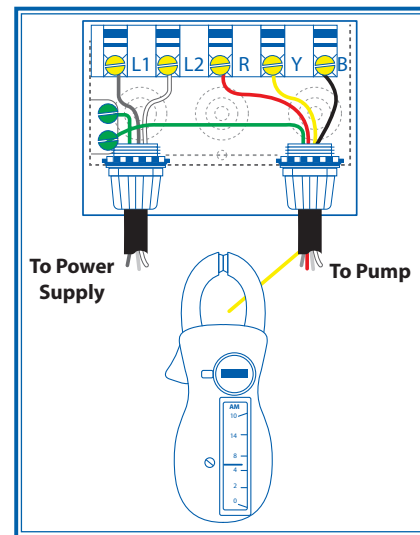
1. Carefully pull the wire being measured away from all other wires.
2. Set the ammeter to the highest scale. After starting a motor, leave ammeter on this scale until current settles down.
3. Place the tongs of the meter around the wire.
4. Change the meter scale to one that gives the best accuracy. This would be a reading between mid-scale and full-scale.
5. Compare the reading with the manufacturer's data.

Basic steps in ohmmeter use

Ohmmeter tests are always made with the power off and with all of the wires disconnected from the control box or the starter. Always follow these general instructions carefully:

1. De-energize the circuit, lock and tag it, and test with a voltmeter to verify that it is de-energized. Then disconnect the items to be tested from all the other circuits.
2. Turn the selector knob to a multiplier that will give a reading as close to mid-scale as possible. Most ohmmeters indicate the resistance (R) times a multiplier, X (a number, usually 1, 10, 100, 1,000, 10,000, etc.) to show what the direct scale reading is to be multiplied by for a correct resistance value.
For example:
RX 10 = scale reading times 10.
RX 10K = scale reading times 10,000 (K = 1,000).
3. Clip the leads together and adjust the zero ohms knob until the needle is over the zero (0). Always zero the meter before every use and every time the selector switch is changed.
4. Unclip the leads and clip to the wires to be tested.
5. Never allow bare meter leads or any bare wires of the circuit being tested to touch the ground, water, or any part of the body, especially the fingers. Otherwise, a false reading will result.

Figure III.1.3



Ammeter reading taken at a submersible control box. To determine current flow, slip tongs around one wire and read amperage with the current on. Refer to meter manufacturer's manual for instructions and recommendations.

Motor continuity test of motor windings and circuit

The **motor continuity test**, for circuit resistance, is used to determine the condition of the motor windings and circuit. Refer to Figure III.1.4 and proceed as follows:

1. Set the selector knob on the lowest scale (RX 1) and follow the general instructions listed in the “Basic steps in ohmmeter use” section.

2. Attach the ohmmeter leads to two of the three motor leads or cable leads, one at a time, and compare readings with those provided by the pump or motor manufacturer.

3. A reading significantly higher than the manufacturer’s data indicates a possible burned (open) winding, loose connection, or wrong motor (different horsepower or voltage rating other than indicated by the nameplate on control box).

4. A considerably lower reading than the manufacturer’s data indicates a possible shorted (burned together) winding, or wrong motor (different horsepower or voltage rating other than indicated by nameplate on control box).

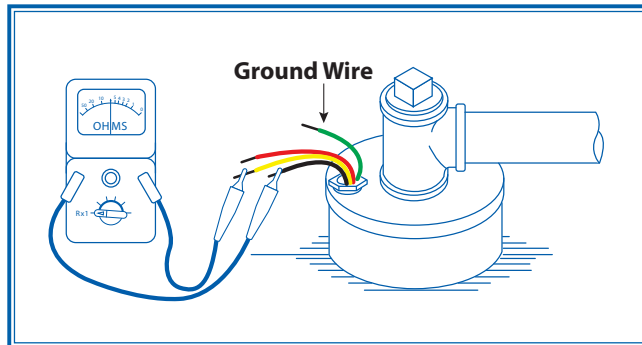
5. An unbalanced reading for a **three-phase motor** indicates a burned winding or faulty connection.

6. A correct reading, but a wrong wire color combination for a three-wire **single-phase motor**, indicates improper matching at the splice. To correct above ground, take the following steps:

- (a) Ignore color of wires and locate the two wires that give the highest ohmmeter reading. Mark the remaining wire “yellow.”
- (b) Mark the wire “black” that in combination with the “yellow” wire [as determined in step (a)] gives the lowest reading.
- (c) Mark the remaining wire “red.”

[NOTE: Colors correspond to the National Electrical Manufacturers Association (NEMA) standards for submersible pump cable.]

Figure III.1.4



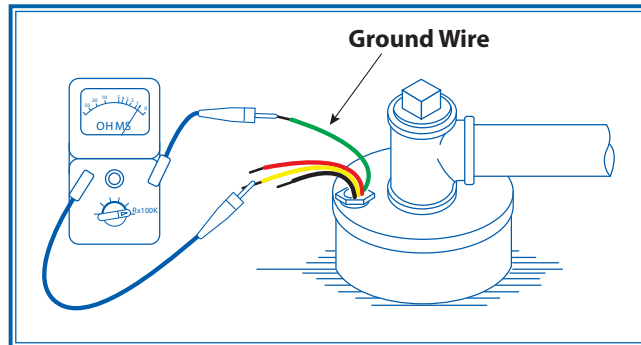
Arrangement of ohmmeter for motor continuity test. Scale is set at RX 1 and leads are connected to any two of the cable wires. Refer to meter manufacturer’s manual for instructions and recommendations.

Insulation or ground test using ohmmeter

To conduct the insulation test or ground test, refer to Figure III.1.5. This test is used to determine if the insulation of the motor or cable has been damaged. It consists of the following:

1. Set the selector knob for the highest setting (RX 100K) and follow general instructions for ohmmeter checks.
2. Attach one ohmmeter lead to one motor lead.
3. Attach the other lead to an unpainted metallic part of the motor or pump. If the unit is in the well, attach to metallic **drop pipe, well casing**, or green ground wire from motor.
4. Proper resistance will be greater than 500,000 ohms (1 on the RX 100K scale). Less resistance than this indicates excessive ground leakage at the splice, in the cable insulation, or in the motor winding. Most manufacturers recommend pulling the motor for further examination and to correct the leak. Resistances between 10,000 ohms and 500,000 ohms do not necessarily indicate a failure, but they do indicate that a failure may occur in the future, if corrective steps are not taken.

Figure III.1.5



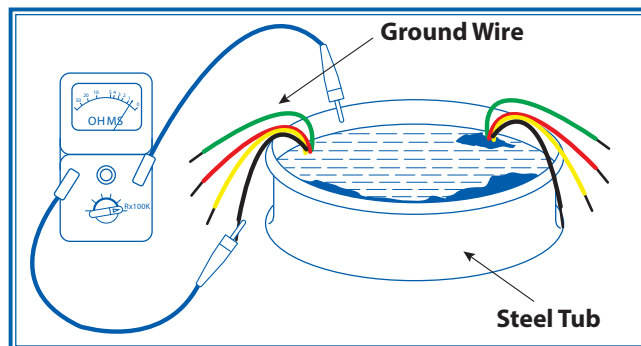
To test insulation with an ohmmeter, set selector knob for highest setting, RX 100K. Connect one meter lead to any other cable lead and the other meter lead to the ground. All three cable wires should be checked in this test.

How to isolate ground leakage cable and/or splice

To isolate ground leakage in cable and/or splice, refer to Figure III.1.6 and proceed as follows:

1. Submerge the cable and splice in a steel barrel of water with both ends out of the water.
2. Set the ohmmeter selector on RX100K and adjust the needle to zero (0) by clipping the ohmmeter leads together.
3. After adjusting the ohmmeter, clip one lead to the barrel and the other to each cable lead individually.
4. If the needle deflects to zero (0) on any of the cable leads, pull the splice out of the water. If the needle falls back to the left to infinity (no reading), the leak is in the splice.
5. If the leak is not in the splice, pull the cable out of the water slowly until the needle falls back to infinity (no reading). When the needle falls back, the leak is at that point in the cable.
6. If the cable or splice is bad, it should be repaired or replaced.

Figure III.1.6



To locate the leak in the cable and/or splice, ground one ohmmeter lead and clip the other lead to the cable wire. Gradually withdraw the wire from the water. When resistance jumps to infinity, the leak is just above the water level. Use a steel tub, or the meter lead should be connected to the ground wire.

Weakness in insulation detected by megohmmeter

Another form of ohmmeter is an **insulation tester** known as the **megohmmeter**, or more commonly, the megger. The megger is used only for measuring insulation resistance. It has a much higher source of internal voltage, at least 500 DCV. The megger is either powered by a generator, which is driven by a hand crank, or by an internal battery and electronic circuit.



You can be electronically shocked if you touch the test leads while testing with a megger.

The megohmmeter is more effective in checking insulation than the standard ohmmeter because of its higher voltage power supply. It can detect weak or damaged insulation that may not be indicated by a standard ohmmeter.

Watt hour meter indicates input horsepower

Another handy electrical instrument, which is always with you on the job, is the power company's **watt hour meter**. If all other power using devices are turned off, a motor power input reading may be made from this meter. All such meters have a disc constant K (sometimes Kh) stamped on the face plate. This shows the number of watts for one revolution of the disc in one hour. By counting the number of disc revolutions (R) in a measured period of time (T) and substituting that figure in the following formula, the power input determination may be made:

$$kW = \frac{3.6 \times K \times R}{T}$$

$$hp = \frac{4.38 \times K \times R}{T}$$

R = revolutions of disc
 T = number of seconds for R revolutions
 K = disc constant (Kh)
 kW = kilowatts (1000 watts)
 hp = horsepower

The horsepower figure in this formula is input motor horsepower and not output, or rated, motor horsepower. To obtain rated motor horsepower or motor output horsepower to the pump, multiply the input horsepower by the motor efficiency expressed as a decimal.

Several pressure gauges and compound gauge also needed

In addition to the electrical instruments described here, several pressure gauges of varying ranges and a compound pressure-vacuum gauge should also be carried in the service kit.

How a pressure gauge can determine proper rotation of three-phase motors

Use the **pressure gauge** to determine proper rotation in three-phase motors. First, run the pump in one direction at shutoff and measure the **discharge pressure**. Then stop the pump and reverse any two of the three power cables. Run the motor again at shutoff and measure the discharge pressure. The direction that gives the highest discharge pressure is the correct rotation. It is key to know the pressure rating of the system being tested.

How a pressure gauge can determine depth to water

It is also possible to determine depth to water with a pressure gauge, but the accuracy depends upon the accuracy of the manufacturer's pump data. To measure depth to water, take the pressure reading against the **shutoff valve**. Subtract this from the total shutoff head of the pump taken from the manufacturer's data. The remainder is the depth to water. All figures must be in either psi or feet of **head**.

How a pressure gauge can measure drawdown

For a desired amount of **drawdown**, the unit should then be allowed to pump for a period of time and occasional readings made with the valve shutoff momentarily. The shutoff pressure will continue to drop until the drawdown level is reached. This is the point where the **pump** is pumping water from the well at the same rate at which water is flowing into the well. This depth is determined in the same way that the **static depth** is determined (Book VIII, Chapter 1).

Compound gauges

The **compound pressure-vacuum gauge** is used to make tests on jet pumps. Readings can determine the condition of the **foot valve**, the **nozzle**, and **venturi**. The gauge can also be used to assist in setting the regulating valve and in checking vacuum-type **air chargers**.

Because there are always conditions where the suction line will be subject to pressure, a combination pressure-vacuum gauge (called a compound gauge) should always be used to avoid gauge damage.

Vacuum gauges used to check jet pump performance

A centrifugal pump or jet pump in good operating condition should be capable of pulling a vacuum up to 25 inches of mercury (Hg), which is equivalent to 28 feet of water. But because **capacity** decreases quite rapidly with an increase in lift, these pumps are normally not operated beyond 22 inches Hg or 25 feet of water. Conversely, the more water the pump is handling, the higher the vacuum reading will normally be in the **suction pipe**.

Most **vacuum gauges** are calibrated in inches of mercury. This can be converted to feet of water by multiplying by 1.13, or for rough estimates, reading the gauge directly as feet of water.

Vacuum gauge installation on shallow well pump

When installing a vacuum gauge, make certain that it is located ahead of the injector. Refer to Figure III.1.7 (page 17). Some units have a tapped opening for attaching the **air-volume control**, located between the injector and the **impeller**. Installed here, the gauge does not show total **suction lift**.

A vacuum gauge located at the pump suction will register the total suction lift at which the pump is operating. This includes vertical distance to water, as well as friction loss in the foot valve, strainer, pipe, and **fittings**. When the pump is stopped, the gauge will record **pressure tank** pressure, if the line is equipped with a foot valve. If not, the gauge will record the vertical distance to the water level.

Most shallow well performance problems center around a loss of capacity. In general, low capacity, coupled with a higher vacuum gauge reading than is warranted by the estimated water level, indicates a restriction in the suction pipe. This may result from a plugged strainer or foot valve or excessive friction loss. It could also indicate a water level lower than estimated.

Low capacity accompanied by a lower vacuum reading than warranted would indicate either (a) an air leak in the suction line or (b) excessive impeller wear ring clearance that allows too much recirculation.

Here are some examples:

1. Conditions ... A pump located 4 to 5 feet above water with short offset (2 to 3 feet) delivers little or no water. Vacuum gauge shows, for example, 20 inches Hg vacuum. Causes ... strainer or foot valve plugged.
2. Conditions ... A pump located 20 feet from water pumps no water; vacuum gauge shows 10 inches Hg or 11.33 feet. Causes ... (a) an air leak in the suction line or (b) excessive impeller wear ring clearance.
3. Conditions ... A pump located within the limits of a suction lift but showing high vacuum is pumping less than the rated capacity. Causes ... (a) excessive offset or (b) too small of a suction line or (c) a partially plugged strainer.

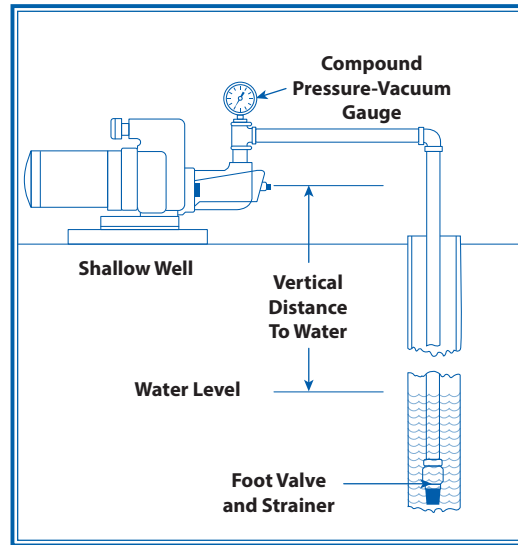
Compound gauge used with deep well jets

A compound pressure-vacuum gauge installed as shown in Figure III.1.8 will indicate some of the pumping problems encountered with **deep well jet pumps**. Part of the **pump capacity** is recirculated through the **drive pipe** back to the injector installed in the well, so it is impossible to determine the water level with the gauge reading. It is possible to develop a positive pressure by changing the setting of the regulating valve. Some manufacturers indicate the most efficient point of operation of their jet pump at a given suction line value. Using this information and the gauge, the regulating valve can be set. In general, this value would range from 18 to 25 feet of suction at the pump as indicated by the gauge.

Some of the pump problem indications and their probable causes are:

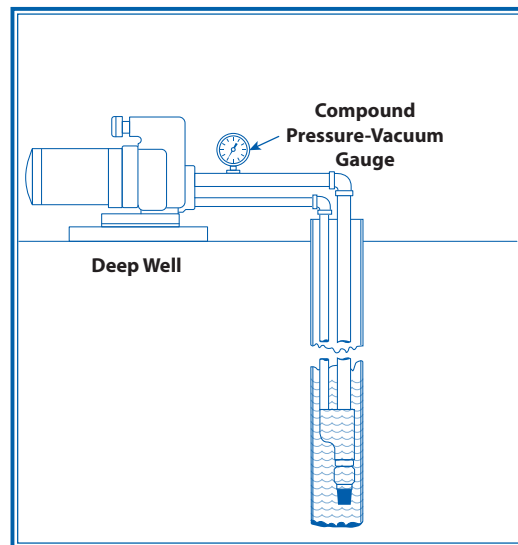
1. Conditions ... A vacuum gauge showing a high reading but pumping no water. Causes ... (a) the water level is beyond the range of the injector setting or (b) friction in the lines is too great due to excessive fittings, too great an offset, injector submerged too much, pipe too small for the length of run or (c) a plugged nozzle or strainer or (d) the **pump discharge** pressure is not high enough because the regulating valve is set too low.
2. Conditions ... Pumping lower than rated capacity. Causes ... (a) the pressure regulating valve setting is too low or (b) excessive friction or (c) wrong injector or (d) excessive submergence.

Figure III.1.7



In a shallow well jet installation, the vacuum gauge is located ahead of the injector as it is shown here.

Figure III.1.8



A compound pressure-vacuum gauge installed on a deep well jet pump is located on the suction line as shown.

Compound gauge used to check air-volume control

The compound vacuum gauge can also be used to determine the amount of suction in the line available for operating the air-volume control (AVC). Most vacuum-operated AVCs require a minimum of 5 to 6 inches Hg during pump operation and a 0 or slight pressure reading when the pump is stopped. Problems are often encountered with shallow well installations where the water level is near the surface. A gauge connected to the AVC **tapping** in the pump case will determine if the conditions are available to operate the AVC . If not, vacuum boosters are available.

Instruments should be used on every installation. Continued practice will assist the installer in recognizing problems as they occur. Installers will gain confidence in the use of the instruments and save hours of service time.



As warned at the beginning of this chapter, make sure all metal that has any possible contact with the motor or cable is **grounded** in compliance with local and national electric codes. Do not touch any live parts when measuring voltage and current, and disconnect the power, lock out and tag the circuit, and measure for voltage on the circuit when doing other testing.

Study Guide Questions - Chapter 1

Answers can be found on page 64

Q. What precautions should be taken when working with electrical circuits?

Q. What precaution must be taken before measuring resistance with an ohmmeter?

Q. How do electrical system measurements relate to water system measurements?

Q. What is a megger and what does it do?

Q. Why use a compound pressure-vacuum gauge?

Notes

Chapter 2

Jet Pump Service

- ✓ Troubleshooting five common jet pump service problems

- ✓ Possible causes

- ✓ Procedures to check

- ✓ Ways to correct

The **jet pump** is used with many domestic water systems. A thorough understanding of the functions of each of the four components in a water system using a jet pump will enable the installer to better handle service problems. These components are the **centrifugal pump**, the jet pump, air controls (including the tank), and the electrical group (motor and **pressure switch**). The functions of each of the other components are thoroughly covered in other chapters.

In this chapter, five common service problems of jet pumps are addressed in charts that list possible causes as well as procedures for checking and correcting each possibility.

To help pinpoint the possible source of trouble when the pump will not start or run (Chart A, pages 22-23), first use a voltmeter to check the voltage at the line side of the pressure switch. If the voltage is 0 or low, the cause of trouble is in step 1, 2, or 3 in the chart. If the reading is OK, check the voltage on the motor side of the pressure switch. A low or 0 reading at this point indicates the trouble is identified in step 5 or 6. A satisfactory reading indicates that the next step is to check the motor terminals. Check out step 7, then proceed with steps 3, 4, 8, or 9, in that order.



Ensure that the electrical instruments you select and use are rated for more than the highest voltage you expect to work on, and that you know how to use them properly and safely. In addition, use only the test leads supplied by the meter manufacturer to troubleshoot circuitry. Never use uninsulated alligator clips for troubleshooting. Their exposed metal can be a shock hazard and can cause arcing electrical faults.

A. Pump Will Not Start or Run

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Blown fuse or circuit breaker.	Check to see if the fuse or circuit breaker is OK.	If it is blown, replace it with a fuse of proper size or trip circuit breaker.
2. Low line voltage.	With the pump motor energized, use the voltmeter to check the pressure switch terminals nearest pump. Check voltage at the source as you work back.	If the voltmeter reading is under the recommended minimum, check the size of wiring from the main switch on the property. If it is OK, contact the power company.
3. Loose, broken, or incorrect wiring.	Check the wiring circuit against the diagram. De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. See that all of the connections are tight and that no short circuits exist because of worn insulation, crossed wires, or other factors.	Rewire any incorrect circuits and tighten connections; replace defective wires.
4. Defective motor.	Check to see that the switch is closed.	Repair, replace, or take it to the motor service station.
5. Defective pressure switch.	Check the switch setting. De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Examine the switch for worn or burnt contacts.	Adjust the switch settings. Check for flow between the pump and the switch, and also the opening or pulse orifice in the switch. If contacts are worn or burnt, replace contacts.
6. Tubing to pressure switch plugged.	Remove the tubing and blow through it.	Clean or replace if plugged.
7. Impeller or seal problem.	De-energize the circuit, lock it out and tag it, then use a screwdriver to try to turn the impeller or motor.	If the impeller will not turn, remove housing and locate the source of binding.

A. Pump Will Not Start or Run (continued)

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
8. Defective start capacitor. Note: Be sure to discharge capacitor before testing.	De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Use an ohmmeter to check the resistance across a capacitor. The needle should jump when contact is made. No movement of the needle means an open capacitor; zero resistance means the capacitor has shorted out.	Replace the capacitor or take the motor to the service station.
9. Motor shorted out.	If the fuse blows or the circuit breaker trips when the pump is started (and external wiring is OK), the motor may be shorted out. Check the wires to the motor for possible short.	Replace the motor.

B. Motor Overheats and Overload Trips Out

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Incorrect line voltage.	Use a voltmeter to check at the pressure switch or terminals nearest pump.	If voltage reading is under the recommended minimum, check size of wiring from main switch on property. If OK, contact the power company. Check voltage at source as you work.
2. Motor wired incorrectly.	Check the motor wiring diagram.	De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Reconnect the motor for proper voltage according to wiring diagram.
3. Inadequate ventilation.	Check the air temperature where the pump is located. If over 100°F, overload may be tripping due to high ambient temperature.	Provide adequate ventilation or move the pump to an area with lower ambient temperature.
4. Prolonged low-pressure water flow.	Continuous operation at very low-pressure places heavy overload on pump. This can cause overload protection to trip.	On a deep well system, check the pressure control valve . Check for worn parts. Check for leaks in the distribution system. Replace worn parts. Repair leaks as necessary.

C. Pump Starts and Stops Too Often

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Leak in pressure tank.	For diaphragm or bladder/pressure tanks, turn off the power to the pump, drain the tank and check the precharge pressure. It should be a minimum of 2 psi below pump cut-in pressure . If lower, check welds, braze joints, mechanical joints, and valve core with a soap solution. If it is defective, replace. IMPORTANT: DO NOT ATTEMPT TO REPAIR.	Replace the tank.
2. Waterlogged tank.	Depress air stem to see if water emerges.	Replace tank.
3. Low air charge.	Drain tank to measure precharge via the air stem.	Precharge should be 2 psi below pressure switch cut-in.
4. Tank too small.	Use manufacturer sizing chart	Replace with proper size tank.
5. Too small pressure differential.	Check pressure switch setting.	Use a 20 psi pressure differential.
6. Faulty pressure switch.	Check the switch setting. Examine the switch contacts for dirt or excessive wear.	Check for flow between the pump and switch, and the opening or pulse orifice in the switch. Replace the switch.
7. Leak on discharge side of system.	Make sure all of the fixtures in the plumbing system are shut off. Then check all of the units (especially ballcocks) for leaks. Listen for the noise of water running.	Check piping system and repair leaks, as necessary.

C. Pump Starts and Stops Too Often (continued)

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
8. Leak on suction side of system.	On shallow well units, install the pressure gauge on suction side. On deep well systems, attach a pressure gauge to the pump. Close the discharge line valve. Then, using a bicycle pump or air compressor, apply about 30 psi pressure to the system. If the system will not hold this pressure when the compressor is shut off, there is a leak on the suction side.	Reprime the pump, spray shaving cream or use dishwashing liquid on the joints, turn on the pump. Visually inspect for an inward leak or suction. Repair leaks, as necessary.
9. Leak in foot valve.	Pull the piping and examine check valve or foot valve.	Repair or replace defective valve.
10. Leak in system.	Turn off valve to house and check all outlets for leaks.	Repair leaks.

D. Pump Will Not Shut Off

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Wrong pressure switch or setting drift.	Lower the switch setting. If the pump shuts off, this was the problem.	Adjust the switch to the proper setting.
2. Defective pressure switch.	Arcing may have caused the switch contacts to weld themselves closed. De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Examine the points and other parts of the switch for defects.	Replace the switch if it is defective. Check for flow between the pump and the switch, and the opening or pulse orifice in the switch.
3. Tubing of pressure switch plugged.	Remove the tubing and blow through it.	Clean or replace the tubing if plugged.
4. Loss of prime.	When no water is being delivered, check the prime of the pump and well piping.	Reprime if necessary.
5. Low well level.	Check the well depth on the pump performance table to make sure the pump and the ejector are properly sized.	If undersized, replace pump or ejector.
6. Plugged ejector.	Remove the ejector and inspect it.	Clean and reinstall if dirty.
7. Leaks.	Turn off valve between house and water system to isolate leak. Check all outlets for water distribution.	Repair leaks.

E. Pump Operates But Delivers Little or No Water

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Low line voltage.	Check the voltage reading at pressure switch or terminals nearest pump.	If the voltage reading is under the recommended minimum, check the size of wiring from the main switch on the property. If OK, contact the power company.
2. Suction leak or system not primed.	When no water is being delivered, the mechanical seal may not be seated properly, resulting in a suction leak condition or failure to prime. Check prime of pump and the well piping.	Reseat the seal. Reprime if necessary.
3. Air lock in suction line.	Check the horizontal piping between the well and pump. If it does not slope upward from the well to the pump, an air lock may form.	Rearrange the piping to eliminate air lock.
4. Undersized piping.	If the system water flow is low, the discharge piping and/or plumbing lines may be undersized. Refigure the friction loss.	Replace the undersized piping.
5. Leak in air-volume control or tubing.	Disconnect the air-volume control tubing at the pump and plug the hole. If the capacity increases, a leak exists in the control tubing.	Tighten all fittings and replace the air-volume control if necessary.
6. Pressure-regulating valve stuck or incorrectly set (deep well only).	Check the valve setting. Inspect the valve for defects.	Reset, clean, or replace the valve as needed.

E. Pump Operates But Delivers Little or No Water (continued)

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
7. Leak on suction side of system.	On shallow well units, install a pressure gauge on suction side. On deep well systems, attach a pressure gauge to the pump. Close the discharge line valve. Then, using a bicycle pump or air compressor, apply about 30 psi pressure to the system. If the system will not hold this pressure when the compressor is shut off, there is a leak on the suction side.	Make sure aboveground connections are tight, then repeat the test. If necessary, pull the piping and repair the leak.
8. Low well level.	Check well depth against pump performance table to make sure the pump and ejector are properly sized.	If undersized, replace the pump or ejector.
9. Wrong pump-ejector combination.	Check the pump and ejector models against the manufacturers' performance tables.	Replace ejector if wrong model is being used.
10. Low well level.	Shut off the pump and allow the well to recover. Restart the pump and note whether water flow drops after continuous operation.	If well is "weak," lower the ejector (deep well pumps), use a tail pipe (deep well pumps), or switch from shallow well to deep well equipment.
11. Plugged ejector.	Remove the ejector and inspect.	Clean and reinstall if dirty.
12. Defective or plugged foot valve and/or strainer.	Pull the foot valve and inspect. Partial clogging will reduce water flow. Complete clogging will result in no water flow. A defective foot valve may cause pump to lose prime, resulting in no water flow.	Clean, repair, or replace as needed. A working foot valve will not cause loss of prime unless it is uncovered by water.

E. Pump Operates But Delivers Little or No Water (continued)

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
13. Worn or defective pump parts or plugged impeller.	Low water flow may result from wear on the impeller or other pump parts. Disassemble and inspect.	Replace worn parts or the entire pump. Clean parts if required.

Study Guide Questions - Chapter 2

Answers can be found on page 64

Q. What is the first step in checking a malfunctioning jet pump?

Q. If the above reading is normal, what is the next step?

Q. What are five common jet pump service problems?

1.

2.

3.

4.

5.

Notes

Chapter 3

Submersible Pump Service

- ✓ Six charts cover 95% of all submersible pump service work ... most of it can be done without touching the pump.

The **submersible pump** is the type used in most new water system installations. Its simplicity of operation, ease of installation, and improved electrical and mechanical design have contributed much to its popularity. In order to gain this acceptance, the manufacturers have had to teach installers how to handle and service the system's electrical parts.

Installers also are required to purchase and learn to use electrical instruments such as ohmmeters, ammeters, insulation resistance meters, and voltmeters or multimeters. The proper selection and use of these instruments, and an adequate knowledge of the functions of the electrical components, has overcome much of the fear of installing and servicing this equipment. These instruments are necessary to help locate sources of trouble and prevent pulling a satisfactory unit.

After mastering use of the instruments and the procedure for checking a unit, installers have only to follow the procedures outlined in the following charts to locate the source of a problem.

These charts cover nearly every kind of submersible pump servicing issue.

As submersible designs have improved, service procedures have also been simplified. Today, troubleshooting submersibles is easy, and, contrary to a widely held impression, most service checks can be made without pulling or touching the pump. Always make all of the aboveground checks before the pump is pulled from the well.



Much of the diagnosis on submersibles involves simple electrical tests, so it is essential that the service contractor be thoroughly familiar with the electrical components of a water system. Manufacturers' service literature generally includes explicit instructions for making electrical tests.

Only two instruments are generally needed — a combination voltmeter/ammeter and an ohmmeter — both of which are inexpensive and readily available from most water systems suppliers.



Ensure that the instruments you select are rated for more than the highest voltage you expect to work on, and that you know how to use them properly and safely. In addition, only use the test leads supplied by the meter manufacturer to troubleshoot circuitry. Never use uninsulated alligator clips for troubleshooting. Their exposed metal can be a shock hazard and can cause arcing electrical faults.

After mastering these instruments, which takes an hour or less, service representatives simply follow systematic troubleshooting procedures to diagnose almost all service troubles that might be encountered with submersibles. These procedures are outlined here. Each of the six charts outlines the procedure for tracing a source of major operating trouble. Together, the charts cover 95 percent or more of all submersible service problems.

A. Fuse, Overload, or Circuit Breaker Trips When Motor Is Started

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Incorrect line voltage.	Check the line voltage terminals in the control box (or connection box in the case of the two-wire models) with a voltmeter. Make sure that the voltage is within the minimum—maximum range prescribed by the manufacturer.	If the voltage is incorrect, contact the power company to correct.
2. Defective control box: a. Defective wiring.	Check all motor and powerline wiring in the control box, following the wiring diagram found inside the box. De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Check that all connections are tight and that no short circuits exist because of worn insulation, crossed wires, or other factors.	Rewire any incorrect circuits. Tighten loose connections. Replace worn wires.
b. Incorrect components.	Check all control box components to see that they are the type and size specified for the pump in the manufacturer's literature. In previous service work, the wrong components may have been installed.	Replace any incorrect component with a component of the size and type recommended by the manufacturer.
c. Defective starting capacitor (skip for two-wire models). NOTE: Be sure to discharge capacitor before testing.	Using an ohmmeter, X1000 scale, determine the resistance across the disconnected starting capacitor . When contact is made, the ohmmeter needle should jump toward 0, and then drift back slowly toward infinity. No movement indicates an open capacitor. Low resistance means that the capacitor is shorted.	Replace defective starting capacitor.
d. Defective relay (skip for two-wire models).	Using an ohmmeter, check the relay coil and contacts. Their resistance should be as shown in the manufacturer's literature.	If coil resistance is incorrect or contacts are defective, replace relay .

A. Fuse, Overload, or Circuit Breaker Trips When Motor Is Started (continued)

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
3. Incorrectly wired pressure switch.	Check the wiring at the pressure switch.	Make sure all line, load, and ground connections in the switch match the diagram.
4. Defective motor winding or cable: a. Shorted or open motor winding.  b. Grounded cable or winding.	Ohmmeter tests are always made with the power off and with all the wires disconnected from the control box or the starter. Check the resistance of the motor winding by using an ohmmeter on the proper terminals in the control box (see manufacturer's wiring diagram). De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. The resistance should match the ohms specified in the manufacturer's data sheet. If too low, the motor winding may be shorted; if the ohmmeter needle does not move, indicating high or infinite resistance, there is an open circuit in the motor winding or cable. Connect one lead of the ohmmeter to the ground wire, then connect the other lead to each motor wire terminal. If the ohmmeter needle moves appreciably when this is done, there is a ground in either the cable or the motor winding.	If the motor winding is defective — shorted or open — the pump must be pulled and the motor replaced. Pull the pump and inspect the cable for damage. Replace damaged cable. If cable checks OK, the motor winding is grounded. Motor must be replaced.
5. Pump locked.	Check the line amps before the trip. If amps are twice normal or higher, the pump is probably locked.	Pull pump, disassemble from motor, and check which one is locked. Replace one, or both, if defective.

B. Pump Operates But Delivers Little or No Water

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Pump may be air-locked.	Stop and start the pump several times, waiting about one minute between cycles. If the pump then resumes normal water flow, air lock was the problem.	If this test fails to correct the trouble, proceed with the steps that follow. Quickly raise and lower pump several times to open check valve and release trapped air.
2. Water level in well too low.	Well production may be too low for pump capacity. Restrict the flow of pump output, then wait for well to recover and restart pump. Check motor amps for low amp reading.	If partial restriction corrects trouble, leave valve or cock at restricted setting. Otherwise, lower pump in well if depth is sufficient. Do not lower if sand clogging might occur.
3. Discharge line check valve installed backward.	Examine check valve on discharge line to make sure that the arrow indicating direction of flow points in the right direction.	Reverse the valve, if necessary.
4. Leak in drop pipe.	Check head pressure at top of well. Raise the pipe and examine for leaks.	Replace the damaged section of the drop pipe .
5. Pump check valve jammed by drop pipe.	When pump is pulled after completing step 4, examine connection of drop pipe to pump outlet. If threaded section of drop pipe has been screwed in too far, it may be jamming the pump's check valve in the closed position.	Unscrew the drop pipe and cut off a portion of threads.
6. Pump intake screen blocked.	Check amps for low reading. The intake screen on the pump may be blocked by sand or mud. Check the screen.	Clean the screen, and when reinstalling the pump, make sure that it is located several feet above the well bottom — preferably 10 feet or more.

B. Pump Operates But Delivers Little or No Water (continued)

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
7. Pump intake screen blocked. Worn components.	The presence of abrasives in the water may result in excessive wear on the impeller, casing, and other close-clearance parts. Before pulling the pump, see if the pump shuts off. If it does not, worn parts are probably the issue.	Pull the pump and replace worn components.
8. Motor shaft uncoupled.	Coupling between motor and pump shaft may have worn out or worked loose. Inspect for this after pulling the pump and looking for worn components, as in step 7.	Tighten all connections and setscrews. Replace parts if worn.

C. Pump Starts Too Frequently

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Pressure switch defective or out of adjustment.	Check the setting on the pressure switch and examine for defects.	Adjust the pressure setting or replace switch.
2a. Leak in pressure tank above water level.	For discharge or bladder-captive air tanks, drain the tank and check the precharge pressure. It should be equal to or 2 psi below pump cut-in pressure . If lower, check welds, braze joints, mechanical joints, and valve core using a soap solution. If defective, replace. DO NOT ATTEMPT TO REPAIR.	Replace tank.
2b. Waterlogged tank.	Depress air stem to see if water emerges.	Replace tank.
3. Leak in plumbing system.	Examine the service line to the house and distribution branches for leaks.	Repair leaks.
4. Discharge line check valve leaking.	Remove and examine.	Replace if defective.
5. Air-volume control plugged.	Remove and inspect the air-volume control.	Clean or replace.
6. Snifter valve plugged.	Remove and inspect the snifter valve .	Clean or replace.
7. Pressure tank has lost charge.	Check tank per Book IV, Chapter 1.	Recharge or replace tank.

D. Fuse, Overload, or Circuit Breaker Trips When Motor Is Running

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Incorrect voltage.	Check the line voltage terminals in the control box (or connection box for two-wire models) with a voltmeter. Make sure that the voltage is within the minimum—maximum range prescribed by the manufacturer.	If voltage is incorrect, contact the power company for service.
2. Overheated control box or starter.	If sunlight or other sources of heat make the box too hot, overload may trip or fuses may blow. If box is hot to the touch, this may be the problem.	Ventilate or shade the box, or remove it from the source of heat.
3. Defective control box components (applies to three-wire models). NOTE: Be sure to discharge capacitor before testing. Short capacitor terminals together. 	De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Use an ohmmeter on the X1000 scale to determine the resistance across the disconnected running capacitor. When contact is made, the ohmmeter needle should jump toward 0, and then drift back slowly toward infinity. No movement indicates an open capacitor; low resistance means the capacitor is shorted. Using an ohmmeter, check the relay coil. Its resistance should be shown in the manufacturer's literature. Re-energize the circuit and check amps in red motor lead with motor running. If amps are much higher than the manufacturer specifies, start-relay contacts are failing to open.	Replace defective components.
4. Defective motor winding or cable. 	Ohmmeter tests are always made with the power off and with all the wires disconnected from the control box or the starter. De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Check the resistance of the motor winding by using an ohmmeter on the proper terminals in the control box (see manufacturer's wiring diagram). The resistance should match the ohms specified in the manufacturer's data sheet. If too low, the motor winding may be shorted. If the ohmmeter needle does not move, indicating high or infinite resistance, there is an open circuit in the motor winding. Ground one lead of the ohmmeter onto the ground wire or any available ground source (drop line or well casing), and then touch the other lead to each motor wire terminal. If the ohmmeter needle moves appreciably when this is done, there is a ground in either the cable or the motor winding.	If either cable or winding is defective — shorted, grounded, or open — the pump must be pulled and serviced. Replace motor and/or cable.
5. Motor is overloading.	If the overloads trip while the pump is operating, check the line amps. If reading is more than 5 percent above the manufacturer's nameplate value, the pump motor is overloading, which indicates a defective pump and/or motor.	Pull pump, disassemble from motor, and replace one or both, if defective.

E. Pump Will Not Shut Off

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Defective pressure switch.	Check the pressure switch to ensure contacts are open at the correct pressure.	Adjust or replace switch.
2. Water level in well too low.	Well production may be too low for the pump capacity. Restrict the flow of pump output, wait for the well to recover, and then start pump.	If partial restriction corrects the issue, leave the valve or cock at restricted setting. Otherwise, lower pump into the well if depth is sufficient. Do not lower if sand clogging might occur.
3. Leak in drop pipe.	Perform pressure test for low-pressure. Raise the pipe and examine for leaks.	Replace the damaged section of the drop pipe.
4. Pump parts worn.	The presence of abrasives in the water may result in excessive wear on the impeller, casing , and other close-clearance parts. Before pulling pump, reduce setting on pressure switch to see if the pump shuts off. If it does, worn parts are probably the issue.	Pull pump and replace worn components.

F. Motor Does Not Start, But Fuses Do Not Blow

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Overload protection tripped.	Check overloads to see if they are operable. Check motor amps.	Reset overloads. Replace defective part or motor. Refer to page 24 to determine cause of tripping.
2. No power.	Check power supply to control box (or overload protection box) by placing a voltmeter across the incoming power lines. Voltage should approximate nominal line voltage.	If no power is reaching the box, contact power company for service.
3. Defective pressure switch.	Check whether contacts are closed and the same voltage is present between load terminals as between line terminals.	If the line voltage is not on the load terminals, replace switch.
4. Defective control box.	De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Examine wiring in the control box to make sure all contacts are tight. Re-energize the circuit and with a voltmeter check voltage at line and motor terminals. If no voltage is shown at terminals, wiring is defective from pressure switch or in control box. With a voltmeter, check the voltage across the output terminals of the pressure switch while the switch is closed. If the voltage is not equal to the line voltage, the switch is not making contact or the contacts are damaged.	Correct faulty wiring or tighten loose contacts. Replace switch.

Study Guide Questions - Chapter 3

Answers can be found on page 65

Q. Why are submersible pumps popular in new water system installations?

Q. What are five electrical instruments used in servicing submersible pumps?

1.

2.

3.

4.

Q. Much of the diagnosis on submersibles involves simple electrical tests. Where can explicit instructions for making electrical tests be found?

Q. What types of checks should be made before pulling a pipe from a well?

Notes

This image shows a full page of blank handwriting practice paper. It features 20 evenly spaced, horizontal orange lines running across the entire width of the page. The background is a solid light gray color. There are no margins, text, or other markings on the page.

Chapter 4

Piston Pump Service

- ✓ Troubleshooting seven common piston pump service problems
- ✓ Possible causes
- ✓ Procedures to check
- ✓ Ways to correct

With the advent of the **jet pump** and the **submersible pump**, the **piston pump** has been decreasing in usage and popularity. Even with the availability of new types, however, there is still some limited demand for piston pumps. Thousands of units are also still in use and will require service.

The potential service problems for piston pumps are organized in seven charts. Each deals with a specific malfunction, and lists procedures for checking and correcting the difficulty.

To help pinpoint the possible source of trouble when the **pump** will not start or run (Chart A, pages 46-47), first use a **voltmeter** to check the **voltage** at the line side of the **pressure switch**. If the voltage is 0 or low, the cause of trouble is in step 1, 2 or 3 in the chart. If the reading is OK, check the voltage on the motor side of the pressure switch. A low or 0 reading at this point indicates the trouble is in step 5 or 6. A satisfactory reading indicates that the next step is to check the motor terminals. Check out step 7, then proceed with steps 3, 4, 8, or 9 in that order.



Ensure that the electrical instruments you select and use are rated for more than the highest voltage you expect to work on, and that you know how to use them properly and safely. In addition, use only the test leads supplied by the meter manufacturer to troubleshoot circuitry. Never use uninsulated alligator clips for troubleshooting. Their exposed metal can be a shock hazard and can cause arcing electrical faults.

A. Pump Will Not Start or Run

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Blown fuse.	With the pump motor energized, use the voltmeter to check the pressure switch terminals nearest the pump.	If the voltage reading is under the recommended minimum, check the size of wiring from the main switch on the property. If OK, contact the power company.
2. Low line voltage.	With the pump motor energized, use the voltmeter to check the pressure switch terminals nearest the pump.	If the voltage reading is under the recommended minimum, check the size of wiring from the main switch on the property. If OK, contact the power company.
3. Loose, broken, or incorrect wiring.	Check the wiring circuit against the diagram. De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Check that all connections are tight and that no short circuits exist because of worn insulation, crossed wires, or other factors.	Rewire any incorrect circuits. Tighten connections, replace defective wires.
4. Defective pressure switch.	Check the switch setting. De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Examine switch contacts for dirt or excessive wear.	Adjust the switch settings. Clean the contacts and replace, if necessary.
5. Tubing to pressure switch plugged.	Remove the tubing and blow through it.	Clean or replace if plugged.
6. Pump mechanically bound.	De-energize the circuit, lock it out and tag it. Turn pump by hand.	Locate the source of binding and repair.

A. Pump Will Not Start or Run (continued)

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
7. Defective start capacitor. NOTE: Be sure to discharge capacitor before testing. 	De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Disconnect capacitor from the motor. Use an ohmmeter to check resistance across capacitor. The needle should jump when the contact is made. No movement means an open capacitor. No resistance means that the capacitor is shorted out.	Replace the capacitor or take the motor to a service station.
8. Motor shorted out.	If the fuse blows when the pump is started (and external wiring is OK), the motor is shorted out.	Replace the motor.
9. Overload protector cut out.	Check the manual reset overload.	Correct the cause of overload by resetting it. Replace component or motor.

B. Pump Operates But Delivers No Water

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Low line voltage.	With the pump motor energized, use the voltmeter to check pressure switch at terminals nearest the pump.	If the voltage reading is under the recommended minimum, check the size of the wiring from the main switch on the property. If OK, contact the power company.
2. Loss of prime (piston pumps).	When no water is delivered, check prime of pump and well piping.	Re-prime if necessary.
3. Broken rod (working heads).	Disconnect rod from the pump head and see if it can be lifted easily.	If the rod is broken, remove the upper part, then fish for lower part or pull the drop pipe. Repair the break.
4. Low well level.	On piston pumps, make sure the water level is no more than 25 feet below pump (less if at elevated altitudes). On working heads, lower the well cylinder by adding more drop pipe and rod. If this results in water flow, the well cylinder was above water level.	If the water level is below 25 feet, the piston pump will not work. Replace it with a submersible or a deep well jet pump. Leave the well cylinder at lower level.
5. Air lock in suction line (piston pumps).	Check the horizontal piping between the well and pump. If it does not slope upward, an air lock may form.	Rearrange the piping to eliminate the air lock.
6. Suction valves stuck in open position (piston pumps).	Remove cover from water end of pump and inspect valves.	Clean out any foreign matter between valves and valve plate. Make sure a watertight closure can occur.

B. Pump Operates But Delivers No Water (continued)

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
7. Leak in suction line (piston pumps or drop-pipe working heads).	On piston pumps, install a vacuum gauge on the suction side and start the pump. Low vacuum means a leaky suction line. On the working heads, attach a pressure gauge to the discharge line, upstream of the main valve. Close the valve. Then using a bicycle pump or air compressor, apply about 30 psi of air pressure to the system. If this pressure is not held, there is a leak in the drop pipe.	Repair leaks as necessary. Repair leaks as necessary.
8. Open foot valve (piston pumps) or check valve (working heads).	Fill the drop pipe or suction line with water. If the water level drops, the lower valve may be defective. Pull drop pipe and inspect foot valve (piston pumps) or check valve (working heads).	Clean, repair, or replace as necessary.
9. Clogged drive point.	If drive point was used in the well, pull the suction line and examine it.	Clean the drive point and reinstall.

C. Low Capacity

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Undersize piping.	If the system discharge is low, the discharge piping and/or plumbing lines may be undersized. Refigure friction loss.	Replace the undersized piping or install a pump with higher discharge pressure.
2. Low well capacity.	Stop the pump and allow the well to recover. Restart pump and note whether the water flow drops after continuous operation. On working head units, low well capacity is indicated by a violent jarring of the drop pipe after continuous operation. This indicates that the air is entering the well.	If possible, lower the suction line to permit greater drawdown.
3. Leaky relief valve (piston pumps).	Examine the built-in relief valve for defect.	If relief valve is leaking, repair or replace.
4. Worn parts.	On piston pumps, examine the valves and valve plate, plunger leathers, and gaskets. On the working head units, pull the rod and examine leathers.	Replace worn or defective parts.

D. Pump Loses Prime (Piston only)

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Suction valves stuck in open position.	Remove the cover from water end of pump and inspect valves.	Clean out any foreign matter between valves and valve plate. Make sure a watertight closure can occur.
2. Leak in suction line.	On piston pumps, install a vacuum gauge on the suction side and start the pump. Low vacuum means a leaky suction line. On the working heads, attach a pressure gauge to the discharge line, upstream of the main valve. Close the valve. Then using a bicycle pump or air compressor, apply about 30 psi of air pressure to the system. If this pressure is not held, there is a leak in the drop pipe.	Repair leaks as necessary. Repair leaks as necessary.
3. Defective relief valve.	Examine the built-in relief valve for defects.	If relief valve is leaking, repair or replace.

E. Pump Starts and Stops Too Often

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Leak in pressure tank.	For the discharge or bladder-captive air tanks, drain the tank and check the precharge pressure. It should be equal to or 2 psi below pump cut-in pressure. If lower, check the welds, braze joints, mechanical joints, and valve core using a soap solution. If defective, replace. DO NOT ATTEMPT TO REPAIR BY WELDING.	Replace tank.
2. Defective air-volume control.	This will lead to a waterlogged tank. Make sure the air-volume control is operating properly. If not, remove and examine for plugging.	Clean or replace defective air-volume control.
3. Faulty pressure switch.	Check the switch setting. Examine the switch contacts for dirt or excessive wear.	Check for flow between the pump and the switch, and the opening or pulse orifice in the switch. Replace the switch.
4. Leak on discharge side of system.	Make sure all fixtures in the plumbing system are shut off. Then check all units (especially ballcocks) for leaks. Listen for the sound of water running.	Repair leaks as necessary.
5. Leak in suction line (piston pumps) or drop line (working heads).	On piston pumps, install a vacuum gauge on the suction side and start pump. Low vacuum means a leaky suction line. On the working heads, attach a pressure gauge to the discharge line, upstream of the main valve. Close the valve. Then using a bicycle pump or air compressor, apply about 30 psi of air pressure to the system. If this pressure is not held, there is a leak in the drop pipe.	Repair leaks as necessary. Repair leaks as necessary.

F. Pump Will Not Shut Off

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Wrong pressure switch setting or setting drift.	Lower the switch setting. If pump shuts off, this was the issue.	Adjust switch to proper setting.
2. Defective pressure switch.	Arcing may have caused switch contacts to weld themselves closed. De-energize the circuit, lock it out and tag it, and test with a voltmeter to verify it is de-energized. Examine points and other parts of switch for defects.	Replace switch if defective.
3. Tubing to pressure switch plugged.	Remove the tubing and blow through it.	Clean or replace if plugged.
4. Loss of prime (piston pumps).	When no water is delivered, check prime of pump and well piping.	Reprime if necessary.
5. Low well level.	On piston pumps, make sure water level is no more than 25 feet below pump (less if at elevated altitudes). On the working heads, lower well cylinder by adding more drop pipe and rod. If this results in water flow, the well cylinder was above the water level.	If water level is below 25 feet, the piston pump will not work. Replace it with a submersible or deep well jet pump. Leave well cylinder at a lower level.

G. Excessive Operating Noise

CAUSE OF TROUBLE	HOW TO CHECK	HOW TO CORRECT
1. Waterlogged tank or air chamber.	Make sure air-volume control is operating properly. If not, remove and examine for plugging.	Clean or replace defective air-volume control.
2. Undersized suction line (piston pumps).	Check manufacturer's recommendations for sizing suction line.	Replace suction line with a larger diameter if undersized.
3. Sticking suction valves (piston pumps).	Remove cover from water end of pump and inspect valves.	Clean out any foreign matter between valves and valve plate. Make sure a watertight closure can occur.
4. Rod slapping against drop pipe (working heads).	Feel rod for play, especially if made of steel.	Install rod guides at 10-foot intervals, or replace steel rod with wood.
5. Low well level.	On piston pumps, make sure water level is no more than 25 feet below pump (less if at elevated altitudes). If water level is below 25 feet, piston pump will not work. Replace with a submersible or deep well jet pump.	On the working heads, lower well cylinder by adding more drop pipe and rod. If this results in water flow, well cylinder was above water level. Leave well cylinder at lower level.
6. Sticking or noisy well cylinder valves (working heads).	Pull well cylinder and examine valves.	If valves operate sluggishly, install a well cylinder with spring-loaded valves. If noise is the problem, switch to a well cylinder with rubber-faced valves.

Study Guide Questions - Chapter 4

Answers can be found on page 65

Q. What is the first test to perform on a non-working piston pump?

Q. List the 7 main potential service problems for piston pumps

1.

2.

3.

4.

5.

6.

7.

Notes

Appendix

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Length				
Inches	(in)	Millimeters	(mm)	25.400
Inches	(in)	Centimeters	(cm)	2.539
Feet	(ft)	Meters	(m)	0.305
Yards	(yd)	Meters	(m)	0.914
Miles (statute)	(mi)	Kilometers	(km)	1.609
Millimeters	(mm)	Inches	(in)	0.039
Meters	(m)	Feet	(ft)	3.281
Centimeters	(cm)	Inches	(in)	0.394
Meters	(m)	Yards	(yd)	1.094
Kilometers	(km)	Miles (statute)	(mi)	0.621
Area				
Square Inches	(in ²)	Square Centimeters	(cm ²)	6.452
Square Feet	(ft ²)	Square Meters	(m ²)	0.093
Square Yards	(yd ²)	Square Meters	(m ²)	0.836
Square Miles	(mi ²)	Square Kilometers	(km ²)	2.590
Acres	(ac)	Hectares	(ha)	0.405
Square Centimeters	(cm ²)	Square Inches	(in ²)	0.155
Square Meters	(m ²)	Square Feet	(ft ²)	10.764
Square Meters	(m ²)	Square Yards	(yd ²)	1.196
Square Kilometers	(km ²)	Square Miles	(mi ²)	0.386
Hectares	(ha)	Acres	(ac)	2.471
Liquid Volume				
Ounces	(oz)	Milliliters	(ml)	29.574
Pints	(pt)	Liters	(l)	0.473
Quarts	(qt)	Liters	(l)	0.946
Gallons	(gal)	Liters	(l)	3.785
Pounds per Cubic Foot	(lb/ft ³)	Kilograms per Cubic Meter	(kg/m ³)	16.018
Pounds per Gallon	(lb/gal)	Kilograms per Cubic Meter	(kg/m ³)	119.826
Milliliters	(ml)	Ounces	(oz)	0.034
Liters	(l)	Pints	(pt)	2.113
Liters	(l)	Quarts	(qt)	1.057
Liters	(l)	Gallons	(gal)	0.264
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Cubic Foot	(lb/ft ³)	0.062
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Gallon	(lb/gal)	0.008
Mass				
Ounces	(oz)	Grams	(g)	28.350
Pounds	(lb)	Kilograms	(kg)	0.454
Grams	(g)	Ounces	(oz)	0.035
Kilograms	(kg)	Pounds	(lb)	2.205
Flow				
Cubic Meters per Hour	(m ³ /h)	Gallons per Minute	(gpm)	4.400
Gallons per Minute	(gpm)	Cubic Meters per Hour	(m ³ /h)	0.227

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Force				
Foot Pound Force	(ft-lbf)	Joules	(J)	1.356
Newtons	(N)	Kilogram Force	(kgf)	0.102
Joules	(J)	Foot Pound Force	(ft-lbf)	0.738
Kilogram Force	(kgf)	Newtons	(N)	9.807
Power				
Horsepower	(hp)	Kilowatts	(kW)	0.746
Horsepower	(hp)	Watts	(W)	745.700
Kilowatts	(kW)	Horsepower	(hp)	1.341
Watts	(W)	Horsepower	(hp)	0.001
Pressure				
Bars	(b)	Pounds per Square Inch	(psi)	14.500
Kilograms per Square Centimeter	(kg/cm²)	Pounds per Square Inch	(psi)	14.500
Pounds per Square Inch	(lb/in²)	Kilograms per Square Meter	(kg/m²)	703.070
Pounds per Square Inch	(lb/in²)	Kilopascals	(kPa)	6.895
Pounds per Square Inch	(lb/in²)	Meters of Water	(m)	0.704
Inches of Mercury	(inHg)	Kilograms per Square Meter	(kg/m²)	345.300
Kilograms per Square Meter	(kg/m²)	Pounds per Square Inch	(lb/in²)	0.001
Kilopascal	(kPa)	Pounds per Square Inch	(lb/in²)	0.145
Meters of Water	(m)	Pounds per Square Inch	(lb/in²)	1.420
Kilograms per Square Meter	(kg/m²)	Inches of Mercury	(inHg)	0.003
1 Atmosphere	14.7 lb/in²	Kilograms per Square Centimeter	(kg/cm²)	1.033
1 Atmosphere	14.7 lb/in²	Kilograms per Square Meter	(kg/m²)	10,335.000
1 Atmosphere	14.7 lb/in²	Kilopascal	(kPa)	101.350
1 Atmosphere	14.7 lb/in²	76.0 Centimeters Mercury	(cmHg)	5.170
1 Atmosphere	29.92 inHg	76.0 Centimeters Mercury	(cmHg)	2.540
Pascal	(Pa)	Newtons per Square Meter	(N/m²)	1.000
Pascal	(Pa)	Kilograms per Square Meter	(kg/m²)	0.102
Temperature				
Degrees Fahrenheit	(°F)	Degrees Celsius	(°C)	(°F-32) 0.556
Degrees Celsius	(°C)	Degrees Fahrenheit	(°F)	(1.8 x °C) + 32
Flow				
Feet per Second	(fps)	Meters per Second	(m/s)	0.305
Miles per Hour	(mph)	Kilometers per Hour	(km/h)	1.609
Gallons per Minute	(gpm)	Liters per Minute	(l/min)	3.785
Gallons per Minute	(gpm)	Cubic Meters per Minute	(m³/min)	0.004
Meters per Second	(m/s)	Feet per Second	(fps)	3.281
Kilometers per Hour	(km/h)	Miles per Hour	(mph)	0.621
Liters per Minute	(l/m)	Gallons per Minute	(gpm)	0.264
Cubic Meters per Minute	(m³/min)	Gallons per Minute	(gpm)	264.172

Glossary

Air Charger: A device installed in plain pressure tanks to maintain correct air volume. (III-1)

Air Lock: Situation that stops water flow from pump; occurs when horizontal piping is not sloped upward between well and pump. (III-2, III-3, III-4)

Air-Volume Control (AVC): Ensures the proper balance of air to water in non-diaphragm, plain steel pressure tanks, by preventing waterlogging of the tank. (III-1, III-2, III-3, III-4)

Ammeter: Instrument to measure electrical current flow in amps. (III-1, III-3)

Amp: Quantity of electricity that flows past a given point in a given period of time. (III-1, III-3)

Capacitor: A device designed to hold an electrical charge using two conductors separated by an insulator. (III-2, III-3, III-4)

Capacity: Amount of water moving past a given point in a given amount of time. (III-1, III-3, III-4)

Casing: A stationary enclosure. (III-1, III-3)

Centrifugal Pump: A pumping mechanism that spins water by means of an “impeller,” pushing it out by centrifugal force. (III-1, III-2)

Check Valve: Prevents water from flowing backwards. (III-2, III-3, III-4)

Compound Pressure-Vacuum Gauge: A gauge that reads both pressure and vacuum. This can be used in testing of a pump discharge or suction. (III-1)

Control Box: Device that contains the start relay and capacitor(s). (III-1, III-3)

Cut-In Pressure *(Also called Pump-Start Pressure):* Pressure level at which a pump turns on. (III-2, III-3, III-4)

Deep Well Jet Pump: Any pump capable of producing water from deeper than 25 feet. (III-1, III-4)

Discharge Pressure: Pressure available for the system after the pressure tank. (III-1, III-4)

Drawdown: Reduction in water level during pumping (measured in feet); the amount of water delivered by the pressure tank between pump shutdown and pump precharge pressure. (III-1, III-4)

Drive Pipe:

- (a) A driven well component consisting of 1 1/4-inch to 2-inch pipe, equipped with a point and well screen, driven below the level of the water table.
- (b) (Also called Pressure Pipe): A pipe connected to the pressure or nozzle side of the ejector body in a deep well jet, through which a surface centrifugal pump forces water. (III-1)

Drive Point *(Also known as Well Point):* A hollow, conically shaped, screened metal point used to make a driven well. (III-4)

Drop Pipe: The pipe found in the well connecting the pump to the water source. (III-1, III-3, III-4)

Ejector *(Also called a Jet):* A water pressure-making device with three parts: body, nozzle, and venturi. Atmospheric pressure forces water into a partial vacuum at the nozzle throat, then into the pumping system where the venturi slows water velocity and converts it into water pressure (III-2)

Electrical Current: Flow of electricity. (III-1)

Fitting: A pipe part used to join together two sections of pipe. (III-1, III-2)

Foot Valve: A screened check valve allowing water to flow into a jet when a pump is running; closes when pump is shut off. Protects pump parts. Used on suction lift applications and located at the bottom of the suction assembly. Keeps the suction line full of liquid. (III-1, III-2, III-4)

Friction Loss: Loss of pressure when water flows through a piping system factoring gallons per minute, pipe length, size, and fittings. Measured in feet of head. (III-1, III-2, III-4)

Gallons Per Minute (gpm): Unit of flow measurement, expressed in gallons per minute. (III-1)

Grounded: Electrical systems that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation. (NFPA 70 – 2014). (III-1, III-3)

Head: Pressure expressed as height in feet. (III-1, III-3, III-4)

Impeller: A rotating disk containing vanes attached to the motor shaft; used in centrifugal pumps. (III-1, III-2, III-3)

Insulation Test *(Also called a Ground Test):* Test used to determine if a motor or cable is damaged. (III-1)

Intake Screen: Keeps debris from clogging impeller of a pump. (III-3)

Jet: See *Ejector*. (III-2)

Jet Pump: A surface-mounted centrifugal pump that has an ejector (venturi) device to increase suction capacity. (III-1, III-2, III-4)

Megohmmeter *(Also called a Megger):* Used to measure insulation resistance and weakness. (III-1)

Motor Continuity Test: Test for circuit resistance; used to determine condition of motor windings and circuit. (III-1)

Multimeter: Digital instrument that offers the functions of an ammeter, voltmeter, and more, in a single device, usually with a liquid crystal display. (III-1, III-3)

National Electrical Code (NFPA 70): Electrical standards code that requires the safe grounding of motor operated water pumps and metal well casings. (III-1)

Nozzle: An ejector component that increases the velocity of water flowing through it by decreasing orifice size to create a partial vacuum in the nozzle throat. (III-1)

Ohm: The unit of electrical resistance. (III-1, III-3)

Ohmmeter: Instrument to measure resistance in an electrical system. (III-1, III-2, III-3, III-4)

Ohm's Law: Expresses the relationship between voltage and current; expressed mathematically as $E = I \times R$, where E is electrical pressure in volts, I is current flow in amps, and R is resistance in ohms. (III-1)

Pipe: Hollow tube used to carry water. Popular types include galvanized steel, copper, and plastic. (III-1, III-2, III-3, III-4)

Piping: System of hollow tubing used to carry water to distribution points. (III-1, III-2, III-4)

Piston Pump *(Also called a Reciprocating Pump):* A shallow well reciprocating pump. No longer used for domestic well systems. Shallow well pump in which the piston reciprocates from one end of the well cylinder to the other. (III-4)

Pounds per Square Inch (PSI): A unit of pressure or force. (III-1, III-2, III-3, III-4)

Pressure: The force exerted in pounds over one square inch area. (III-1, III-2, III-3, III-4)

Pressure Control Valve: The purpose of this valve is to divert part of the pump output down to the ejector, ensuring adequate pressure to operate the ejector regardless of flow to the tank or service. This valve provides the proper back pressure necessary to carry the drive water down the pressure (drive) pipe to the ejector in the well. Proper adjustment of the valve during installation is basic to operation of the deep well jet unit. (III-2)

Pressure Gauge: A device that measures pounds per square inch (psi) in a water system. (III-1, III-2, III-4)

Pressure Switch: An electrical switch activated by system pressure to control starting and stopping of the pump. (III-2, III-3, III-4)

Pressure Tank: Vessel used to provide cycle control of the pump. (III-1, III-2, III-3, III-4)

Prime: Condition in which a suction pipe and pump intake are filled with water so that the pump is ready for operation. (III-2, III-4)

Pump: A mechanical device that moves liquid or gas by pressure or suction; a device that converts mechanical torque and motion into hydraulic fluid power. (III-1, III-2, III-3, III-4)

Pump Capacity: The maximum number of gallons per hour or gallons per minute that a pump is able to move through a water system. (III-1, III-3)

Pump Cut-In Pressure (*Also known as Pump-Start Pressure*): A predetermined low pressure in the water system that activates the pressure switch to energize the motor and start the pump. (III-2, III-3, III-4)

Pump Discharge: Place where water exits the pump. (III-1)

Pump Motor: Electrical motor that operates the pump in a water system. (III-2, III-3, III-4)

Relay: Component of a control box. (III-3)

Resistance: The degree of obstacle presented by a material to the flow of electric current; measured in ohms. (III-1, III-2, III-3, III-4)

Short Circuit: An unwanted electrical current between a negative and positive source. Short circuits can damage equipment and cause sparks and fire; an interruption in the flow of electricity. (III-2, III-3, III-4)

Shutoff Valve: Valve installed between the well and tank, making it possible to drain a portion of the system for repairs, instead of draining all of it. A device used to separate a component from the system, e.g., tank, pump. Valves can be of the ball, globe, or gate design. (III-1)

Single-Phase Motor: Type of submersible pump motor that is not inherently self-starting and requires an auxiliary starting method. (III-1)

Snifter Valve: Valve that allows installer to change the pressure if desired. (III-3)

Static Depth: The depth to a well's water surface when water is static – that is, not being pumped. (III-1)

Submersible Pump: An adapted centrifugal pump and motor designed to be placed completely below the water surface. (III-1, III-3, III-4)

Suction Lift: The low pressure generated on the inlet in the suction of a pump that lifts water up into the pump. (III-1)

Suction Pipe: A pipe through which well water is drawn to the surface. (III-1)

Tapping: Outlet for water in plumbing system. (III-1)

Three-Phase Motor: A motor operating on three-phase power only. It has high starting and breakdown torque, high efficiency, medium starting current, and a long lifespan. (III-1)

Vacuum Gauge: A device used to check pump performance by measuring the total suction lift. (III-1, III-4)

Valve: Any device used to control flow in a water system. (III-1, III-2, III-3, III-4)

Venturi: A component that slows high velocity water due to its increasing orifice size, creating relatively high-water pressure. (III-1)

Voltage: Electrical “pressure.” (III-1, III-2, III-3, III-4)

Voltmeter: Device used for measuring electrical voltage. (III-1, III-2, III-3, III-4)

Watt Hour Meter: Measures motor power input; used by power companies. (III-1)

Well Casing: Steel or plastic lining permanently installed in drilled wells to prevent cave-ins or contamination by surface water. (III-1, III-3)

Well Cylinder: Used with piston pump in deep well applications. Commonly used with windmills and working head pumps. (III-4)

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Study Guide Answers

Chapter 1

- Q.** What precautions should be taken when working with electrical circuits?
- A.** Wear electrically rated, regularly tested rubber gloves and boots; do not touch live parts when checking voltage and current; and disconnect the power, lock out and tag the circuit, and test for voltage when making all other checks. Make sure metal control boxes, motors, and all metal parts are connected to power supply ground in compliance with local and national electrical codes before doing any servicing.

If you do not have regularly tested rubber gloves and boots, reference the OSHA lockout/tagout requirements for hazardous energy, <https://www.osha.gov/laws-regs/regulations/standardnumber>.

If you missed this question, go back to page 9 for information on basic instruments.

- Q.** What precaution must be taken before measuring resistance with an ohmmeter?
- A.** The power always must be shut off before measuring resistance.
- If you missed this question, go back to page 12 for information on basic steps in ohmmeter use.*
- Q.** How do electrical system measurements relate to water system measurements?
- A.** Electrical current (amps) may be likened to water flowing (capacity) in a piping system. The resistance (ohms) of an electrical system may be compared to the pipe friction loss in a pipe of a given size. Voltage is electrical “pressure.”
- If you missed this question, go back to page 11 for information on voltage, current and resistance.*

- Q.** What is a megger and what does it do?
- A.** The megger or megohmmeter is a type of ohmmeter used only to measure insulation resistance.
- If you missed this question, go back to page 15 for information on insulation weakness.*

- Q.** Why use a compound pressure-vacuum gauge?
- A.** Use a compound pressure-vacuum gauge to test jet pumps. Readings can determine the condition of the foot valve, the nozzle, and venturi. The gauge can also be used to assist in setting the regulating valve and in checking vacuum-type air chargers.

If you missed this question, go back to pages 16-17 for information on compound gauges.

Chapter 2

- Q.** What is the first step in checking a malfunctioning jet pump?
- A.** Check voltage at the line side of the pressure switch using a voltmeter.
- If you missed this question, go back to page 21 for information on jet pumps.*
- Q.** If the above reading is normal, what is the next step?
- A.** Check the voltage on the motor side of the pressure switch.
- If you missed this question, go back to pages 21-23 for information on how to check why the pump will not start or run.*
- Q.** What are five common jet pump service problems?
- A.** Pump won’t start or run; motor overheats and overload trips out; the pump starts and stops too often; pump will not shut off; and pump operates but delivers little or no water.
- If you missed this question, go back to pages 22-30 for jet pump troubleshooting information.*

Chapter 3

- Q. Why are submersible pumps popular in new water system installations?
- A. Because of their simplicity of operation, ease of installation, and improved electrical and mechanical design.
- If you missed this question, go back to page 33 for information on submersible pump service.*
- Q. What are five electrical instruments used in servicing submersible pumps?
- A. Ohmmeter, ammeter, insulation resistance meter, and voltmeter or multimeter.
- If you missed this question, go back to page 33 for information on submersible pump service.*
- Q. Much of the diagnosis on submersibles involves simple electrical tests. Where can explicit instructions for making electrical tests be found?
- A. In manufacturers' service literature.
- If you missed this question, go back to page 33 for information on submersible pump service.*
- Q. What types of checks should be made before pulling a pipe from a well?
- A. All the aboveground checks.
- If you missed this question, go back to pages 35-42 for information on submersible pump service.*

Chapter 4

- Q. What is the first test to perform on a non-working piston pump?
- A. First, use a voltmeter to check the voltage at the line side of the pressure switch.
- If you missed this question, go back to page 45 for information on piston pump service.*
- Q. List the 7 main potential service problems for piston pumps
- A. Pump won't start or run; pump runs but does not deliver water; low capacity; pump loses prime (piston type only); pump starts and stops too often; pump will not shut off; excessive operating noise.
- If you missed this question, go back to pages 46-54 for information on piston pump service*

Notes

[illegible]



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BOOK IV

Components

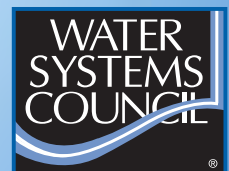


WATER SYSTEMS HANDBOOK

*A complete text on wells:
their design, operation, and maintenance*

13TH EDITION

Published by



WATER SYSTEMS HANDBOOK

BOOK IV

Components

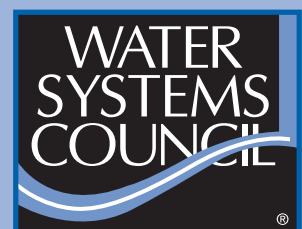
13TH EDITION



**A complete text
on wells:
their design,
operation, and
maintenance**

**Published by
Water Systems Council**

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A Word Of Caution



The products described in this Handbook, including all products using electrical current, can result in serious harm if not used with EXTREME CAUTION and in strict accordance with manufacturers' instructions. Professional assistance is recommended and should always be sought when utilizing unfamiliar equipment.

The products, materials, information, and instructions in this publication are provided for informational purposes only. This publication is not intended to provide instructions or recommendations relating to the selection, adoption, or use of equipment. All information is provided from sources believed to be reliable, accurate, and comprehensive. However, all information, including without limitation product descriptions and functionality is provided "as is" without any express or implied warranty of any kind, including warranties of title, merchantability, noninfringement of intellectual property, compatibility, or fitness for any purpose or use. In no event shall the Water Systems Council or its members, agents, employees, directors, or officers be liable for any damages or other claims whatsoever, including, without limitation, any direct, indirect, special, punitive, or consequential damages, whether from harm, loss of profits, business interruption, loss of information, or related expenses arising out of errors, omissions, or the use of or inability to use the materials, products, information, or services as provided in this Handbook, even if the Water Systems Council or its members have been advised of the possibility of such damages.

Introduction to Wells

Water is life's most vital resource. Through the centuries, people have searched for water, fought for it, and sometimes died for it. No living organism can exist without water.

Consequently, clean and plentiful groundwater is necessary for everyday life. As described in this handbook, groundwater is the reservoir of water that seeps downward through the soil to the water table below the earth's surface. About 98 percent of all fresh water available in the nation at any time is groundwater, which fills the porous beds of rock and sand that make up the earth's crust.

Groundwater is an ideal water supply, for it is pure and wholesome. Filtered by the underground formations through which it passes, groundwater has a degree of purity seldom attained by surface waters.

Natural groundwater reservoirs have many advantages. They have huge capacities, they are relatively inexpensive to tap by means of wells, and they lose little water by evaporation. Above all, they are dependable sources of water.

In the United States alone, more than 115 million people get their drinking water from groundwater every day. More than 23 million American households are supplied from individual, private wells.

A modern well is both flexible and functional. A variety of pumps is available to lift water from all types of wells, from the shallowest to the deepest. These systems are made automatic and dependable by many types of controls and accessories. Groundwater is there when needed. Additional equipment may be added to the system for treatment to ensure better quality of life.

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About this Handbook

The **WATER SYSTEMS HANDBOOK** provides basic information on well design, operation, and maintenance to boost the professional knowledge of well industry personnel.

Before you begin your studies, please take a few moments to familiarize yourself with the format of this handbook. The handbook is divided into eight books. Each includes several chapters that cover the most important aspects of wells. At the end of each chapter, you will find a **Quiz**. You can use this quiz as a learning tool to review the noteworthy points in each chapter. Answers to the quiz can be found at the end of each book. If you miss an answer, follow the directions to take you back to where the information is located in the chapter.

For quick reference, you will find that highlighted text is generally defined in a **Glossary** at the back of each book, where you will also find a topical **Index**. While illustrations appear in each chapter, you will also see tables and charts referenced in text and located in the **Appendix** at the back of each book. A handy metric system reference also appears in each appendix.

We hope that studying the information in this handbook will prepare you for your job as a well professional, charged with the important responsibility of helping to ensure access to pure, plentiful well water for families across America.

Water Systems Council

Dedication

This 13th Edition of Water Systems Handbook is dedicated to the millions of Americans who rely on private water systems to provide safe, sustainable water supply and to the water well professionals in the water well industry.

The 13th Edition is also dedicated in memory of Jeff Wellen for his many years of leadership and service to WSC and the water well industry.

Special thanks to the members of the Water Systems Council Technical Committee, who initiated and completed revisions to this 13th Edition.



The Water Systems Council (WSC) is a national nonprofit organization, dedicated to promoting the wider use of wells as safe, sustainable, and cost-effective drinking water systems; protecting groundwater resources and users of well water, and ensuring a safe drinking water supply for well owners. WSC members include major manufacturers of the integral components of wells and other drinking water systems, leading distributors of these components, and various drinking water professionals.

WSC is the only national nonprofit organization with programs solely focused on private water wells and small, shared wells.

www.watersystemscouncil.org

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Chapter 1

Pressure Tanks

- ✓ Pressure tanks
- ✓ Functions
- ✓ Types
- ✓ Selection
- ✓ Installations
- ✓ Troubleshooting

Most private water systems are powered by an electric motor and incorporate a closed **pressure tank**. The four essential components of such a system are the **pump, tank, control**, and other accessories.

This chapter discusses domestic water systems from the **pump discharge** through the **tank outlet**. It includes information on selecting a tank of proper type and size as well as various product options to meet the specific needs of each water supply system.

Functions of a pressure tank

The functions of a pressure tank are threefold:

1. Protect and prolong the life of the pump and **pressure switch** by preventing rapid cycling of the **pump motor**. Most manufacturers recommend a maximum frequency.
 - A properly sized tank should provide a minimum 1 gallon tank drawdown equal to 1 gpm pump capacity for 1/3 hp to 3/4 hp pumps, and 2 gallons drawdown for every 1 gpm pump capacity for 1 hp to 5 hp pumps.
 - 1 pump start in a 5 minute period for 1/3 hp to 3/4 hp pumps, and 1 pump start per 15 minute period for 1 hp to 5 hp pumps.
2. Supply water under pressure between pump cycles.
3. Provide additional water storage under pressure to assist meeting total demands of a system, if the pump or well is incapable of supplying the required capacity. For low producing wells/sizing issues, refer to Book VIII, Chapter 3.

Definitions

Throughout the discussion of this part of the total water system, certain terms will be used. It's important that you understand these terms so that you can relate their usage in the proper manner:

Capacity – gallons or storage gallons at a given pressure range.

Cycle rate – the frequency of pump start and stop per hour.

Demand – the gallons of water required within a specific time frame.

Drawdown – the amount of water delivered by the **pressure tank** between pump shutdown and tank **precharge pressure** (Figure IV.1.1a).

Minimum operating pressure – the lowest pressure that will support fixture demand.

Peak demand period – the time period during which the greatest amount of water is consumed by the users of various household fixtures.

Precharge – any air charge put in a **diaphragm tank** or **bladder tank** at the factory above one atmosphere (14.7 psi) (Figure IV.1.1b).

Pressure – the force exerted in pounds over one square inch area.

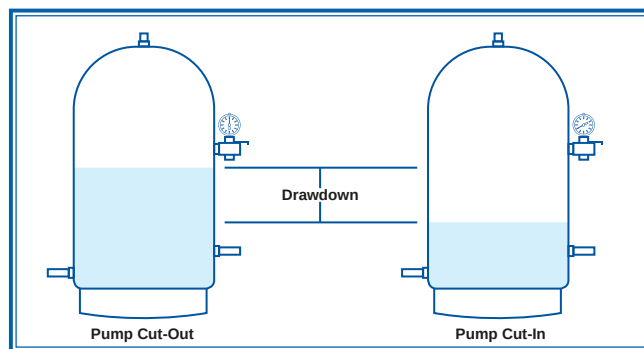
Pump-start pressure, (also known as **pump cut-in pressure**) – a predetermined low pressure in the water system that activates the pressure switch to energize the motor and start the pump.

Supplemental supply – the quantity of water stored between the tank precharge and pump cut-in pressure for a pressure differential greater than 2 psi.

Usable water – the amount of water, including drawdown and supplemental supply, a pressure tank gives between pump stop and precharge pressure, usually associated with low producing wells.

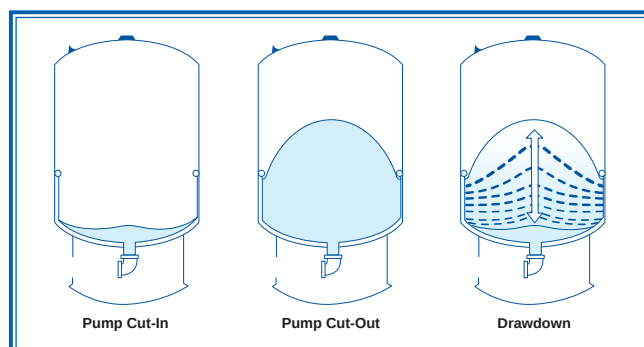
Waterlogging – the complete loss of air in a tank. This is indicated by rapid pump cycling and clicking of contacts on pressure switch.

Figure IV.1.1a



Plain steel tank drawdown.

Figure IV.1.1b



Precharge diaphragm type or bladder type tank for drawdown.

Pressure tank designs

Water is, for all practical purposes, incompressible. So it's necessary to provide compressible air pressure with stable energy (air under pressure), which acts upon the water to force it to the point of use.

When water is drawn out of the pressure tank, the air expands. When water is pumped into the tank, the air is compressed. This provides a way to pressurize the water in the system when the pump isn't running.

Because another characteristic of water is its ability to absorb air, the design of the pressure tank must have provisions to replenish the absorbed air or a means to prevent absorption.

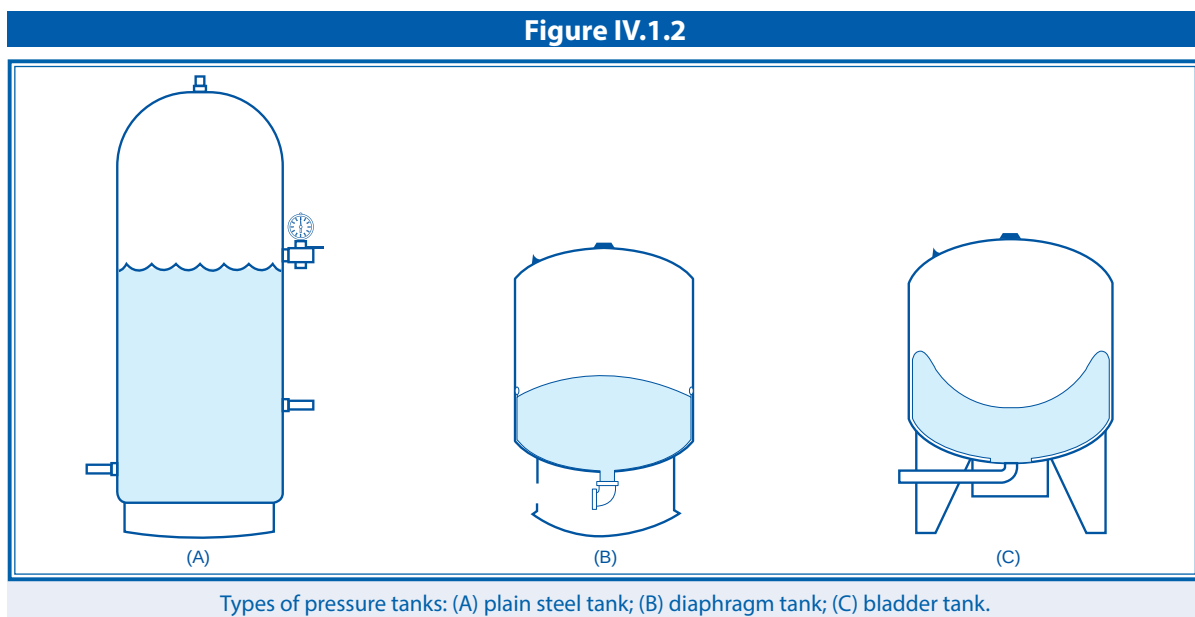
There are three basic types of pressure tank designs, as shown in Figure IV.1.2: (A) **plain steel tanks/ non-diaphragm composite tanks**, (B) **diaphragm tanks**, and (C) **bladder tanks** with complete separation between air and water.

Plain steel tank/ non-diaphragm composite tanks

The plain steel pressure tank is shown in Figure IV.1.2(A). This type of pressure tank can be *designed for use in a vertical or horizontal position*. The tank discharge should always be located near the bottom of the tank. This type has no barrier separating the air from the water. It has connections for an inlet/outlet near the bottom. There is also a separate connection for the **air-volume control** that is usually located at the level where the water will be when the pump starts. Air-volume controls are of the air add/air release type.

Precharge diaphragm/bladder tank

The diaphragm type or bladder type pressure tank shown in Figures IV.1.2(B) and IV.1.2(C) uses a mechanical locked-in flexible separator that completely isolates the air from the water. The tank is precharged at the factory. A **snifter valve** allows the installer to change the pressure, if desired. Because air and water are completely separated, an air-volume control is not required. Only one water connection is required that serves as both inlet and outlet for the tank.



Pump selection

Before calculating the tank size, the **capacity** of the pump (gph or gpm) delivered to the tank inlet must be known (Book VIII), using Table IV.1.1.

Table IV.1.1

Average Water Consumption for Home and Farm Use						
Private Residences						
Outlets	Flow Rate gpm	Total Usage Gallons	Bathrooms in Home			
			1	1 ½	2-2 ½	3-4
Shower or Bathtub	5	35	35	35	53	70
Lavatory	4	2	2	4	6	8
Toilet	4	5	5	10	15	20
Kitchen Sink	5	3	3	3	3	3
Automatic Washer	5	35	-	18	18	18
Dishwasher	2	14	-	-	3	3
Normal seven (7) minute peak demand (gallons)			45	70	98	122
Minimum sized pump required to meet peak demand without supplemental supply		Divide peak demand by 7	7 gpm (420 gph)	10 gpm (600 gph)	14 gpm (840 gph)	17 gpm (1020 gph)
Notes: Values given are average and do not include higher or lower extremes. Peak demand can occur several times during morning and evening hours.						
Yard Fixtures			Farm Use			
Garden Hose - ½"	3 gpm		Horse, Steer	12 gpd		
Garden Hose - ¾"	6 gpm		Dry Cow	15 gpd		
Sprinkler	3-7 gpm		Milking Cow	35 gpd		
Alternate Capacity Methods: Calculate the number of bathrooms x 4 gpm = ? (Note that 1/2 baths are considered as full baths) Count the number of fixtures in a home including outside hose bibs. Supply one gallon per minute each.			Hog	4 gpd		
			Sheep	2 gpd		
			Chicken/100	6 gpd		
			Turkey/100	6 gpd		
			Fire	20-60 gpm		

Pressure tank selection

The proper size tank can be selected from Table IV.1.2. An example follows:

- In this example, 7 gallons per minute is used.
- Assuming a pressure range of 30 to 50 psig and using a diaphragm/ bladder type tank, select from Table IV.1.2. the required total tank volume ... 25 gallons.
- This size tank assures a minimum pump run time of 1 minute and a drawdown of 7 gallons.

If the pump capacity is below the peak demand, an alternative system may require a two-pump system with additional tanks.

Table IV.1.2

Pump Capacity			TOTAL TANK VOLUMES (Gallons)					
			Pressure Switch On-Off Setting					
			20-40 psi		30-50 psi		40-60 psi	
gph	gpm	Gallons	"Bladder or Diaphragm"	"Standard Galvanized Steel"	"Bladder or Diaphragm"	"Standard Galvanized Steel"	"Bladder or Diaphragm"	"Standard Galvanized Steel"
240	4	4	10	25	15	40	15	55
300	5	5	15	30	15	50	20	70
360	6	6	15	40	20	60	20	85
420	7	7	20	45	25	70	25	100
480	8	8	20	50	25	80	30	110
540	9	9	25	60	30	90	35	125
600	10	10	30	65	30	100	40	140
660	11	12	35	80	40	120	45	165
720	12	13	35	85	40	130	50	180
780	13	15	40	100	50	150	55	210
840	14	17	45	110	55	170	65	235
900	15	19	50	125	60	190	70	265
960	16	20	55	130	65	200	75	280
1020	17	23	65	150	75	230	85	320
1080	18	25	70	160	80	250	95	350
1140	19	27	75	175	85	270	100	375
1200	20	30	80	195	95	300	110	415
1260	21	33	90	215	105	330	125	460
1320	22	36	100	235	115	360	135	500
1380	23	38	105	245	125	380	140	530
1440	24	41	110	265	135	410	155	570
1500	25	44	120	285	140	440	165	610
1560	26	47	130	305	150	470	175	655
1620	27	50	135	325	160	500	185	700
1680	28	53	145	345	170	530	200	735
1740	29	57	155	370	185	570	215	790
1800	30	60	165	390	195	600	225	835

Note: *Actual values may vary somewhat with field conditions.

Installation of pressure tanks

The pressure tank has now been selected and is ready to be installed into an average system. For details, see the tank manufacturer's installation instructions.

However, what if it's not an average system? An **average system** has enough well yield and pump capacity to handle the system's peak demand. When a well is not capable of yielding enough water, the pump, although capable of delivering the demand capacity, will be restricted by the well.

In this case, there are several options available to the installer to prevent the pump from running dry:

1. electrodes placed in the well
2. throttling valve
3. secondary tank and pump
4. low pressure cutoff switch
5. provide for supplemental drawdown (between precharge and pump cut-in pressure)
6. other pump protection devices
7. variable frequency drive (VFD) with built in protection

The size of the pressure tank will also have to be increased because it will now have to be called on to aid the pump in satisfying the peak system demand. *Contact your local tank or pump dealer to obtain the proper tank selection.*

Tanks are installed inside or outside a dwelling. The well pit and underground installations are usually subject to local or state codes.

When placing a tank underground, it should be placed below the frost line and above the water table, installed in the position recommended by the manufacturer, set on a firm foundation and surrounded with earth or sand firmly tamped, and backfilled free of rocks or gravel immediately adjacent to the tank.

Pressurizing tanks for supplemental supply

In cases where the pump cannot meet peak demand, a supplemental supply is required. This can be accomplished by adding tank capacity or changing pressure settings (revisit Figure IV.1.1a and Figure IV.1.1b, page 10).

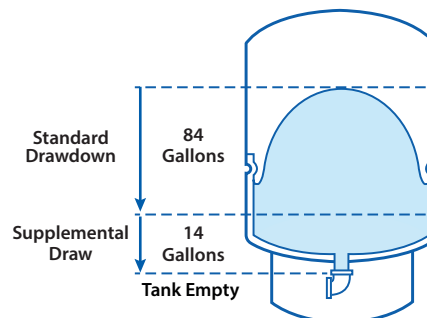
Extra tank capacity

If the demand is greater than what is available from the tank by the difference in pressure method, extra tank capacity is required. Reference Table IV.1.1 (page 12).

HOW TO CALCULATE EXTRA TANK CAPACITY

Example: 2-Bathroom Home

Peak Demand (gallons):	98 gal
Pump Capacity	12 gpm
X Peak Demand Period:	7 min.
= Water Delivery:	84 gal
Peak Demand (gallons):	98 gal
- Water Delivery:	84 gal
= Extra Capacity:	14 gal
(Add 14) gallons of tank drawdown)	



Troubleshooting Pressure Tanks

Precharge diaphragm type or bladder type:

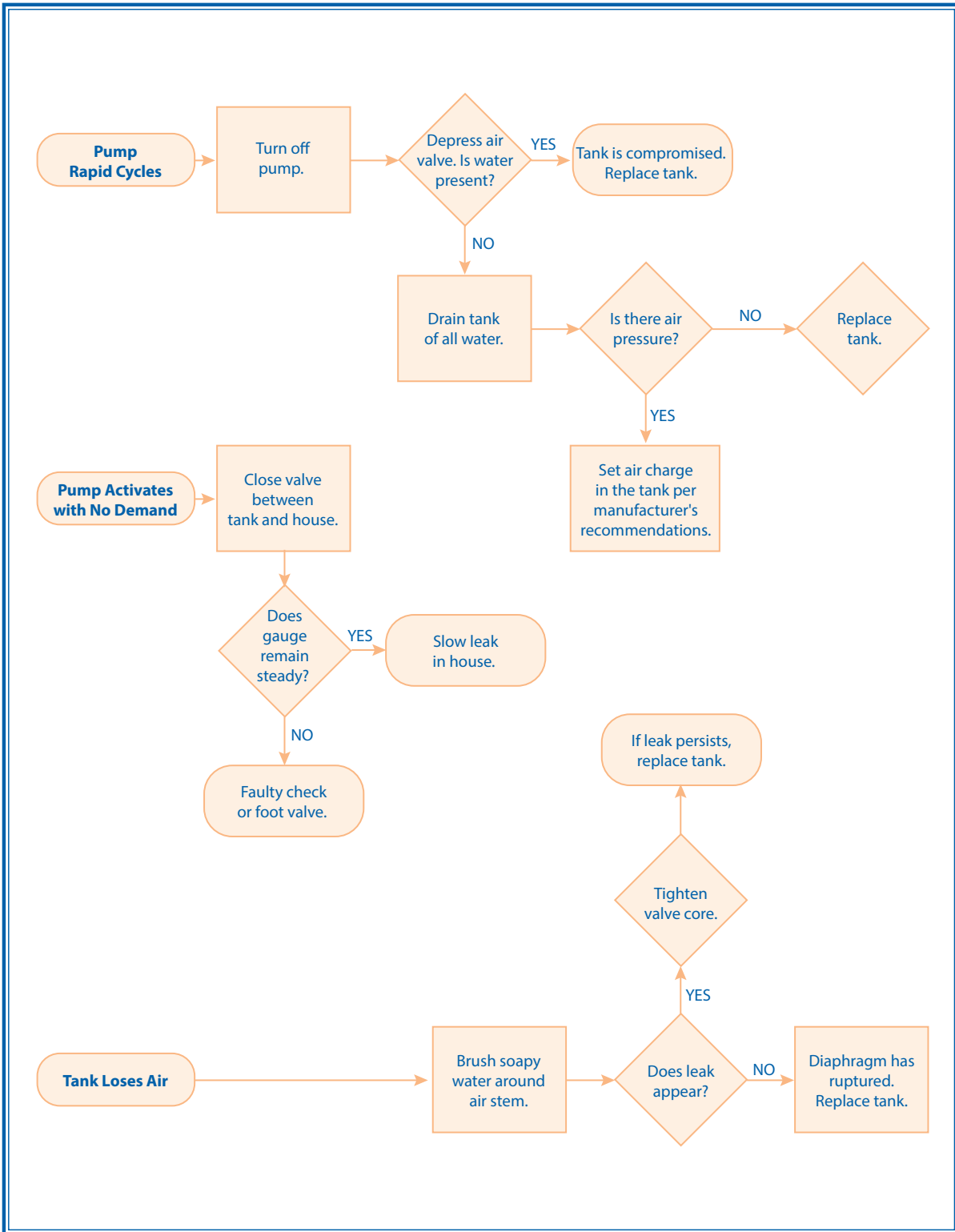
- ✓ 1. Observe water system operation. Note any unusual activity (for example: short cycling, air, and water spurting from the faucet in the sink).
- ✓ 2. Measure water drawdown from switch cutoff point to switch cut-on point. Compare drawdown with data for that ...size tank. Reference Table IV.1.2 (page 13). Note that drawdown may vary from published data up to 25 percent due to system conditions.
- ✓ 3. If drawdown does not measure up to specification data, do the following:
 - (a) Check the pressure switch setting. Note the cut-on pressure on gauge. Note the cutoff pressure on gauge. Adjust if necessary. The usual switch differential is 20 psi.
 - (b) Check air pressure in the tank. Turn the electrical power off to the pump. Drain the system tank until 0 psi is on gauge, check pressure at snifter valve on top or side of tank under cap with pressure gauge. The **pressure gauge** should indicate the same pressure or 2 psi below the pump cut-on pressure unless supplementary drawdown is being used. Correct the air pressure as necessary.
 - (c) Check for air leaks. Cover all welded seams and snifter valves with soapy water solution. Look for bubbles carefully for 10 to 15 minutes. If no leaks are found, re-check air pressure in the tank; it should be the same as before. If pressure has dropped, disconnect the tank from the system and check for leakage at the water connector. Replace the cap tightly.

Plain steel tanks:

- ✓ Follow steps 1, 2, and 3(a) above, and then:
 - (b) Check for air leaks above the air-volume control using a soap solution.
 - (c) Check the air-volume control for possible contamination or malfunction.

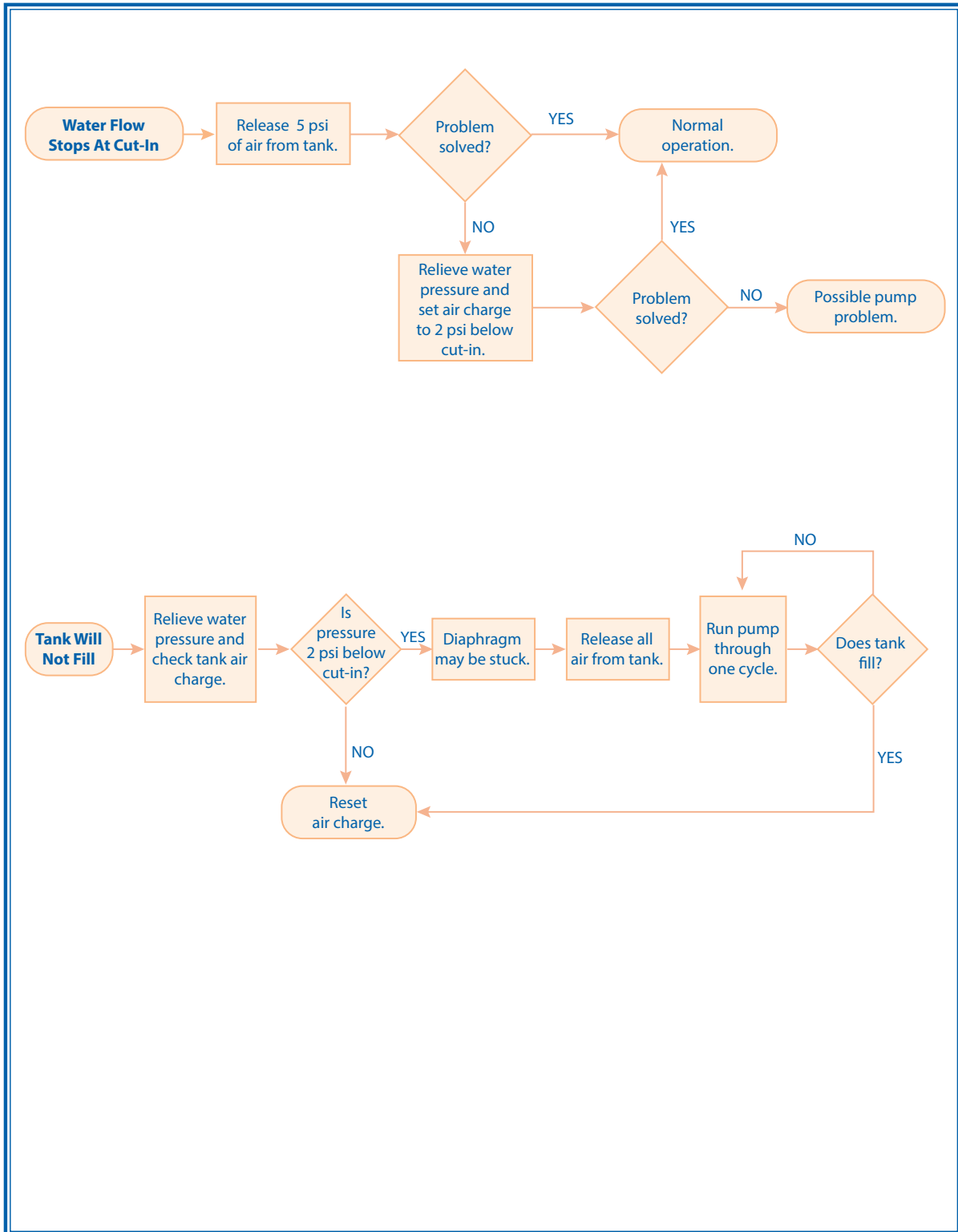
Well Tank

Troubleshooting Guide



Well Tank

Troubleshooting Guide



Study Guide Questions - Chapter 1

Answers can be found on page 51

Q. What are the two essential components of a private water system?

Q. What are the functions of a pressure tank.

Q. What are the three main types of pressure tanks?

Chapter 2

Other Water System Components

- ✓ Water well components
- ✓ Types and sizing of pipes
- ✓ Valve selection
- ✓ Planning an efficient water system

Water systems, regardless of size, need to be planned and properly constructed by knowledgeable professionals. The number of water-using outlets, the **flow** capacity, and the pressure needed for each outlet must be considered. This information is necessary to properly plan the size of piping, **pump**, pressure tank, and other associated components.

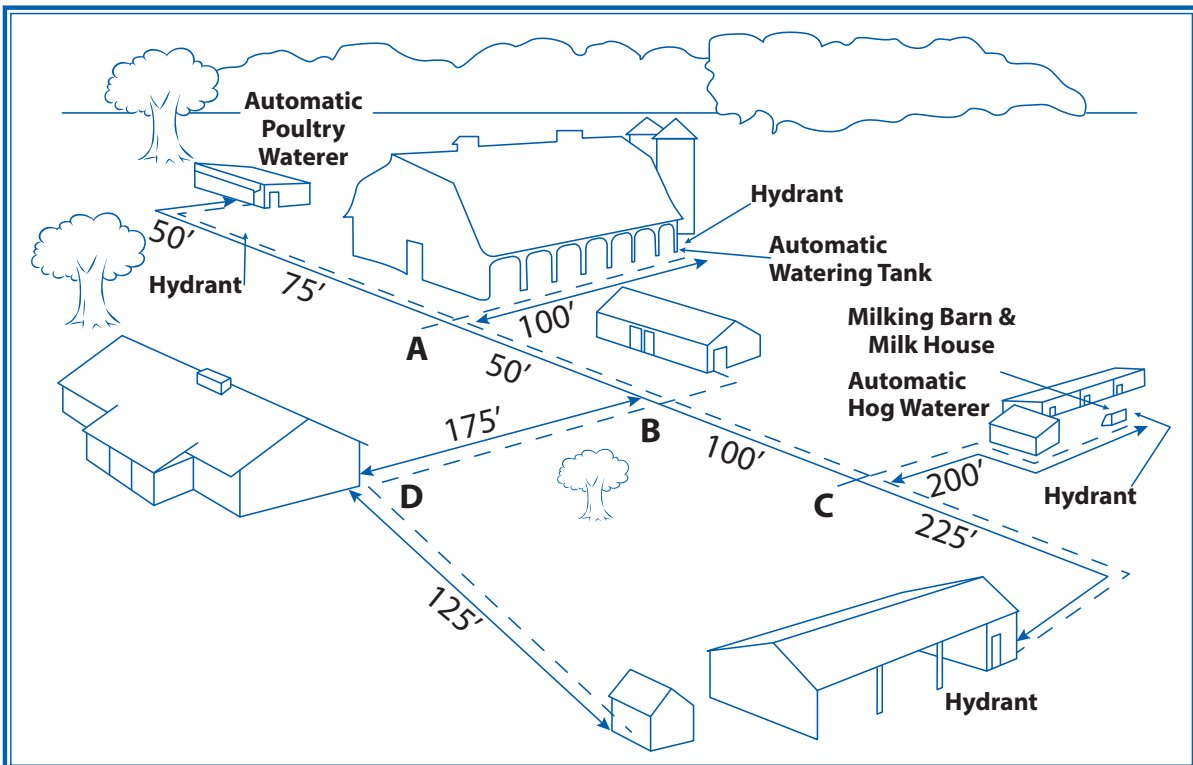
Figure IV.2.1

Diagram of main piping with branches.

Distribution starting point

Water needs to be carried to the farthest point through the system so the **pipe** that carries the water must be of ample size to supply the water needed for each outlet with necessary capacity and pressure. The planning stages for the system are important to ensure this and planning will affect the selection of the pump and components. Make a diagram of the main pipe line with branches similar to Figure IV.2.1 (Page 20), and determine the water demand at each branch. A reference chart of water requirements (Table IV.1.1, Page 12) will assist in figuring the maximum capacity required in each line or branch.

After measuring the pipe line and knowing its required capacity, the next step is to determine the main and branch line pipe sizes. Refer to the **Friction Loss Tables** (Appendix) for the most suitable pipe size to carry the **peak capacity** requirement with a reasonable amount of **head** loss. Usually a minimum pressure of 20 psi should be maintained at each outlet. Some water-using devices require higher operating pressures, and the lines to these devices should be adequately sized.

All pumps are also affected to some degree by the pipe size from the pump. The **friction loss** between the water level in the well and the pressure tank can reduce the capacity of the pump. To prevent this condition, refer to the Friction Loss Tables (Appendix) and the manufacturer's recommendations for the proper size of pipe for the corresponding pump.

Types of pipe used

Three popular types of pipe are available for water distribution systems – **galvanized steel pipe, copper pipe, and plastic pipe**. The type of pipe selected depends on the following factors:

- Underground soil corrosion
- Corrosion inside the pipe
- Safe working pressure
- Effect of freezing
- Local plumbing codes
- Ease of installation
- Cost
- Weight

Corrosion or deposits inside the pipe will occur in galvanized steel with acid, alkaline, and hard waters. Copper is typically very corrosion-resistant but may be penetrated rapidly in water containing free carbon dioxide. Plastic pipe is very resistant to inside corrosion.

Rated working pressures of galvanized steel and copper are higher than plastic and are far higher than needed on most domestic installations. Plastic pipe should be chosen by type and rated working pressure to suit the application.

Local plumbing codes vary and may limit, or mandate, the use of certain materials.

Pipe fittings

Just as there are different types of pipe for pump installations and supply lines, there are different types of **fittings**, and methods for attaching each type. Among the products available are slip-type couplings, insulated couplings, unions, and fittings made of plastic to retard vibration and reduce noise. PVC or other plastic pipes are widely used inside the well to the pump. Plastic pipes are also commonly used from the well to the inside of the home. Recommendations for insert fittings for the plastic pipe to the inside of the home are metallic such as stainless steel or lead-free brass.

Tank tees

Tank tees (Figure IV.2.2(A), page 23) are special pipe fittings that connect the water supply pipe from the well to the pressure tank. These tees also provide the needed tapplings and a convenient location to install the **pressure-relief valve**, **pressure gauge**, and pressure switch.

Tank tees are available in a variety of different lengths, end connections, number of tapplings, and pipe sizes. They are manufactured in four different materials – galvanized iron, brass, PVC, and stainless steel – each of which has its advantages.

Effects of torque

When a **submersible pump** is started, the **torque** developed by the motor must be restrained by the pipe from the pump or by other means. Torque from the pump motor rotates in the direction that can loosen or unscrew threaded joints and other parts of the pump support system. Unscrewing joints will break the electrical cable to the pump and may cause loss of the submersible pump.

A **torque arrestor** (Figure IV.2.2(B), page 23) is most often used to counter motor torque. The torque arrestor should be clamped around the pipe directly above the pump or according to the manufacturer's instructions. Additional torque arrestors should be used at each interval of 100 feet above the first torque arrestor.

Protection of electrical cable to pump

The electrical cable to the **submersible pump** must be protected from damage all the way from the power source to the pump near the bottom of the well. To protect the cable inside the well, **cable guards** (Figure IV.2.2(C), page 23) should be installed along every 20-25 feet of pipe from above the torque arrestor to the pitless adapter or top of the well.

Cable guards hold the pipe and cable in the center of the well. They keep the pump cable from hitting the inside of the **well casing** and damaging the cable's outer insulation.

The electrical cable also needs to be attached or strapped to the pipe above the pump to be sure that the cable is not damaged between cable guards or torque arrestors. The recommended method to strap the cable to the pipe is with plastic or nylon cable ties every 10 feet. **Cable ties** are more reliable than tape because they can hold more weight and will not come loose over time.

NOTE: Check local and state codes.

Waterproof electrical splices

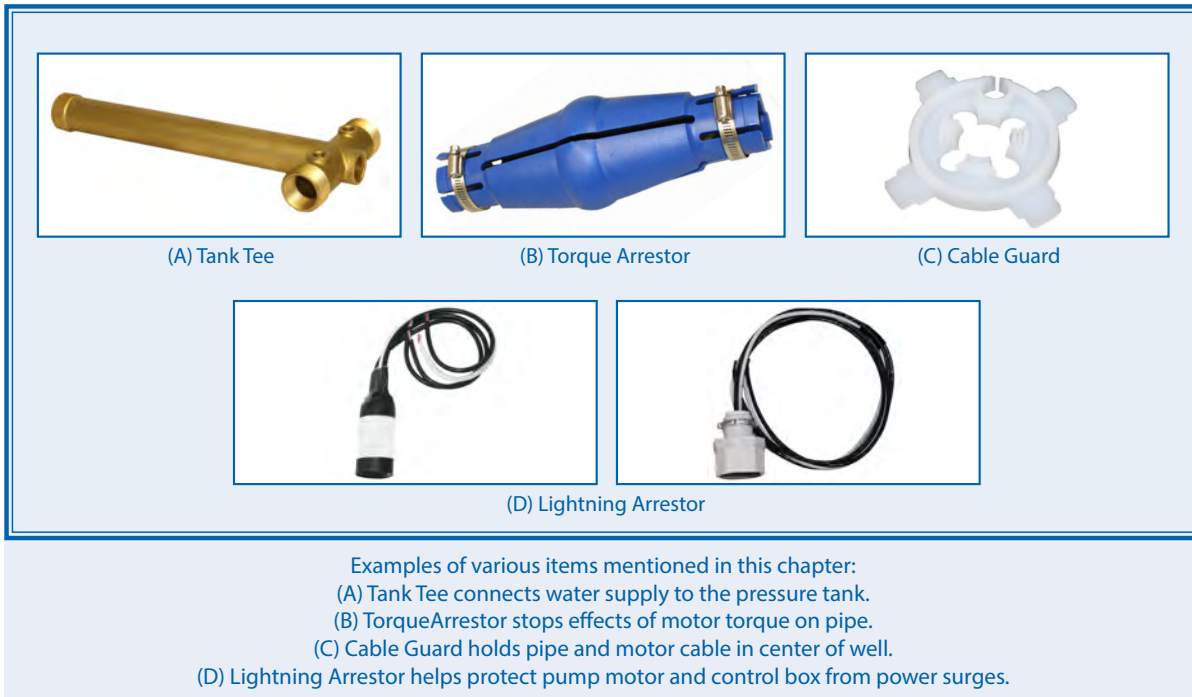
All splices of the electrical cable underwater in the well or underground need to be waterproof and properly **grounded** for safety as well as in compliance with the **National Electrical Code (NFPA 70)**.

Heat-shrink sleeves with crimp connectors are commonly used today to ensure a reliable **waterproof electrical splice**. This splice is easy to do even in freezing weather. First, strip the insulation off the wire ends as needed for the crimp connector. Slide the heat-shrink sleeve over one wire of the pair, and crimp the two wire ends inside the crimp **connector**. Center the shrink sleeve over the splice and apply heat to it using a broad-flame torch or a butane lighter. Start shrinking the sleeve in the center and move out to evenly shrink the sleeve over the entire splice, or start at one end of the sleeve and move across the length to eliminate air bubbles. Be sure to use a heat-shrink sleeve that is labeled as waterproof by the manufacturer. Avoid thin-walled sleeves that are not waterproof.

Lightning arrestor

Lightning or other power surges can damage the pump and water system when protection is not provided. It is essential that control boxes for submersible motors and pressure switches be installed with **lightning arrestors** (Figure IV.2.2(D)), and that they are properly grounded according to the manufacturer's recommendation (Book VI, Chapter 2).

Figure IV.2.2



Check valves to control flow

More than one **check valve** (Figure IV.2.3(A), page 25) should always be used in submersible pump installations. A **line check valve**, if the pump does not have a built-in check valve, should be installed in the discharge pipe within 25 feet of the pump and below the drawdown level of the water in the well. For deeper settings, a line check valve is recommended every 200 feet.

Swing-type check valves should never be used with submersible pumps. With a swing-type valve, when the pump stops, there is a sudden reversal of flow before the valve closes, causing a sudden change in the velocity of the water.

Spring-loaded check valves should be used because they are designed to close quickly when the water flow stops and before it begins to move in the reverse direction. There is little or no velocity of flow when the spring-loaded valve closes and no **hydraulic shock** or water hammer is produced.

Check valves are used to hold pressure in the system when the pump stops. They also prevent **backspin**, water hammer, and **upthrust** inside the pump. Any of these three conditions, or a combination of them, can lead to pump or motor failure, plus shortened service life or operating problems in the system.

With no check valve, or if the check valve fails, the water in the discharge pipe can flow back down into the well when the motor stops. This will cause the pump and motor to spin in the reverse direction and could result in the pump's unscrewing from the pipe and the unit's falling farther down the well. If the motor attempts to start while spinning backward, damage could occur to the shaft of both the pump and motor. If the motor does start, it could continue spinning in the reverse direction, which could result in excessive **downthrust** on the motor thrust bearing and cause damage. If the motor is not turning at the proper speed, the result could be excessive **motor thrust bearing** wear because of inadequate lubrication.

With no check valve, or with a leaking check valve, the pump may start with inadequate **head** conditions that could cause an uplifting (upthrust) of the **impellers** in the pump. The impellers could rub against the **diffuser**, resulting in damage and excessive wear. The performance of the pump will diminish or the pump will fail. An **overload condition** may occur resulting in increased current (amps) on the motor that could cause motor failure.

Water hammer – Water hammer will occur when there is a rapid shutdown of water flow or an abrupt change in flow. For example, if the lowest check valve is more than 30 feet above the standing water level in the well, or the lower check valve leaks and the check valve above holds, a partial vacuum is created inside the discharge piping. On the next pump start, water moving at a very high velocity fills the void and strikes the closed check valve and the stationary water in the pipe above it, causing a hydraulic shock. This shock can split the check valve or pipe, break pipe joints or couplings, and damage the pump and/or motor. Water hammer is an easily detected noise. When discovered, the system should be shut down to avoid damage, and the pump installer contacted to correct the problem.

Weight of pipe and pump

The weight hanging below the check valve must be considered when the valve is installed and must be within the rating of the valve manufacturer.

In a deep well installation or when more than 100 feet of pipe are below the valve, a **heavy-duty valve** or valve recommended by the manufacturer should be used (Figure IV.2.3(B), page 25). For higher weight applications, this type of heavy-duty valve may be referred to as a drop pipe check valve.

Follow the manufacturer's instructions for installation, because check valves are valves and must not be treated as a pipe coupling or damage to the valve could result.

Foot valves

The operation of most **shallow well jet pumps** and **deep well jet pumps** is dependent, in part, on the proper functioning of the **foot valve** (Figure IV.2.3(C), page 25). This valve is installed at the end of the suction pipe or below the **jet** in the well to prevent backflow. Without a foot valve, suction lines will lose a prime every time the pump shuts off. This valve needs good positive shut off to prevent loss of prime and pump cycling when there is no demand.

Wherever possible, a foot valve should be used on shallow and deep well jet pump water systems to assure a positive **prime** from the water level in the well to the pump. This is necessary to protect vital pump parts such as rotary seals, sealing rings and other parts that may be damaged by heat if the pump operates without a water flow.

Shutoff valves

Shutoff valves, such as gate valves or ball valves, should be installed between the tank and the supply line for the entire water system. This makes it possible to drain only the necessary portion of the system each time repairs or changes are made.

Flow-control valves

Flow-control valves are used to reduce or limit the amount of pump capacity primarily to prevent an overload condition (high amps) on the motor and upthrust condition on the pump. When system conditions exist that could allow the pump to deliver too much capacity, a flow-control valve may be installed to restrict or limit this flow to an adequate amount. Valves of this type, as shown in Figure IV.2.3(D), are commonly installed on showers or other water-using appliances to limit the gallons per minute flow to these outlets. A set flow rate to equipment such as irrigation systems can also be maintained with flow-control valves.

Pressure-relief valve

High pressure can result if the pressure switch that controls the pump is damaged, or if the pump stays on too long. Most submersible pumps can develop pressure exceeding the rated working limits of the pressure tank or the distribution system. Excess water pressure can damage water system components as well as the pressure tank if not corrected immediately, so a pressure-relief valve (Figure IV.2.3(E)) is recommended. Relief valves are spring-controlled. For water service, these are generally adjusted to relieve pressure higher than 100 psi.

Whenever there is a question of safety, a relief valve should be used. A pressure and temperature relief valve is required by almost all plumbing codes for water heaters, and it is also important to install a **pressure-relief valve** for water system tanks (Figure IV.2.4, page 26). The size and selection of the relief valve should be based on the capacity of the pump at the relief pressure setting, and it should have positive reseating. Discharge of relief valve should be directed to an adequate drain.

Figure IV.2.3



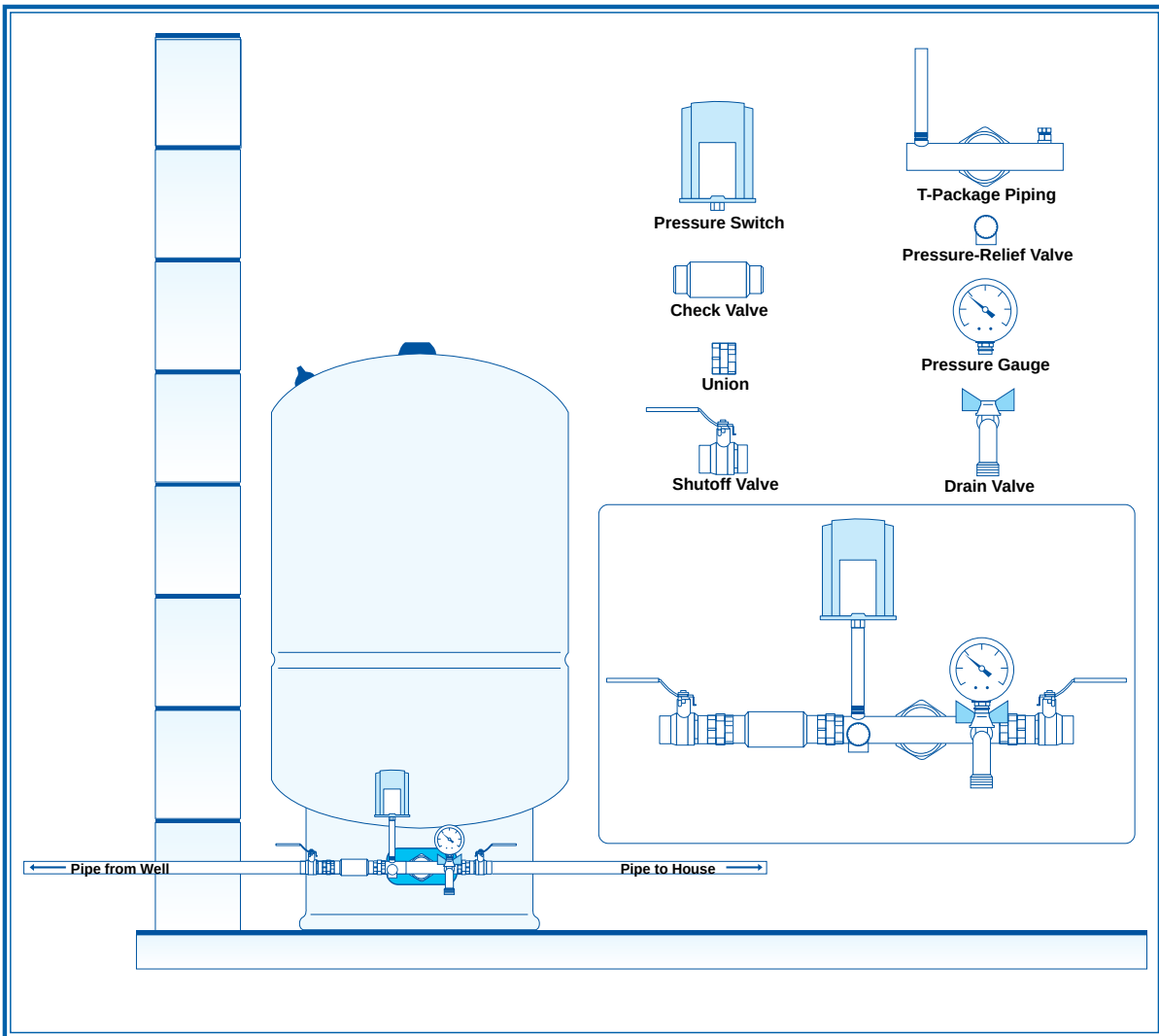
Various types of valves used in water system piping:

- (A) check valve prevents backward flow;
- (B) heavy-duty check valve holds weight of pump, pipe, water, etc., inside well and prevents backward flow;
- (C) foot valve maintains prime with jet pump system;
- (D) flow-control valve limits water supply; and
- (E) pressure-relief valve prevents damage to system by excessive pressure.

Frost-proof wall faucets

Frost-proof wall faucets are installed similar to **sillcocks** through the outside wall of a house or building. The water shutoff valve for the faucet extends far enough into the house to prevent freezing. After each use, the water drains from the faucet to the outside (Figure IV.2.4).

Figure IV.2.4



Typical installation of water system pressure tank and other components.

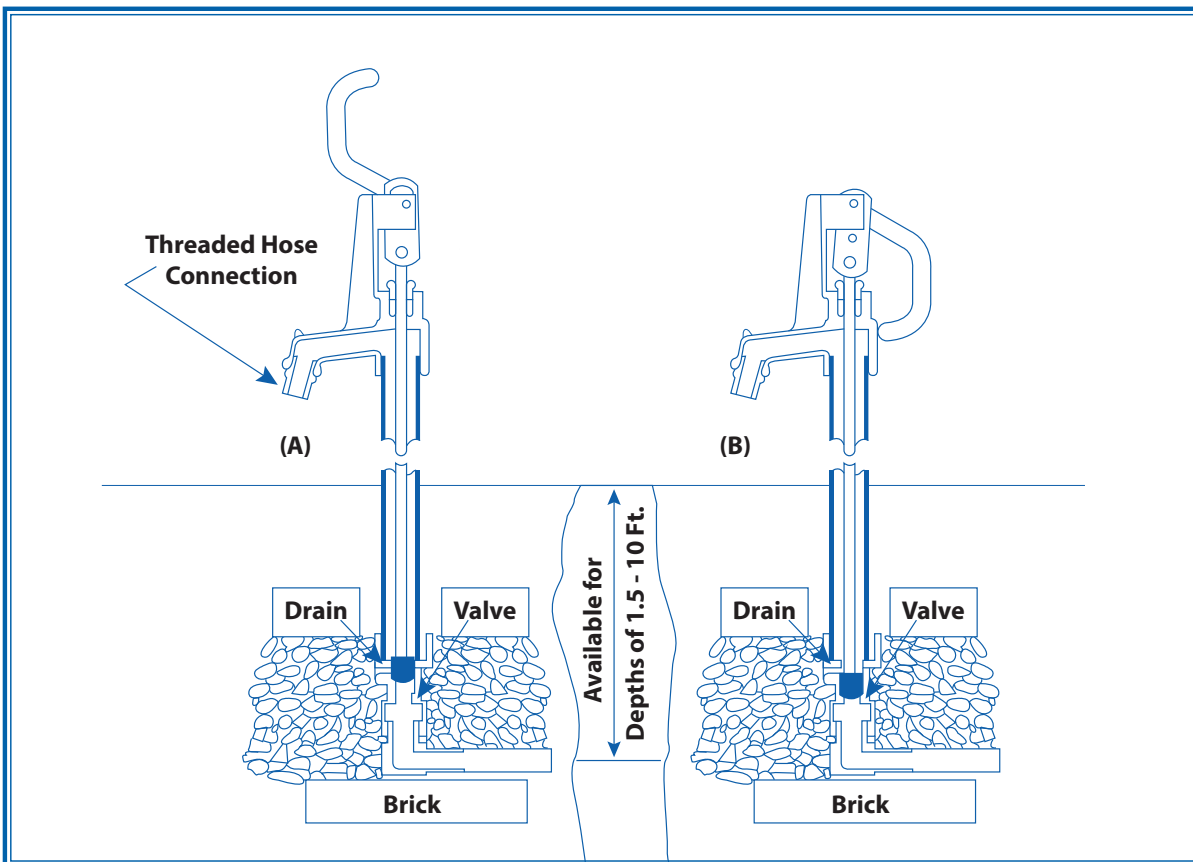
Frost-proof yard hydrants

Frost-proof yard hydrants make it possible to have year-round water service without danger of freezing. A yard hydrant can be installed in almost any outdoor location where a water supply outlet is needed, as long as a water system supply pipe can be buried below the depth of frost.

The **shutoff valve** for a yard hydrant is also buried below the frost line. After each use of the hydrant, water is drained from its standpipe and outlet through the drain hole and into the ground below frost depth (Figure IV.2.5).

NOTE: Check local and state codes.

Figure IV.2.5



Frost-proof hydrants (A) and (B) are designed for use where freezing is a problem.
 (A) When water is turned on, the drain hole is automatically closed.
 (B) When water is turned off, the drain hole is open. Water in the riser drains to sump.

Study Guide Questions - Chapter 2

Answers can be found on page 52

- Q. What factors determine the type of pipe - whether galvanized steel, copper or plastic - to be used in a water distribution system?

- Q. Describe some problems that may be caused by torque?

- Q. Name some of the uses of check valves.

- Q. What other types of valves may be used in water systems?

Chapter 3

Pitless Adapters, Pitless Units, Pitless Kits, and Vermin-Resistant Well Caps

- ✓ Pitless adapters, pitless units, and pitless kits provide sanitary connections
- ✓ Prevent the entrance of contaminants
- ✓ Permit termination of water wells above the ground surface
- ✓ Vermin-Resistant wells work in conjunction with pitless devices to assure sanitary conditions

The **well pit** – for many years a common method to provide convenient access to underground lateral pipe connections below the freeze line on individual water systems is generally unsanitary. The pit invites drainage into the well from possible contaminated surface and near-surface sources.

Pitless well construction, in contrast, sharply reduces the possibility of contaminated water entering the well and system and avoids pit construction costs as well as the need to inspect and regulate pits.

Sanitary water supply

Pitless adapters, pitless units, or pitless kits are the sanitary way to complete water wells. These devices are designed for permanent attachment to the water **well casing**. They provide sanitary connections, thus preventing contaminants from entering surface or near-surface sources through openings into the well or potable water supply. Pitless adapters, units, and kits are watertight in design and construction, and permit the termination of the well above the ground surface.

Other reasons to use pitless equipment

Pitless adapters, pitless units, and pitless kits – sometimes known as diverting devices, sanitary underground discharges, attachments, and connectors have many other advantages in addition to sanitation. They conduct water from the well, protect the water from temperature extremes, and permit convenient access to the well and to water systems parts within the well without exterior excavation or disruption of the earth. Pitless equipment also costs considerably less than pump houses and well pits.

Pitless adapters, units, and kits make it possible for the well casing to extend above the ground level. A discharge connection, located below the frost line, is permanently buried. Water from the well comes up through the pipe from the pump and is connected to the **discharge outlet** that is part of one or more removable seal joints.

This permits the **drop pipe** and pumping equipment in the well to be easily removed from above ground for repair or servicing. The **tank**, **pump**, and **pump controls** can be placed in a heated location such as a basement or utility room offset from the well. Check local and state codes for usage and location.

Types of pitless designs

There are three basic types of pitless equipment design adapters, units, and kits. All types of high-quality pitless equipment are listed by the Water System Council as approved under standard Performance Requirements for Pitless Adapters, Pitless Units, and Well Caps – ASSE Standard #1093-2019/WSC Standard **PAS-97** (2019). Visit <https://www.assewebstore.com/product-standards/> or <https://www.watersystemscouncil.org/resources/well-standards/> to purchase a copy of the Performance Requirements for Pitless Adapters, Pitless Units, and Well Caps – ASSE Standard #1093-2019/WSC Standard PAS-97 (2019). The most current listing of products meeting the Standard can be found at www.watersystemscouncil.org. These products were tested by an independent laboratory and are certified Performance Requirements for Pitless Adapters, Pitless Units, and Well Caps – ASSE Standard #1093-2019/WSC Standard PAS-97 (2019).

Pitless adapters – Below ground pitless adapters connect through the well casing below the frost line. Public health authorities usually recommend that the casing extend 12 inches above ground.

In a typical installation (Figure IV.3.1, page 32), a hole is cut in the casing at the recommended level. The outside section of the adapter is held in place against the outside of the casing for connection to the **discharge pipe** taking the potable water to the pressure tank. The inside section of the adapter is connected to the top of the drop pipe, lowered into the well, and then moved into sealing position.

Pitless adapters used on a 4-inch well casing should be the clamp on style so that nothing protrudes into the well.

Depending on the manufacturer's design, an adapter is connected to the casing by welding; by a clamp and gasket; or by a threaded nipple, gasket, collar, and nut. When properly installed, the adapter is watertight.

Pitless units – As the name implies, pitless units come as complete factory-assembled equipment ready for installation. The installer specifies the well diameter and the "bury depth" (length needed to drop below the frost line). The well casing is then cut off at this depth.

The inside components are removed and the unit is connected to the top of the casing, usually by threading, welding, or compression gasketing. After the discharge pipe is connected to the outside of the unit, the inside components are attached to the drop pipe and lowered into sealing position. Pitless units are usually pressure-tested at the factory to check the internal seals, and, when properly installed, the connections are watertight.

Pitless kits – These are a compromise between a pitless adapter and a pitless unit. Kits typically include internal components similar to those in pitless units, and connections to the well casing similar to pitless adapters. Pitless kits usually do not have any parts that would obstruct the inside of the well when pulled for service, so they can be used with 4-inch well casing and a submersible pump.

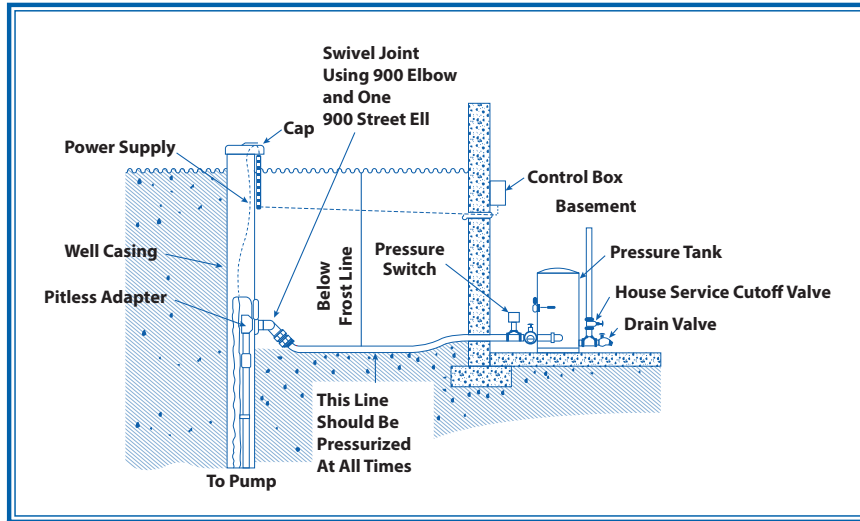
Pitless kits vary in design and installation method, depending on the manufacturer. All brands and designs of pitless kits connect to the well casing by a clamp and gasket or welding. When properly installed, the pitless kit is watertight.

Pressure maintains sanitation

Pitless equipment is designed for use with shallow well jet pumps, deep well jet pumps, submersible pumps, and **working head pumps**. The **piping** from the well or pitless site should be under pressure for sanitary protection.

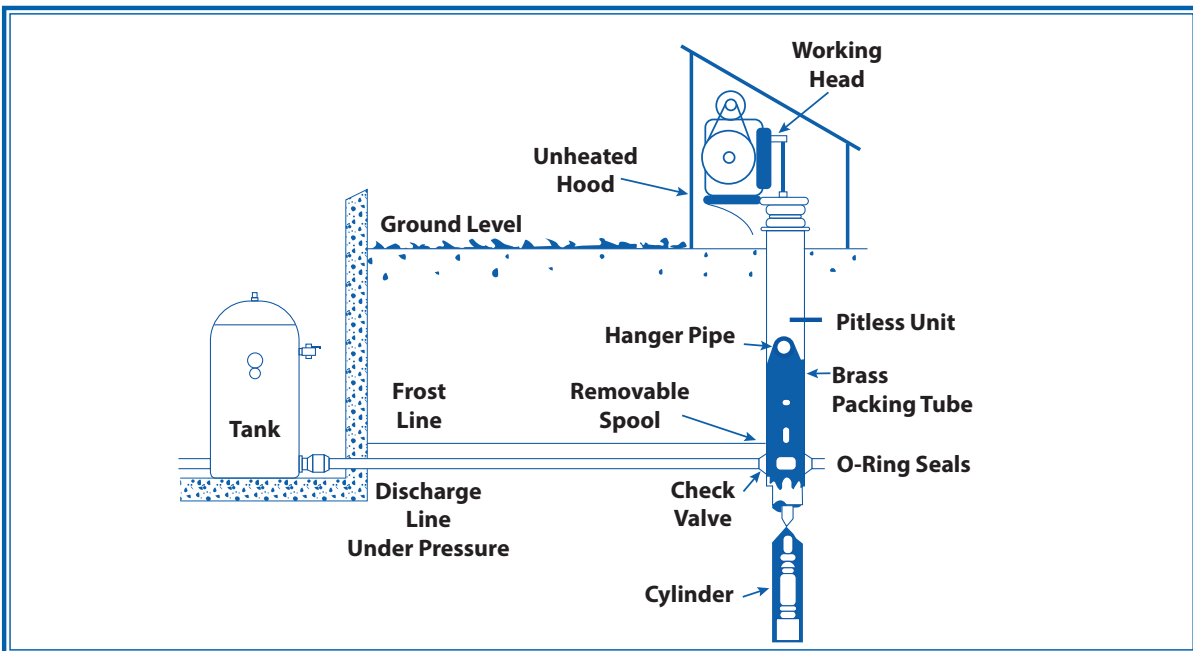
In a submersible pump pitless installation (Figure IV.3.1), pressure in the piping is achieved by placing a **check valve** in the **drop pipe**, directly below the removable seal joint inside the well. When the pump stops, if there is a drain-down air system, the underground line is kept under pressure. Some pitless adapters have built-in check valves in the seal joint area, in which case the drop pipe check valve is not required. Systems using tanks with floating air seals require only the check valve near the top of the submersible pump.

Figure IV.3.1



Pitless unit for submersible pump, typical installation.

Figure IV.3.2



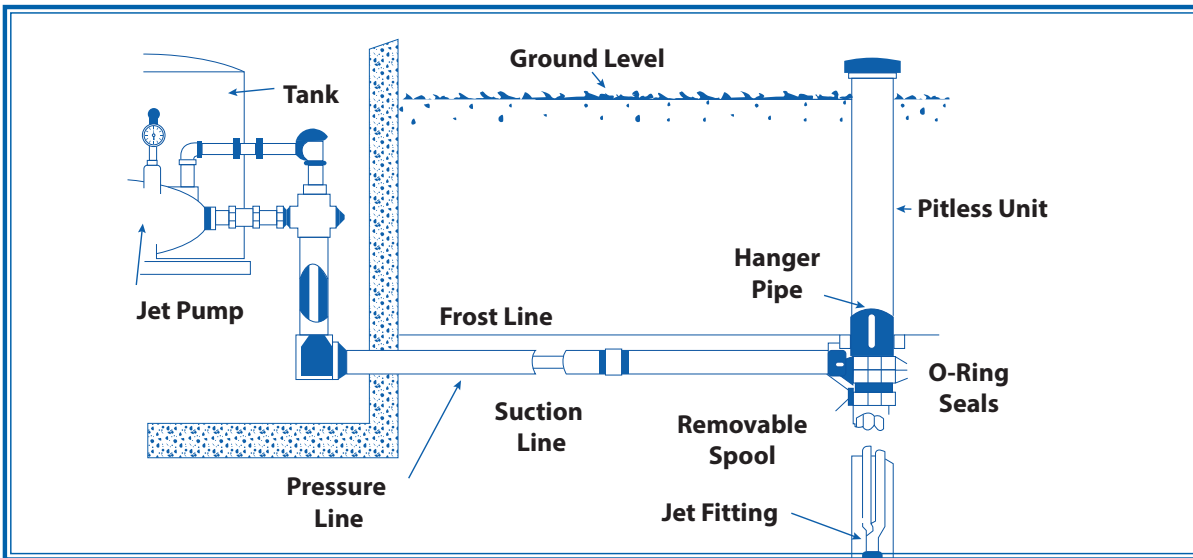
Pitless unit for deep well reciprocating or working head, typical installation.

Pressurizing the offset suction line on either a twin-pipe deep well jet pump or **single-pipe (packer type) deep well jet pump** within pitless construction is accomplished by running the **suction pipe** concentrically inside the pressure pipe, thus forming a pressure conduit around the suction pipe (Figure IV.3.2). The piping is brought out of this concentric arrangement for connection to the pump by means of a **casing adapter**.

Deep well requirements

Deep well working heads (stroke type) require a **drop pipe** and cylinder arrangement rather than tubular construction in which the casing is used as the wall of the cylinder (Figure IV.3.3). A built-in check valve that will permit the pump rod to pass through is needed in order to pressurize the underground line in the removable seal joint. A working head pitless adapter also requires a packing tube around the pump rod that is attached to the sealing device. Any leaks that appear as the packing leathers wear are returned to the well by means of water returns.

Figure IV.3.3

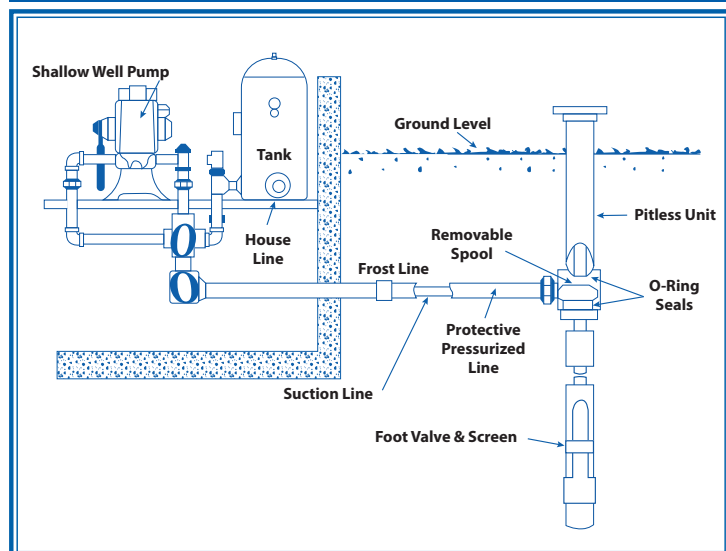


Pitless unit for two-pipe jet, concentric piping, in typical installation.

Shallow well requirements

Shallow well suction pumps require a pressure conduit around the suction or delivery pipe on the offset run (Figure IV.3.4). This is done by dead-ending the pressure conduit on the outside boss of the concentrically arranged underground discharge tee. The piping is brought out of the concentric arrangement at ground level or in a basement, at a point above known flood level. A conduit seal cross provides for water under pressure to be delivered to the pressure tank or to return to the outside conduit from the discharge side of the pump.

Figure IV.3.4



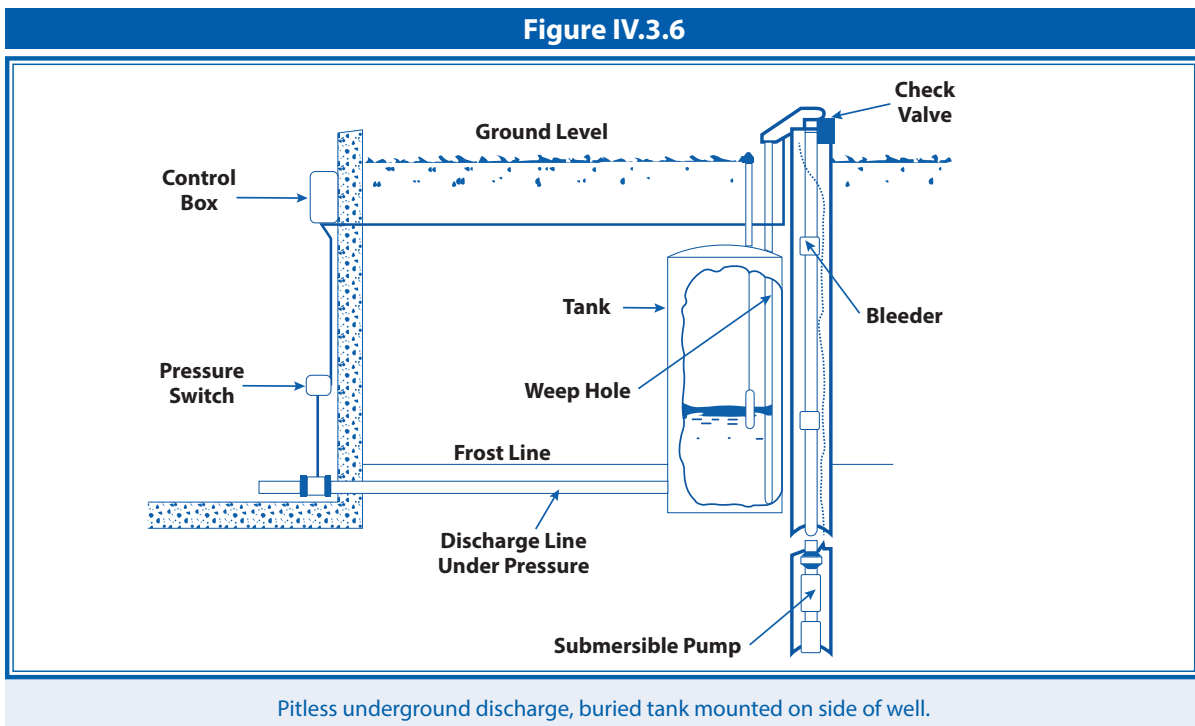
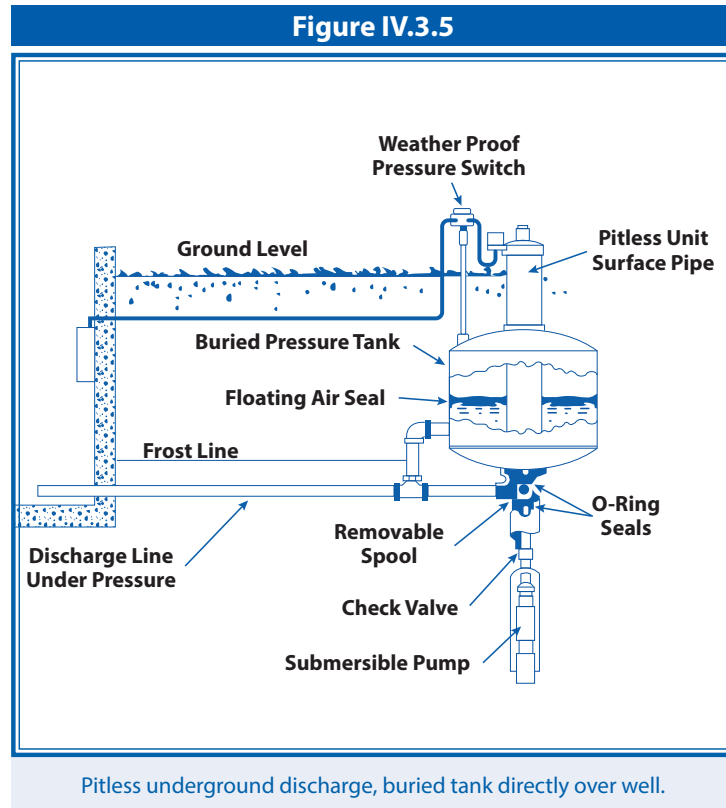
Plain steel tank drawdown.

Pitless buried tank

A variation of the pitless adapter approach is the **pitless buried tank** (Figure IV.3.5), which usually combines the pitless unit and the tank, and locates them directly over the well. Internal well parts can be removed without disturbing the underground piping or the buried tank.

An alternate method straps the tank to the pitless unit riser pipe (Figure IV.3.6). Another locates the tank on the discharge line at a specified distance from the pitless unit and the well. The pitless buried tank is practical only for use with submersible pumps and deep well reciprocating (stroke type) pumps.

Pitless buried tanks permit the entire water system to be located at or near the well, with only service lines under pressure leaving the well. On some buried tanks, the pressure switch and other pump controls can be located at the well, thus isolating the water system from buildings for fire protection purposes. Advantages of the buried tank are that it frees space in the house for other purposes, provides colder drinking water and eliminates moisture condensation found on tanks housed indoors.



Vermin-resistant well caps

To further assure a sanitary water supply, an approved watertight **well cap** is used with the approved pitless adapter, pitless unit or pitless kit (Figure IV.3.7). This cap, which is usually made of thermoplastic or aluminum, covers and encloses the upper termination of a pitless unit or the well casing. The well cap provides protection to the exposed portion of the well casing by being tamper-resistant, forming a protective cover from the elements, and being resistant to the entry of vermin or contaminants.

High-quality vermin-resistant well caps of various designs are listed by the Water Systems Council as approved under standard Performance Requirements for Pitless Adapters, Pitless Units, and Well Caps – ASSE Standard #1093-2019/WSC Standard PAS-97 (2019). The most current listing of products, including well caps, meeting the Standard can be found at <https://www.watersystemscouncil.org/resources/well-standards>. Listed well caps were tested by an independent laboratory and are certified to have passed the testing standard Performance Requirements for Pitless Adapters, Pitless Units, and Well Caps – ASSE Standard #1093-2019/WSC Standard PAS-97 (2019).

Figure IV.3.7



NOTE: Be sure to ask for and use only high-quality pitless adapters, pitless units, pitless kits, and vermin-resistant well caps listed as approved under the standard Performance Requirements for Pitless Adapters, Pitless Units, and Well Caps – ASSE Standard #1093-2019/WSC Standard PAS-97 (2019), the industry standard for quality in pitless equipment and vermin-resistant well caps. Refer to www.watersystemscouncil.org for the most current approved product list.

Study Guide Questions - Chapter 3

Answers can be found on page 53

Q. Give some reasons for using pitless adapters, pitless units, or pitless kits.

Q. What is the purpose of a pitless buried tank?

Q. What is the purpose of a vermin resistant well cap?

Appendix

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Example Conversion Chart: Fittings to Equivalent Length of Pipe

FITTINGS	EQUIVALENT LENGTH OF PIPE FOR DIFFERENT FITTINGS (Feet)												
	Size of Fittings (Inches)												
	1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4	5	6	8	10
90° Ell	1.5	2.0	2.7	3.5	4.3	5.5	6.5	8.0	10.0	14.0	15.0	20.0	25.0
45° Ell	0.8	1.0	1.3	1.7	2.0	2.5	3.0	3.8	5.0	6.3	7.1	9.4	12.0
Long Sweep Ell	1.0	1.4	1.7	2.3	2.7	3.5	4.2	5.2	7.0	9.0	11.0	14.0	-
Close Return Bend	3.6	5.0	6.0	8.3	10.0	13.0	15.0	18.0	24.0	31.0	37.0	39.0	-
Tee Straight Run	1.0	2.0	2.0	3.0	3.0	4.0	5.0	-	-	-	-	-	-
Tee Side Inlet or Outlet	3.3	4.5	5.7	7.6	9.0	12.0	14.0	17.0	22.0	27.0	31.0	40.0	-
Pitless Adapter	3.3	4.5	5.7	7.6	9.0	12.0	14.0	17.0	22.0	27.0	31.0	40.0	-
Ball or Globe Valve Open	17.0	22.0	27.0	36.0	43.0	55.0	67.0	82.0	110.0	140.0	160.0	220.0	-
Angle Valve Open	8.4	12.0	15.0	18.0	22.0	28.0	33.0	42.0	58.0	70.0	83.0	110.0	-
Gate Valve Fully Open	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.7	2.3	2.9	3.5	4.5	-
Check Valve (Swing)	4.0	5.0	7.0	9.0	11.0	13.0	16.0	20.0	26.0	33.0	39.0	52.0	65.0
In-Line Check Valve (Spring)	4.0	6.0	8.0	12.0	14.0	19.0	23.0	32.0	43.0	58.0	-	-	-
Foot Valve	4.0	6.0	8.0	12.0	14.0	19.0	23.0	32.0	43.0	58.0	-	-	-

NOTE: The user should reference the manufacturer's product literature.

Example Steel Pipe Friction Loss

		STEEL PIPE: FRICTION LOSS PER 100 FEET OF PIPE													
gpm	gph	Feet of Head (Feet)													
		Pipe Size (Inches)													
		3/8	1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4	5	6	8	10
1	60	4.30	1.86	0.26	-	-	-	-	-	-	-	-	-	-	-
2	120	15.00	4.78	1.21	0.38	-	-	-	-	-	-	-	-	-	-
3	180	31.80	10.00	2.50	0.77	-	-	-	-	-	-	-	-	-	-
4	240	54.90	17.10	4.21	1.30	0.34	-	-	-	-	-	-	-	-	-
5	300	83.50	25.80	6.32	1.93	0.51	0.24	-	-	-	-	-	-	-	-
6	360	-	36.50	8.87	2.68	0.70	0.33	0.10	-	-	-	-	-	-	-
7	420	-	48.70	11.80	3.56	0.93	0.44	0.13	-	-	-	-	-	-	-
8	480	-	62.70	15.00	4.54	1.18	0.56	0.17	-	-	-	-	-	-	-
9	540	-	-	18.80	5.65	1.46	0.69	0.21	-	-	-	-	-	-	-
10	600	-	-	23.00	6.86	1.77	0.83	0.25	0.11	0.04	-	-	-	-	-
12	720	-	-	32.60	9.62	2.48	1.16	0.34	0.15	0.05	-	-	-	-	-
15	900	-	-	49.70	14.70	3.74	1.75	0.52	0.22	0.08	-	-	-	-	-
20	1,200	-	-	86.10	25.10	6.34	2.94	0.87	0.36	0.13	-	-	-	-	-
25	1,500	-	-	-	38.60	9.65	4.48	1.30	0.54	0.19	-	-	-	-	-
30	1,800	-	-	-	54.60	13.60	6.26	1.82	0.75	0.26	-	-	-	-	-
35	2,100	-	-	-	73.40	18.20	8.37	4.42	1.00	0.35	-	-	-	-	-
40	2,400	-	-	-	95.00	23.50	10.79	3.10	1.28	0.44	-	-	-	-	-
45	2,700	-	-	-	-	30.70	13.45	3.85	1.60	0.55	-	-	-	-	-
70	4,200	-	-	-	-	68.80	31.30	8.86	3.63	1.22	0.35	-	-	-	-
100	6,000	-	-	-	-	-	62.20	17.40	7.11	2.39	0.63	-	-	-	-
150	9,000	-	-	-	-	-	-	38.00	15.40	5.14	1.32	-	-	-	-
200	12,000	-	-	-	-	-	-	66.30	26.70	8.90	2.27	0.74	0.30	0.08	-
250	15,000	-	-	-	-	-	-	-	42.80	14.10	3.60	1.20	0.49	0.13	-
300	18,000	-	-	-	-	-	-	-	58.50	19.20	4.89	1.58	0.64	0.15	0.05
350	21,000	-	-	-	-	-	-	-	79.20	26.90	6.72	2.18	0.88	0.23	0.07
400	24,000	-	-	-	-	-	-	-	103.00	33.90	8.47	2.72	1.09	0.28	0.09
450	27,000	-	-	-	-	-	-	-	130.00	42.75	10.65	3.47	1.36	0.35	0.11
500	30,000	-	-	-	-	-	-	-	160.00	52.50	13.00	4.16	1.66	0.42	0.14
550	33,000	-	-	-	-	-	-	-	193.00	63.20	15.70	4.98	1.99	0.51	0.16
600	36,000	-	-	-	-	-	-	-	230.00	74.80	18.60	5.88	2.34	0.60	0.19
650	39,000	-	-	-	-	-	-	-	-	87.50	21.70	6.87	2.73	0.69	0.22
700	42,000	-	-	-	-	-	-	-	-	101.00	25.00	7.93	3.13	0.80	0.26
750	45,000	-	-	-	-	-	-	-	-	116.00	28.60	9.05	3.57	0.91	0.29
800	48,000	-	-	-	-	-	-	-	-	131.00	32.40	10.22	4.03	1.02	0.33
850	51,000	-	-	-	-	-	-	-	-	148.00	36.50	11.50	4.53	1.15	0.37
900	54,000	-	-	-	-	-	-	-	-	165.00	40.80	12.90	5.05	1.27	0.41
950	57,000	-	-	-	-	-	-	-	-	184.00	45.30	14.30	5.60	1.41	0.46
1000	60,000	-	-	-	-	-	-	-	-	204.00	50.20	15.80	6.17	1.56	0.50

NOTE: The user should reference the manufacturer's product literature.

Example Plastic Pipe Friction Loss

		PLASTIC PIPE: FRICTION LOSS PER 100 FEET OF PIPE												
gpm	gph	Feet of Head (Feet)												
		Pipe Size (Inches)												
		3/8	1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4	6	8	10
1	60	4.25	1.38	0.36	0.11	-	-	-	-	-	-	-	-	-
2	120	15.13	4.83	1.21	0.38	0.10	-	-	-	-	-	-	-	-
3	180	31.97	9.96	2.51	0.77	0.21	0.10	-	-	-	-	-	-	-
4	240	54.97	17.07	4.21	1.30	0.35	0.16	-	-	-	-	-	-	-
5	300	84.41	25.76	6.33	1.92	0.51	0.24	-	-	-	-	-	-	-
6	360	-	26.34	8.83	2.69	0.71	0.33	0.10	-	-	-	-	-	-
8	480	-	63.71	15.18	4.58	1.19	0.55	0.17	-	-	-	-	-	-
10	600	-	97.52	25.98	6.88	1.78	0.83	0.25	0.11	-	-	-	-	-
15	900	-	-	49.68	14.63	3.75	1.74	0.52	0.22	-	-	-	-	-
20	1,200	-	-	86.94	25.07	6.39	2.94	0.86	0.36	0.13	-	-	-	-
25	1,500	-	-	-	38.41	9.71	4.44	1.29	0.54	0.19	-	-	-	-
30	1,800	-	-	-	-	13.62	6.26	1.81	0.75	0.26	-	-	-	-
35	2,100	-	-	-	-	18.17	8.37	2.42	1.00	0.35	0.09	-	-	-
40	2,400	-	-	-	-	23.55	10.70	3.11	1.28	0.44	0.12	-	-	-
45	2,700	-	-	-	-	29.44	13.46	3.84	1.54	0.55	0.15	-	-	-
50	3,000	-	-	-	-	-	16.45	4.67	1.93	0.66	0.17	-	-	-
60	3,600	-	-	-	-	-	23.48	6.60	2.71	0.93	0.25	-	-	-
70	4,200	-	-	-	-	-	-	8.83	3.66	1.24	0.33	-	-	-
80	4,800	-	-	-	-	-	-	11.43	4.67	1.58	0.41	-	-	-
90	5,400	-	-	-	-	-	-	14.26	5.82	1.98	0.52	-	-	-
100	6,000	-	-	-	-	-	-	-	7.11	2.42	0.63	0.08	-	-
125	7,500	-	-	-	-	-	-	-	10.83	3.80	0.95	0.13	-	-
150	9,000	-	-	-	-	-	-	-	-	5.15	1.33	0.18	-	-
175	10,500	-	-	-	-	-	-	-	-	6.90	1.78	0.23	-	-
200	12,000	-	-	-	-	-	-	-	-	8.90	2.27	0.30	-	-
250	15,000	-	-	-	-	-	-	-	-	-	3.36	0.45	0.12	-
300	18,000	-	-	-	-	-	-	-	-	-	4.85	0.63	0.17	-
350	21,000	-	-	-	-	-	-	-	-	-	6.53	0.84	0.22	-
400	24,000	-	-	-	-	-	-	-	-	-	-	1.08	0.28	-
500	30,000	-	-	-	-	-	-	-	-	-	-	1.66	0.42	0.14
550	33,000	-	-	-	-	-	-	-	-	-	-	1.98	0.50	0.16
600	36,000	-	-	-	-	-	-	-	-	-	-	2.35	0.59	0.19
700	42,000	-	-	-	-	-	-	-	-	-	-	-	0.79	0.26
800	48,000	-	-	-	-	-	-	-	-	-	-	-	1.02	0.33
900	54,000	-	-	-	-	-	-	-	-	-	-	-	1.27	0.41
950	57,000	-	-	-	-	-	-	-	-	-	-	-	-	0.46
1000	60,000	-	-	-	-	-	-	-	-	-	-	-	-	0.50

NOTE: The user should reference the manufacturer's product literature.

Example Copper Pipe Friction Loss

		STEEL PIPE: FRICTION LOSS PER 100 FEET OF PIPE									
gpm	gph	Feet of Head (Feet)									
		Pipe Size (Inches)									
		3/8	1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4
1	60	6.20	1.80	0.39	-	-	-	-	-	-	-
2	120	19.60	6.00	1.20	-	-	-	-	-	-	-
5	300	-	30.00	5.80	1.60	-	-	-	-	-	-
7	420	-	53.00	11.00	3.20	2.20	-	-	-	-	-
10	600	-	-	19.60	5.30	3.90	-	-	-	-	-
15	900	-	-	37.00	9.90	6.20	2.10	-	-	-	-
18	1080	-	-	55.40	16.10	6.90	3.20	-	-	-	-
20	1200	-	-	-	18.50	10.40	3.90	-	-	-	-
25	1500	-	-	-	27.70	14.30	5.30	1.50	-	-	-
30	1,800	-	-	-	39.30	18.70	7.60	2.10	-	-	-
35	2,100	-	-	-	48.50	25.40	10.20	2.80	-	-	-
40	2,400	-	-	-	-	30.00	13.20	3.50	1.20	-	-
45	2,700	-	-	-	-	39.30	16.20	4.20	1.60	-	-
50	3,000	-	-	-	-	-	19.40	5.10	1.80	-	-
60	3,600	-	-	-	-	-	27.70	6.90	2.50	1.10	-
70	4,200	-	-	-	-	-	40.00	9.20	3.50	1.40	-
75	4,500	-	-	-	-	-	41.60	9.90	3.70	1.60	-
80	4,800	-	-	-	-	-	45.00	11.60	4.20	1.80	-
90	5,400	-	-	-	-	-	50.80	13.90	4.80	2.20	-
100	6,000	-	-	-	-	-	-	16.90	6.20	2.80	-
125	7,500	-	-	-	-	-	-	25.40	8.60	3.70	-
150	9,000	-	-	-	-	-	-	32.30	11.60	4.80	1.20
175	10,500	-	-	-	-	-	-	41.60	16.20	6.90	1.70
200	12,000	-	-	-	-	-	-	57.80	20.80	9.00	2.20
250	15,000	-	-	-	-	-	-	-	32.30	13.90	3.50
300	18,000	-	-	-	-	-	-	-	41.60	18.50	4.60
350	21,000	-	-	-	-	-	-	-	-	32.30	5.80
400	24,000	-	-	-	-	-	-	-	-	39.30	7.20
450	27,000	-	-	-	-	-	-	-	-	44.00	9.20
500	30,000	-	-	-	-	-	-	-	-	-	11.10
750	45,000	-	-	-	-	-	-	-	-	-	23.10
1000	60,000	-	-	-	-	-	-	-	-	-	37.00

NOTE: The user should reference the manufacturer's product literature.

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Length				
Inches	(in)	Millimeters	(mm)	25.400
Inches	(in)	Centimeters	(cm)	2.539
Feet	(ft)	Meters	(m)	0.305
Yards	(yd)	Meters	(m)	0.914
Miles (statute)	(mi)	Kilometers	(km)	1.609
Millimeters	(mm)	Inches	(in)	0.039
Meters	(m)	Feet	(ft)	3.281
Centimeters	(cm)	Inches	(in)	0.394
Meters	(m)	Yards	(yd)	1.094
Kilometers	(km)	Miles (statute)	(mi)	0.621
Area				
Square Inches	(in ²)	Square Centimeters	(cm ²)	6.452
Square Feet	(ft ²)	Square Meters	(m ²)	0.093
Square Yards	(yd ²)	Square Meters	(m ²)	0.836
Square Miles	(mi ²)	Square Kilometers	(km ²)	2.590
Acres	(ac)	Hectares	(ha)	0.405
Square Centimeters	(cm ²)	Square Inches	(in ²)	0.155
Square Meters	(m ²)	Square Feet	(ft ²)	10.764
Square Meters	(m ²)	Square Yards	(yd ²)	1.196
Square Kilometers	(km ²)	Square Miles	(mi ²)	0.386
Hectares	(ha)	Acres	(ac)	2.471
Liquid Volume				
Ounces	(oz)	Milliliters	(ml)	29.574
Pints	(pt)	Liters	(l)	0.473
Quarts	(qt)	Liters	(l)	0.946
Gallons	(gal)	Liters	(l)	3.785
Pounds per Cubic Foot	(lb/ft ³)	Kilograms per Cubic Meter	(kg/m ³)	16.018
Pounds per Gallon	(lb/gal)	Kilograms per Cubic Meter	(kg/m ³)	119.826
Milliliters	(ml)	Ounces	(oz)	0.034
Liters	(l)	Pints	(pt)	2.113
Liters	(l)	Quarts	(qt)	1.057
Liters	(l)	Gallons	(gal)	0.264
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Cubic Foot	(lb/ft ³)	0.062
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Gallon	(lb/gal)	0.008
Mass				
Ounces	(oz)	Grams	(g)	28.350
Pounds	(lb)	Kilograms	(kg)	0.454
Grams	(g)	Ounces	(oz)	0.035
Kilograms	(kg)	Pounds	(lb)	2.205
Flow				
Cubic Meters per Hour	(m ³ /h)	Gallons per Minute	(gpm)	4.400
Gallons per Minute	(gpm)	Cubic Meters per Hour	(m ³ /h)	0.227

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Force				
Foot Pound Force	(ft-lbf)	Joules	(J)	1.356
Newtons	(N)	Kilogram Force	(kgf)	0.102
Joules	(J)	Foot Pound Force	(ft-lbf)	0.738
Kilogram Force	(kgf)	Newtons	(N)	9.807
Power				
Horsepower	(hp)	Kilowatts	(kW)	0.746
Horsepower	(hp)	Watts	(W)	745.700
Kilowatts	(kW)	Horsepower	(hp)	1.341
Watts	(W)	Horsepower	(hp)	0.001
Pressure				
Bars	(b)	Pounds per Square Inch	(psi)	14.500
Kilograms per Square Centimeter	(kg/cm²)	Pounds per Square Inch	(psi)	14.500
Pounds per Square Inch	(lb/in²)	Kilograms per Square Meter	(kg/m²)	703.070
Pounds per Square Inch	(lb/in²)	Kilopascals	(kPa)	6.895
Pounds per Square Inch	(lb/in²)	Meters of Water	(m)	0.704
Inches of Mercury	(inHg)	Kilograms per Square Meter	(kg/m²)	345.300
Kilograms per Square Meter	(kg/m²)	Pounds per Square Inch	(lb/in²)	0.001
Kilopascal	(kPa)	Pounds per Square Inch	(lb/in²)	0.145
Meters of Water	(m)	Pounds per Square Inch	(lb/in²)	1.420
Kilograms per Square Meter	(kg/m²)	Inches of Mercury	(inHg)	0.003
1 Atmosphere	14.7 lb/in²	Kilograms per Square Centimeter	(kg/cm²)	1.033
1 Atmosphere	14.7 lb/in²	Kilograms per Square Meter	(kg/m²)	10,335.000
1 Atmosphere	14.7 lb/in²	Kilopascal	(kPa)	101.350
1 Atmosphere	14.7 lb/in²	76.0 Centimeters Mercury	(cmHg)	5.170
1 Atmosphere	29.92 inHg	76.0 Centimeters Mercury	(cmHg)	2.540
Pascal	(Pa)	Newtons per Square Meter	(N/m²)	1.000
Pascal	(Pa)	Kilograms per Square Meter	(kg/m²)	0.102
Temperature				
Degrees Fahrenheit	(°F)	Degrees Celsius	(°C)	(°F-32) 0.556
Degrees Celsius	(°C)	Degrees Fahrenheit	(°F)	(1.8 x °C) + 32
Flow				
Feet per Second	(fps)	Meters per Second	(m/s)	0.305
Miles per Hour	(mph)	Kilometers per Hour	(km/h)	1.609
Gallons per Minute	(gpm)	Liters per Minute	(l/min)	3.785
Gallons per Minute	(gpm)	Cubic Meters per Minute	(m³/min)	0.004
Meters per Second	(m/s)	Feet per Second	(fps)	3.281
Kilometers per Hour	(km/h)	Miles per Hour	(mph)	0.621
Liters per Minute	(l/m)	Gallons per Minute	(gpm)	0.264
Cubic Meters per Minute	(m³/min)	Gallons per Minute	(gpm)	264.172

Glossary

Air-Volume Control (AVC): Ensures the proper balance of air to water in non-diaphragm, plain steel pressure tanks, by preventing waterlogging of the tank. (IV-1)

Average System: An average water system has enough well yield and pump capacity to handle the system's peak demand. (IV-1)

Backspin: Results when water flows back into pump and spins in a reverse direction. (IV-2)

Bladder Tank *(Also called a Diaphragm Tank):* Well water pressure tank containing a flexible membrane (diaphragm or air bladder) that becomes compressed as water is pumped in. (IV-1)

Cable Guard: Protects cable inside well by holding the pipe and cable in the center of the well. (IV-2)

Cable Tie: Ties that fasten the cap to the pump from a submersible pump. (IV-2)

Capacity: Amount of water moving past a given point in a given amount of time. (IV-1, IV-2)

Casing Adapter: A device that seals the top of the well casing and allows the water coming from the pump to reach a packer-type jet ejector using the casing as the drive pipe. (IV-3)

Check Valve: Prevents water from flowing backwards. (IV-2, IV-3)

Connectors: Connectors are commonly to ensure a reliable electrical splice. (IV-2, IV-3)

Control: Device used to maintain ideal operating conditions in a pump. (IV-1, IV-2, IV-3)

Copper Pipe: Type of water distribution pipe that can last as long as 80 years, but as little as 10 years in poor soil conditions. Very corrosion-resistant, but can be penetrated in water containing free carbon dioxide. (IV-2)

Cut-In and Cut-Out: An electrical pressure switch activated by the pressure in a pressure tank. When the pressure drops to a low set-point, (cut-in) it turns the pump on. At a high point (cut-out), it turns the pump off. (IV-1)

Cut-In Pressure: *(Also called Pump-Start Pressure):* Pressure level at which a pump turns on. (IV-1)

Cycle Rate: The frequency of pump starts and stops per hour. (IV-1)

Deep Well Jet Pump: Any pump capable of producing water from deeper than 25 feet. (IV-2, IV-3)

Demand: The gallons of water needed within a specific timeframe. (IV-1, IV-2)

Diaphragm Tank: *See Bladder Tank.* (IV-1)

Diffuser: Pump component that converts water velocity to pressure. (IV-2)

Discharge Outlet: An outlet through which water is piped from the pump in a pitless well. It is located below the frost line and is permanently buried. (IV-3)

Discharge Pipe: A pipe that takes potable water to the pressure tank in a pitless installation. (IV-2, IV-3)

Downthrust: Potentially damaging pressure on the pump motor thrust bearing that is created when water in a discharge pipe flows backward due to a missing or faulty check valve. This causes motor to spin backward, creating downthrust. (IV-2)

Drawdown: Reduction in water level during pumping (measured in feet); the amount of water delivered by the pressure tank between pump shutdown and pump precharge pressure. (IV-1, IV-2, IV-3)

Drop Pipe: The pipe found in the well connecting the pump to the water source. (IV-2, IV-3)

Electrical Cable: Special cable designed to transmit electricity from one location to another. In submersible pumps, electrical cables must be protected from hitting the well casing by use of cable guards installed along every 50 feet of pipe. (IV-2)

Fittings: A pipe part used to join together two sections of pipe. (IV-2)

Flow: Measure of water volume moved in a given length of time, typically measured as gpm. (VI-2)

Flow-Control Valves: Valve used to limit the amount of pump capacity to prevent an overload condition (high amps) on the motor and upthrust condition on the pump. (IV-2)

Foot Valve: A screened check valve allowing water to flow into a jet when a pump is running; closes when pump is shut off. Protects pump parts. Used on suction lift applications and located at the bottom of the suction assembly. Keeps the suction line full of liquid. (IV-2, IV-3)

Friction Loss: Loss of pressure when water flows through a piping system factoring gallons per minute, pipe length, size, and fittings. Measured in feet of head. (IV-2)

Friction Loss Tables: Tables that help determine the most suitable pipe size to carry the peak capacity requirement with a reasonable amount of head loss. (IV-2)

Frost-Proof Wall Faucet: Faucet installed on the outside wall of a house, but the water shutoff valve for the faucet extends far enough into the house to prevent freezing. After each use, the water drains from the faucet to the outside. (IV-2)

Frost-Proof Yard Hydrant: Hydrant that allows year-round water service without freezing. The water supply pipe and the shutoff valve are buried below the frost line. After each use of the hydrant, water is drained from its standpipe and outlet through the drain hole and into the ground below frost depth. (IV-2)

Galvanized Steel Pipe: Type of water system pipe with a normal life expectancy of 30 years; 10 years in acid soil. (IV-2)

Grounded: Electrical systems that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation. (NFPA 70 – 2014). (IV-2)

Head: Pressure expressed as height in feet. (IV-2, IV-3)

Heat-Shrink Sleeve: Sleeve made of a material that shrinks when heated, used to create a waterproof electrical cable splice. (IV-2)

Heavy-Duty Valve *(Also called Drop Pipe Check Valve):* Check valve designed for deep well installations or for when more than 100 feet of pipe are below the valve. (IV-2)

Hydraulic Shock *(Also called Water Hammer):* Noise caused by a partial vacuum in discharge piping. This shock can split the check valve or pipe, break pipe joints or couplings, and damage the pump and/or motor. (IV-2)

Impeller: A rotating disk containing vanes attached to the motor shaft; used in centrifugal pumps. (IV-2)

Lightning Arrestor: A device for protecting electrical equipment from damage by lightning or other power surges. (IV-2)

Line Check Valve: Allows liquid to flow in one direction only; used in discharge line to prevent reverse flow. (IV-2)

Minimum Operating Pressure: The lowest pressure that will support fixed demand. (IV-1)

Motor Thrust Bearing: A bearing designed primarily for thrust loads in motors. A bearing is a component used to reduce friction in a machine. It can be damaged by backspin that causes excessive thrust. (IV-2)

National Electrical Code (NFPA 70): Electrical standards code that requires the safe grounding of motor-operated water pumps and metal well casings. (IV-2)

Overload Condition: Condition of excessive amps that can occur when a pump lacking an operating check valve starts under zero head conditions, causing upthrust of impellers in the pump. A resulting overload on the motor causes motor failure. (IV-2)

Packer: The space between a single pipe and the well casing serves as the pressure pipe. A deep well jet pump system that requires 2-inch or 3-inch well casing and has one pipe down in the well to the jet assembly. (IV-3)

PAS-97: Performance standard for pitless well equipment from ASSE and Water Systems Council. (IV-3)

Peak Capacity: The maximum capacity needed in each line or branch of a water distribution system; used to select pipe size. (IV-2)

Peak Demand: The maximum number of gallons of water needed within a specific timeframe. (IV-1)

Peak Demand Period: The time period during which the greatest amount of water is consumed by the users of various household fixtures. (IV-1)

Pipe: Hollow tube used to carry water. Popular types include galvanized steel, copper, and plastic. (IV-2, IV-3)

Piping: System of hollow tubing used to carry water to distribution points. (IV-2, IV-3)

Pitless Adapter: An underground discharge connector that connects to a well casing; used in most submersible systems to prevent freezing and eliminates chances of contamination. (IV-2, IV-3)

Pitless Buried Tank: Variation of the pitless adapter approach that combines the pitless unit and the tank, locating them over the well. These permit the entire water system to be located at or near the well, with only service lines under pressure leaving the well. The pitless buried tank frees space in the house, provides colder drinking water, and eliminates the moisture condensation found on indoor tanks. (IV-3)

Pitless Kit: A compromise between a pitless adapter and a pitless unit. Kits include internal components similar to those in pitless units, and well casing connections similar to those in pitless adapters. (IV-3)

Pitless Unit: A complete, factory-assembled pitless equipment unit ready for installation. (IV-3)

Pitless Well: Type of well that reduces possibility of contaminated water intrusion. (IV-3)

Plain Steel Tank: Pressure tank with no barrier separating air from water. Can be designed for vertical or horizontal installation. (IV-1, IV-3)

Plastic Pipe: Type of water system pipe considered satisfactory for all soil conditions; generally lasts longer than galvanized steel or copper pipe. (IV-2)

Precharge: Any air charge put in a diaphragm tank or bladder tank at the factory above one atmosphere. (IV-1)

Precharge Pressure: The pressure of compressed air in an air pressure tank. (IV-1)

Pressure: The force exerted in pounds over one square-inch area. (IV-1, IV-2, IV-3)

Pressure Gauge: A device that measures pounds per square inch (psi) in a water system. (IV-1, IV-2)

Pressure-Relief Valve: controls maximum pressure in system. (IV-2)

Pressure Switch: An electrical switch activated by system pressure to control starting and stopping of the pump. (IV-1, IV-2, IV-3)

Pressure Tank: Vessel used to provide cycle control of the pump. (IV-1, IV-2, IV-3)

Prime: Condition in which a suction pipe and pump intake are filled with water so that the pump is ready for operation. (IV-2)

psi: (*Pounds per Square Inch*): A unit of pressure or force. (IV-1, IV-2)

Pump: A mechanical device that moves liquid or gas by pressure or suction; a device that converts mechanical torque and motion into hydraulic fluid power. (IV-1, IV-2, IV-3)

Pump Capacity: The maximum number of gallons per hour or gallons per minute that a pump is able to move through a water system. (IV-1, IV-2)

Pump Control: A pump's pressure switch and other regulating devices. (IV-3)

Pump Cut-In Pressure (*Also known as Pump-Start Pressure*): A predetermined low pressure in the water system that activates the pressure switch to energize the motor and start the pump. (IV-1)

Pump Discharge: Place where water exits the pump. (IV-1)

Pump Motor: Electrical motor that operates the pump in a water system. (IV-1, IV-2)

Pump-Start Pressure (*Also know as Pump Cut-In Pressure*): A predetermined low pressure point in the water system that activates the pressure switch to energize the motor and start the pump. (IV-1)

Shallow Well Jet Pump: A pump that produces lower than atmospheric pressure at its inlet and lifts water with a suction pipe. Limited to wells with depths of 25 feet or less. (IV-2, IV-3)

Shutoff Valve: Valve installed between the well and tank, making it possible to drain a portion of the system for repairs, instead of draining all of it. A device used to separate a component from the system, e.g., valves can be of the ball, globe, or gate design. (IV-2)

Sillcock: Outdoor faucet. (IV-2)

Snifter Valve: Valve that allows installer to change the pressure if desired. (IV-1)

Spring-Loaded Check Valve: A check valve designed to close quickly when water flow stops. (IV-2)
Submersible Pump: An adapted centrifugal pump and motor designed to be placed completely below the water surface. (IV-2, IV-3)

Suction Pipe: A pipe through which well water is drawn to the surface. (IV-2, IV-3)

Supplemental Supply: The quantity of water stored between the tank precharge and pump cut-in pressure: used in cases where the pump cannot meet peak demand. (IV-1)

Swing-Type Check Valve: A check valve that shuts off water flow but causes sudden reversal of flow. (IV-2)

Tank: A container that stores water from a well before it enters the distribution system. Tanks are installed inside or outside a dwelling, placed in well pits, or buried underground. (IV-1, IV-2, IV-3)

Tank Outlet: Opening through which water leaves the tank. (IV-1)

Tank Tee: Special pipe fittings that connect the water supply pipe from the well to the pressure tank. (IV-2)

Tapping: Outlet for water in a plumbing system. (IV-2)

Torque: The rotary force transmitted by the driving shaft of the pump. (IV-2)

Torque Arrestor: A rubber friction creation device designed to prevent damage to a pump and pump wire from startup torque/recoil that causes the pump to slap/rub the side of the casing. (IV-2)

Upthrust: Condition caused when pump with leaky or nonexistent check valve starts under zero head conditions. Can cause premature wear in motors. (IV-2)

Usable Water: The amount of water, including drawdown, that a pressure tank provides between pump stop and minimum operating pressure; usually associated with low-producing wells. (IV-1)

Water Hammer: *See Hydraulic Shock.* (IV-2)

Waterlogging: The complete loss of air in a tank. This is indicated by rapid pump cycling and clicking of contacts on pressure switch. (IV-1)

Waterproof Electrical Splice: Heat-shrink sleeves with crimp connectors are commonly used to ensure a waterproof splice. All splices of electrical cable located under water in the well or underground must be waterproof and grounded for safety and compliance with the National Electrical Code (NFPA 70). (IV-2)

Well Cap: Protective cover, usually made of aluminium or thermoplastic, that seals the upper end of a well to keep out the elements, contaminants, and vermin. (IV-3)

Well Casing: Steel or plastic lining permanently installed in drilled wells to prevent cave-ins or contamination by surface water. (IV-2, IV-3)

Well Pit: Underground vault, located below the frost line, that provides access to a well's tank and underground lateral pipe connections; now considered unsanitary and obsolete due to the introduction of pitless adapters. (IV-1, IV-3)

Working Head Pump: *See deep well reciprocating pump.* (IV-3)

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Notes

[illegible]

Study Guide Answers

Chapter 1

Q. What are the three essential components of a private water system?

A. **The pump, tank, and control.**

If you missed this question, go back to page 9 for information on pressure tanks.

Q. What are the functions of a pressure tank?

A. **It protects and prolongs the life of the pump by preventing rapid cycling of the pump motor; provides water under pressure for delivery between cycles; and provides additional water storage under pressure to assist the pump in meeting the total demands of a system if the pump or well is incapable of supplying the required capacity.**

If you missed this question, go back to page 9 for information on functions of a pressure tank.

Q. What are the three main types of pressure tanks?

A. **Plain steel or non-diaphragm composite tank, diaphragm tank, and bladder tank.**

If you missed this question, go back to page 11 for information on pressure tank designs.

Chapter 2

Q. What factors determine the type of pipe – whether galvanized steel, copper or plastic to be used in a water distribution system?

A. **Underground soil corrosion, corrosion inside the pipe, safe working pressure, effect of freezing, local plumbing codes, ease of installation, cost, and weight.**

If you missed this question, go back to page 21 for information on types of pipe used.

Q. Describe some problems that may be caused by torque?

A. **Torque can loosen or unscrew threaded joints and other parts of the pump support system. Unscrewing joints will break the electrical cable to the pump and may cause loss of the submersible pump.**

If you missed this question, go back to page 22 for information on effects of torque.

Q. Name some of the uses of check valves.

A. **Check valves are used to hold pressure in the system when the pump stops. They also prevent backspin, water hammer and upthrust inside the pump.**

If you missed this question, go back to page 23 for information on check valves to control flow.

Q. What other types of valves may be used in water systems?

A. **Line check valves, foot valves, shutoff valves, flow-control valves, and pressure-relief valves.**

If you missed this question, go back to pages 23-25 for information on various valves.

Chapter 3

Q. Give some reasons for using pitless adapters, pitless units, or pitless kits.

A. They provide sanitary connections, thus preventing contaminants from entering surface or near-surface sources through openings into the well or potable water supply. They also permit the termination of the well above the ground surface, conduct water from the well, protect the water from temperature extremes, and permit access to the well and water systems parts within the well without exterior excavation or disruption of the earth. Pitless equipment also costs considerably less than pump houses and well pits.

If you missed this question, go back to pages 30-31 for information on a sanitary water supply.

Q. What is the purpose of a pitless buried tank?

A. Pitless buried tanks permit the entire water system to be located at or near the well, with only service lines under pressure running away from the well.

If you missed this question, go back to page 34 for information on pitless buried tanks.

Q. What is the purpose of a watertight well cap?

A. It helps ensure a sanitary water supply.

If you missed this question, go back to page 35 for information on watertight well caps.

Notes



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Water Quality Assurance



WATER SYSTEMS HANDBOOK

*A complete text on wells:
their design, operation, and maintenance*

13TH EDITION

Published by



WATER SYSTEMS HANDBOOK

BOOK V

Water Quality Assurance

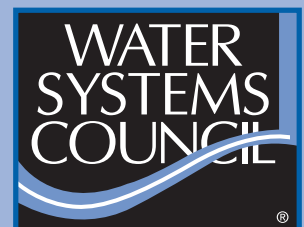
13TH EDITION



**A complete text
on wells:
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A Word Of Caution



The products described in this Handbook, including all products using electrical current, can result in serious harm if not used with EXTREME CAUTION and in strict accordance with manufacturers' instructions. Professional assistance is recommended and should always be sought when utilizing unfamiliar equipment.

The products, materials, information, and instructions in this publication are provided for informational purposes only. This publication is not intended to provide instructions or recommendations relating to the selection, adoption, or use of equipment. All information is provided from sources believed to be reliable, accurate, and comprehensive. However, all information, including without limitation product descriptions and functionality is provided "as is" without any express or implied warranty of any kind, including warranties of title, merchantability, noninfringement of intellectual property, compatibility, or fitness for any purpose or use. In no event shall the Water Systems Council or its members, agents, employees, directors, or officers be liable for any damages or other claims whatsoever, including, without limitation, any direct, indirect, special, punitive, or consequential damages, whether from harm, loss of profits, business interruption, loss of information, or related expenses arising out of errors, omissions, or the use of or inability to use the materials, products, information, or services as provided in this Handbook, even if the Water Systems Council or its members have been advised of the possibility of such damages.

Introduction to Wells

Water is life's most vital resource. Through the centuries, people have searched for water, fought for it, and sometimes died for it. No living organism can exist without water.

Consequently, clean and plentiful groundwater is necessary for everyday life. As described in this handbook, groundwater is the reservoir of water that seeps downward through the soil to the water table below the earth's surface. About 98 percent of all fresh water available in the nation at any time is groundwater, which fills the porous beds of rock and sand that make up the earth's crust.

Groundwater is an ideal water supply, for it is pure and wholesome. Filtered by the underground formations through which it passes, groundwater has a degree of purity seldom attained by surface waters.

Natural groundwater reservoirs have many advantages. They have huge capacities, they are relatively inexpensive to tap by means of wells, and they lose little water by evaporation. Above all, they are dependable sources of water.

In the United States alone, more than 115 million people get their drinking water from groundwater every day. More than 23 million American households are supplied from individual, private wells.

A modern well is both flexible and functional. A variety of pumps is available to lift water from all types of wells, from the shallowest to the deepest. These systems are made automatic and dependable by many types of controls and accessories. Groundwater is there when needed. Additional equipment may be added to the system for treatment to ensure better quality of life.

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About this Handbook

The **WATER SYSTEMS HANDBOOK** provides basic information on well design, operation, and maintenance to boost the professional knowledge of well industry personnel.

Before you begin your studies, please take a few moments to familiarize yourself with the format of this handbook. The handbook is divided into eight books. Each includes several chapters that cover the most important aspects of wells. At the end of each chapter, you will find a **Quiz**. You can use this quiz as a learning tool to review the noteworthy points in each chapter. Answers to the quiz can be found at the end of each book. If you miss an answer, follow the directions to take you back to where the information is located in the chapter.

For quick reference, you will find that highlighted text is generally defined in a **Glossary** at the back of each book, where you will also find a topical **Index**. While illustrations appear in each chapter, you will also see tables and charts referenced in text and located in the **Appendix** at the back of each book. A handy metric system reference also appears in each appendix.

We hope that studying the information in this handbook will prepare you for your job as a well professional, charged with the important responsibility of helping to ensure access to pure, plentiful well water for families across America.

Water Systems Council

Dedication

This 13th Edition of Water Systems Handbook is dedicated to the millions of Americans who rely on private water systems to provide safe, sustainable water supply and to the water well professionals in the water well industry.

The 13th Edition is also dedicated in memory of Jeff Wellen for his many years of leadership and service to WSC and the water well industry.

Special thanks to the members of the Water Systems Council Technical Committee, who initiated and completed revisions to this 13th Edition.



The Water Systems Council (WSC) is a national nonprofit organization, dedicated to promoting the wider use of wells as safe, sustainable, and cost-effective drinking water systems; protecting groundwater resources and users of well water, and ensuring a safe drinking water supply for well owners. WSC members include major manufacturers of the integral components of wells and other drinking water systems, leading distributors of these components, and various drinking water professionals.

WSC is the only national nonprofit organization with programs solely focused on private water wells and small, shared wells.

www.watersystemscouncil.org

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Chapter 1

Water Contaminants

- ✓ Introduction

- ✓ Contaminant categories

- ✓ Contaminant effects

- ✓ Acceptable Water Contaminants

Water is the most plentiful and vital liquid in the world. No life as we know it could exist without water. It carries nutrients to maintain life and washes away waste matter.

Water can dissolve all elements to a certain degree. Gases are held between its molecules. Sediment and living organisms are held in suspension. This is why the quality of water varies so greatly, and why treatment of water is necessary.

Although the need to protect water from undesirable **contamination** has long been recognized, and treatment processes are commonplace, two sets of circumstances during the last several decades have changed the ways safe and potable water for drinking is produced.

First, the promulgation of a complex set of environmental laws, in particular the **Safe Drinking Water Act of 1974** and its Amendments in 1986 and 1996, has resulted in federal and state regulations that must be followed by public water systems. By definition, a **public water system** is one that delivers piped water for human consumption to at least 15 service connections or regularly serves at least 25 individuals.

Second, developments in science, particularly in the ability to detect smaller quantities of chemical substances in water and in the understanding of how certain substances can produce illness in humans, have resulted in more stringent rules covering the quality of water provided for public consumption.

Introduction

Both the nature of contaminants and their respective treatment technologies can best be understood with an understanding of the water **molecule** itself. It is **dipolar** with both a positive and negative side (Figure V.1.1).

Consequently, the water molecules attract and hold other particles with opposite charges. For this reason, absolutely pure water is a rarity. All water samples have some amount of “contamination”, either visible or not. Water quality may be viewed as a measure of contaminants present. The basic issue in water quality is the acceptability of the contaminants present.

Water treatment is simply the process of changing the **source water** into product water of our desired quality. The water treatment process may involve the removal of specific contaminants, the addition of new contaminants, or the exchange of one contaminant for another (Figure V.1.2).

For drinking water in our homes, the basic standard for water quality is established by the U.S. EPA as the National Drinking Water Regulation. This standard establishes required and recommended limits to the type and amount of “contaminants” allowed in our water. For process water in manufacturing, agriculture, food, and medicine, there are a wide range of industrial standards for contaminant limits. Many of these have limits which far exceed those of drinking water.

Contaminant categories

There are four categories of water contaminants: suspended solids, dissolved solids, microbes, and organics. These categories differ in their interaction with water and in their origin as either minerals or living matter.

Because of their own polar nature, the water molecules are attracted to each other. This attraction, called hydrogen bonding, produces a medium which can suspend small particles. These suspended solids are not attracted to the water molecule itself because they have no charge. They are merely suspended within the water medium. Many of these are visible to the naked eye but some are too small to be visible to the naked eye. Typical suspended solids include Ferric (orange) iron colloids and fine silt.

Since the size of suspended particles is so small, we cannot use the inch or even the millimeter scale. The scale used is **microns**. To appreciate the size of a micron, consider that a period (.) on a page of paper is 615 microns in diameter. The use of the micron scale allows us to specify the relative size of suspended solids. For example, a human hair has a diameter of about 100 microns. We can usually see a suspended solid when it has a size greater than 40 microns (Figure V.1.3, page 11).

Figure V.1.1

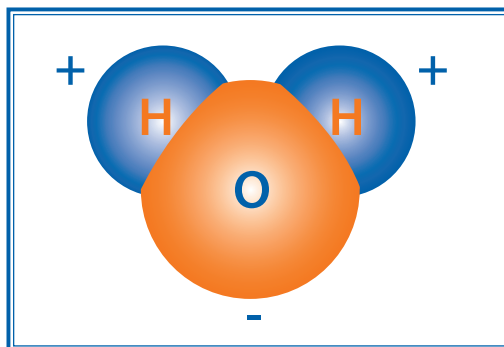
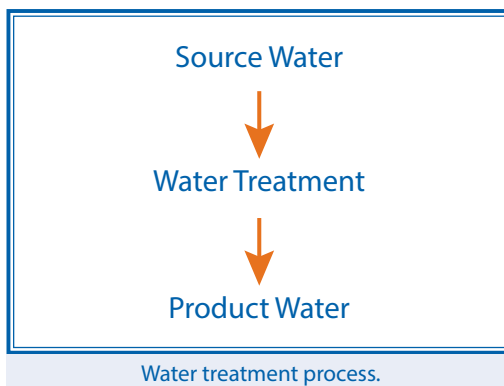


Figure V.1.2

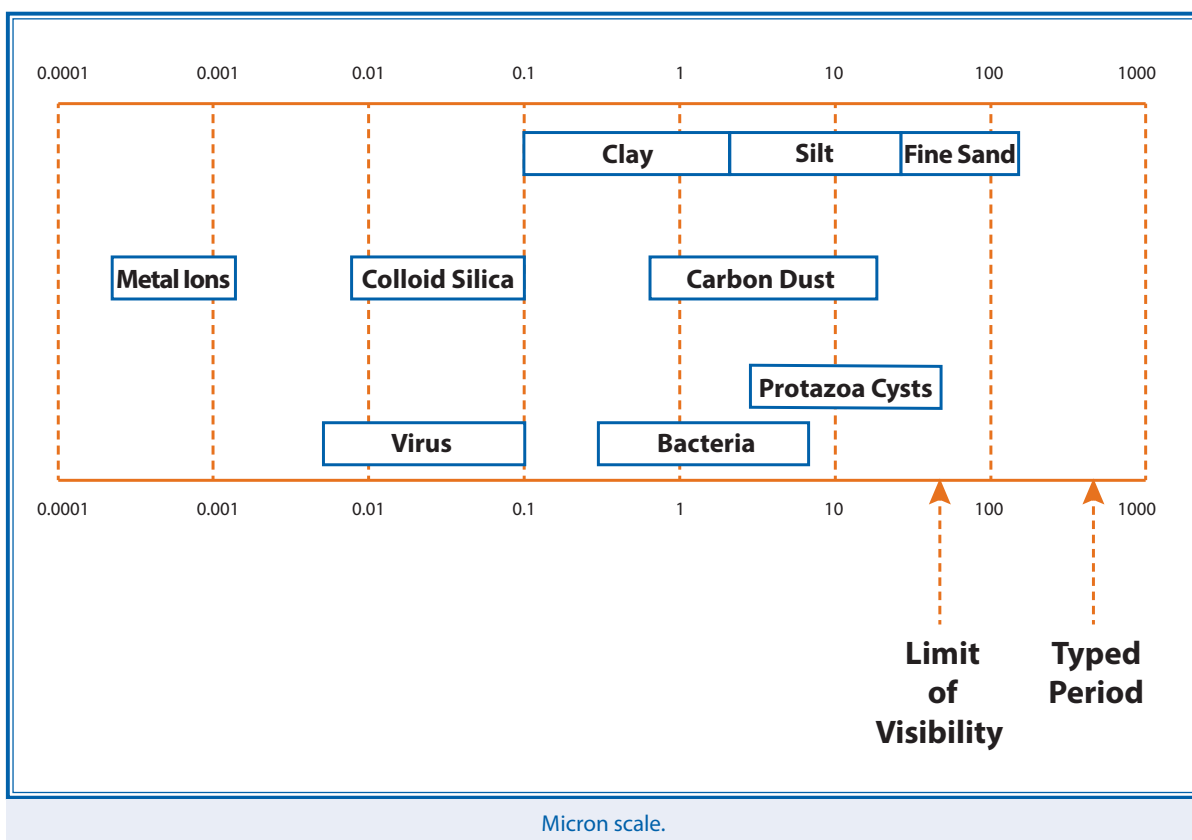


Most of the **suspended solids** we are familiar with are from non-living solids which originate as minerals and are called inorganic. There is another category of living suspended solids which is considered separately in water quality. These are **microbes**, including **bacteria**, **virus**, and **protozoa**. These are organic-based suspended solids: organic because they are living particles and suspended because they do not interact with water.

Another type of particle exhibits either a positive or a negative charge. These are called **ions**. When they are in water, these ions are called **dissolved solids**. They are distinguished from suspended solids because dissolved solids interact with the dipolar water molecules. Common dissolved solids include calcium, sodium, Ferrous (clear) iron, chloride, and nitrate ions.

The fourth category of contaminant interacts with the water molecule as a dissolved solid but has a structure similar to living matter rather than mineral matter. These are dissolved **organics**. They are distinguished from mineral-based dissolved solids by their composition of carbon and hydrogen atoms, among others. The more prominent dissolved organics include **methyl tert-butyl ether (MTBE)** and perfluorooctanesulfonic acid (PFOA). These organics are addressed separately because they have unique characteristics.

Figure V.1.3



Contaminants effects

The effects of the contaminants in our water vary widely, especially by type. And once again, some effects are negative, some neutral, and some are positive. The issue with any contaminant is whether its presence is acceptable at a given concentration. For example, a single particle of iron in a gallon of water will provide no observable effect, but when that concentration of iron particles is enough to provide an orange color to the gallon of water, that presents a contaminant problem.

The concentration of contaminants is expressed in primarily two ways: weight of the contaminant per the volume of water, and the weight of contaminant per the weight of water. The principal weight-per-volume terminology in the water industry is milligrams per liter (mg/l). That is one-thousandth of a gram for every liter of water. A variation of this term, and a thousand times less concentrated, is micrograms per liter (mg/l). The weight-per-weight measurement is **parts per million** (ppm). That is one weight of contaminant per a million weights of water. Again, variations include parts per billion (ppb) and parts per trillion (ppt).

These very small concentrations are difficult to visualize. A milligram per liter or part per million is the same as one minute in 2 years; a part per billion is one second in 32 years; and a part per trillion is a single second in 320 centuries.

The effect of suspended solids, other than microbes, is primarily cosmetic (Table V.1.1). Suspended solids provide color and cloudiness (turbidity) to water, making it less palatable. Additionally, they may create issues with the operation of appliances by forming a solid mass around moving parts or in appliance filters. Suspended solids are typically measured in milligrams per liter.

Table V.1.1

Contaminant	Dangers	Units Of Measure
Suspended	Cosmetic, Residues	mg/l, ppm
Microbes	Pathogens, Biofilm	CFU/ml
Dissolved	Scale, Corrosion, Carcinogens	mg/l, ppm
Organics	Carcinogens	mg/l, ppm

The dangers of microbes are well known, documented, and appreciated. Besides the threat posed by **pathogen** microbes—those affecting health—even the non-pathogens may pose a cosmetic concern with slime build-up inside tanks or pipes which is called **biofilm**. The ultimate danger from microbes is their ability to multiply and increase their numbers by producing colonies. The concentration of microbes is based upon this ability to multiply. The term used is colony forming units per milliliter, or CFU/ml.

Dissolved solid are invisible but provide the widest array of objectionable effects in well water. Some dissolved solids like calcium hardness cause scaling in piping and in appliances, some like arsenic affect our health or are poisonous, and others like low pH cause corrosion of metals. Dissolved solids also include a number of gases. Dissolved solids are typically measured as mg/l or ppm.

The dangers of organics range from disagreeable odor, like some esters, to life-threatening carcinogenic properties like MTBE or Trichloroethylene (TCE). Most of these were created by manufacturing and agricultural technologies. Organics are also measured as mg/l or ppm (Table V.1.2).

Table V.1.2

Common Contaminants Found In Water			
Common Name	Chemical Name	Adverse Effect	Found In Water As
Lime	Calcium carbonate	Hardness	Dissolved solid
Dolomite	Magnesium carbonate	Hardness	Dissolved solid
Sulfate salts	Sodium sulfate	Taste & cathartic	Dissolved solid
Silt, Clay	Turbidity	Sediment, taste	Suspended solid
Nitrate salts	Nitrates	Headaches, nausea, pregnancy Category C	Dissolved solid
Common salt	Sodium chloride	Taste & cathartic	Dissolved solid
Iron	Ferrous iron	Rust stains	Dissolved solid
	Ferric iron	Rust stains	Suspended orange or black solid
Manganese	Manganese	Black stains	Dissolved solid
	Manganese oxide	Black stains	Suspended black solid
Carbon dioxide	Carbon dioxide	Corrosive gas	Dissolved gas
Rotten egg odor	Hydrogen sulfide	Corrosive gas bad odor	Dissolved gas
Marsh gas	Methane	Inflammable gas	Dissolved organic gas
Fluoride	Fluoride	Bone disease	Dissolved solid
Oxygen	Oxygen	Oxidizing and corrosive	Dissolved gas
Acid reactives	Indicated by pH value	Below 7 – Acid, Corrosive	Dissolved matter
Alkaline reactives	Indicated by pH value	Above 7 – Alkaline, Non corrosive	Dissolved matter
Arsenic	Arsenite (Arsenic III) Arsenite (Arsenic V)	Toxic	Dissolved solid

Pathogenic bacteria - Disease producing bacteria such as typhoid.

Non-pathogenic bacteria - Non-disease producing, slime-forming bacteria. Some use dissolved iron as food and plug water pipes with their rusty bodies, producing bad odors and tastes.

Acceptable Water Contaminants

Water quality

Water quality is the definition of the contaminant levels in a specific body of water, whether it is the water available in a particular well or the contaminant level within a lake or reservoir. Water quality may include some obvious characters such as taste, odor, or clarity. However, since most contaminants are not obvious to our normal senses, water quality specification will also include the concentration of the invisible contaminants such as dissolved solids, microbes, and organics.

There are numerous water contaminant test kits available for measuring specific contaminants. However, for accuracy, the best source for determining water quality is through a recognized testing laboratory. Many water treatment manufacturers offer such tests free of charge, but their scope of testing is limited to a set number of contaminants.

Product water

The statement of the desired water quality is called the **product water**. The product water may include any number of contaminant concentration limits. For drinking water, the product water is defined nationally by the standard drinking water regulations from the U.S. EPA. As a mandatory supplement to these national standards, many states enact more stringent regulations for drinking water in their state. Beyond these written standards, the individual user may have an expectation for water quality which is even more stringent.

The *U.S. National Drinking Water Regulations*, administered by the U.S. EPA, provides national guidance on the product water quality for drinking water in public water supplies. The regulations are divided into four contaminant categories: **maximum contaminant level (MCL)** standards are enforceable limits of concentration for contaminants, **secondary maximum contaminant level (SMCL)** standards are recommended (not enforceable) limits which are considered aesthetic requirements, and **maximum contaminant level goals (MCLG)** standards which are considered important to the U.S. EPA, but are not yet enforced. The **maximum residual disinfectant level (MRDL)** is the highest acceptable concentration of disinfectant residual. See Table V.1.3 (page 15) for some of the U.S. EPA standards.

Beyond the standard drinking water regulations, the U.S. EPA and individual states have established specific standards for the use of **groundwater** and surface water for public water systems which provide water for human consumption for at least 15 service connections OR serves an average of at least 25 people for any 60 days per year.

Table V.1.3

U.S. EPA National Drinking Water Regulations (Partial)		
Contaminant	Maximum Contaminant Level	
Primary Inorganic MCL		
Arsenic	0.01	mg/l
Microbes	1.3	mg/l
Lead	0.015	mg/l
Nitrate	10	mg/l
Fluoride	4	mg/l
Primary Organic MCL		
Trichloroethylene (TCE)	0.005	mg/l
Toluene	1	mg/l
Polychlorinated Biphenyls (PCB)	0.0005	mg/l
Total Trihalomethanes (THM)	0.08	mg/l
Primary Radionuclides MCL		
Gross Alpha	15	pCi/L*
Gross Beta	4	millirems
Uranium	0.03	mg/l
Secondary SMCL		
Iron	0.3	mg/l
Manganese	0.005	mg/l
Total Dissolved Solids (TDS)	500	mg/l
pH	6.5 - 8.5	units
Disinfectant Residual MRDL		
Chlorine	4	mg/l
Chloramine	4	mg/l

*Picocuries per liter of air.

Note: U.S. EPA maximum contaminant levels (MCLs): Some states may set limits for contaminants even lower than those set by the U.S. EPA. Check with your local health department or state environmental agency for maximum levels used in your state. Well owners should use these maximums as guidelines to know when to treat their drinking water.

Study Guide Questions - Chapter 1

Answers can be found on page 64

Q. What is the defining character of the water molecule?

Q. Define water treatment.

Q. What are the four basic categories of contaminants in water?

1.

2.

3.

4.

Q. What is water quality?

Q. What is a public water system?

Chapter 2

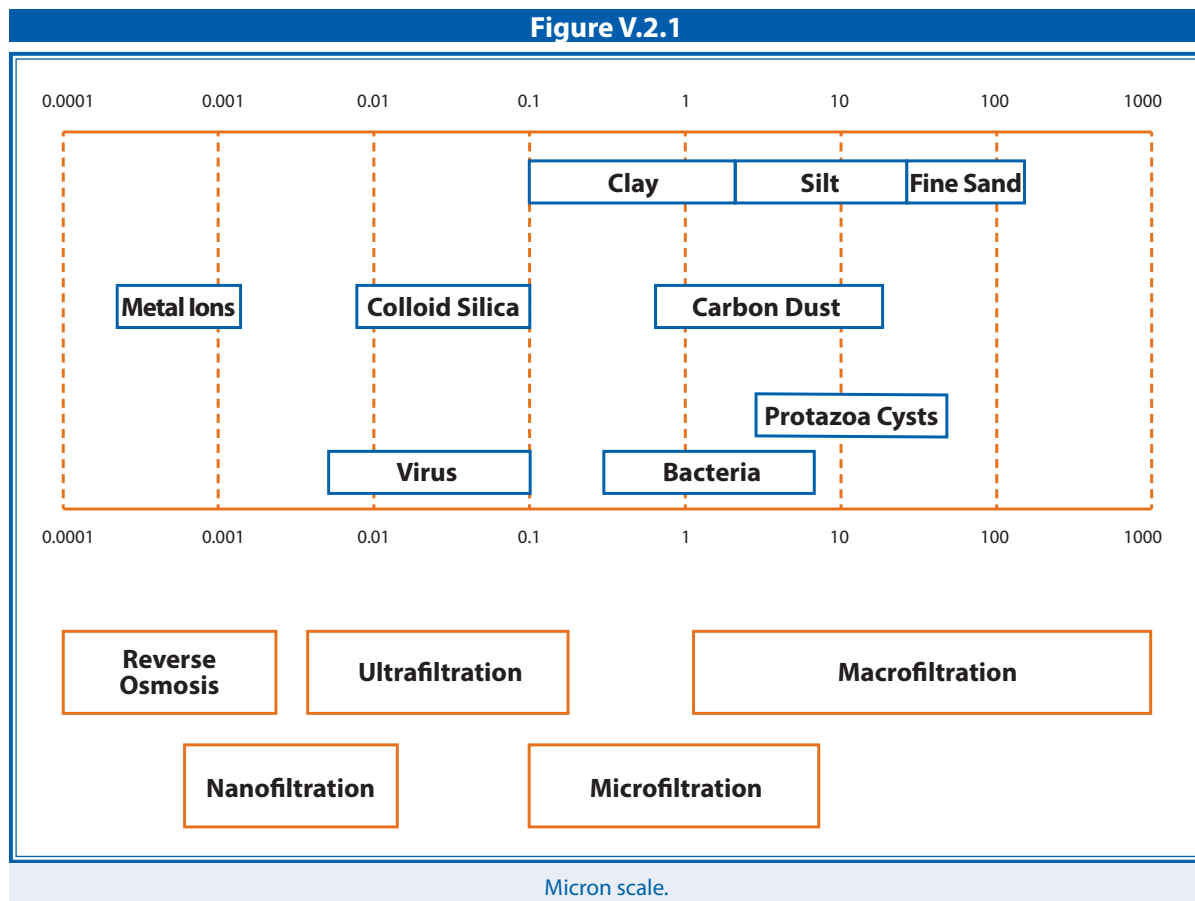
Water Treatment Technologies

- ✓ Suspended solids filtration
- ✓ Oxidation
- ✓ Ion exchange
- ✓ Reverse osmosis
- ✓ Neutralization
- ✓ Ultraviolet light
- ✓ Chemical disinfection
- ✓ Ultrafiltration disinfection
- ✓ Heat disinfection
- ✓ Adsorption
- ✓ Aeration

The process of water treatment is taking the source water that is provided—as from a specific well or from a specific municipal supplier—and modifying the “contaminants” in that water to provide a product water which is acceptable. It is sometimes unnecessary and possibly undesirable to remove all contaminants from the water source while achieving the desired water quality.

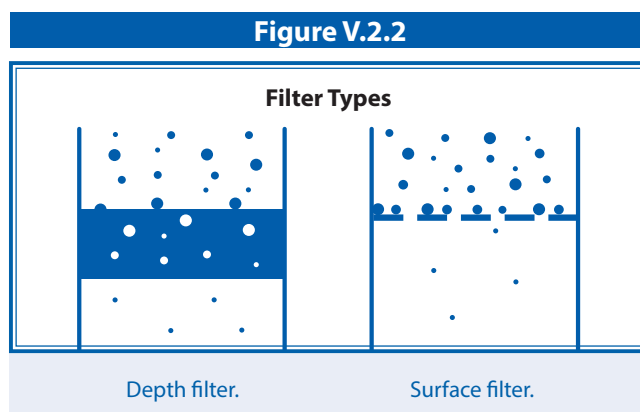
Suspended solids filtration

Filtration is primarily a sieving process of capturing suspended solids as the water supply flows through a solid medium. The sieve size must be sufficiently small to capture the size of suspended solid. The source water is then pushed through the sieve by either gravity or by an applied pressure as from a water pump. The level of filtration refers to the size of solid which is captured by the filter. These filtration levels are grouped for convenience into five categories: **macrofiltration, microfiltration, ultrafiltration, nanofiltration, and hyperfiltration** (also known as reverse osmosis). With few exceptions, depth filters are macrofilters, whereas surface filters may be microfilters, ultrafilters, nanofilters or hyperfilters (Figure V.2.1).



The actual filtering may be achieved in two principal ways: by surface filtration and depth filtration (Figure V.2.2).

Surface filtration consists in a single physical barrier to the passage of contaminant particles. The surface has pores which are smaller than the size of the targeted solid. These filtering surfaces are called **membranes**. Membranes have a specific range of pore size which determines the level of filtration for that surface.



Depth filtration consists in a volume of media rather than a single surface. As the water flows through the media, larger solids are captured by the media particles and retained as the water and remaining smaller particles pass through. Various **media** as sand/gravel are typically packed into a tank, and the source water is piped to flow through the top of the media. The filtered water is collected at the bottom of the media tank by a plastic screen which has a slit size which prevents the media from passing through. The specific **depth filter media** is selected based upon its effective filtering level, typically from 10 to 40 microns. Depth filters are also manufactured from plastic into cartridges. The depth filter cartridge, typically a spun polypropylene or string wound product, is placed inside a filter housing.

Reverse osmosis

Osmosis is a natural process which takes place within all living cells of plants, animals, and humans. All living cells have membranes. In the natural process of osmosis, when a membrane with very small pores is placed between waters of different concentrations of dissolved solids, the water molecules will migrate from the side of lowest concentration of dissolved solids through the membrane to the side of higher concentration. The dissolved solids do not pass through the membrane, only the water molecules. This process, called osmosis, is driven by the dipolar nature of the water molecule. Osmosis is a primary function taking place in the roots of plants and in human kidneys.

In reverse osmosis (RO) technology, pressure is created on the higher concentration side of the membrane in order to force the pure water molecules back across the membrane surface, thus “reversing” osmosis. In water treatment RO technology, the pressure is generated by the well pump or by an additional booster pump.

The RO process reduces the concentration of dissolved solids in the water. The rate of reduction in total dissolved solids by RO technology, called the rejection, is in the range of 95-98%. This reduction includes all component dissolved solids. The efficiency of RO is enhanced by, among other factors, an increased pressure and an increased temperature.

Oxidation

Some dissolved solids may be removed from water by first oxidizing them from their dissolved state to their suspended solid state. The resulting solids are then filtered as previously described. To achieve the oxidation process, an **oxidizing agent** such as air, chlorine, or hydrogen peroxide is added to the water. The method of exposing the dissolved solids to the oxidizing agent is accomplished by three different methods. In liquid injection, the oxidizing agent is injected into the water stream with a chemical feed pump; in air injection, air (with oxygen as the oxidizer) is inducted or is pumped into the water stream with an air pump; in media oxidation, an oxidizer forms a coating on the media within a media tank. Oxidizing media include birm, pyrolucite, and manganese greensand.

Ion exchange

Dissolved solids consist in charged particles called ions. The charges of specific ions vary in strength. Within their respective positive or negative groups, charge ions may be rank ordered based upon their respective charge intensity. Ion exchange technology exploits this rank order.

In ion exchange technology, a media, called **resin**, is manufactured to include numerous charged exchange sites. On these sites are placed a seed ion with a relatively weak charge. When water containing stronger charged ions passes through, the media sites release the seed ion and attracts the stronger charged ion. This process is called ion exchange. Ion exchange technology may be applied to either positive or negative ions. Ion exchange resin used to attract positive ions is called cation resin, and the resin used to attract negative ions is called anion resin (Tables V.2.1 and V.2.2).

Cation resin used in the common “water softener” uses sodium as the seed ion. It can remove the positive ions of calcium (hardness) and ferrous iron through the ion exchange process. The resin captures the calcium and iron ions and releases the sodium seed ions to the water flow. **Anion** resin, used for treatment of nitrates or sulfates uses chloride as the seed ion. It removes nitrates and sulfates through ion exchange. The anion resin captures the nitrate and sulfate ions and releases the chloride seed ions to the water flow. The result is **soft water**.

Some natural organic matter (NOM) from wells near surface water may be removed with anion “scavenger” resins.

Table V.2.1

Cation Charge Comparison		
Cation	Symbol	
Hydrogen	H ⁺	Low ↑ Charge Strength ↓ High
Ammonium	NH ₄ ⁺	
Sodium	Na ⁺	
Potassium	K ⁺	
Magnesium	Mg ⁺⁺	
Calcium	Ca ⁺⁺	
Ferrous Iron	Fe ⁺⁺	
Manganese	Mn ⁺⁺	
Radium	Ra ⁺⁺	
Lead	Pb ⁺⁺	

Table V.2.2

Anion Charge Comparison		
Cation	Symbol	
Hydroxide	OH ⁺	Low ↑ Charge Strength ↓ High
Chloride	Cl ⁻	
Bicarbonate	HCO ₃ ⁻	
Nitrate	NO ₃ ⁻	
Fluoride	F ⁻	
Carbonate	CO ⁻²	
Sulfate	SO ₄ ⁻²	
Silica	SiO ⁻²	
Uranium	U ⁻³	

Neutralization

The **pH** of water refers to its level of acidity. Water with a pH of below 7.0 is called acidic, and water with a pH above 7.0 is called basic, or alkaline (Figure V.2.3). Water with an acidic quality will tend to dissolve metals such as copper or galvanized pipe. Water with a base quality will tend to cause dissolved solids to precipitate into suspended solids as scale.

Many naturally occurring water sources have a low pH. The technology of raising the pH of water is termed neutralization and is intended to bring the pH to a neutral 7.0 pH. The most common technologies used for **neutralization** are the use of a neutralizing media filter and the injection of a neutralizing chemical. Both technologies add a chemical, typically a form of sodium carbonate, to the water which raises the pH.

Ultraviolet light

Ultraviolet light (UV) is electromagnetic radiation of between 10 and 400 **nanometers** wavelength.

UV light is deadly for microbes, such as bacteria, virus, and protozoa. Specifically, the band of UV around 254 nanometers wavelength quickly damages the DNA of microbes enough that they become sterilized—they lose their ability to reproduce. This makes UV a valuable treatment tool for microbe contamination. However, the UV radiation must be applied at the required intensity and for sufficient time for the radiation to have the desired effect.

This combination of strength (intensity) and time are important in most treatments for microbes and is called **contact time**. There are two components to contact time: strength and exposure time (Figure V.2.4). The manufacturers of UV lights design each UV for a specific flow rate. By testing, they determine the size of the UV bulb and the dimensions of the UV chamber to ensure that the water passing through the chamber at a specific flow rate will ensure that any microbe passing through will receive the required dosage of UV radiation and will therefore become sterilized. The danger of pathogenic microbes to the human body is not from one or two stray microbes; rather the danger is from microbe colonies which invade and reproduce within human cells. This deactivation is the basis for disinfection by UV light.

Figure V.2.3

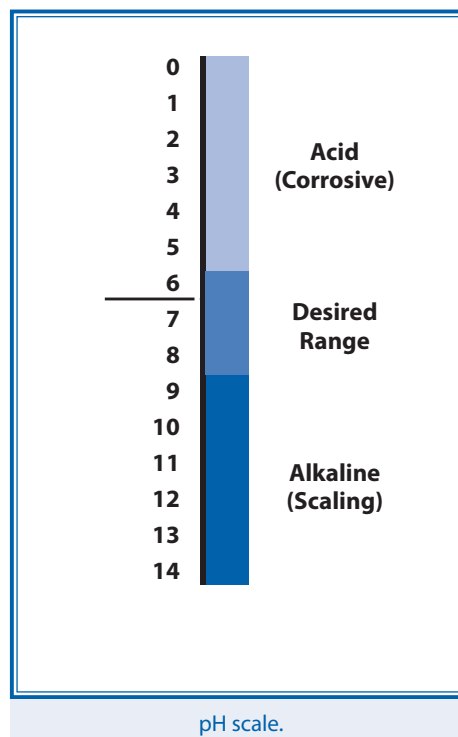


Figure V.2.4

$$\text{Contact Time (mg-min/L)} \\ \text{CT} = \text{C} \times \text{t}$$

Concentration (of Disinfectant) X Time of Exposure
or
Intensity of UV Bulb X Time of Exposure

Chemical disinfection

In chemical **disinfection**, the microbe is killed by the oxidation of its cell wall. Just as with UV light, effective disinfection requires the necessary contact time. The contact time for chemical disinfection is the product of chemical dose multiplied by the exposure time to that dose. The higher the dose of a chemical, the lower the amount of exposure time that is required; the lower the dose, the longer exposure time is required. Contact time is typically achieved using contact tanks which slow the flow of water between the chemical injection point and the first point of intended use.

The effectiveness of disinfection technologies, including chemical injection, is measured by the “log reduction” of specific microbe categories. Log reduction refers to a ten-fold decrease in microbe population. For example, a 1-log reduction in bacteria means that the population of bacteria is reduced by 90%; a 2-log reduction in virus means the population of virus is reduced by 99%; a 3-log reduction in protozoa means that the population of protozoa is reduced by 99.9%, and so on. (The log number means the number of 9s that appear in the percentage).

The most common chemical for disinfection in water treatment is **chlorine**. In most applications of chlorine disinfection, a solution of 5.25% sodium hypochlorite (commercially available as “bleach”) is diluted with water in a solution tank. The solution is then injected into the service water stream with a chemical feed pump.

After the injection, the water stream will enter a contact tank arrangement to ensure disinfection. The contact time for disinfection is controlled by (1) the dilution of the chlorine in the solution tank, (2) the injection rate of the feed pump, and (3) the size and configuration of the contact tanks.

Other chemicals are also commonly used for disinfection, including hydrogen peroxide solution and ozone gas. Hydrogen peroxide is used in a similar fashion as chlorine. Ozone, however, is a gas and requires an on-site ozone generator. All of the chemical disinfectants have a unique effectiveness as a disinfectant, and so require a unique contact time.

Ultrafiltration disinfection

As noted earlier, ultrafiltration (UF) is a membrane (surface) process which filters at about 0.01 microns. Since most microbes are larger than this, UF is used as a disinfection process to remove the microbes from the water stream. The most common membrane configuration for UF disinfection is the hollow fiber which consists in a bundle of small tubes of membrane. In hollow fiber filtration, the flow is either from the outside of the fibers to the inside these tubes or vice versa. It is important that care be exercised to prevent the growth of biofilm on the fiber surface.

Heat disinfection

High temperature can also be used as a water treatment technology in two primary ways. Water at a temperature above 180° will kill microbes after about 20 minutes. This is the reason for a Boil Water Advisory in the event of municipal water contamination. Industry employs this technology extensively, but for residential applications some will use a small distiller. High temperature also enhances the evaporation of some dissolved organics, as discussed on page 24 under aeration.

Adsorption

For removal of organic contaminants, the most widely used technology is **adsorption** of the organics by activated carbon. **Carbon** is marketed in granulated form for use in tanks, and in a block form for use in cartridges. The extreme porosity of activated carbon makes it an effective treatment for the removal of most organic contaminants including many of the prescription medicines which have been released into our water sources. The removal effectiveness is highly influenced by the contact time (water flow per volume) of the carbon. **Activated carbon** is also an effective tool for the removal of chlorine and chloramine from water. A particular form of carbon, called catalytic carbon, acts as both an oxidizer and an adsorbent. It is employed primarily as an oxidizing medium as discussed earlier. However, it does possess adsorption capacity as well.

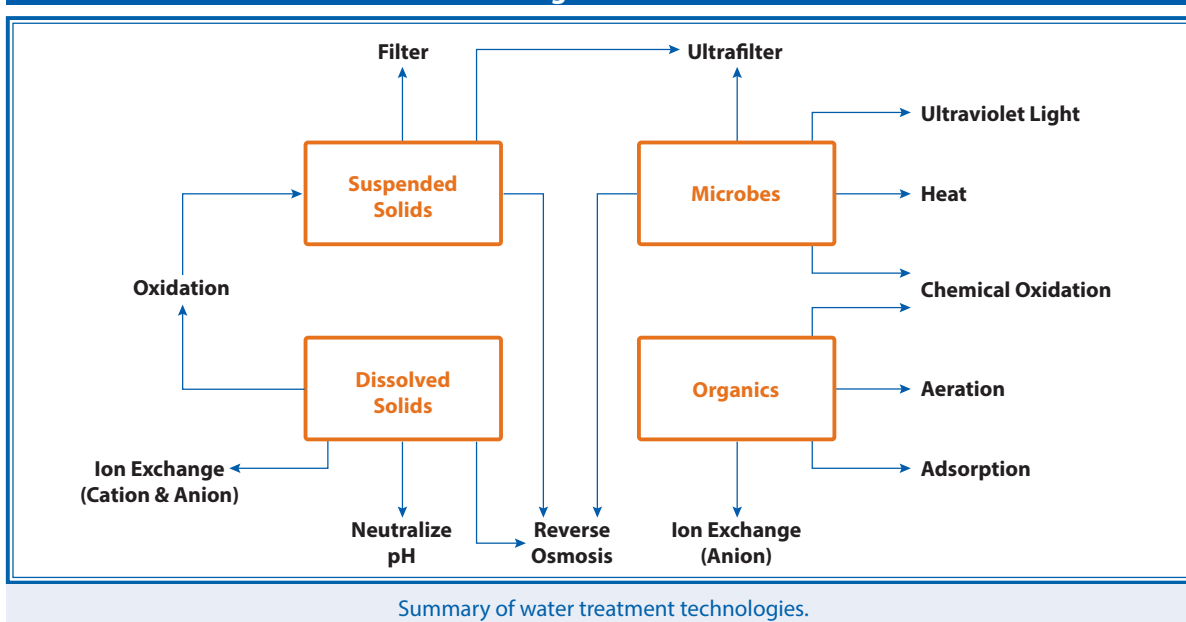
Other adsorption media are also available for removal of organic or inorganic contaminants. These media are specifically designed to absorb a particular range of contaminants. The oldest of these is activated alumina, sometimes called simply alum. Other media have a synthetic composition including some resin-based media. Such media are used to remove specific contaminants such as arsenic or fluorides from water.

Aeration

Aeration involves the exposure of water to the air. The exposure may be for one of two purposes: the oxidation of dissolved solids or the removal of harmful dissolved gases. Aeration exposes the water to oxygen which turns iron or hydrogen sulfide to suspended solids. Gas removal from water is through the process of diffusion. Air venting is used for gas removal such as radon, methane, and other volatile organics.

Aeration for oxidation is achieved by either induction directly into the water stream, or by providing an air bubble through which the water stream must pass. An air bubble is achieved by an air pump. Such applications require that the air bubble be replaced periodically in order to retain an effective supply of oxygen in the bubble. Aeration for the removal of dissolved gases is achieved by exposing the water to the atmosphere. This may be done using an air vent. For more effective gas removal, however, the water is released to an atmospheric tank for aeration. This water is then repressurized with a pump for distribution.

Figure V.2.5



Study Guide Questions - Chapter 2

Answers can be found on page 64

Q. What is the difference between depth filtration and surface filtration?

Q. What technology is applied by a water softener?

Q. What are the two components of contact time for chemical disinfection of water?

Q. Provide at least two examples of treatment against microbes in water.

Chapter 3

Water Treatment Specification

- ✓ Sequencing of technologies
- ✓ Sizing of water treatment
- ✓ Flow and pressure

The specification of a water treatment system requires five steps:

1. The water source must be analyzed for contaminants. (Book V, Chapter 1).
2. The user must decide what the product water quality should be. (Book V, Chapter 2).
3. The specific technologies are specified to achieve the desired product water. (Book V, Chapter 3).
4. If multiple technologies are specified, the technology sequence is specified.
5. The individual technologies are specified for size.

This chapter addresses steps 4 and 5.

Sequencing of technologies

When multiple technologies are required to achieve the desired product water quality, the technologies should be sequenced in order to provide the most effective and efficient results. Although many factors will play in the final train of equipment, the following guidelines should influence the selection.

1. First, kill the bugs. If bacteria, especially pathogens, are present, then the system should start with disinfection.
2. Remove the heavy sediment. If large suspended particles are present, then filtration should remove these so that they do not clog the remaining technologies.
3. For most technologies pH will be important. Accordingly, the pH should be adjusted to provide the optimum effectiveness of the following technologies.

4. Oxidation is used to eliminate the undesirable dissolved solids. This typically will involve oxidizing media.
5. Carbon at this point can be used to reduce the chlorine level prior to ion exchange.
6. The ion exchange technology follows. If both cation and anion resins are used, the cation always precedes the anion to prevent fouling of the anion.
7. Membrane technologies, reverse osmosis, or ultrafiltration (UF) are normally applied at this point. If both reverse osmosis and UF are to be employed, the UF precedes the reverse osmosis as an effective prefilter.
8. Ultraviolet light is the last in the train since its effectiveness is strongly influenced by the water quality.

Sizing of water treatment

Each item of water treatment must be sized based upon the maximum projected flow rate and volume of average water usage. There are several aids for these determinations. Some aids are simple such as estimating flow by counting bathrooms or estimating volume by the number of occupants. A more sophisticated approach is the use of water supply fixture units (WSFU) as defined by the Uniform Plumbing Code (UPC). See Book VIII for determining flow rate and volume.

However, many times there is an overriding limit to either flow or volume, as in well situations. The flow capacity of the well pump or the well yield may limit the fixture requirement in some cases. In these cases, the user must decide whether the water treatment will be sized based upon the requirements of the fixtures or the limitations of the well production system. The user may decide to increase the capacity of the well production system if the current system is less than the fixture requirements.

Filtration

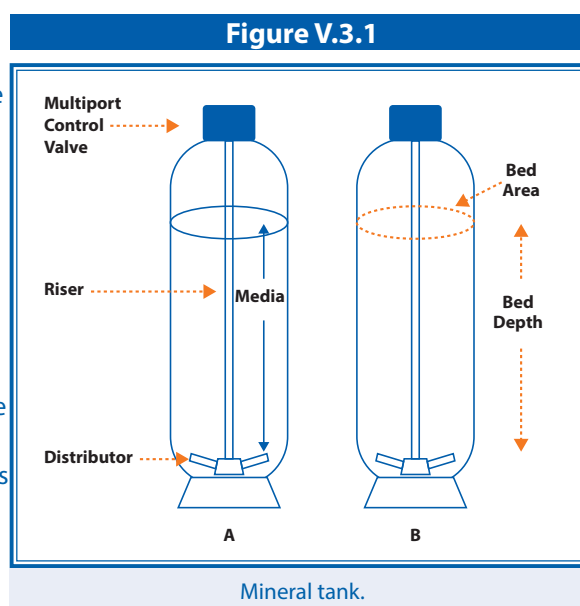
There are two components to the specification of filtration: the level of filtration and the flow rate. The level of filtration, which refers to the **micron rating** of the **filter**, specifies the size of suspended solids which will be captured by the filter. Referring to Figure V.1.3 (page 11), the level selection refers to a vertical line on the graph. Suspended solids to the right of the line will be filtered, while suspended solids to the left will pass through that filter. The flow rate selection is based upon the choice of either cartridge filter or media filter.

Cartridge filter

The manufacturers of cartridge filters offer charts which provide a recommended flow rate maximum for each cartridge. These charts relate flow rate through the cartridge with the consequent pressure drop. The higher the flow rate through the cartridge, the higher the pressure drop. Cartridge filters must also be replaced periodically. As the cartridge filters the water, suspended particles are captured. The accumulation of particles increases the pressure drop between the inlet flow and the outlet flow. Typically a pressure drop from 10 to 15 psi is cause to replace the cartridge with a new one.

Media filters

A media filter consists in a vertical cylindrical pressure vessel with a multiport control valve on top and a **riser pipe** which is connected to a **distributor** at the bottom of the tank, as shown in Figure V.3.1. The multiport valve functions as a conduit which routes the water through the filter system. See Chapter 5 for a description of the multiport control valve. The media tank is filled to about 60% with a specific type of treatment media. In normal service flow, untreated water enters the multiport valve and is directed to the top of the media. The water flows down through the media to the distributor. The now treated water enters the fine slots in the distributor, flows up the riser and back to the multiport valve. The multiport valve then routes the water through its outlet as treated water.



The sizing for media filters is based upon the **bed area**, in square feet, of the top of the media bed (Figure V.3.1). Media manufacturers offer an estimate of the maximum flow per square foot of media surface for effective filtration. For most media filters, this limitation is between 5 gpm and 8 gpm per square foot. Examples are contained in Book VIII. Since this limitation is “per square foot”, if a higher flow rate is required, then a larger diameter tank will be necessary. Note that the **bed depth** of the media is not a sizing factor for filters. All media filters have a bed depth of about three feet.

The desired service flow limitation for media filters may be overridden by the required **backwash** flow rate. Media filters are designed for continuous use, unlike cartridge filters which must be replaced periodically. Like cartridge filters, the pressure drop across the filter will increase as contaminant particles are captured within the media bed. When the pressure drop becomes too large the media must be cleaned of accumulated particles. This is accomplished by redirecting the flow of incoming water up through the media, and then out to drain. This process is called **backwashing**. The redirecting is accomplished by the control valve. The trigger for the backwash may be by time delay, by volume of treated water, by pressure drop, or manually. Media manufactures also specify the flow rate required for effective media cleaning during backwash. The specified backwash is provided in gallons-per-minute per square foot (gpm/sqft), in a similar fashion to the specified service flow rate.

Oxidation filters

Oxidation filters are sized in similar fashion to other media filters. For most oxidation filters, there is a required pH range since a high pH generally favors oxidation. Additionally, the service rate (in gpm/sqft) may be particularly low in order to have sufficient contact time for oxidation to take place.

Neutralization filters

Neutralization filters are sized in a similar fashion to other media filters in regards to service and backwash rates. However, neutralization media is sacrificial. It raises the pH of water by dissolving in the water. Consequently, after a period of time, the new media must be added to the media tank. For this reason, most neutralizer filters have a plug on the top dome of the media cylinder which is intended for the addition of new neutralizing media.

Ion exchange media

Ion exchange filters provide a medium—called resin—for the exchange of ions between those contained in the media (seed ions) and those in the untreated water (target ions). In the common water softener, for example, the sodium ions (seed ions) contained in the cation media are released into the water in exchange for the targeted **hardness** ions (calcium, magnesium, iron) which are then retained in the cation media. There are two factors involved in sizing for ion exchange: flow rate and capacity. The flow rate is typically provided in gallons per minute (gpm) per cubic feet of resin media within the tank. This rate is normally around 10 gpm per cubic foot.

Ion exchange filters also have a specified **capacity** limitation. The capacity of a water softener is the total amount of hardness, in grains, that can be removed (exchanged) by a newly regenerated system. Once all of the seed ions have been exchanged for the targeted ions, the resin must be regenerated with more seed ions. The source for **regeneration** by seed ions is the **brine tank**. The brine tank provides a reservoir of concentrated seed ions (typically sodium and chloride) for resin regeneration. During the regeneration process, an **injector** (also known as **inductor**) in the multiport valve draws the seed ions from the brine tank reservoir and directs this flow through the resin bed. The flow of seed ions coming from the brine tank is highly concentrated. This flow, because it is so highly concentrated, reverses the ion exchange by replacing the seed ions onto the resin beads and discharging the hardness ions.

The limit of the resin to exchange the target ions is called the capacity of the resin. The capacity is typically specified as kilograins (Kgr) per cubic foot of resin. That is, the capacity for capturing target ions is 1000 grains (Kgr) of the target ions for each cubic foot of ion exchange resin.

The exchange capacity for ion exchange resins is determined by the amount of the seed ion that is used for **regenerating** the resin. The range in amounts for the sodium chloride regenerant is typically between 6 and 15 pounds of salt per cubic foot of resin. Fully regenerated cation resin, after regeneration with 15 pounds per cubic foot of resin, has a capacity of about 30,000 grains hardness ions. If the untreated water contains 10 grains of hardness, then the capacity of this regenerated resin will be 3000 gallons for one cubic foot, 6000 gallons for two cubic feet, and so on. Further detail is available in Book VIII.

The amount of salt used for regeneration will affect the resulting capacity of the water softener. The old standard prior to 2000 was 15 pounds of salt per cubic foot of resin, resulting in a softening capacity of 30,000 grains. With improvements in the injector systems, modern softeners can regenerate with less salt per cubic foot and achieve capacities which allow less salt to be used in the treatment of water. Table V.3.1 shows the capacity results from various levels of salting, and Chapter VIII contains additional information.

Table V.3.1

Water Softner Regeneration Efficacy		
Salt Level	Regeneration Capacity	Salt Use Grains Per Pound
15	30,000	2000 Gr/Lb
10	27,000	2700 Gr/Lb
8	24,000	3000 Gr/Lb
6	20,000	3333 Gr/Lb

Membrane filters

Membrane filter flow rates are determined primarily by the square foot of membrane surface, the trans-membrane pressure, and the water temperature. Greater surface area, higher temperature, and higher trans-membrane pressure increase the flow rate. Membrane system manufacturers will specify the flow rate according to a standard temperature of 250° C (770° F) and a standard inlet pressure of 60 psi. Manufacturers can supply charts which specify the expected production rate under other than standard temperature and/or pressure conditions. Ultrafilters, nanofilters, and **reverse osmosis** are specified in a similar fashion. In conditions of lower water temperature and/or pressure, it is not uncommon for a membrane user to raise either condition in order to achieve a higher treated water production. This can be accomplished with a water heater or a booster pump. The trans-membrane pressure is the difference between the pressure on the untreated side of the membrane and the pressure on the treated side. This trans-membrane pressure determines the **efficiency** of the membrane. A common membrane strategy is to use a booster pump just before the membrane system in order to raise the inlet pressure.

Dead-end filtration such as microfilters and ultrafilters, have a single (untreated) inlet and a single (treated) outlet. Since their function is to capture suspended solids, they must be backwashed periodically. Their efficiency is a factor of the frequency and volume for this backwash (to drain). The efficiency is a measure of the percentage of treated water obtained from the total water consumed by the filter.

Crossflow filtration membrane systems, such as reverse osmosis and some ultrafilters, have a single (untreated) inlet flow plus a (treated) outlet flow called the **permeate** and a (surface cleaning) drain flow called the concentrate. These filters do not require a “backwash” because of the continuous flow across the membrane surface (Figure V.3.2). The efficiency of crossflow membranes, which is called the **recovery**, is the percentage of treated water compared with the total inlet water. Most small point of use (POU) reverse osmosis units have an efficiency, or recovery, of 15-20%. This means that for every 100 gallons of water consumed by the reverse osmosis, only 15-20 gallons are available as treated water; the other 80 to 85 gallons goes to drain. Table V.3.2. compares the recovery for POU, larger Point of Entry (POE), and commercial and industrial (C/I) reverse osmosis systems.

Recovery becomes an important factor in sizing reverse osmosis units, especially for low yielding wells.

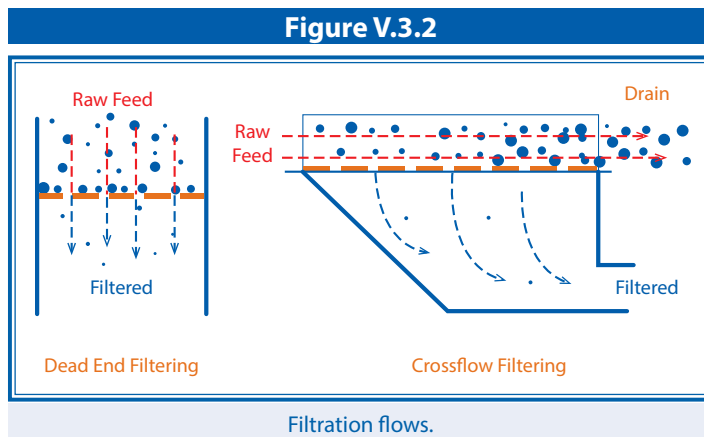


Table V.3.2

Reverse Osmosis Unit Efficiency		
Model	Recovery	Treated Water 100 Gallons Consumed
POU	15	15 Gal
POE	40	40 Gal
C/I	70	70 Gal

Ultraviolet light

Ultraviolet (UV) light systems consist in a stainless-steel cylinder with an inlet and outlet opening at the ends of the cylinder. Within the cylinder is a UV bulb enclosed within a clear quartz sleeve. A separate voltage transformer turns low voltage into high voltage, typically over 240 volts. This high voltage irradiates the mercury vapor within the UV bulb, and UV radiation is emitted. In service, the untreated water flows into the cylinder at one end and travels along its length to exits at the other end. Most UV units may be installed with the cylinder in either the vertical or horizontal position.

UV light sizing is determined by the UV manufacturer. As with all disinfection technologies, the disinfection dosage is a function of concentration times the exposure time. The radiation standard dosage for UV disinfection (NSF 55) is established at 40 mj/cm². Manufacturers measure the radiation at the farthest point from the bulb during a specified flow rate through the UV chamber. Manufacturers will normally install a flow restrictor with a specific UV system to ensure that the desired dosage is achieved. UV bulbs are manufactured to retain their intensity for at least 9,000 hours, or one year of continuous use. Accordingly, the bulbs must be replaced every year.

Chemical disinfection

Chemical injection systems include at least a chemical holding tank, a chemical **injection pump**, and an injector which is installed in the untreated water pipe. The holding tank is where a solution of a disinfection chemical is mixed with water to form a solution at a specific concentration. The chemical feed pump transfers the chemical solution into the water stream through an injector.

The key to sizing for chemical disinfection is the target dosage. There are two primary dosage factors in chemical disinfection: chemical concentration and the exposure or contact time. The dosage is changed by altering either of these factors. The concentration itself is a function of the chemical mixture being injected and the injection rate into the untreated water flow. Various formulas are available to calculate the dosage from a given chemical mixture, an injection rate, and the untreated water flow rate.

The contact time (CT) is a function of mixing and volume prior to the first POU. For effective disinfection, the target dosage must be achieved throughout the untreated water volume for the specified contact time. The holding vessels between injection and the first POU are rated by their volume and internal geometry which affects their mixing effectiveness. For this reason some systems use pipe lengths with internal baffles called in-line mixers to contribute to mixing. These are normally employed immediately after the point of injection.

Adsorption

In a similar fashion as ion exchange resins, adsorption media have a specific capacity. The manufacturers will specify a capacity per cubic foot of media for a specific target contaminant. However, there are other contaminants which will also be adsorbed along with the target contaminant. For volume sizing it is important to determine the presence and the concentration of other contaminants which will also be adsorbed since these will limit the adsorption capacity of your target contaminant. For example, a carbon filter intended to remove MTBE from the water will also adsorb other organic contaminants which are in the water. The difference between ion exchange resins and adsorption media is that the adsorption media cannot be economically “regenerated”. Instead it must be replaced. It is important, therefore, that adsorption capacity be well understood.

Flow and pressure

In addition to all of the above, another factor may become important, especially in larger water treatment systems. Each item of water treatment equipment and each length of piping will cause a pressure loss when water flows. Specifically, all multiport valves are rated with a **flow coefficient (Cv)** which allows the calculation of pressure drop at any flow through the valve. Pipe manufacturers provide detailed tables which show the pressure loss for various flow rates through their pipes. Media manufacturers also provide linear graphs which allow the calculation of the pressure drop across any media bed. See Book VIII for a discussion on these factors.

Study Guide Questions - Chapter 3

Answers can be found on page 65

Q. What is the two criteria for sizing an item of water treatment?

Q. What determines the flow rate of a media filter?

Q. What is the capacity of a water softener?

Q. How often should an ultraviolet light bulb be replaced?

Chapter 4

Water Treatment Applications

- ✓ Multiport valves
- ✓ Mineral tanks
- ✓ Brine tanks
- ✓ Operating conditions

Multiport valves

Most tank-based treatment systems employ a **multiport valve**. The purpose of the multiport valve is to direct the inlet untreated flow through the equipment for water treatment and system cleaning. The multiport valve consists in two primary components: the valve body and the timer (Figure V.4.1). The valve body performs the mechanical function of directing the flow of inlet water.

The timer mechanism is the brains of the system and controls the operation of the valve body.

The valve body is a plastic (noryl) or metal (brass or stainless steel) vessel with a drive mechanism, six ports, and internal fluid connections. The ports consist in: untreated inlet, treated outlet, mineral tank top opening, mineral tank bottom distributor, drain, and brine tank. The drive mechanism is a mechanical assembly, usually a piston or cam, which connects the ports. It is driven by an electric motor, and the motor is controlled by the timer.

The drive mechanism can generate six different flow paths in a mineral tank system system (Figure V.4.2, page 35). In the **service flow**, the inlet water is directed to the top of the mineral tank, down through the mineral into the bottom distributor, and out the treated water outlet port. In the backwash flow, the inlet water is directed to the bottom distributor, up through the media to the tank top opening and out of the valve through the drain port. In the regeneration flow, the inlet water is directed through an internal injector, then down through the tank top opening, down through the mineral into the bottom distributor, then out through the drain port. In the fast **rinse** flow, the inlet water is directed to the top of the mineral tank, down through the mineral into the bottom distributor, and then out the drain port. The purpose of the fast rinse is to settle and repack the media bed. The last flow is the refill flow. This flow is the same as the service flow, but there is also water released through the injector port to the brine tank. The sequence and the timing of these cycles are controlled by the timer.

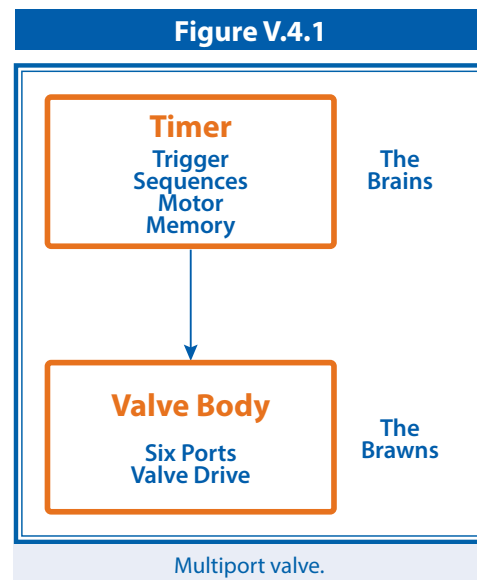
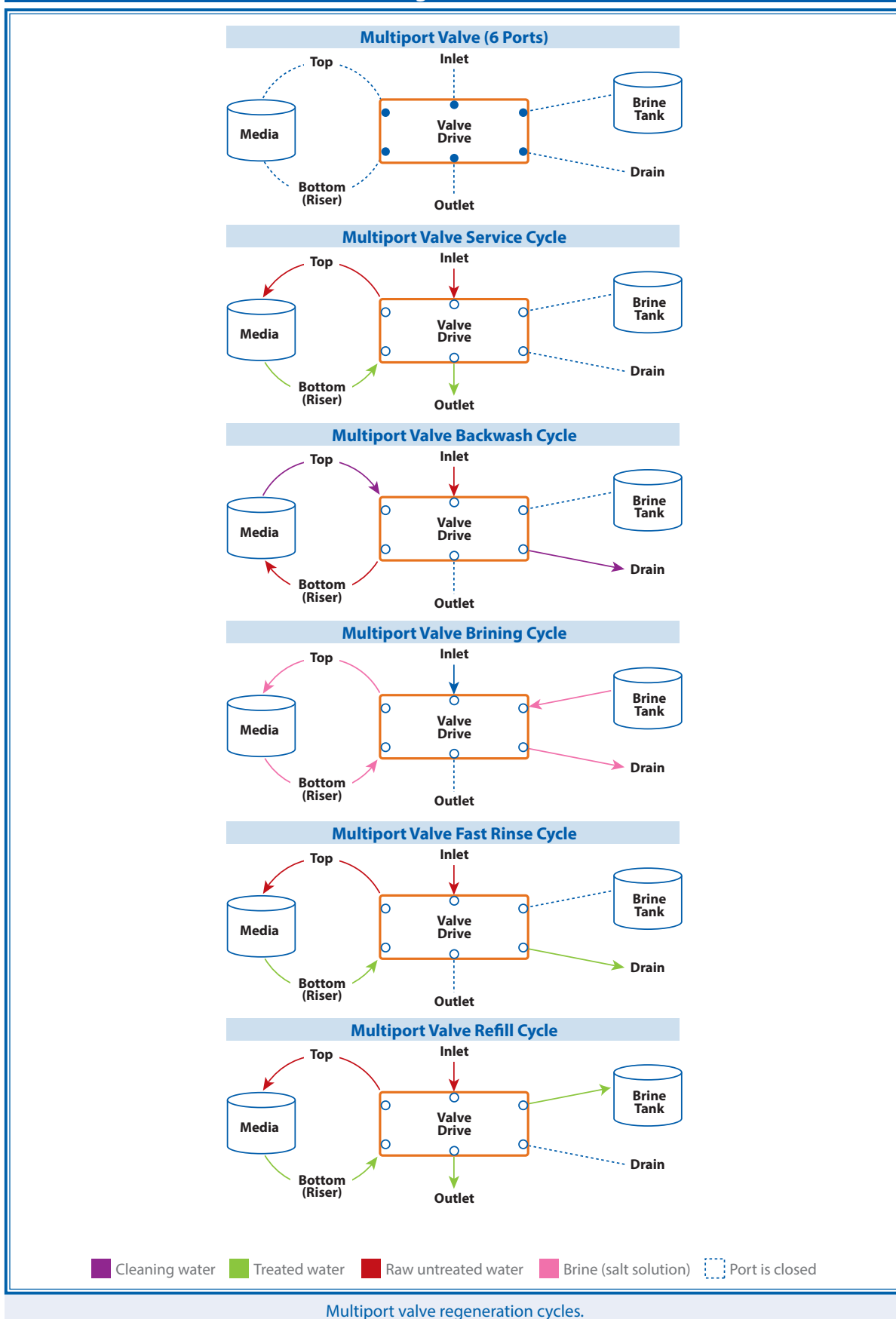


Figure V.4.2



There are three flow control locations on a multiport valve. The backwash flow control is located on the drain port of the valve and controls the flow of water to drain during the backwash cycle. All valves, filters, oxidizers, and ion exchange have a specific drain line flow control (DLFC). The injector and the refill flow controls are used only when a regenerant is used to clean the media. The injector is employed during regeneration to draw the regenerant from the brine tank. The flow is from the brine tank to the valve. The brine line flow control (BLFC) is employed during the refill cycle to replace the water in the brine tank. The flow is from the valve to the brine tank.

The valve timer performs two principal functions: it triggers the start of the system cleaning cycle, and it controls the cleaning sequence once the trigger activates. The trigger is of three types: clock, meter, or external. The clock timer triggers the cleaning cycle based only upon the day of the week and time of day, regardless of the volume of water treated. The meter timer counts the gallons of water being treated and triggers the cleaning cycle based upon the volume of water which has actually been treated. Timers may be electrical-mechanical or electronic. The more modern electronic timers also accumulate historical flow and use statistics which are useful in tracking water use and in detecting potential problems.

Mineral tanks

Mineral tanks are the primary component of all media-based systems. Tanks are made of plastics or metal and have a variety of sizes and openings. With mineral tanks, the service flow is top to bottom. The untreated water enters the tank on top, flows down through the media, and then enters a slotted distributor on the tank bottom. The most common configuration is the **top mounted valve** (Figure V.4.3). With this arrangement, the valve opening is on top of the tank. A pipe, called the riser, extends from the valve to the bottom-mounted distributor. Service flow through the valve is then directly into the top of the tank, down through the media, into the bottom distributor, up the riser, and back into the valve on top.

Another common arrangement, especially with steel tanks, is the **side mount valve**. In this configuration, the valve is mounted along the vertical side of the mineral tank and is connected to a side mount adapter. The side mount adapter connects to both the top of the tank and to the distributor at the bottom of the tank.

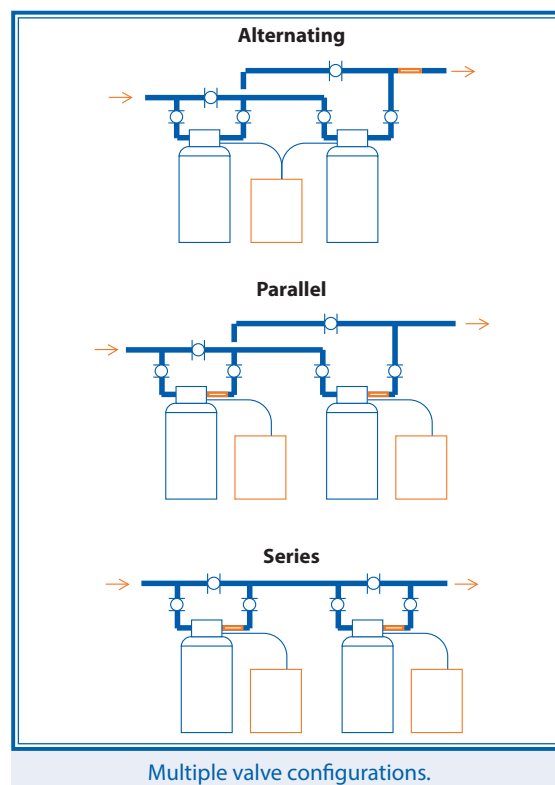
Mineral tanks may be arranged as single service or multiple service. The multiple tank arrangement may be parallel, alternating, or series flow (Figure V.4.4).

In an **alternating system**, the untreated water enters and exits only one of the multiple mineral tanks at a time. The other tank is idle. At the time of cleaning (backwash), the service flow shifts to the idle tank, the previous service tank is cleaned, and then goes into idle. The alternating configuration provides the full-service flow rate 24/7.

Figure V.4.3



Figure V.4.4

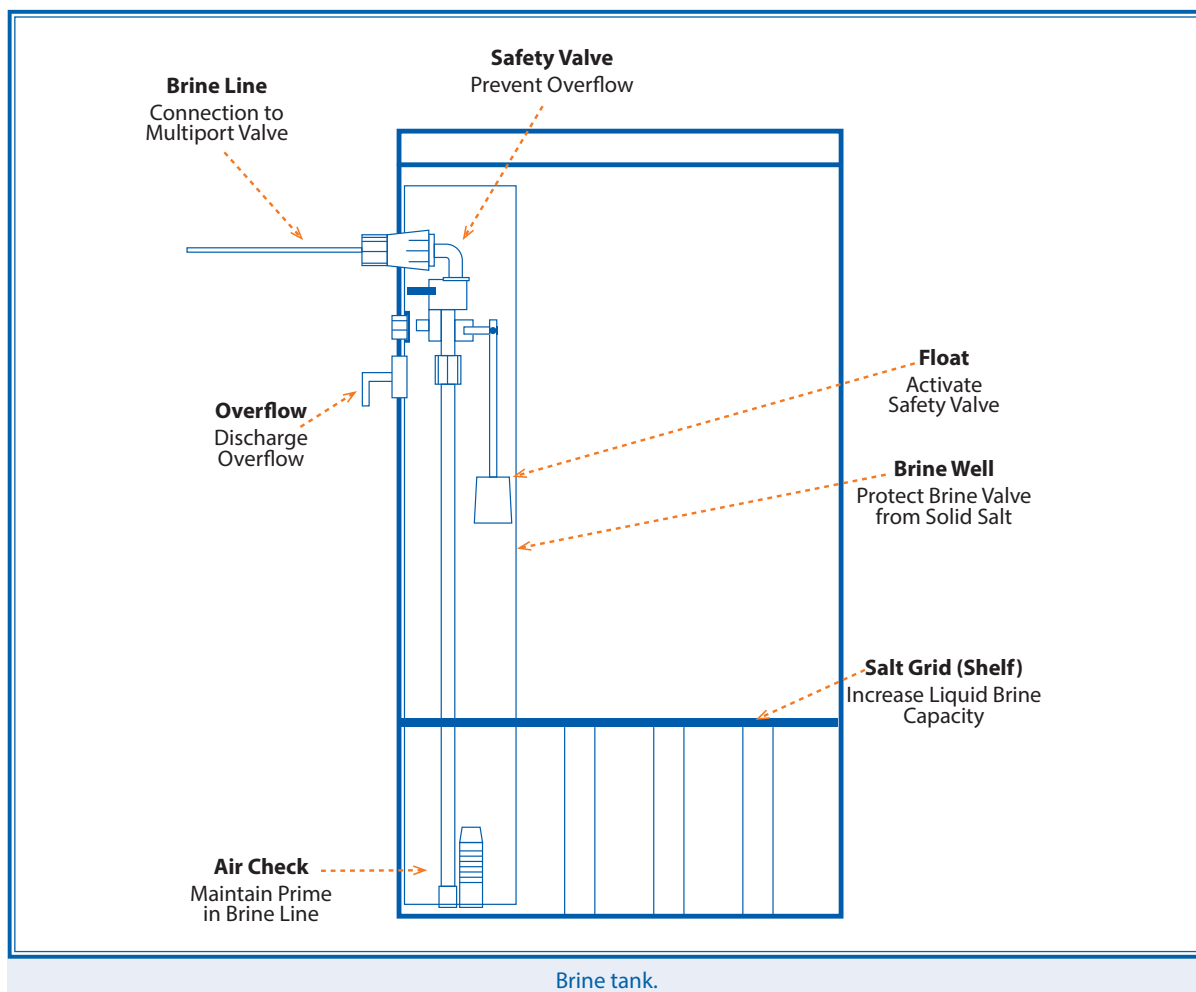


In an **parallel system**, untreated water enters multiple mineral tanks from the same, untreated source, and discharges the treated water into a single manifold. A parallel configuration provides 24-hour service and requires a lower backwash rate because each of the parallel tanks will backwash separately. In series tanks, the untreated water enters and exits the first tank, then enters and exits the second tank, and so on. The series configuration provides greater contact time with the media.

Brine tanks

Brine tanks are only used when there is a regenerant chemical in use. The most common example is the cation water softener which uses sodium chloride as the regenerant. Brine tanks are designed to provide a reservoir for regenerant chemicals which are used to clean and regenerate the tank media. The brine tank stores the solid regenerant. Water in the brine tank becomes saturated with the regenerant. During regeneration of the media, the saturated regenerant is drawn from the brine tank by the injector in the multiport valve. Then during the last of the cleaning cycles, called refill, water is sent back to the brine tank. This water dissolves the solid regenerant until it becomes saturated. The saturated regenerant is then ready for the next regeneration cycle. Brine tanks are connected with the multiport valve at the injector port. Brine tanks typically include a safety brine valve with a float to prevent overflow, and a bottom combined slotted opening and air check (Figure V.4.5).

Figure V.4.5



Operating conditions

Water equipment manufacturers specify specific operating conditions for the effective employment of the equipment. These conditions normally include, as a minimum, a range of acceptable temperatures and pressures. However, many technologies include other limitations including the pH and the levels of other contaminants. It is important that the equipment is operated within the manufacturer's guidelines.

Maintenance

All water treatment technologies require some level of **preventive maintenance** (PM). These are measures taken to delay or prevent failure of the device. As with other plumbing fixtures, preventive maintenance measures focus upon those components which are vulnerable to fouling or to mechanical failure. Service manuals which detail recommended maintenance practices should be included with each water treatment system.

For filters, PM includes keeping the filtering medium clear of collected particles. This is accomplished by periodic backwashing the media. These backwash cycles should be at the flow rate which is specified by the media manufacturer. Media manufacturers specify the recommended backwash flow rate in gpm per square foot of media bed. Typical backwash rates range from 8 to 10 gpm per square foot. Details are included in Book VIII. The frequency of the backwash cycle is determined by the amount of sediment that is being captured by the media. As the amount of captured sediment increases, the pressure drop across the filter will also increase. The backwash frequency for most residential media filters is 3-7 days.

For ion exchange systems, the two most important maintenance checks are to replace the salt in the brine tank and to ensure that the inductor (or injector) nozzle is free of debris. Otherwise, the induction process will not occur at the prescribed rate. This means that the inductor should be inspected and cleaned periodically.

For media neutralizers, the maintenance must include periodic replacement of the dissolved calcite mineral.

For chemical injection and regenerant systems, PM includes replacement of the chemical or regenerant which has been used. For ion exchange systems which use a saturated regenerant like sodium chloride or potassium chloride, the replacement process is easily achieved by merely adding additional solid regenerant to a brine tank. However, for chemical injection systems like neutralizers and disinfectants the replacement process will likely require the mixing of specific portions of solid chemical and water. Inaccurate mixtures may result in the system failure. Consequently, the most important maintenance check is to ensure that the chemical solution is prepared correctly.

For UV light systems, PM includes periodic cleaning of the quartz sleeve and annual replacement of the UV bulb.

If the system fails, then corrective maintenance measures must be taken in order to return the device to its operating capability. Water treatment manufacturers include logic tables for troubleshooting of system failures and warranty terms. Like any home appliance, it is important to retain the system manual and the contact information of the system vendor.

Study Guide Questions - Chapter 4

Answers can be found on page 65

Q. What are the two primary components of a multiport valve?

Q. What are the six different flow paths which a multiport valve can generate?

Q. What mineral tank arrangement will allow 24-hour continuous and uninterrupted service?

Q. What are the two most important maintenance checks for a water softener?

Q. What is the most important maintenance check for a chemical injection system?

Notes

Chapter 5

Water Treatment Equipment and Service Reliability

- ✓ Certified products
- ✓ Certified service
- ✓ Efficiency

As with any manufactured product line, there is a wide array of stated and inferred performance claims, some of which are erroneous or misleading. “Buyer beware” is a proven rule when it comes to selection of these products and to those service organizations which claim technical skills. The best practice to ensure quality products and services is to seek out those which are endorsed by a reputable third party.

Certified products

There are several national organizations offering **certification** of the performance of water treatment products. The most notable include the National Sanitation Foundation (NSF), the Water Quality Association (WQA), and the International Association of Plumbing and Mechanical Officials (IAPMO). Each of these and others provide a third-party testing and certification protocol for the performance of specific **water treatment devices** against a written performance standard. When reviewing an equipment pedigree, it is important to appreciate both the certifying agent and the performance standard to which it is certified. Some of the more common certification standards are:

- NSF 63 Release of harmful contaminants
- NSF 44 Performance of cation ion exchange filters
- NSF 53 Performance of filters against specific health threats and effects
- NSF 55 Performance of ultraviolet lights against microbes
- NSF 58 Performance of reverse osmosis systems

Certified service

Similarly with installation and service companies, the validation by recognized third party agencies may provide the best reference for employment. Both national and regional agencies offer training and certification for the service of water treatment equipment and systems. Affiliation with professional associations, like the WQA, the National Groundwater Association (NGWA), or their regional and local chapters provides a credential of reliability. Such certified individuals provide the best opportunity for correct analysis, prescription, installation, and service for water treatment systems.

Efficiency

Manufacturers and dealers of water treatment equipment design a wide range of performance specifications for their products. Some manufacturers also have their products certified by an independent testing agency and publish these certified performance specifications. The most important of these performance specifications for water treatment equipment are water and salt use efficiency.

For media filters, the factors which influence water use efficiency are the density of the media and the geometry of the distribution system. The backwash (cleaning) cycle for filters requires that the backward flow effectively lifts the media bed so that contaminant particles can be removed from the media. The denser the filter media, the higher the required rate of backwash flow for this cleaning cycle.

For water softeners, the most significant factor which influences both water and salt use efficiency is the choice of timer in the multiport control valve. As noted in Chapter 4, the cleaning cycle may be triggered by either a clock or meter timer. Clock timers use the passage of time (days) as the trigger for starting the cleaning cycle regardless of how much water has been treated by the water softener. Consequently, cleaning cycles are triggered unnecessarily while softening capacity remains in the water softener. Meter (demand) timers using **demand based regeneration** however will trigger the cleaning cycle based upon water usage and only when the capacity of the softener has been exhausted. Since all cleaning cycles discharge both water and salt to the drain, the meter timer provides the more efficient performance.

For membrane systems, including reverse osmosis and ultrafilters, the measure of efficiency is the volume of treated product water provided by the membrane system divided by the total amount of untreated water processed. As noted in Chapter 3, this factor is called the recovery.

Study Guide Questions - Chapter 5

Answers can be found on page 66

Q. What is the best practice to ensure the quality of water treatment products?

Q. What is the best practice to ensure the quality of water treatment service?

Q. What type of multiport valve timer provides the most efficient water treatment service?

Notes

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Chapter 6

Water System Disinfection and Water Testing

- ✓ Procedures for disinfecting water systems
- ✓ Testing water for drinking safety

Some states in the United States have water well codes that require the pump installer or water well contractor to disinfect the well system. After the water system is pressurized, the entire water distribution system should be disinfected. A water test should be conducted after disinfection to confirm it is safe before water is consumed.

Chlorine is an effective disinfectant which is used to treat harmful bacteria in water in a process called **chlorination**. **Shock chlorination** is the process for chlorination of the water well and the entire water distribution system. The recommended procedure outlined here is for basic disinfection of the well and distribution system. The following instructions and charts are provided as guidance. Please refer to your local or state health department or environmental agency for instructions on disinfecting a well. The instructions provided by local or environmental agencies supersede the instructions below.

Procedure for disinfecting water wells

Liquid chlorine in the form of household bleach and food grade white vinegar can be used to disinfect a well. When chlorine is added to water, the pH level will rise. Food grade white vinegar is used to lower the water's pH level so the chlorine will work effectively. Make sure to use a new bottle of regular bleach, as it can lose potency over time. Do not use splashless bleach, scented bleach, stabilized swimming pool chlorine products, or non-chlorinated "pool shock" products as they are not effective enough to clean drinking water.



Be careful when handling chlorine solutions. Wear rubber gloves, goggles, and a protective apron.
If chlorine accidentally gets on your skin, flush immediately with clean water.

Caution

Bleach added to water with a pH below 5.0 will release chlorine gas which is toxic. This procedure should be done only in a well-ventilated area since it will cause the release of chlorine gas which is a pulmonary and skin irritant.

Do not pour bleach or vinegar directly on electrical connections or the pitless adapter (if applicable) as this can cause damage to these components.

Determine the amount of water in the well known as standing well volume (SWV). This is accomplished by knowing the total depth of the well and subtracting the depth to water multiplied by the gallons per foot the well can hold. Refer to the well log, use Table V.6.1 and the equation to find the SWV.

SWV = depth of well – depth to water x gallons per foot in well

Once the SWV is calculated, follow the steps below:

Table V.6.1	
Well Casing Diameter (Inches)	Water Volume Per Foot of Water Depth
4	0.65
6	1.4
8	2.6
10	4.1
12	6

Step 1

Consider the general water quality of the well. High levels of iron, sulfur, or hard water will influence the effectiveness of the disinfection process. Using Table V.6.2 or Table V.6.3 (page 47) on the following page, calculate how much liquid chlorine bleach and vinegar is needed.

The following instructions and charts are provided as guidance. Please refer to your local or state health department or environmental agency for instructions on disinfecting a well. The instructions provided by local or environmental agencies supersede the instructions below.

Table V.6.2		
Disinfection Quantities for Average Well Water Quality NO Sulfur, low to moderate bacteria and hardness		
Standing Well Volume (gallons)	pH Control (white vinegar) Food Grade	Chlorine Required, min. 5.25% (Sodium Hypochlorite)*
50	1½ cups	1 cup
100	3 cups	2 cups
150	1 quart	2½ cups
200	5½ cups	3½ cups
250	6½ cups	1 quart
300	8 cups	5 cups
350	½ gal + 1 cup	6 cups
400	½ gal + 2½ cups	7 cups

Source: Moravec Water Wells – www.moravecwaterwells.com, prior to note.
*Amount of hypochlorite should be at least 5.25%; however, most household bleach now contains 8.25% sodium hypochlorite.

Table V.6.3

Recommended Disinfection High Quantities of Bacteria, Iron, Hardness, and Sulfur		
Standing Well Volume (gallons)	pH Control (white vinegar) Food Grade	Chlorine Required, min. 5.25% (Sodium Hypochlorite)*
50	5 ½ cups	3 ½ cups
100	½ gal + 2 ½ cups	6 ½ cups
150	1 gallon	½ gal + 2 cups
200	1 gal + 5 cups	½ gal + 5 ½ cups
250	1 ½ gal + 2 cups	1 gal + 1 cup
300	2 gallons	1 gal + 1 quart
350	2 gal + 5 cups	1 ½ gal
400	2 ½ gal + 2 ½ cups	1 ½ gal + 3 cups
Source: Moravec Water Wells – www.moravecwaterwells.com, prior to note. *Amount of hypochlorite should be at least 5.25%; however, most household bleach now contains 8.25% sodium hypochlorite.		

Step 2

Turn the power to the pump OFF. Place any water treatment equipment into the bypass mode. Failure to do so could result in a breakdown of the treatment media.

Step 3

Remove the cap on the top of the well. Pour the required amount of vinegar followed by the required amount of chlorine into the well in one rapid, continuous flow, avoiding all electrical connections and pitless adapter, if applicable. This procedure should be done only in a well-ventilated area since it will cause the release of chlorine gas which is a pulmonary and skin irritant.

Step 4

Turn the power back ON.

Step 5

Attach a clean hose to a nearby faucet and place the other end into the top of the well. Open the faucet and recirculate the chlorinated water for one hour, washing down the entire inside of the well casing and pump piping to remove any excess chlorine residue. Turn off the hose and recap the well.

Step 6

Open each indoor faucet one by one and let the water run until a strong odor of chlorine is detected. Shut off faucet.

Step 7

Allow the chlorine solution to remain in the well and plumbing system for 8 hours, or overnight.

Step 8

Flush the entire system until the smell of chlorine is no longer detected. First, run the chlorinated water outdoors, but be careful to avoid areas that drain into lakes or streams because it can kill fish and other aquatic life. The solution can, likewise, kill grass and shrubs, as well as disrupt septic systems. A good choice may be a backyard ditch (make sure the ditch is not connected to a lake or stream) or side area that will partially contain the solution while it is absorbed by the soil.

Step 9

After the chlorine is out of the system, turn off the outside faucets and turn on the remaining indoor faucets to flush them. Rusty water may come from the faucets at first, so flush until the water is clear. This should only take a few minutes.

Step 10

After the entire system has been flushed out, shut down all faucets. Change any water treatment filters and clean water treatment devices separately per the manufacturer's or the water treatment professional's instructions. Once cleaned, put water treatment into service. Chlorination of the water well system is now complete.

Procedures for disinfecting water treatment equipment

The materials of construction of modern water conditioners will not support bacterial growth, nor will these materials contaminate a water supply. However, the normal conditions that exist during shipping, storage, and installation may lead to some level of bacterial presence. It is therefore advisable to disinfect items of water treatment immediately after installation. Additionally, as noted below, it is advisable to test the completely installed system for microbe contamination.

Some water treatment systems may also require periodic disinfection based upon the bacterial risk of the water well. The product water should be tested for microbe contamination after each disinfection procedure.

Depending upon the conditions of use, the style of conditioner, the type of ion exchanger, and the disinfectants available, a procedure may be adopted for system disinfection. The most commonly used disinfectants, sodium or calcium hypochlorite, are satisfactory for use with ion exchange resins and most filtering and oxidizing media. For membrane-based systems, such as reverse osmosis and ultrafilters, the manufacturers guidelines should be consulted as regards to limits in the concentration and exposure to the disinfectant.

Sodium hypochlorite

These solutions are available under trade names such as Clorox Bleach*. The amount of sodium hypochlorite should be at least 5.25%; however, most household bleach now contains 8.25% sodium hypochlorite.

DOSAGE. For ion exchange resins use 1.2 fluid ounces of the at least 5.25% disinfectant for each cubic foot of resin. (This amount will be applied directly to the brine tank as noted below.) For other equipment mix a solution of two teaspoons of bleach with each gallon of water.

APPLICATION. For ion exchange systems, add the required dosage to the brine tank. The brine tank should already have water in it. Then proceed with a normal regeneration cleaning cycle. For other water treatment equipment, add the solution dosage above to completely fill the equipment. Allow the solution to stand for at least 10 minutes; then flush thoroughly.

FOLLOW-UP. It is recommended that after the disinfection process, the treated water be tested for chlorine to ensure that the system has been correctly flushed of the disinfectant.

Testing water

No water system is really complete and ready to use until the water has been tested at a minimum of bacteria and shown to be safe. After the system is installed and proper chlorination procedures are completed for the entire distribution system, the water should be tested for **coliform bacteria**. In most cases, if the well is properly constructed and the entire system is properly disinfected, the water will not contain coliform bacteria.

Nitrates are also often checked in groundwater in many public and private supplies, especially in agricultural areas. Check with the local health department to determine whether nitrate or other tests are commonly done on drinking water in the area.

Most states require that a water sample be taken on any new well or water system installation to verify that it is safe to drink. Check the state's water well standards to see whether the contractor, local health official, or homeowner is required to sample the system.

- If the water well code requires that a local health official test the system, the water systems professional is encouraged to notify officials that the system is completed and ready to be tested.
- If homeowners are required to test the system, the water systems professional can offer to perform this service, as most homeowners do not know proper procedures for testing water. If the homeowner does the sampling and the coliform test does not pass, it may be that the system is unsafe or that incorrect sampling procedures were used.

Proper water testing begins with a clean faucet from which to take the sample. If a sample is taken from a faucet that the family will drink from, and passes the test, this ensures that the entire water system (well, water lines, pressure tank, and plumbing) is safe.

Many state codes also require a **sampling faucet**. This faucet is usually installed where the water line enters the building, which is prior to the pressure tank. This sampling faucet should be a state-recognized code-approved faucet with no threaded outlet connection. It should be installed at a level above the floor (as the state code requires) and be easily accessible to facilitate collection of water. The purpose of this sampling faucet is to take a sample of water directly from the well.

If a well was just chlorinated, sufficient time should be allowed for the chlorine to dissipate so there is no chlorine residue, or test results may be inaccurate. Inexpensive chlorine test kits are available if there is any question about residue.

Obtain a coliform bacteria sample bottle from a state-certified lab. These bottles are sterilized by the lab and should be kept closed until the water sample is ready to be drawn. If the laboratory has not provided sampling instructions when preparing to draw the sample, then follow these steps:

1. Identify the sampling faucet from which the sample will not be well taken.
2. Remove the washer and aeration device from the faucet.
3. Disinfect the faucet with either isopropyl alcohol or bleach and let it stand for 4-5 minutes. Some states or counties require that a flame is used to superheat the metal to disinfect it.
4. Turn the water on and allow it to run until there is a noticeable change in temperature or until the well pump has come on and started to fill the tank (about 5 minutes). This is to ensure that there is fresh water in the system.
5. Reduce the flow of water and fill the container being careful not to touch the inside of the bottle or cap. Do not breathe on the cap or blow air inside the bottle. Fill the container to just below the cap; do not let the bottle overflow.
6. Close the sample container by reinstalling the cap.
7. Fill out the chain of custody (COC) data sheet, including the time and date, to be sent with the sample bottle.
8. Send the bottle to the lab immediately. Most labs require that samples arrive at their lab within 48 hours after the test water is drawn, for complete accuracy. Test results are usually returned within two weeks.

Some labs only issue a pass/fail or positive/negative result for coliform bacteria in water. If the water test fails or shows a positive result, ask for a count so that it can be determined whether there is a real problem (high count) or whether improper sampling procedures may have been followed (low count).

If the initial test from a drinking faucet fails, a second test sample should be taken from the sampling faucet or elsewhere, as required by state code. This will help determine whether the coliform bacteria problem is in the well or in the distribution system.

If the second test taken from the sampling faucet comes back safe, then one can assume the well is providing safe water, and that the distribution system is causing the problem. Examine the distribution system to see whether it is possible to identify the source of the coliform bacteria. Rechlorinate the distribution system, if necessary.

If the test taken from the sampling faucet fails, rechlorination of the well is recommended, and a subsequent test should be taken to determine that the water is now safe.

Other procedures for disinfection

Many other procedures exist for disinfecting wells, pressure systems, and distribution systems. Check state and local codes.

Study Guide Questions - Chapter 6

Answers can be found on page 66

Q. What does chlorine do in water?

Q. What is the first step in basic disinfection of a well?

Q. List some forms of chlorine recommended in disinfecting water.

Q. What is a sampling faucet?

Appendix

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Length				
Inches	(in)	Millimeters	(mm)	25.400
Inches	(in)	Centimeters	(cm)	2.539
Feet	(ft)	Meters	(m)	0.305
Yards	(yd)	Meters	(m)	0.914
Miles (statute)	(mi)	Kilometers	(km)	1.609
Millimeters	(mm)	Inches	(in)	0.039
Meters	(m)	Feet	(ft)	3.281
Centimeters	(cm)	Inches	(in)	0.394
Meters	(m)	Yards	(yd)	1.094
Kilometers	(km)	Miles (statute)	(mi)	0.621
Area				
Square Inches	(in ²)	Square Centimeters	(cm ²)	6.452
Square Feet	(ft ²)	Square Meters	(m ²)	0.093
Square Yards	(yd ²)	Square Meters	(m ²)	0.836
Square Miles	(mi ²)	Square Kilometers	(km ²)	2.590
Acres	(ac)	Hectares	(ha)	0.405
Square Centimeters	(cm ²)	Square Inches	(in ²)	0.155
Square Meters	(m ²)	Square Feet	(ft ²)	10.764
Square Meters	(m ²)	Square Yards	(yd ²)	1.196
Square Kilometers	(km ²)	Square Miles	(mi ²)	0.386
Hectares	(ha)	Acres	(ac)	2.471
Liquid Volume				
Ounces	(oz)	Milliliters	(ml)	29.574
Pints	(pt)	Liters	(l)	0.473
Quarts	(qt)	Liters	(l)	0.946
Gallons	(gal)	Liters	(l)	3.785
Pounds per Cubic Foot	(lb/ft ³)	Kilograms per Cubic Meter	(kg/m ³)	16.018
Pounds per Gallon	(lb/gal)	Kilograms per Cubic Meter	(kg/m ³)	119.826
Milliliters	(ml)	Ounces	(oz)	0.034
Liters	(l)	Pints	(pt)	2.113
Liters	(l)	Quarts	(qt)	1.057
Liters	(l)	Gallons	(gal)	0.264
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Cubic Foot	(lb/ft ³)	0.062
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Gallon	(lb/gal)	0.008
Mass				
Ounces	(oz)	Grams	(g)	28.350
Pounds	(lb)	Kilograms	(kg)	0.454
Grams	(g)	Ounces	(oz)	0.035
Kilograms	(kg)	Pounds	(lb)	2.205
Flow				
Cubic Meters per Hour	(m ³ /h)	Gallons per Minute	(gpm)	4.400
Gallons per Minute	(gpm)	Cubic Meters per Hour	(m ³ /h)	0.227

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Force				
Foot Pound Force	(ft-lbf)	Joules	(J)	1.356
Newtons	(N)	Kilogram Force	(kgf)	0.102
Joules	(J)	Foot Pound Force	(ft-lbf)	0.738
Kilogram Force	(kgf)	Newtons	(N)	9.807
Power				
Horsepower	(hp)	Kilowatts	(kW)	0.746
Horsepower	(hp)	Watts	(W)	745.700
Kilowatts	(kW)	Horsepower	(hp)	1.341
Watts	(W)	Horsepower	(hp)	0.001
Pressure				
Bars	(b)	Pounds per Square Inch	(psi)	14.500
Kilograms per Square Centimeter	(kg/cm²)	Pounds per Square Inch	(psi)	14.500
Pounds per Square Inch	(lb/in²)	Kilograms per Square Meter	(kg/m²)	703.070
Pounds per Square Inch	(lb/in²)	Kilopascals	(kPa)	6.895
Pounds per Square Inch	(lb/in²)	Meters of Water	(m)	0.704
Inches of Mercury	(inHg)	Kilograms per Square Meter	(kg/m²)	345.300
Kilograms per Square Meter	(kg/m²)	Pounds per Square Inch	(lb/in²)	0.001
Kilopascal	(kPa)	Pounds per Square Inch	(lb/in²)	0.145
Meters of Water	(m)	Pounds per Square Inch	(lb/in²)	1.420
Kilograms per Square Meter	(kg/m²)	Inches of Mercury	(inHg)	0.003
1 Atmosphere	14.7 lb/in²	Kilograms per Square Centimeter	(kg/cm²)	1.033
1 Atmosphere	14.7 lb/in²	Kilograms per Square Meter	(kg/m²)	10,335.000
1 Atmosphere	14.7 lb/in²	Kilopascal	(kPa)	101.350
1 Atmosphere	14.7 lb/in²	76.0 Centimeters Mercury	(cmHg)	5.170
1 Atmosphere	29.92 inHg	76.0 Centimeters Mercury	(cmHg)	2.540
Pascal	(Pa)	Newtons per Square Meter	(N/m²)	1.000
Pascal	(Pa)	Kilograms per Square Meter	(kg/m²)	0.102
Temperature				
Degrees Fahrenheit	(°F)	Degrees Celsius	(°C)	(°F-32) 0.556
Degrees Celsius	(°C)	Degrees Fahrenheit	(°F)	(1.8 x °C) + 32
Flow				
Feet per Second	(fps)	Meters per Second	(m/s)	0.305
Miles per Hour	(mph)	Kilometers per Hour	(km/h)	1.609
Gallons per Minute	(gpm)	Liters per Minute	(l/min)	3.785
Gallons per Minute	(gpm)	Cubic Meters per Minute	(m³/min)	0.004
Meters per Second	(m/s)	Feet per Second	(fps)	3.281
Kilometers per Hour	(km/h)	Miles per Hour	(mph)	0.621
Liters per Minute	(l/m)	Gallons per Minute	(gpm)	0.264
Cubic Meters per Minute	(m³/min)	Gallons per Minute	(gpm)	264.172

Glossary

Adsorption: The process in which one gas, liquid, or solid material (adsorbate) forms a superficial monomolecular layer on another (substrate). A related term, Adsorption, is the process in which the gas, liquid, or solid material is retained within another absorbent. (V-2, V-3)

Activated Carbon: A water treatment medium, found in block, granulated, or powdered form, which is produced by heating carbonaceous substances (bituminous coal or cellulose-based substances such as wood or coconut shell) to form pores, thus creating a highly porous adsorbent material. Activated carbon is commonly used for dechlorination and for reducing trace and soluble materials such as organic chemicals and radon from water. (V-2)

Aeration: The process which brings water and air in close contact in order to remove dissolved gases (such as carbon dioxide) and oxidizes dissolved metals such as iron, hydrogen sulfide, and volatile organic chemicals (VOCs). (V-2)

Alternating System: A dual automatic softener system functioning with one unit in service and one on standby. When a predetermined gallonage of softened water has passed or when a monitor detects hard water breakthrough, the idle or standby unit automatically goes into service. The spent unit then regenerates and becomes the idle/standby unit. (V-4)

Anion: An ion with a negative charge. An anion [such as chloride (Cl⁻), nitrate (NO₃⁻), bicarbonate (HCO₃⁻), or sulfate (SO₄²⁻)] may result from the dissociation of a salt, acid, or alkali. (V-2, V-3)

Backwashing: The process in which the media within a mineral tank is subjected to flow opposite the service flow direction to loosen and remove suspended solids. The backwash flow is directed to drain. (V-3, V-4)

Bacteria: Single-celled organisms (singular form bacterium) which lack well-defined nuclear membranes and other specialized functional cell parts and reproduce by cell division or spores. (V-1), (V-2), (V-3), (V-6)

Bed Area: The measurement in square feet of the internal surface of the media within a tank. (V-3)

Bed Depth: The measurement in inches of the height of media within a media tank through which the water passes in the process of water treatment. (V-3)

Biofilm: An accumulation of sessile microbial growth attached on the surface of a support material, such as the interior surface of water pipe or water storage vessels. Bacteria within the film may be protected from the action of disinfectants and sanitizers. (V-1), (V-2)

Brine: A strong normally saturated solution of salt (usually sodium chloride or potassium chloride) with total dissolved solids concentrations in the range of 26 percent used in the regeneration stage of cation and/or anion exchange water treatment equipment. (V-3), (V-4), (V-6)

Brine Tank: A holding tank where a highly concentrated solution of salt or potassium is stored for an ion exchange system. The brine tank must be periodically replenished with sodium or potassium pellets. (V-3), (V-4), (V-6)

Capacity: As relates to softening or ion exchange:

1. the expected number of days the equipment will be in service;
2. the expected number of gallons of product water delivered; or
3. the grains of total hardness removed. (V-2, V-3)

Carbon: An element which is found in almost all living or formerly living matter including plants, proteins, organics, and hydrocarbons. Carbon combines readily with oxygen to form carbon dioxide. In water treatment applications, the term "carbon" is sometimes used as a short reference for activated carbon. (V-1), (V-2), (V-3)

Cation: A positively charged ion in an electrolyte solution, attracted to the cathode under the influence of a difference in electrical potential. Sodium ion (Na⁺) is a cation. (V-2), (V-3), (V-4), (V-5)

Certification:

1. As used by professional testing laboratories, the proven determination that a representative sample of the equipment model has met the requirements of the respective test standard.
2. As by professional education institutions the granting of certified status to individuals who have passed a certification examinations. (V-5)

Chlorination: The treatment process in which chlorine gas or a chlorine solution is added to water for disinfection and control of microorganisms. Chlorination is also used in the oxidation of dissolved iron, manganese, and hydrogen sulfide impurities. (V-6)

Chlorine: A gas widely used in the disinfection of water and as an oxidizing agent for organic matter, manganese, iron, and hydrogen sulfide. Chlorine is known to react with organic matter in the water to form trihalomethanes (THMs), a suspected carcinogen. (V-2), (V-3), (V-6)

Coliform Bacteria: A particular group of bacteria primarily found in human and animal intestines and wastes. These bacteria are widely used as indicator organisms to show the presence of such wastes in water and the possible presence of pathogenic (disease-producing) bacteria. *Escherichia coli* (*E. coli*) is one of the fecal coliform bacteria widely used for this purpose. (V-6)

Contact Time: The time in minutes the water is in contact with a filter medium. As relates to disinfection, the time the water can contain the disinfectant to assure potability. Contact time may also be called retention time. (V-2), (V-3), (V-4)

Contaminant: Any undesirable physical, chemical, or microbiological substance or matter in a given water source or supply. Anything in water which is not H₂O may be considered a contaminant. (V-1), (V-2), (V-3), (V-5)

Crossflow Filtration: A type of filtration that uses the sheer force of tangential flow across the filtering membrane surface to keep the particle buildup to a minimum. (V-3)

Dead End Filtration: A flow pattern in which all water flows through the medium or membrane (as opposed to cross flow filtration) thus allowing a buildup of a particulate layer on or near the surface of the medium and requiring periodic backwashing, repeated cleaning, or cartridge replacement. (V-3)

Demand Based Regeneration: A method of automatically initiating regeneration or recycling in filters, deionizers, or softeners after a pre-determined metered volume of water has been processed. (V-5)

Depth Filter: Depth (deep bed) filters use a tortuous path to entrap particles deep within the body of the filtration media. The path enables electrostatic and intermolecular forces between the solids, causing them to clump together, adhere to the media, or form a bridge between voids that blocks the passage of additional particles. (V-2)

Dipolar: Having a partial negative end and a partial positive end. The partially positive end of a polar molecule is attracted to the partially negative end of another. (V-1), (V-2)

Disinfection: The treatment of water to inactivate, destroy, and/or remove pathogenic (disease-producing) bacteria, viruses, cysts, and other microorganisms (but not completely eliminating all microorganisms) for the purpose of making the water microbiologically safe for human consumption. A disinfection operation should reduce the total viable microorganism population by 99.9 to 99.9999 percent. (V-2), (V-3), (V-6)

Dissolved Solids: The weight of matter, including both organic and inorganic matter, in true solution in a stated volume of water. The amount of dissolved solids is usually determined by filtering water through a 0.45 pore-diameter micron filter and weighing the filtrate residue left after the evaporation of the water at 180 degrees celsius. (V-1), (V-2), (V-3)

Distributor: A fitting, usually installed at the top and bottom of the tank in a loose media system, which is designed to produce even flow through all sections of an ion exchanger or filter media bed. (V-3), (V-4)

Drinking Water Regulation: Standards that define allowable water quality limits for potable and domestic water supplies. The U.S. Environmental Protection Agency (EPA) is responsible for the *National Primary Drinking Water Regulations*, which are health-related standards that establish the Maximum Contaminant Levels (MCLs) for regulated substances in drinking water. (V-1)

Efficiency: As relates to ion exchange, a measure of the effectiveness of the operational performance of an ion exchanger, usually based on the ratio of output per unit of input. This ratio is often expressed as the amount of regenerant required to produce a unit of contaminant reduction capacity. (V-2), (V-3), (V-5)

Filter: A device installed as part of the water system through which water flows for the purpose of removing turbidity, taste, color, iron, or odor. Filters can be loose media beds in tanks or cartridge-type devices and filter media may be used for mechanical, adsorptive, neutralizing, or catalyst/oxidation filtration processes. (V-1), (V-2), (V-3), (V-4), (V-5), (V-6)

Filter Media: The selected materials in a filter that form the barrier to the passage of filterable suspended solids or dissolved molecules. (V-2)

Flow Coefficient: The volume of water at 60°F (in U.S. gallons) that will flow through a valve per minute with a pressure drop of 1 psi across the valve. (V-3)

Groundwater: Water that flows or seeps downward and is filtered by underground formations to attain a high degree of purity; ideal drinking water supply. Utilized by wells. (V-1), (V-6)

Hardness: A measurable property of water brought about by the presence of calcium and magnesium ions (and other multivalent metallic ions) that can cause scale formation, soap curd, water spotting, and harshness in fabrics laundered in such water. (V-1), (V-2), (V-3)

Inductor (or Injector) : A component that utilizes venturi effect to inject a small amount of one fluid into the flow of another fluid. (V-3), (V-4)

Injection Pump: A device that pumps a chemical solution fuel into a water stream. (V-3)

Ion: An atom or group of atoms which carries an electrical charge as the result of having lost or gained electrons. Positively charged ions are called cations; negatively charged ions are called anions. (V-1), (V-2), (V-3), (V-5), (V-6)

Ion Exchange: A reversible chemical process in which ions from an insoluble permanent solid medium (usually a resin) are exchanged for ions in a solution or fluid mixture surrounding the insoluble medium. The superficial physical structure of the solid is not affected. The direction of the exchange depends upon the selective attraction of the ion exchanger resin for the certain ions present and the concentrations of the ions in the solution. The process for exchange of positive ions is termed cation exchange; the process for exchange of negative ions is termed anion exchange. (V-2), (V-3), (V-4), (V-5), (V-6)

Macrofiltration: Particle filtration from water of insoluble solid particles larger than 1.0 micron by passing it through a porous medium. (V-2)

Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable. (V-1)

Maximum Contaminant Level Goal (MCLG): The highest level of a contaminant below which there is no known or expected risk to health. MCLGs are not enforceable. (V-1)

Maximum Residual Disinfectant Level (MRDL): The level of a disinfectant allowed in drinking water. (V-1)

Media: A selected group of materials used in filters and filter devices to form barriers to the passage of certain solids or molecules which are suspended or dissolved in water. (V-2), (V-3), (V-4), (V-5), (V-6)

Membrane: A thin sheet or surface film, either natural or man-made, of microporous structure that performs as an efficient filter of particles down to the size range of chemical molecules and ions. Such membranes are termed “semipermeable” because some substances will pass through, but others will not. (V-2), (V-3), (V-5), (V-6)

Methyl tert-butyl ether (MTBE): A flammable, volatile organic liquid which has been used as a gasoline additive since 1979. As a result of several studies indicating its toxic effects upon humans and its appearance in groundwater aquifers, MTBE has been phased out of use beginning in 2000. The U.S. EPA has not yet established a concentration limit for MTBE in drinking water. (V-1)

Microbe (Microorganism): A living organism invisible or barely visible to the naked eye and generally observable only through a microscope. Microorganisms are generally considered to include algae, bacteria, fungi, protozoa, and viruses. (V-1), (V-2), (V-4), (V-6)

Microfiltration: The separation or removal from a liquid of particulates and microorganisms in the size range of 0.1 to 2 microns in diameter. (V-2)

Micron: A metric unit of length equal to one millionth of a meter or one thousandth of a millimeter or about 0.00003937 inches. (V-1), (V-2), (V-3)

Micron Rating: A measurement applied to filters or filter media to indicate the particle size at which suspended solids above that size will be removed. (V-3)

Molecule: The smallest particle of an element or compound that retains all of the characteristics of the element or compound. A molecule is made up of one or more atoms. (V-1), (V-2)

Multiport Valve: A master control valve used in a filter, deionizer, or water softener to control all the necessary steps in the regeneration process or the backwashing and rinse down of filters. (V-3), (V-4)

Nanofiltration: A membrane treatment process which falls between reverse osmosis and ultrafiltration on the filtration/separation spectrum. (V-2)

Nanometer: One billionth of a meter, and equal to one millimicron or 10 angstroms. (V-2)

Neutralizing: The addition of either an acid to a base or a base to an acid to produce a more nearly neutral solution. The use of alkaline or basic materials such as calcite or soda ash to neutralize acidity of some water is common practice in water processing. (V-2), (V-3)

Organics: Term often used to describe any (or all) of the compounds, natural or man-made, with chemical structures based upon carbon. Examples are hydrocarbons, wood, sugars, proteins, methane, plastics, petroleum-based compounds, solvents, pesticides, herbicides, trihalomethane (THM), and trichlorethylene (TCE). (V-1), (V-2)

Osmosis: The natural tendency for water to spontaneously pass through a semipermeable membrane separating two solutions of different concentrations (strengths). (V-2), (V-3), (V-5), (V-6)

Oxidizing Agent: A chemical substance that gains electrons by bringing about the oxidation of other substances in chemical oxidation and reduction (redox) reactions. Examples of oxidizing agents include oxygen, ozone, chlorine, peroxide. (V-2)

Oxidization Filter: A type of filter used to change the valence state of dissolved molecules, making them insoluble and, therefore, filterable. For example, a filter that oxidizes ferrous iron sulfur by use of catalytic media such as manganic oxides and then filters the oxidized precipitates out of the water. (V-3)

Parallel System: A multiple-mineral tank water treatment system in which all of the mineral tanks filter simultaneously, doubling the flow rate capacity of a single vessel. (V-4)

Parts Per Million: A measure of proportion by weight which is equivalent to one unit of weight of solute (dissolved substance) per million weights of solution. Since one liter of water weighs one million milligrams, one ppm is equal to one milligram per liter (mg/L). (V-1)

Pathogen: Microorganisms that can cause disease in other organisms or in humans, animals, and plants. (V-1), (V-2), (V-3)

Permeate: That portion of the feedwater which passes through a membrane to become the treated product water. (V-3)

pH: The degree of the acidity or basicity of a solution as measured on a scale (“pH scale”) of 0 to 14. The midpoint of 7.0 on the pH scale represents neutrality—that is, a “neutral” solution is neither acidic nor basic. (V-1), (V-2), (V-3), (V-4), (V-6)

Preventive Maintenance: Service performed on a regular basis to reduce the likelihood of failure. Once failure occurs the service is called corrective maintenance. (V-4)

Product Water: Water that has been through the total treatment process and meets the quality standards required for the intended use. (V-1), (V-2), (V-3), (V-6)

Protozoa: Microscopic, usually single-celled microorganisms which live in water and are relatively larger in comparison to other microbe. (V-1), (V-2)

Public Water System: One that delivers piped water for human consumption to at least 15 service connections or regularly serves at least 25 individuals. (V-1)

Recovery: A percentage defined as the ratio of permeate flow rate divided by feed flow rate x 100%. (V-3)

Regeneration: The use of a chemical solution (regenerant) to displace the contaminant ions deposited on the ion exchange resin during the service run and replace them with the kind of ions necessary to restore the capacity of the exchange medium for reuse. (V-3), (V-4), (V-5), (V-6)

Regeneration Cycle: The several steps including backwash, application of regenerant, dilution, and fresh or deionized water rinse necessary to accomplish regeneration of an ion exchange bed or oxidizing filter. (V-4), (V-5)

Resin: As used in the water processing industry, this term refers to specifically-manufactured organic polymer beads used in softening and other ion exchange processes to remove dissolved salts from water. (V-2), (V-3), (V-6)

Reverse Osmosis: A water treatment process that removes undesirable materials from water by using pressure to force the water molecules through a semipermeable membrane. This process is called “reverse” osmosis because the pressure forces the water to flow in the reverse direction (from the concentrated solution to the dilute solution) to the flow direction (from the dilute to the concentrated) in the process of natural osmosis. (V-2), (V-3), (V-4), (V-6)

Rinse: In softening or ion exchange applications, the step in the regeneration process in which fresh water is passed through the bed of resin to remove any excess or spent regenerant prior to placing the softener into service. (V-4)

Riser Pipe (Mineral Tanks): The central (internal) pipe which carries the processed water from the bottom of the media or resin bed into the service lines or directs backwash water to the bottom of the media or resin bed. (V-4)

Safe Drinking Water Act (SDWA): The national legislation first passed by the U.S. Congress and signed into law by the President in 1974 and amended in 1986. The SDWA directs the U.S. EPA to promulgate and enforce standards for safe drinking water necessary to protect public health at public water systems. (V-1)

Sampling Faucet: A code approved faucet with no threaded outlet connection and installed above the floor. It is used to take water samples for testing. (V-6)

Secondary Maximum Contaminant Level (SMCL): Federal non-enforceable recommendations which establish limits for drinking water constituents which may affect the aesthetic quality of water, and the public's acceptance of it as safe. (V-1)

Service Flow: The rate in U.S. gallons per minute (gpm) or liters per minute (L/min) at which a given water processing system can deliver product water. The rating may be for intermittent peak flow or constant flow. (V-3), (V-4)

Shock Chlorination: The process by which home water systems such as wells, springs, and cisterns are disinfected using household liquid bleach (or chlorine). Shock chlorination is the most widely recommended means of treating bacterial contamination in home water systems. (V-6)

Side Mount Valve: A multiport valve that is mounted on the side of the mineral tank, as opposed to the top of the mineral tank. (V-4)

Sodium Hypochlorite: Liquid bleach; used as a source of chlorine in water treatment. Laundry bleach available from grocery stores is 5.25 percent chlorine and commercial strength bleach available from swimming pool suppliers or chemical companies is usually 12.5 percent chlorine. (V-2), (V-6)

Soft Water: Water which contains less than 1.0 grain per gallon (<17.1 milligrams per liter (mg/L) or parts per million (ppm)) of total hardness. (V-1), (V-2)

Source Water:

1. Water, usually from wells or surface sources, which has had no previous treatment and is entering a water processing system or device.
2. Water at the inlet side of any water treatment system or device. (V-1), (V-2)

Surface Filtration: Filtration that occurs at the surface layer (as opposed to within the body depth) of the filter and is accomplished by passing the material to be filtered over a grating, screen, sieve, or membrane fabric with micro-sized holes. (V-2)

Surface Water: All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors which are directly influenced by surface water. (V-2)

Suspended Solids: Solids that either float on the surface or are suspended in water or other liquids. (V-1), (V-2), (V-3)

Top Mounted Valve: A multiport valve that is mounted on the top of the mineral tank, as opposed to the side of the mineral tank. (V-4)

Total Dissolved Solids (TDS): The total weight of the solids that are dissolved in the water, given in ppm per unit volume of water. (V-2)

Trichloroethylene (TCE): An organic compound used as a solvent in industry since the 1950's and found in ground water. TCE was proven to be toxic and a carcinogen in the 1970's. The U.S. EPA has established a Maximum Contaminant Level (MCL) of 0.005 mg/l for drinking water. (V-1)

Turbidity: The amount of small particles of solid matter suspended in water as measured by the amount of scattering and absorption of light rays caused by the particles. (V-1)

Ultrafiltration: A method of cross flow filtration (similar to reverse osmosis but using lower pressures) which uses a membrane to separate small colloids and large molecules from water and other liquids. The ultrafiltration process falls between reverse osmosis and microfiltration in terms of the size of particles removed, with ultrafiltration removing particles in the 0.002 to 0.1 micron range, and typically rejecting organics over 1,000 molecular weight while passing ions and smaller organics. (V-2), (V-3)

Ultraviolet Light (UV): Radiation (light) having a wavelength shorter than 3900 angstroms, the wavelengths of visible light, and longer than 100 angstroms, the wavelengths of x-rays. Ultraviolet light is used as a disinfectant. (V-2), (V-3), (V-4), (V-5)

Virus: A parasitic infectious microbe, composed almost entirely of protein and nucleic acids, which can cause disease(s) in humans. Viruses can reproduce only within living cells. They are 0.004 to 0.1 microns in size, and about 100 times smaller than bacteria. (V-1), (V-2)

Water Softener: A device, product, or equipment that reduces the presence of water hardness to less than 1 gpg expressed as calcium carbonate equivalent via chemical, physical, or other means. In residential and commercial applications, the most common water softener consists of a pressurized water treatment device in which hard water is passed through a bed of cation exchange media for the purpose of exchanging calcium and magnesium ions for sodium or potassium ions, thus producing a softened water which is more desirable for laundering, bathing, and dishwashing. (V-2), (V-3), (V-4), (V-5)

Water Treatment: Any method of purposefully changing the quality of water between its source and point of use. (V-1), (V-2), (V-3), (V-4), (V-5), (V-6)

Water Treatment Device: Any point-of-use or point-of-entry device that changes the quality of the water supply by any means, including, but not limited to, filtration, distillation, adsorption, ion exchange, reverse osmosis, or other treatment. (V-5, V-6)

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Notes

[illegible]

Study Guide Answers

Chapter 1

- Q. What is the defining character of the water molecule?
- A. A dipolar with positive and negative side, which causes it to interact with other charged particles.
- If you missed this question, go back to page 10 for information on introduction.*
- Q. Define water treatment.
- A. The process of modifying the contaminant level in a source water to achieve a desired product water quality.
- If you missed this question, go back to page 10 for introduction.*
- Q. What are the four basic categories of contaminants in water?
- A. Suspended solids, microbes, dissolved solids, and organics.
- If you missed this question, go back to page 10-11 for information on contaminant categories.*
- Q. What is water quality?
- A. The contaminant level is a specific sample of water.
- If you missed this question, go back to page 14 for information on water quality.*
- Q. What is a public water system?
- A. A system that delivers piped water for human consumption to at least 15 service connections or which regularly serves at least 25 individuals.
- If you missed this question, go back to page 14 for information on product water.*

Chapter 2

- Q. What is the difference between depth filtration and surface filtration?
- A. Depth filtration is the process of capturing suspended solids within a filtering media; surface filtration is the process of capturing suspended solids upon a single surface.
- If you missed this question, go back to page 19 for information on suspended solids filtration.*
- Q. What technology is applied by a water softener?
- A. Ion exchange technology, specifically cation exchange.
- If you missed this question, go back to page 21 for information on ion exchange.*
- Q. What are the two components of contact time for chemical disinfection of water?
- A. Contact time is the product of the concentration of the strength (expressed as milligrams per liter) and the time of exposure (expressed in minutes).
- If you missed this question, go back to page 22 for information on ultraviolet light.*
- Q. Provide at least two examples of treatment against microbes in water.
- A. Ultrafiltration, ultraviolet light, heat, and chemical oxidation.
- If you missed this question, go back to pages 22-24 for information on ultraviolet light, ultrafiltration disinfection, and heat disinfection.*

Chapter 3

- Q. What are the two criteria for sizing an item of water treatment?
- A. **Maximum flow rate and the volume of the average daily water usage.**
If you missed this question, go back to page 28 for information on sizing of water treatment.
- Q. What determines the flow rate of a media filter?
- A. **Area, in square feet, of the media bed surface.**
If you missed this question, go back to page 29 for information on media filters.
- Q. What is the capacity of a water softener?
- A. **The total amount of hardness, in grains, that can be captured by a newly regenerated system.**
If you missed this question, go back to page 30 for information on ion exchange media.
- Q. How often should an ultraviolet light bulb be replaced?
- A. **Ultraviolet bulbs should be replaced each year (9,000 hours if used).**
If you missed this question, go back to page 32 for information on ultraviolet light.

Chapter 4

- Q. What are the two primary components of a multiport valve?
- A. **Timer and valve body.**
If you missed this question, go back to page 34 for information on multiport valves.
- Q. What are the six different flow paths which a multiport valve can generate?
- A. **Service, backwash, regeneration, fast rinse, brining, and refill.**
If you missed this question, go back to page 35 for information on multiport valves.
- Q. What mineral tank arrangement will allow 24-hour continuous and uninterrupted service?
- A. **Alternating and parallel.**
If you missed this question, go back to page 36-37 for information on mineral tanks.
- Q. What are the two most important maintenance checks for a water softener?
- A. **Replace the salt in the brine tank and to ensure that the inductor (or injector) nozzle is free of debris.**
If you missed this question, go back to page 38 for information on treatment of domestic water.
- Q. What is the most important maintenance check for a chemical injection system?
- A. **To ensure that the chemical solution is prepared correctly.**
If you missed this question, go back to page 38 for information on treatment of domestic water.

Chapter 5

Q. What is the best practice to ensure the quality of water treatment?

A. **The best practice to ensure the quality of water treatment products is to use certified products.**

If you missed this question, go back to page 41 for information on treatment of domestic water.

Q. What is the best practice to ensure the quality of water treatment service?

A. **The best practice to ensure the quality of water treatment service is to use certified service technicians.**

If you missed this question, go back to page 41 for information on treatment of domestic water.

Q. What type of multiport valve timer provides the most efficient water treatment service?

A. **The meter timer provides the most efficient water treatment service.**

If you missed this question, go back to page 42 for information on treatment of domestic water.

Chapter 6

Q. What does chlorine do in water?

A. **Chlorine treats for bacteria in water.**

If you missed this question, go back to page 45 for information on water system chlorination.

Q. What is the first step in basic disinfection of a well?

A. **To determine the amount of water in the well (standing well volume).**

If you missed this question, go back to page 46 for information on procedure for disinfecting.

Q. List some forms of chlorine recommended in disinfecting water.

A. **Sodium or calcium hypochlorite.**

If you missed this question, go back to page 49 for information on procedures for disinfecting water treatment equipment.

Q. What is a sampling faucet?

A. **Code-approved faucet with no threaded outlet connection.**

If you missed this question, go back to page 49 for information on testing water.



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Electrical Safety, Controls, & Regulators

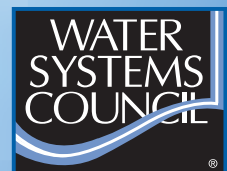


WATER SYSTEMS HANDBOOK

*A complete text on wells:
their design, operation, and maintenance*

13TH EDITION

Published by



WATER SYSTEMS HANDBOOK

BOOK VI

Electrical Safety, Controls, & Regulators

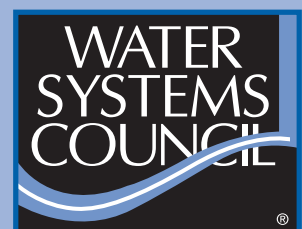
13TH EDITION



**A complete text
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Water Systems Council**

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A Word Of Caution



The products described in this Handbook, including all products using electrical current, can result in serious harm if not used with EXTREME CAUTION and in strict accordance with manufacturers' instructions. Professional assistance is recommended and should always be sought when utilizing unfamiliar equipment.

The products, materials, information, and instructions in this publication are provided for informational purposes only. This publication is not intended to provide instructions or recommendations relating to the selection, adoption, or use of equipment. All information is provided from sources believed to be reliable, accurate, and comprehensive. However, all information, including without limitation product descriptions and functionality is provided "as is" without any express or implied warranty of any kind, including warranties of title, merchantability, noninfringement of intellectual property, compatibility, or fitness for any purpose or use. In no event shall the Water Systems Council or its members, agents, employees, directors, or officers be liable for any damages or other claims whatsoever, including, without limitation, any direct, indirect, special, punitive, or consequential damages, whether from harm, loss of profits, business interruption, loss of information, or related expenses arising out of errors, omissions, or the use of or inability to use the materials, products, information, or services as provided in this Handbook, even if the Water Systems Council or its members have been advised of the possibility of such damages.

Introduction to Wells

Water is life's most vital resource. Through the centuries, people have searched for water, fought for it, and sometimes died for it. No living organism can exist without water.

Consequently, clean and plentiful groundwater is necessary for everyday life. As described in this handbook, groundwater is the reservoir of water that seeps downward through the soil to the water table below the earth's surface. About 98 percent of all fresh water available in the nation at any time is groundwater, which fills the porous beds of rock and sand that make up the earth's crust.

Groundwater is an ideal water supply, for it is pure and wholesome. Filtered by the underground formations through which it passes, groundwater has a degree of purity seldom attained by surface waters.

Natural groundwater reservoirs have many advantages. They have huge capacities, they are relatively inexpensive to tap by means of wells, and they lose little water by evaporation. Above all, they are dependable sources of water.

In the United States alone, more than 115 million people get their drinking water from groundwater every day. More than 23 million American households are supplied from individual, private wells.

A modern well is both flexible and functional. A variety of pumps is available to lift water from all types of wells, from the shallowest to the deepest. These systems are made automatic and dependable by many types of controls and accessories. Groundwater is there when needed. Additional equipment may be added to the system for treatment to ensure better quality of life.

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About this Handbook

The **WATER SYSTEMS HANDBOOK** provides basic information on well design, operation, and maintenance to boost the professional knowledge of well industry personnel.

Before you begin your studies, please take a few moments to familiarize yourself with the format of this handbook. The handbook is divided into eight books. Each includes several chapters that cover the most important aspects of wells. At the end of each chapter, you will find a **Quiz**. You can use this quiz as a learning tool to review the noteworthy points in each chapter. Answers to the quiz can be found at the end of each book. If you miss an answer, follow the directions to take you back to where the information is located in the chapter.

For quick reference, you will find that highlighted text is generally defined in a **Glossary** at the back of each book, where you will also find a topical **Index**. While illustrations appear in each chapter, you will also see tables and charts referenced in text and located in the **Appendix** at the back of each book. A handy metric system reference also appears in each appendix.

We hope that studying the information in this handbook will prepare you for your job as a well professional, charged with the important responsibility of helping to ensure access to pure, plentiful well water for families across America.

Water Systems Council

Dedication

This 13th Edition of Water Systems Handbook is dedicated to the millions of Americans who rely on private water systems to provide safe, sustainable water supply and to the water well professionals in the water well industry.

The 13th Edition is also dedicated in memory of Jeff Wellen for his many years of leadership and service to WSC and the water well industry.

Special thanks to the members of the Water Systems Council Technical Committee, who initiated and completed revisions to this 13th Edition.



The Water Systems Council (WSC) is a national nonprofit organization, dedicated to promoting the wider use of wells as safe, sustainable, and cost-effective drinking water systems; protecting groundwater resources and users of well water, and ensuring a safe drinking water supply for well owners. WSC members include major manufacturers of the integral components of wells and other drinking water systems, leading distributors of these components, and various drinking water professionals.

WSC is the only national nonprofit organization with programs solely focused on private water wells and small, shared wells.

www.watersystemscouncil.org

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Chapter 1

Electrical Safety on the Job

- ✓ Important on-the-job electrical safety precautions
- ✓ Electrical supply and protection
- ✓ Electrical circuits
- ✓ Ground fault circuit interrupters
- ✓ Overhead power lines
- ✓ Toward protecting people

Working on electrical circuits safely

Avoiding electrical injury while working on water well pump systems depends on several important factors, including hazard awareness, knowledge and experience, proper tools and equipment, meeting code requirements, and always following safe work procedures. First and foremost, electrical work should only be done by qualified personnel. **NFPA 70E 2004** (Standard for Electrical Safety in the Workplace) defines a “qualified person” as one who has skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training on the hazards involved.

Whether performing electrical repairs, or simply working around pump equipment, always turn off the electrical power unless it must be on to perform the work needed. It may sometimes seem like an unnecessary step, but taking a few minutes to de-energize a pump circuit may save your life. When de-energizing a system, be certain to turn off all sources of power to the circuits. Simply turning off a circuit breaker will de-energize many residential pump systems, but a larger commercial system may require turning off the pump and then opening a disconnecting switch. Next, **“lock out and tag”** the circuit at the disconnecting device or breaker. This involves installing a padlock (for which you have the only key) on a breaker or switch to prevent anyone else from turning the circuit back on while you are still working on it. Mark the lock with a warning tag.

Multiple locks can be installed if more than one person is working on the same circuit. After removing power and locking out and tagging the circuit, use an appropriately rated **voltmeter** equipped with safe test leads to check that the circuit in question is actually off. Do this by measuring for **voltage** between each of the power conductors, and between all power conductors and the grounding conductor (and/or a **grounded** electrical box, conduit, etc.). Be sure to check for voltage on the input and output sides of controllers, switches, and fuse blocks, as well as on leads from sensors and other control equipment.

Treat the circuit as if energized while making these voltage checks.

OSHA regulations (29 CFR) mandate lock out and tagging procedures for electrical work. Part 1926 applies to construction work sites, and Part 1910 to most other circumstances:

- [29 CFR \(1926.417\(b\)\)](#) "Equipment and controls that are de-energized shall be rendered inoperative and shall have tags attached at all points where such equipment or circuits can be energized. A circuit can be rendered inoperative by placing a lock for which you have the only key on the breaker or circuit box."
- [29 CFR 1910-333\(b\)\(2\)](#) "Lockout and tagging. While any employee is exposed to contact with parts of fixed electric equipment or circuits which have been de-energized, the circuits energizing the parts shall be locked out or tagged or both in accordance with the requirements of this paragraph."
- [29 CFR 1910.333 \(b\)\(2\)\(iii\)\(A\)](#) "A lock and a tag shall be placed on each disconnecting means used to de-energize circuits and equipment on which work is to be performed."
- [29 CFR 1910.333\(b\)\(2\)\(iii\)\(B\)](#) "Each tag shall contain a statement prohibiting unauthorized operation of the disconnecting means and removal of the tag."

Sometimes the power must remain on to perform a task, such as making voltage or current measurements to troubleshoot a problem on a pump circuit. When this is the case, the following tips can help prevent someone from being shocked by accidentally touching a live conductor or part:

- Work carefully and deliberately, use sufficient lighting and avoid distractions.
- Wear electrically-rated gloves and safety glasses and use electrically-rated insulated tools.
- Use an appropriately rated **voltmeter** or **ammeter** with safe test leads; be sure it is in good condition, and understand its correct operation.
- Don't wear jewelry such as rings, watches, chains, and bracelets, and don't work while wet.
- Because there is potential for violent electrical arcing when working on energized circuits, even on residential systems, you should always wear long-sleeved fire-resistant work clothes rated for electrical arc protection. On higher power installations, such as large three-phase commercial pump systems, you may need to wear more specialized fire-resistant protective clothing, including a face shield. Consult **NFPA 70E 2004** (Standard for Electrical Safety in the Workplace), for more information on the protective equipment and clothing needed for electrical work.
- When electrical testing is complete, de-energize the circuit, lock it out, tag it and test it for voltage before continuing repairs.
- Also, ensure that all metal parts of a water well system and its power supply are grounded in accordance with appropriate codes. The National Electrical Code (NFPA 70) paragraph 250.112 states "...non-current-carrying metal parts of the kinds of equipment described in 250.112 (L) and (M) shall be grounded regardless of voltage."

[\(L\) Motor-Operated Water Pumps](#). Motor-operated water pumps, including the submersible type.

[\(M\) Metal Well Casings](#). Where a submersible pump is used in a metal well casing, the well casing shall be bonded to the pump circuit equipment grounding conductor."

Ground fault circuit interrupters (GFCI)

A common cause of electrical shock during pump installation and repair is accidental contact with live conductors, either directly or through damaged insulation. **Ground fault circuit interrupters (GFCIs)** can prevent injury to people in the most common electrical shock situation, the phase-to-ground electrical shock.

GFCIs are permanently installed circuit protection devices that can detect very small amounts of current “leaking” out of its intended path. Commonly available GFCIs can detect 4 to 6 **milliamperes** (1 milliampere = 1/1000 of an amp) of leakage current to ground and open the circuit to prevent a potentially deadly shock. GFCIs are available for single-phase and three-phase installations, at ratings up to 480V and 100A.

The 2005 National Electrical Code does not require GFCIs on water well pump circuits. The use of GFCIs in water well pump systems, however, is good electrical practice and can protect the installer and the customer from possible electrocution.

Overhead power lines

All water well pump installation and maintenance workers need to know about overhead power line hazards and how to avoid them. If accidental power line contact occurs, everyone at the job site needs to know what to do and, just as importantly, what not to do. Overhead power lines are not insulated. They operate at several thousand volts or higher. Contact with any power line can kill you and your coworkers. In a typical power line contact accident, when equipment such as a pump hoist truck touches a power line, the truck chassis becomes energized to a high voltage. Serious injuries can occur when workers on the ground touch any part of the hoist truck or any equipment, cables, or loads connected to the truck. High-voltage shocks may also affect workers walking or standing near the energized truck.

- When arriving at a jobsite, look up to see if any power lines are in the vicinity. Plan the job to avoid working near any lines you see, including service drops. OSHA regulations (29 CFR, 1910.333 (c)(3)(iii) (A)) require you to stay at least 10 feet away from power lines carrying up to 50,000 volts, but most people, including electricians, can't tell the voltage of a power line simply by looking at it. Play it safe – stay at least 35 feet away from all power lines with any part of a drill rig or pump hoist truck, its cables, or any hoisted equipment.
- Try to anticipate situations that could put you too close to a power line. It is easy to accidentally come too close to a line while concentrating on other aspects of a job. For instance, the top of a hoist boom being raised or lowered may come closer to a power line than anticipated. Hoist and winch ropes that are safe when slack may contact a power line when under tension. A hoist boom can come closer to a power line than planned if the truck is on uneven ground, or if a stabilizer jack gives way. Finally, never store materials or equipment (pumps, casings, pipes) underneath or anywhere near power lines.
- If you must work in the vicinity of overhead power lines, use extreme caution. It's a good idea to erect barriers and/or warning signs to keep anyone from operating equipment or handling tools and supplies closer than 10 feet from the lines (the OSHA-required clearance is more if the power line is more than 50,000 volts). In addition, assign a crew member as a spotter, positioned to easily observe that 10 feet of clearance from power lines is maintained at all times when maneuvering, raising, or operating equipment. Never move a drill rig with its mast raised. If you must work less than 10 feet from power lines, the only legal and safe way to do so is to have the electric utility company de-energize and visibly ground the lines.

A Word Of Caution



If you do accidentally contact a power line, the following procedures may save your life:

When you are on the drill rig or hoist truck:

- Stay on board (unless forced off by a fire) until the contact is eliminated or the utility has de-energized the line. Getting off the truck is very dangerous.
- Warn anyone not on board to stay away from the truck. Try to move the mast or boom out of contact with the power line, if this can be done safely without touching the ground.
- If you are forced to get off the truck due to a fire, jump well clear. Try to land upright with your feet close together; don't fall back against the truck. Most importantly, do not touch the truck and the ground at the same time. Quickly move away from the truck using short shuffling steps or by hopping. Keeping your feet close together reduces the risk of shock.

When you are not on the drill rig or hoist truck, but are working near it:

- Do not touch or approach the truck; move away as previously described.
- Call the local emergency services for injured personnel, and the local utility company to de-energize the lines if the truck can't be moved away.
- If a co-worker appears injured due to the power line contact, do not approach the victim or the truck to provide help – you could easily become another victim. Wait until the power line has been de-energized by the utility company.
- If the power line appears to de-energize on its own, do not assume it's safe. Many utility circuits are equipped with automatically reclosing circuit breakers that trip and reset several times after a line contact accident. You cannot know whether the power line is re-energized or not.

Study Guide Questions - Chapter 1

Answers can be found on page 62

- Q. Before working on an electrical circuit, be sure that all power sources are turned off. To ensure that no one else might re-energize the circuit, it is a good practice to “lock out and tag.” What does that mean?

- Q. What is GFCI and what does it do?

- Q. What is a safe distance to keep between you and any 50,000-volt power lines?

Notes

[illegible]

Chapter 2

Electrical Supply and Protection

- ✓ Electrical supply overview
- ✓ Allowable voltage variations
- ✓ Grounding
- ✓ Motor protection
- ✓ Lighting arrestors for pump motors

The most common service for homes in the United States is 120-volt and 240-volt, 60 Hertz, single-phase electricity. The 240-volt service is supplied by two lines from the secondary coil of a transformer; 120 volts is supplied by either of the 240-volt lines and a third line connected to the midpoint of the secondary, called neutral. This neutral line is grounded and is usually white.

Three-phase service is generally supplied for industry and other large power users. The most common three-phase voltages are 208, 240, 480, and 600 volts to allow for as much as a 5 percent voltage drop in distribution lines. The nameplate voltages on motors and equipment are 200, 230, 460, and 575.

Allowable voltage variations

Voltage variation at the service entrance is normally held to within plus or minus 10 percent of rated **voltage** by the power company. This would mean a range of 216 to 264 volts on a 240-volt system. Electric motors are designed to operate satisfactorily within this range. Power companies typically hold the voltage variation of networks to plus or minus 5 percent of rated voltage. Particular care should be taken, however, with size and length of supply wiring if the supply voltage is close to the low limit.

An inadequately-sized pump and house wiring causes a further variation in voltage. This is particularly noticeable and important at the instant an electric motor starts, when the current that flows is many times greater than while the motor is running. Wiring must be heavy enough to maintain adequate voltage when supplying the high starting current.

Wire sizes that will carry the rated current without overheating will not necessarily maintain rated voltage. The voltage drop in the wiring is proportional to the current (amps), the length of the wire, and the cross-sectional area. Long lines, therefore, must use larger wire to keep the voltage drop within limits. Refer to the Cable Selection Charts in the Appendix for information on required cable size for various motor ratings or the motor manufacturer's published technical data.

Grounding necessary

One electrical supply line is generally connected to the earth to eliminate any hazardous voltage, a practice known as **grounding**. When possible, both the transformer and the service entrance are grounded. On a 240-volt single-phase three-wire system, for example, the neutral (center tap) of the transformer is usually grounded, and the maximum voltage from any supply line to the ground is 120 volts.

The failure of insulation on any item of electrical equipment can subject the user to dangerous electric shock because one of the electrical lines is then unintentionally connected to the equipment enclosure or housing. When this happens, a voltage equal to the line voltage can appear between the enclosure and the ground. To protect the user from such perilously high voltages, the enclosure must be grounded by connecting it to the service ground through direct wiring or a grounding plug and receptacle. The ground wire should not be a smaller size than the supply wire. An insulation failure on such a grounded enclosure will cause the circuit protective device (usually a fuse or circuit breaker) to open and avoid a shock hazard to the user.

Types of motor protection needed

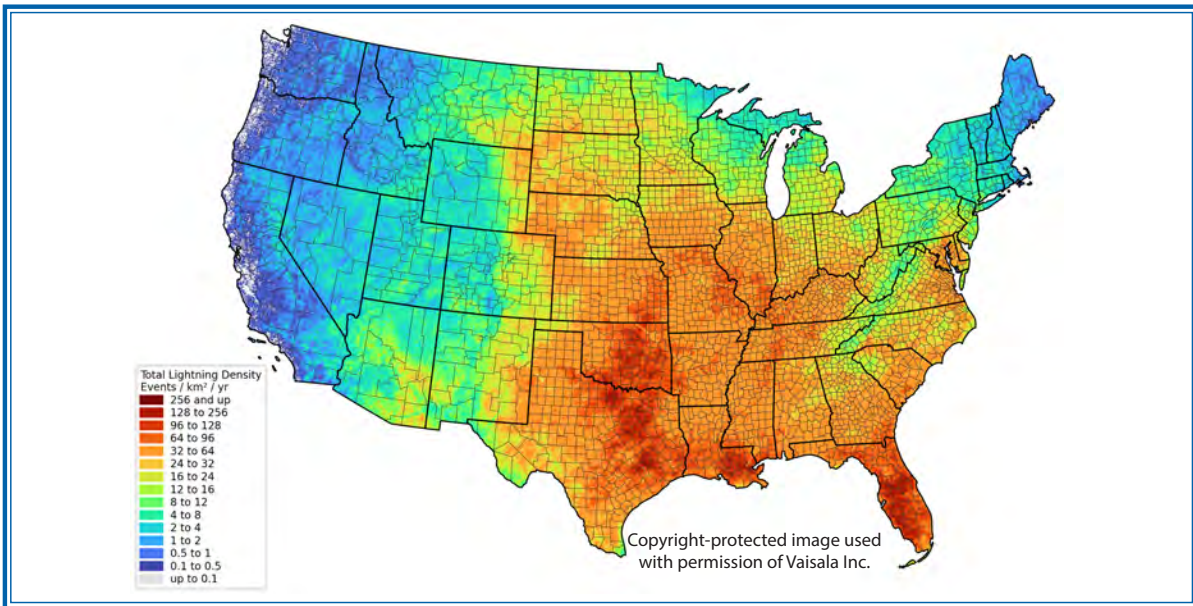
The primary cause of motor failure is overheating, which results in destruction of the motor insulation. Motor overheating is caused by overloading, a locked rotor, rapid cycling, or loss of cooling. Optional protection devices may be installed on motors to shut off the current when overheating occurs. However, motor protectors must not trip from the high current required for normal motor starts, but must trip rapidly if the motor fails to start.

Motor protectors must allow the motor to carry the maximum allowable current continually, yet must trip even at low no-load currents if the motor overheats. A motor will overheat at no-load if excessive current flows from current imbalance between phases or supply voltages are outside allowable limits or minimum flow velocities are not maintained.

A **thermal switch** in the motor will protect it against continuous overload but will not act fast enough to protect a motor that does not start. An **over-current protector** can guard against overloading and failure to start, but it cannot protect against overheating from loss of cooling. Air-cooled motors, such as jet pump motors, are protected by a combination thermal switch and over-current protector located in the motor. This method, known as **inherent thermal protection**, guards against overheating due to any condition at any load.

Many **submersible motors** also have inherent thermal protection. Some rely on external devices or a combination of devices such as fuses and circuit breakers operated by heaters or magnetic coils. Low-water-level protectors are of the low flow or electrode type. A **low-flow protector** opens the circuit if the pump is operating continuously but is pumping less than a predetermined minimum amount of water. The electrode-type opens the circuit if the water level falls below the lower of the two electrodes suspended in the well.

Figure VI.2.1



Isoceraunic map showing the density of electrical (thunder and lightning) storms in various parts of the country. Colors indicate the average number of thunderstorms per year that can be expected. The greater their density, the more need there is for lightning protection on pumps.

Lightning arrestors

Most lightning damage to residential electrical equipment is caused by high-voltage surges entering a building through power lines. Power companies protect their equipment and lines for 10,000 volts, which is higher than most appliances can tolerate.

The insulation of properly designed electric motors will withstand at least 2.4 times their rated voltage plus 1,200 volts for one second (1,750 volts for a 230-volt motor) from line to ground. Generally they will withstand much higher voltages than this, but not 10,000 volts, so additional devices are required to protect pump motors from lightning damage. Properly applied **lightning arrestors** offer such protection; however, there is nothing that will protect the motor from a direct lightning strike.

Figure VI.2.1 shows the density of electrical storms throughout the country. The greater the density, the more need for lightning protection on pumps. A lightning arrestor is a protective device connected between the power lines and the ground.

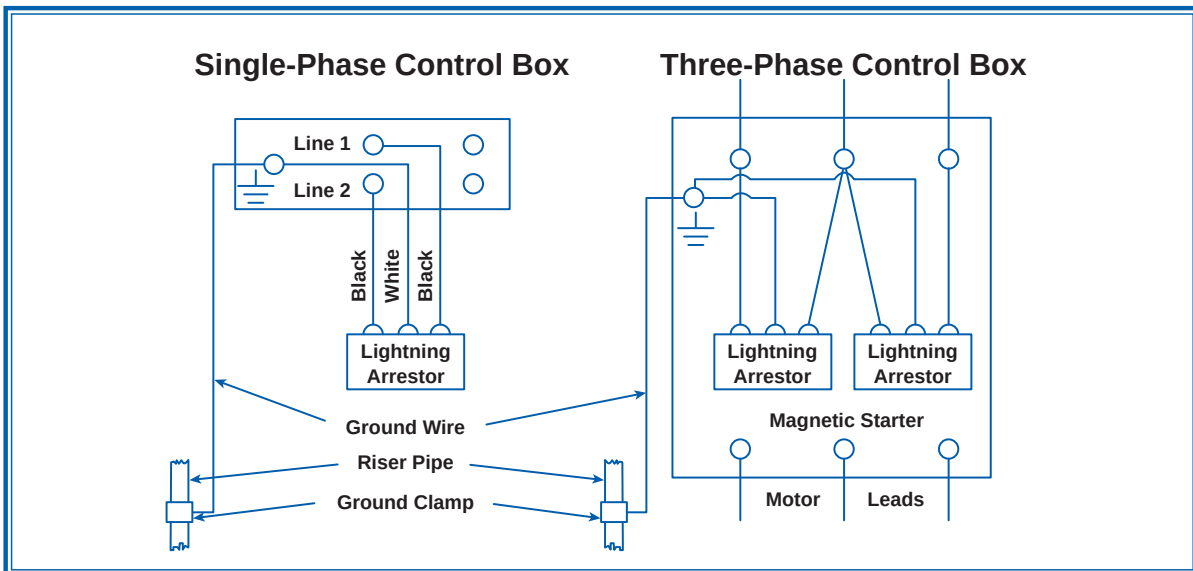
The arrestor is an insulator to normal voltage, but automatically becomes a low-resistance conductor to ground when the voltage between the power line and the ground exceeds a set amount, called the **impulse sparkover voltage**. A lightning arrestor must conduct currents of as much as 10,000 amps harmlessly to the ground and must be able to repeat this performance with no maintenance. Figure VI.2.2 (page 18) shows the typical wiring of lightning arrestors on both single-phase and three-phase control boxes.

Three types of lightning arrestors are available: **expulsion arrestor**, **valve (pellet) arrestor**, and **relay arrestor**. An expulsion arrestor consists of an air gap and a gas-generating material. During normal voltage, the air gap insulates the power lines from the ground. If the line-to-ground voltage exceeds the arrestor's impulse sparkover voltage, the air gap sparks over and short circuits the line to the ground. The resulting current that flows through the special material in the arrestor produces a gas, which in turn blows out the arc. An expulsion arrestor is designed for outdoor installation only.

The **valve arrestor** consists of many pellets of nonlinear material separated by small air gaps. The material presents a low resistance to high voltages and a high resistance to low voltages. At the impulse sparkover voltage, the air gaps sparkover and the nonlinear pellets short circuit the power line to the ground. When normal voltage returns, the resistance of the pellets automatically increases, and the air gap voltages are reduced to the point where current ceases to flow.

The relay arrestor consists of an electrical component insulated and sealed inside a case. The electrical component arrestor directs all voltage surges above approximately 600 volts to a ground wire that is part of the arrestor. All other details and connections for this type of arrestor are the same as for the other types of arrestors. Contact manufacturer for recommendation.

Figure VI.2.2



Typical wiring circuits of lightning arrestors on single-phase (left) and three-phase (right) control boxes. On three-phase boxes, a minimum of two arrestors must be used. With two-wire submersibles, arrestors can be mounted on junction boxes. Two types of protection are described in the text.

Where to install arrestors

Either an expulsion or valve arrestor located at the electric service entrance will help to protect all electrical equipment in a residence from lightning attempting to enter through the power lines. The effectiveness of aboveground arrestors requires an excellent low-resistance connection between the arrestor ground terminal and the motor frame.

When a lightning strike enters the earth, it seeks the lowest-resistance path to a perfect ground, which often is underground wiring. Additional arrestors are required to protect submersible motors if lines between the service entrance and the well head are vulnerable.

If the strike enters the underground cable to a **submersible pump**, it will travel into the house in one direction and to the pump motor in the other. A service entrance arrestor or an arrestor connected to the motor control box in the residence will not protect the pump motor from this type of lightning strike.

The pump motor can be protected in one of two ways. The arrestor can be located at the well head. Or, the cable can be enclosed in metal pipe from the house to the well, and the arrestor can then be located at the service entrance or at the motor control box in the residence. Many small submersible motors now include **internal surge arrestors** that directly connect their motor windings and frames and offer excellent protection.

Study Guide Questions - Chapter 2

Answers can be found on page 62

Q. Define grounding.

Q. What is the primary cause of motor failure and what is its solution?

Q. What is a lightning arrestor and what does it do?

Notes

Chapter 3

Protective Controls

- ✓ Operating and safety controls
- ✓ Accessories and auxiliary protective controls
- ✓ Toward protecting equipment from damage and fire

Grounding Caution



All electrical controls must be permanently grounded and wired in accordance with the **National Electric Code (NEC)** and applicable local codes. Failure to properly ground the controls can result in serious or fatal injury.

The National Electrical Code (NFPA 70) paragraph 250.112 states "...non-current-carrying metal parts of the kinds of equipment described in 250.112 (L) and (M) shall be grounded regardless of voltage.

(L) Motor-Operated Water Pumps. "Motor-operated water pumps, including the submersible type."

(M) Metal Well Casings. "Where a submersible pump is used in a metal well casing, the well casing shall be bonded to the pump circuit equipment grounding conductor."

Operating and safety controls

The function of any **control** is to regulate the performance of and/or protect the equipment for its intended use. To accomplish this, controls fall into two basic categories:

- **operating controls**, which instruct the equipment when to operate and when to cease operation; and
- **safety controls**, which are designed to prevent damage to equipment in the event of a malfunction.

For water systems, the primary operating control is the **pressure switch**, which senses the **pressure** of water delivered to a **tank** and tells the **pump** when to start and stop. If a water system has an **open tank** in place of a **pressure tank**, a **float switch** is used for the same purpose. On small water systems, one of these two switches can be used to directly start and stop electrical current flowing to the pump motor. In larger equipment, additional operating controls are needed and these are called **magnetic motor starters** or **contactors**.

Electrical controls, or **auxiliary protection devices**, serve two basic purposes: (1) They provide a manual or automatic way to disconnect electricity to the equipment from the power source, when excessive current flows to the equipment. (2) They also protect the equipment from overheating caused by overload, lack of water, voltage variations, or other causes situations. In the case of **submersible pumps**, they may protect the pump and the **pump motor** if too little water flows through the pump's motor section.

Electrical controls are intended to protect equipment from damage and prevent fires. They are not intended to protect people from electric shock.

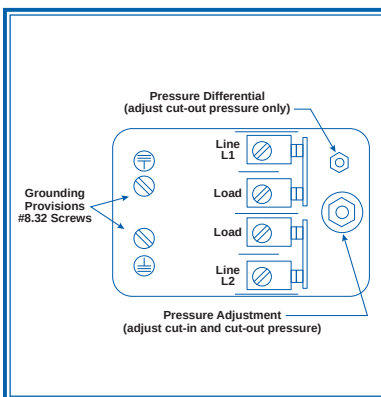
The pressure switch

Most pressure switches in use today operate on the same principle: Changes in pressure are sensed by a flexible diaphragm and transferred to a lever that operates an electric switch.

They are mounted on the high-pressure side of the **pump** or at the **tank**, so they have a fluid connection between the high-pressure water and switch-sensing element (Figure VI.3.1).

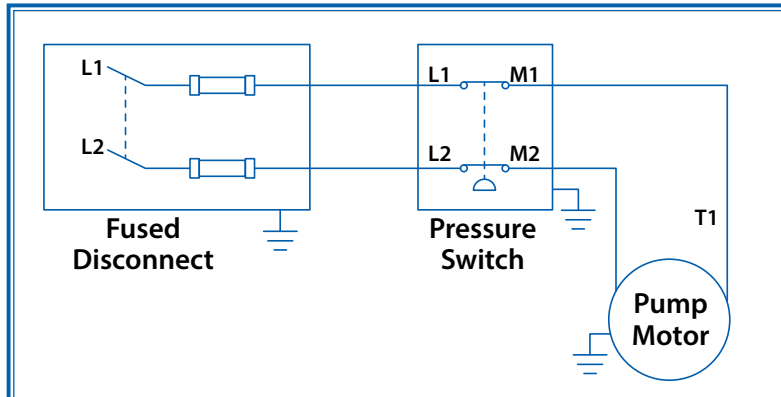
As shown in Figure VI.3.2, the opening and closing of the pressure-switch contacts controls the flow of current from L1 to T1 and L2 to T2, which starts and stops the pump. It is common practice to make and break both sides of the electrical circuit with a double-pole single-throw (DPST) pressure switch as shown.

Figure VI.3.1



Electromechanical pressure switch used in most water systems with pumps below 1.5 hp.

Figure VI.3.2



Pump wiring diagram of a typical single-phase two-wire installation in which a pressure switch opens or closes the circuit directly to the pump motor. These figures are for illustrative purposes, not intended to serve as wiring guides for any particular installation.

NOTE: Ground wire has been omitted to simplify diagram.



Caution

Pressure switch adjustments of any kind should only be made by qualified personnel. Improper adjustments may result in mechanical damage to the system and/or risk of personal injury.

Pressure switches for **reciprocating**, **centrifugal**, and **jet pumps** are usually factory preset. Typical preset pressure-switch ranges are 20/40 psi, 30/50 psi, and 40/60 psi, but these settings can usually be adjusted.

Solid-state pressure controls or **digital pressure controls** (Figure VI.3.3) can be used when a closer pressure differential is required. Differentials as low as 10 psig can be obtained when a constant-type pressure is required. The advantage of using the solid-state or digital pressure control with any standard pump is increasing in popularity. However, a closer pressure differential requires a 25% larger pressure tank.

The float switch

If a gravity tank or reservoir is used for water storage instead of the more common pressure tank, a float switch is employed to turn the pump on or off (Figure VI.3.4). The float responds to a rise and fall in the water level in the pressure tank rather than to pressure.

Figure VI.3.2 (page 22) shows a simple wiring diagram of a typical single-phase two-wire installation in which the operating switch, whether **float switch** or **pressure switch**, opens or closes the circuit directly to the pump motor. Note that the **fused disconnect switch** is placed in the circuit before the operating control. The **National Electrical Code (NEC)** requires such a switch in every installation and it should be located within easy view while servicing.

Figure VI.3.3



Solid-state pressure or digital pressure control with built-in low pressure cut-off and pump cycle control. Controls pressure to 10 psig differential and allows for constant pressure.

Figure VI.3.4

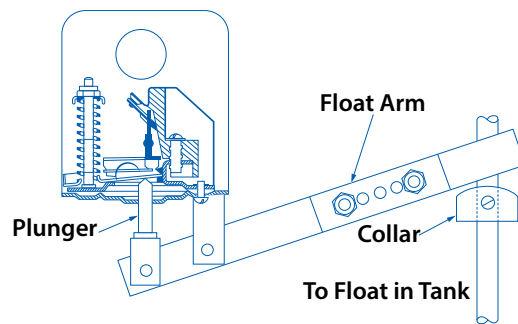


Diagram of a float switch used with a gravity tank or reservoir.

Motor starters

In systems where the power requirements of the pump exceed the electrical rating of the float or pressure switch and in most three-phase installations, auxiliary starting equipment is employed. The float or pressure switch serves as a pilot device that opens or closes the circuit to a **starter** or **contactor** whose heavier-rated contacts actually open or close the pump circuit.

In general, electrical safety controls and protection devices are applied in series with the pressure control in the pilot circuit. Figure VI.3.5 shows a typical single-phase two-wire circuit for a pump with a starter. Note that the disconnect is fused and that the starter is supplied with an automatic or manually reset **overload relay**. Only the current required to operate the starter coil passes through the pressure switch.

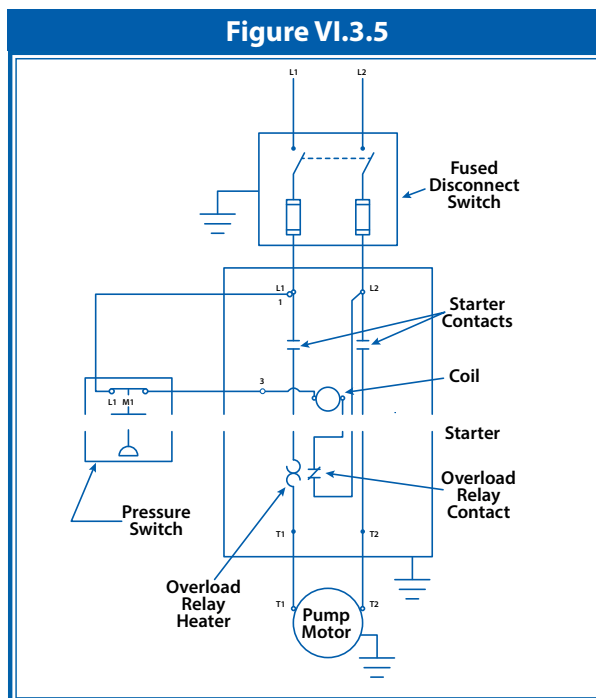
Submersible motors are very heat sensitive and require special quick-trip overload protectors. Ambient-compensated, quick-trip overload protection is the accepted method. Any deviation from the manufacturer's recommendation for sizing, and thus full protection, could jeopardize the life of the motor and void the warranty.

Installers should check with local electrical inspectors to see that installations comply with wiring codes. In nearly every case, the National Electrical Code (NEC) is used as the basis for local codes or ordinances. Non-current-carrying metal parts, such as motor frames and disconnect boxes, should be grounded to the electrical system ground.

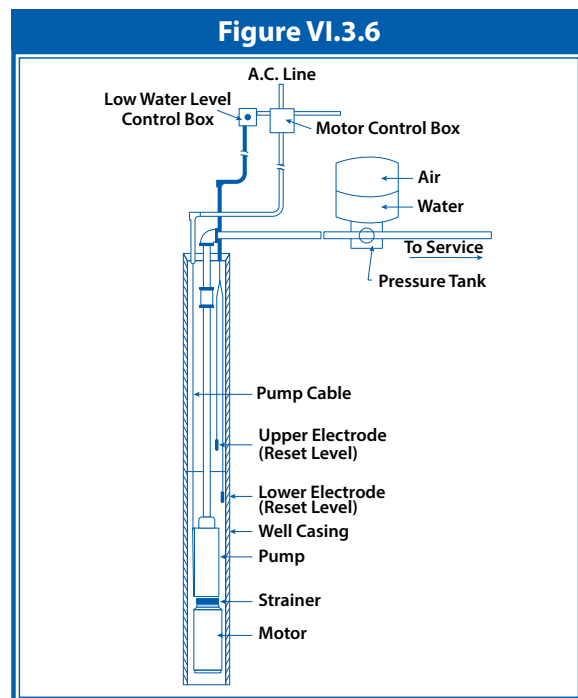
Accessories and auxiliary protective controls

In domestic water systems beyond motor overload protection, the requirement for equipment protection is primarily confined to prevention of continued pump operation without normal water flow through the pump. It is not common practice to add this type of protective equipment to small aboveground reciprocating, centrifugal, or jet pumps.

Submersible pumps, however, may be easily damaged beyond repair should water flow cease at the pump. Every submersible should be protected if there is any possibility that the well may go dry or the intake screen may clog. A variety of protective devices are available.



Pump wiring diagram for a single-phase circuit with starter.
NOTE: Ground wire has been omitted to simplify diagram.



The electrode low-water cutoff system for a submersible pump.

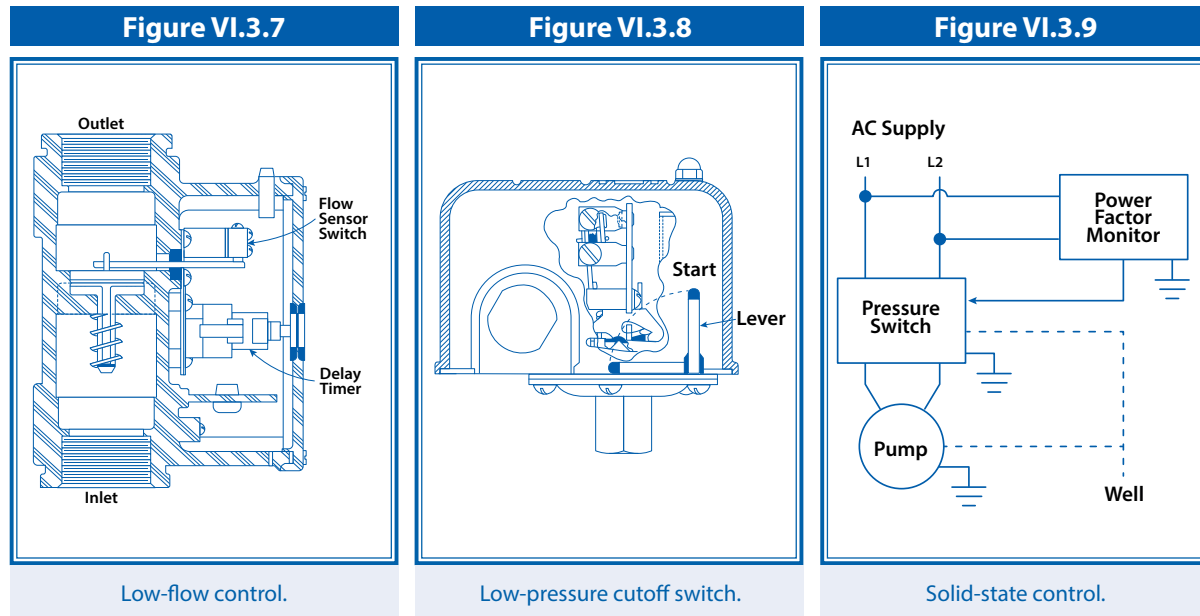
The electrode-operated **low-water cutoff** (Figure VI.3.6, page 24) consists of a relay box and two electrodes suspended in the well. In submersible-pump installations, the lower electrode is usually set in the well just above the pump. The upper electrode, which resets the control, is installed at a level somewhat above the lower cut-out level, depending upon the well's recovery rate. In operation, should the water level drop below the lower electrode, the relay will break the electrical circuit to the motor until the water level recovers to submerge the upper electrode. The submersible pump is thus prevented from running or starting dry.

Another type of protective device is the low-flow control (Figure VI.3.7). Several types are manufactured.

Should water flow become inadequate, the control will start a time delay circuit that in turn will shut off pump operation in 30 to 90 seconds. **Low-flow controls** are equipped with manual or automatic reset after a minimum period of recovery time.

Another protective control system is the **low-pressure cutoff switch** (Figure VI.3.8). This device detects a drop in pressure below the normal **cut-in pressure** of the pressure switch and will shut down the pump. After it has shut down, a lever must be manually reset to restart the pump.

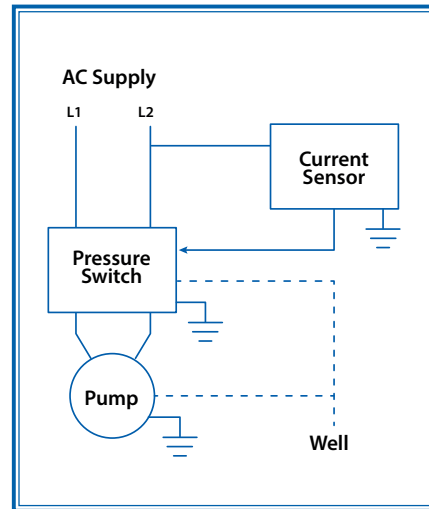
Solid-state controls that incorporate a variety of protective functions are available. The control in Figure VI.3.9 monitors power and is designed to protect a submersible pump from running without water, either from too little water or a clogged inlet screen. A significant drop in the power is detected in split-phase, capacitor-start and in some capacitor run motors used to drive submersible pumps. It has an automatic restart feature after a time delay.



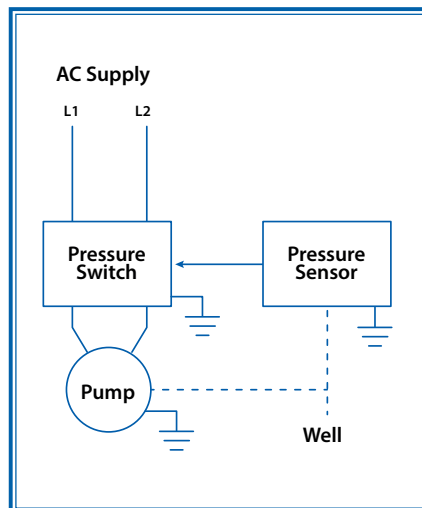
The device shown in Figure VI.3.10 is a current-sensitive low-water control that monitors the current drawn by the motor and protects the submersible pump from low water, based on the fact that a pump running without water draws less current than when it pumps water. This control automatically attempts to restart the pump after a time delay and works on most types of motors.

The device shown in Figure VI.3.11 is a pressure-sensitive low-water control that senses a lack of water due to loss of **wellhead pressure**, and eventually shuts off a submersible pump to protect it. This control continually attempts to restart the pump after a preset time delay, which can be adjusted at installation. These controls are separate from and in addition to the pressure switch that controls the pump's on/off cycle.

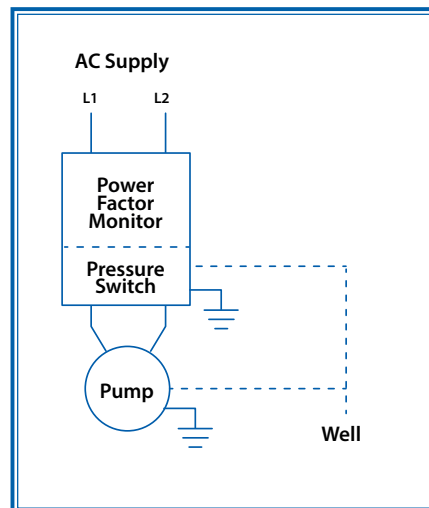
The submersible pump **system monitor** in Figure VI.3.12 incorporates a microcomputer merged with the standard on/off pressure switch. The microcomputer continuously monitors the power factor of the pump's motor for low water and also detects rapid cycling, high or low voltage, and excessively long runs. When one of these abnormal conditions is detected, the microcomputer activates condition indicator lights on top of the enclosure and, in most cases, shuts off the pump motor. The microcomputer is programmed to restart the pump automatically if the condition corrects itself within a reasonable length of time. This device operates with split-phase, capacitor-start and some capacitor-run motors.

Figure VI.3.10


Current-sensitive low-water control.

Figure VI.3.11


Pressure-sensitive low-water control.

Figure VI.3.12


System monitor: current- and pressure-sensitive low-water control.

NOTE: Ground wire has been omitted from Figures VI.3.9 (page 25) - VI.3.12 to simplify diagrams.

A completely mechanical **liquid-level control** for low-yield wells is shown in Figure VI.3.13. A float moves vertically around the riser pipe, adjusting a built-in bypass valve. If a well's yield declines, the float will drop, opening the regulating valve and allowing water to be recirculated within the well. The valve will adjust the rate of delivery to be equal to well yield.

Controls are selected to fit the specific needs of a water system. Small domestic systems may require only a disconnect and pressure control.

Larger three-phase submersibles may require the entire spectrum of operating and protective control devices.

The pump manufacturer and a field representative can supply the information and size required by any installation.

Three-phase motor protection

Advanced protection devices for three-phase motors are available and can provide much greater levels of protection than traditional overload relays. These devices can offer feedback on motor performance as well. Typically, these devices provide overload protection by directly measuring current flow on all three phases, and thus react much more quickly and accurately than thermal relays. These devices also offer additional protection against dry run, overvoltage and undervoltage, current imbalance, excessive motor temperatures, and ground fault. Some of the more advanced devices provide real time data on motor performance and include detailed feedback for troubleshooting. With some of these advanced protectors, the potential for pump control via external sensors, PLCs, or integration into SCADA systems becomes possible.

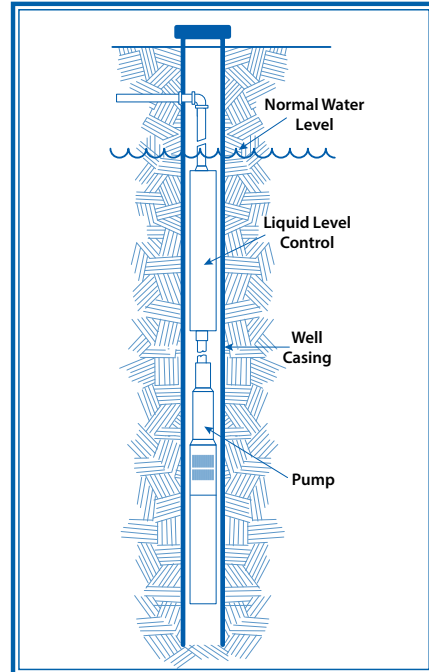
Overpressure devices

A **pressure-relief valve** (Figure VI.3.14) should be used on any system where the pump could develop a greater pressure than the system's rating. Typically, the pressure switch stops the pump, but if a switch or the wiring malfunctioned, the pump would keep running, and excessive pressures could result.

The pressure-relief valve should be installed in the tank inlet or pump discharge line as close to the pump as possible. It should be large enough to relieve the rated capacity of the pump at or below the working pressure of the lowest-rated system component. Water should be plumbed into an appropriate drain. Before installation, make sure there is no blockage or way to block the line to the pressure-relief valve.

An **electrical overpressure switch** may also be used to limit maximum system pressure in conjunction with a relief valve. This device is similar to a pressure switch except that it is used as a pressure-limit control and must be reset manually.

Figure VI.3.13



Liquid-level control.

Figure VI.3.14



Pressure-relief valve.

Accessories for plain steel tanks with and without float separator

Two types of **vacuum-operated air controls** are shown in Figure VI.3.15. These controls are used on jet pump installations that have 5 feet or more of **suction lift**. When installed on suction lifts of less height, as on deep well jets with positive suction head, a vacuum booster will be required for proper functioning of the air control.

Figure VI.3.15

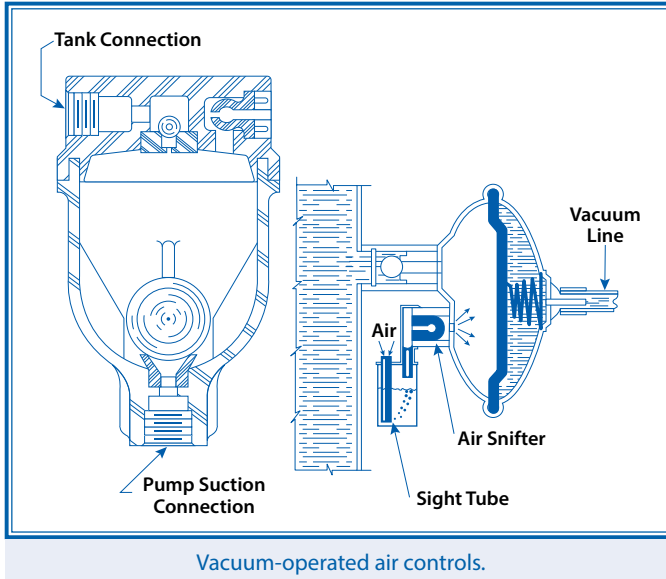


Figure VI.3.16

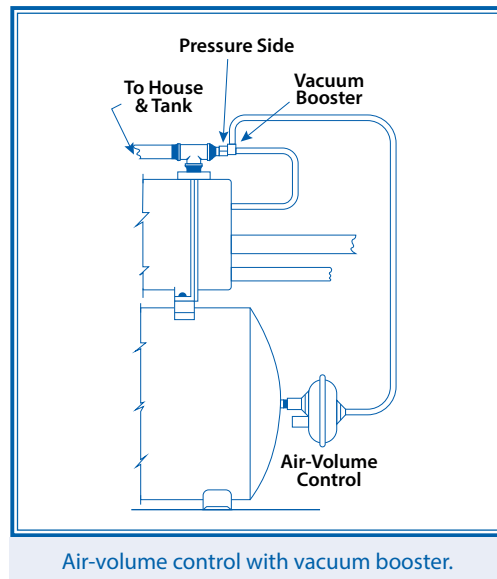
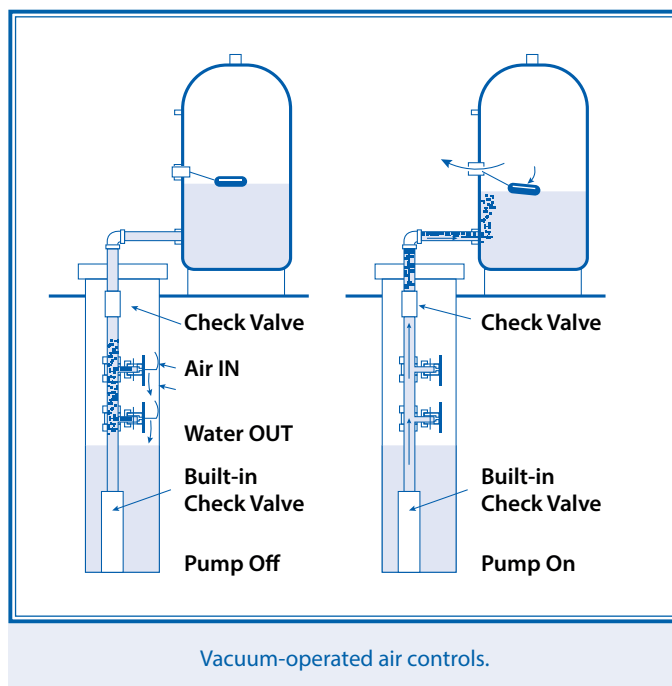


Figure VI.3.16 shows a typical installation of an air-volume control with vacuum booster that is used on deep well jet pumps when the suction lift is less than 5 feet. Manufacturers of this equipment caution installers to select the proper size of air-volume control device. It is possible to install a control that is too small to add enough air, but it is not possible to install a control that is too large, because the vacuum-operated air controls will only add air as needed.

Air-release control

The **air-release control** device illustrated in Figure VI.3.17 is used to release excess air from the tank. Each time the pump cycles, air is added to the tank through a bleeder and snifter valve. Excess air is released by a float valve assembly in the upper side tapping of the tank.

Figure VI.3.17



Study Guide Questions - Chapter 3

Answers can be found on pages 62-63

Q. How and why should electrical system controls be grounded?

Q. What does a control do, and what are the two basic categories?

Q. Who is qualified to alter a pressure switch?

Q. Submersible pumps require controls that jet pumps do not require. What are these and why are they necessary?

Q. Name two devised for handling overpressure.

Notes

Chapter 4

Constant Pressure Systems

- ✓ Overview of current constant pressure technologies
- ✓ Mechanical pressure-control products
- ✓ Electronic pressure-control products

Constant pressure systems that operate by means of variable frequency drives (VFD), electrical pressure switches, or mechanical pressure regulation devices are used in water well applications in which customers desire a more constant supply of water pressure under continuous demand than that offered by typical systems with a pressure switch with a 20 psi spread between turn-on pressure and turn-off pressure. The main purpose of these products is to provide an essentially constant pressure in the water system application, limiting pressure fluctuations to only a few psi. For purposes of this chapter, a constant pressure system is defined as:

“A pumping system designed to maintain a relatively constant source of pressure around a selected pressure setpoint, regardless of demand, by controlling the speed of the motor, reducing the pressure differential of the pressure switch or operation of other mechanical components, based on feedback from a pressure-sensing device.”

There are many residential, agricultural/ irrigation, and commercial/industrial/municipal applications that require a source of constant water pressure. Constant pressure systems currently on the market are generally capable of providing this pressure in one form or another. Tolerances of allowed pressure fluctuations vary among system designs. It is not the intent of this document to compare the differing specifications of units on the market, but to provide an overview of current technologies.

Constant pressure systems are broadly separated into two categories: **mechanical pressure-control products** and **electronic/electrical pressure-control products**. Mechanical products are comprised of pressure-control valve devices and flow-regulating valve devices. Electronic (electrical) products encompass all systems that utilize a **variable frequency drive (VFD)** to change the speed of the pump motor or pressure switches/controls that have the differential pressure reduced.

In addition to providing an overview of these constant pressure technologies, this chapter will discuss some operational details.

I. MECHANICAL PRESSURE-CONTROL PRODUCTS

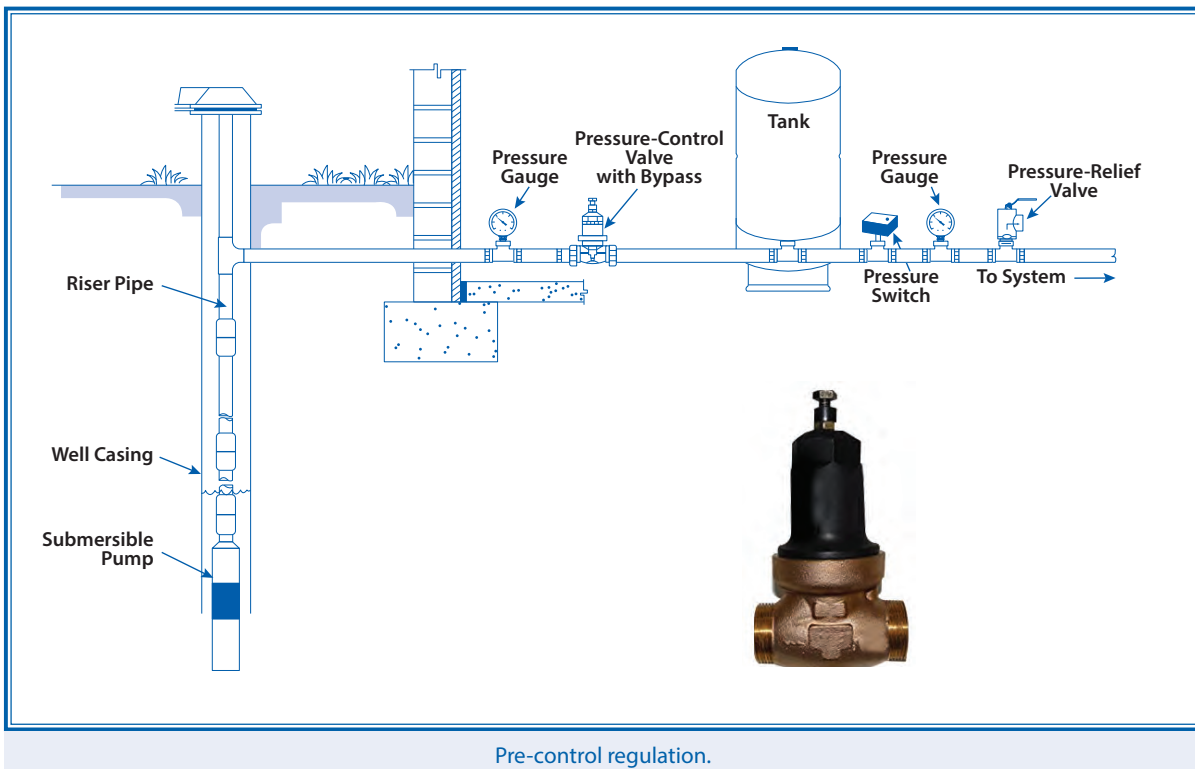
In well water supply systems, mechanical pressure-control devices are divided into two groups: **control devices** and **control bypass devices**.

Regulating devices

Regulating devices are divided into **pre-control regulation** and **post-control regulation** types. The control is the means of turning the pump on or off and is typically comprised of a pressure activated switch (**pressure switch**) that can interrupt power to the pump, either directly or by a secondary control circuit.

Devices to control the demand pressure and flow can be used to reduce the cyclic effect of conventional water pump controls, and are used to ensure constant pressure. These valves provide a constant pressure over a wide range of flow rates. Additionally, these systems (1) allow the use of a smaller pressure tank if space is a problem, and (2) reduce the amount of electricity because it stops pump cycling and lowers water hammering.

Figure VI.4.1



Pre-control regulation.

NOTE: Be sure to address the higher pipe pressure and pipe rating (psi) between the pump and the throttling pressure-control valve.

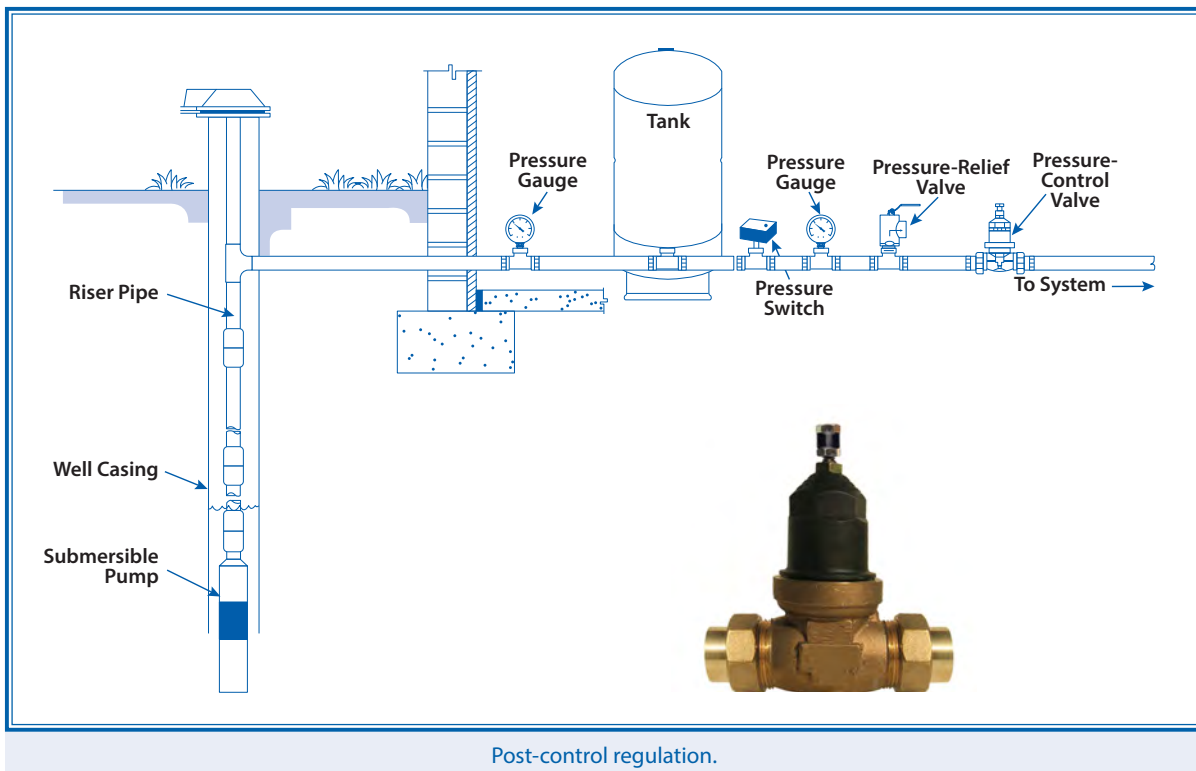
Pre-control regulation in the supply line can be utilized if the regulation can be set below the pressure switch cut out pressure. Generally, this regulator is set halfway between the pump **cut-in and cut-out pressures**. This setting will maintain pump power and limit cycling while supplying regulated pressure. In order to turn off the pump power, a regulator is required. This bypass must be sized in such a way that it will not affect regulation during periods of demand. Differential pressure regulated valves maintain constant pressure throughout a range of demand and bypass control valves, which can be used to adjust bleed rate and dictate cycle time. The valve orifice or bypass rate must be adequate to provide motor cooling in low flow conditions. Some motor manufacturers recommend using a flow inducing sleeve to be sure the motor is cooled at the low flow rates.

The **pressure-control valve (PCV)** with bypass (Figure VI.4.1, page 32) allows the pressure to go from the pump cut-in to the set regulated pressure (pressure below pump cut-out) and continues to deliver the preset pressure until the demand ends. When the demand ends, the pump raises the system pressure through the bypass to the cut-out pressure sensed by the pressure switch, allowing the pump to shut off. The water pumped through the regulator bypass is stored in the **pressure tank**. When there is demand, water is initially drawn from the pressure tank until system cut-in pressure is attained.

Pre-control regulating devices can offer constant pressure after a single pressure drawdown and a return to the set point and continued demand. With proper regulator bypass control and pressure tank sizing, pump operation can be optimized. Several manufacturers offer regulators with internally calibrated bypasses that allow simplified installation and preset calibration.

Regulating line (system) pressure downstream of the pressure tank and pressure switch (Figure VI.4.2) will supply regulated pressure within full flow range of the pump curve. All pressure-control valves (PCV) in this application are automatically self-compensating for downstream pressure fluctuation regardless of flow rate. These types of PCVs are used for regulating constant pressure in municipal water distribution systems, pump booster systems in high rise buildings, and irrigation systems, etc. The resultant backpressure requires consideration in control settings and tank sizing; this application requires the sizing of the pressure tank as described in Book VIII, Chapter 3.

Figure VI.4.2



Post-control regulation.

Control bypass devices

After pump startup, a **control bypass device** is used to eliminate the pressure switch control from the pump run circuit. When the pump is allowed to run at full service, pump and pipe size considerations must be made with regard to service demands. System pressure is regulated by the pump performance curve, relative to demand.

Control bypass devices are available in the form of **flow switch controls** (flow switch activation of electrical circuits to maintain pump power during flow).

A simple **flow switch control** comprised of a flow sensor and contact switch will activate a control relay to bypass the pressure switch power contacts at times of flow. When this bypass circuit is active, the pump will continue to run until demand flow has ended and the expansion tank pressure has reached maximum pump head. A pressure tank is used to limit frequent starts and short run times. Circuit timers can be incorporated to enhance the pump cycle run times.

Operation of this type of system results in **maximum pump head** system pressure. Upon demand, the system pressure falls, emptying the expansion tank to pump cut-in pressure; the pump starts and the power bypass circuit allows the pump to operate at full capacity in relation to flow. When demand ends and the expansion tank is filled to maximum pump head, the flow is stopped or reduced to a preset minimum flow, and the pressure switch resumes control of pump power. The system pressure at this time is above cut-out pressure, and the pressure switch interrupts the power to the pump.

II. ELECTRONIC PRESSURE-CONTROL PRODUCTS

Electronic variable speed pump controllers in the water industry employ a **variable frequency drive (VFD)** to maintain constant pressure in a water system by changing the speed of the pump to match the variations in demand for water. Based on feedback, typically from a pressure sensor, the VFD adjusts the **frequency** sent to the motor in order to change the speed of the pump and maintain a constant pressure. By increasing frequency, the speed of the pump is increased. Conversely, decreasing the frequency reduces the speed of the pump.

There are currently two major types of variable speed pump controllers in the water well industry: integrated variable speed pump control systems and non-integrated variable speed pump control systems.

Integrated systems contain VFD electronics that are integrated into the motor unit. These systems are continually submerged in cool groundwater to cool the VFD circuitry.

Non-integrated systems locate the VFD electronics at the surface, separate from the pump and motor, and are used to power conventional submersible motors. Non-integrated VFDs can be adapted to most conventional submersible pumps with proper programming and sizing, but some non-integrated VFD devices available in the industry are built specifically for conventional pumps and do not require additional programming.

VFD fundamentals

As Figure VI.4.3 illustrates, increasing the frequency of the sinusoidal power waveform applied to the motor increases the speed of the motor. In a conventional submersible application in the United States, motors receive AC voltage at a constant frequency of 60 Hz, which fixes their speed at one value.

Synchronous speed or revolutions per minute (rpm) in an induction motor is determined by the equation:

$$\text{rpm} = \left(\frac{120 \times \text{Frequency}}{\# \text{ poles}} \right)$$

From this relation, it can be seen that motor speed can be changed by altering either the frequency applied to the motor, or the number of poles in the motor. The number of poles in a motor is a matter of physical construction; changing this number is an impractical and inefficient way to dynamically change motor speeds.

The lower operating frequency of a VFD-controlled constant pressure system can be estimated from the 60 Hz performance curve using the following equation:

Lower Operating Frequency =

$$\sqrt{(\text{Required TDH at low flow conditions} / \text{Curve TDH at low flow conditions}) \times \text{line frequency}}$$

The primary components of the required TDH are the target pressure (multiplied by 2.31 to convert to feet), the static well level, well drawdown, and friction loss between the pump and the point at which the pressure is being monitored.

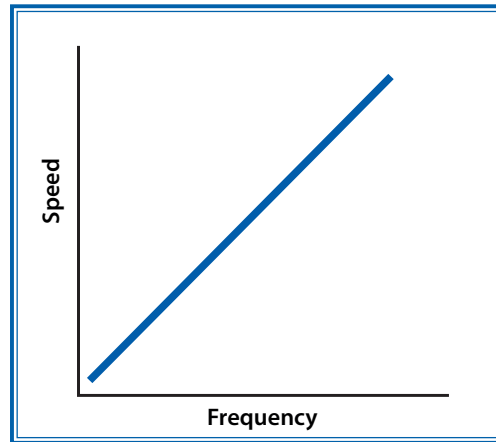
If the system has negligible drawdown and friction loss, the required TDH remains relatively constant regardless of flow. Using the example shown in Figure VI.4.4, the lower operating frequency would be $\sqrt{(449/706)} \times 60 \text{ Hz} = 48 \text{ Hz}$.

Often both friction and drawdown are reduced when operating at lower flows. In these instances, the TDH the pump needs to provide is reduced. Using the example shown in Figure VI.4.4, the lower operating frequency would be $\sqrt{(298/706)} \times 60 \text{ Hz} = 36 \text{ Hz}$.

The curves in Figure VI.4.4 demonstrate that the greatest opportunity to reduce the operating speed of the pump occurs on pumps with high head rise to shutoff, significant well drawdown, and/or friction loss.

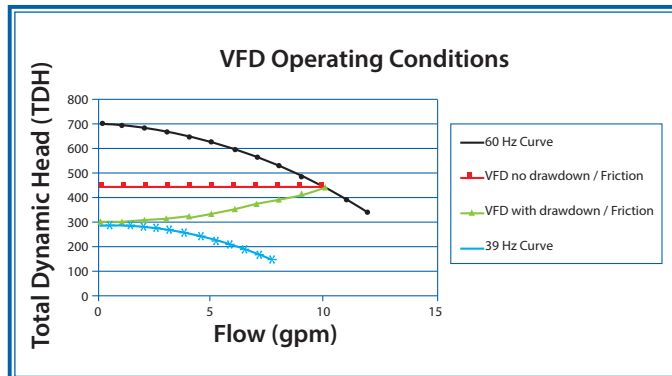
VFD systems typically use a technique referred to as **pulse width modulation (PWM)** to control the speed of the motor. The VFD circuitry creates a high voltage DC power source from the single-phase or three-phase AC input. This high DC voltage is smoothed by filtering and fed to power transistors, which are operated as very fast switches turning on and off. When they are on, full power is applied to the motor, and, when off, zero power is applied.

Figure VI.4.3



Motor speed changes linearly with the frequency applied.

Figure VI.4.4

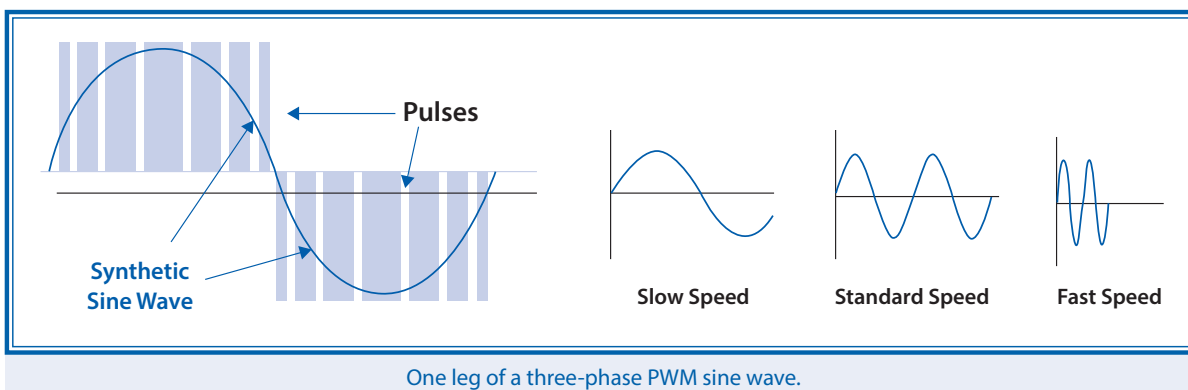


Operating range of a typical VFD-driven pump.

Three-phase power is created with this technique, so the motor is being driven with pulses of power on each phase. The amount of time these transistors are turned on is determined by a microprocessor that measures the load demand typically supplied by a pressure sensor. The microprocessor then adjusts motor power and motor speed by varying the time the transistors remain on or off. Each pulse can be shortened or lengthened in duration. A lengthening of the pulses applies more power to the motor and a shortening of the pulses applies less. The mean value of these pulses forms an artificial sinusoidal voltage of the desired **frequency** and amplitude. By speeding up or slowing down the pattern shown in Figure VI.4.5, the apparent frequency, and thus motor rpm, can be changed.

To sense changes in demand, typical VFD **constant pressure systems** rely on either a pressure sensor or a pressure switch. A pressure sensor provides a continuous and exact measurement of pressure over a wide range, while a pressure switch is set to a fixed target pressure and operates over a cut-in/cut out differential of about 1 psi or less, compared with a traditional pressure switch operating with a differential of 20 psi. The VFD reads this information and adjusts the speed accordingly in order to maintain the target pressure. It is important to note that pressure switches used in VFD constant pressure systems are not standard pressure switches and are not interchangeable. These are typically special low-voltage switches that have a small differential (< 1 psi) and do not carry a load across the contacts. Each device has its own characteristics and consultation of the manufacturer might be necessary.

Figure VI.4.5



Application

Variable speed pump controllers have been used for industrial and light commercial water systems applications for many years. Customers purchase residential variable speed pump controllers to provide a more constant pressure supply of water than can be delivered by conventional systems. These constant pressure systems typically limit pressure fluctuations to only a few psi, which is undetectable by end users. A conventional system utilizing a 30-50 psi pressure switch can experience pressure fluctuations up to 20 psi, which is more easily detectable.

In addition to household uses, variable speed pump controllers are employed to maintain even distribution of water in symmetrical or larger irrigation zones. Additionally, these systems are used in **ground source heat pumps** to maintain constant pressure in the household, reducing the need for water storage, and minimize pump cycling. Occasionally, these devices are used as boosters to increase and maintain pressure in a water system that supplies insufficient pressure. Other advantages include improved efficiency and lower motor maintenance.

In the environmental industry, variable speed pump controllers are commonly used in remediation and groundwater sampling applications. A typical example is maintaining a constant water level in wells surrounding landfills, in which the speed of the pump is adjusted according to water levels in the well. Purging of monitoring wells and sampling at low flow rates are other common uses for these devices in environmental applications. Industrial and light commercial customers have used VFD for constant pressure applications.

Pressure tanks with variable speed controllers

There is a major difference between constant pressure systems and traditional pump systems. In constant pressure systems, the pressure tank does not control the operation of the pump as it does in traditional pump systems where the **pressure tank** is utilized for storage and to minimize pump cycling and provide adequate drawdown for minimum pump run time. In a constant pressure system, the tank is used more as a cushion to smooth water flow past the pressure sensing device.

In constant pressure applications, the pump starts almost immediately and continues to run while there is demand, so that the drawdown in the pressure tank is minimal. Pressure tanks used with variable-speed pump control systems act primarily to minimize pressure fluctuations and provide enough water to meet initial flow and pressure demands until the pump satisfies demand, typically in a matter of a few seconds.

Pressure tank requirements vary by product and manufacturer, so refer to the manufacturer's recommendations to ensure proper operation.

VFD-powered variable-speed pump controller systems offered by various manufacturers are equipped with a range of differing features, but most share the common benefit of providing customers with a source of constant water pressure. All VFDs are driven by intelligent microprocessor designs that allow the addition of built-in motor protection features not typically found on traditional pressure switch systems unless added as accessories.

Some features common to both integrated and non-integrated VFD systems are the following:

- Dry run protection - Moving parts in a pump are water-lubricated, and if run for any length of time without that lubrication, the pump will be damaged. Systems employ various methods to detect dry run and can shut off the pump, protecting it from damage.
- Soft start - Traditional pumping systems are started and stopped by the opening and closing of a relay contact, which instantaneously applies full voltage and current to the motor windings. The resulting large inrush currents produce a temporary overheating of the windings. Additionally, the mass of the rotor goes from a dead rest to full speed in an instant, generating a strong mechanical torque. Both of these by-products cause wear and tear on the motor and pump end. Thus, a VFD-driven motor can withstand many more start-stop cycles in a given period of time than a relay contact-driven motor.

A soft-starter provides a gradual increase of voltage when the power is applied to the motor, reducing the amount of inrush. A VFD does the same thing when power is applied to the motor. However, while running, the VFD regulates the speed of the motor through a predetermined band of frequencies while a soft starter regulates the motor voltage only for a short pre-programmed time period at startup, but runs at full speed after the time has expired.

- **Overload** - VFD electronics can detect overload conditions immediately and shut a pump down to preserve the life of the motor. VFD reaction times are much quicker and more accurate than traditional thermal relay protection devices. Motor manufacturers have criteria for max amperage. Consult with the motor manufacturer to set amperage values correctly.
- **Overvoltage and undervoltage** - Fluctuation in voltage supplies, common in some parts of the country, can cause excessive heating or loading of unprotected motors, resulting in reduced lifetimes. VFDs do not apply line voltage directly to the motor. The VFD circuitry acts as a buffer between line voltage and the motor, and by design can accept wide tolerances in input voltages and still provide stable, regulated power to the motor. Every VFD manufacturer sets specific design limitations for overvoltage and undervoltage criteria. Consult with the manufacturer for specific details.
- **Motor speed and power consumption** - Motor speed and power consumption data are provided by integrated drives containing electronic intelligence in the motor, and may be available in some non-integrated drives. This information provides useful insights into the operation and performance of the pump and motor, and serves as a guide in troubleshooting problems. Naturally, power consumption changes with the speed of the motor.

Pressure switches (controls)

Pressure switches (controls) can be either electrical/mechanical (Figure VI.4.6) or electronic/solid state (Figure VI.4.7). They monitor and control the water system by electrically “starting” or “stopping” the pump at pre-set water system pressures. Pressure switches are used on any model submersible, reciprocating and jet pump system and are normally set at the factory with a 20 psig differential pressure. Since most well systems use these switch controls, the system is normally referred to as a “conventional system.” Some consumers are now requesting that the system have a narrower pressure differential. To meet these demands, some pressure switches, also referred to as controls, have now been designed with differential pressures down to 8 psig or ± 4 psig from what is referred to as the set point or the halfway pressure point in order to provide a more “constant pressure.” These pressure switches can still be adjusted in the field for different pressure ranges. When using a differential less than 20 psig, a larger pressure tank is required in order to maintain a minimum run time. Consult the pressure tank manufacturer.

Figure VI.4.6



An example of a typical, standard electrical/mechanical pressure switch.

Figure VI.4.7



Examples of electronic/solid state pressure switches.

Electrical/Mechanical

Some of the features are:

- Narrower differential pressure: Pressure differentials down to ± 6 psig are available to work as a constant pressure system.
- User-friendly: Able to be used with any pump. Easy to retrofit.
- Manual on/off switch: Allows optional on/off for the pressure switch to manually turn off the pump system for extended periods of time.
- Heavy-duty pressure switches: Can be used for up to 5 hp pumps without using a magnetic starter.
- Automatic low pressure/water cut off: If system pressure is lost for any reason, a low water condition for example, the automatic lower pressure/water cut-off feature will open the contacts, turning off the pump. Low water or loss of water or system pressure will cause the pump to be cut off. After the fault in the system has been corrected, the pressure switch has to be manually reset with the provided lever.

Electronic/Solid State Pressure Switches (Controls)

Some of the features are:

- Narrower pressure differential: Some solid state controls provide pressure differentials down to ± 4 psig. Using the lower differential pressure requires that the size of the pressure tank be increased. Consult the pressure tank manufacturer.
- Solid state controls: The contacts are solid state and are not affected by moisture, ants, etc., or rapid cycling.
- Solid state components: Digital gauge provides the contractor with an accurate pressure reading when diagnosing the system.
- Diagnostics: Assist the contractor in determining the cause of the problem by providing low pressure cut-off with automatic reset, rapid cycle indicator to identify a leak in the tank, and automatic shut-off and reset when voltage varies beyond $\pm 10\%$.
- Analog output: Some electronic controls provide an optional analog output to use with drive applications for constant pressure systems or auxiliary pressure monitoring.
- User-friendly: Electronic/solid state pressure switches/controls can be used with any existing pump. They do not have to be specified to work with certain pumps. Follow the specifications for pump size, amperage, and voltage requirements.

Just like mechanical switches, electronic controls have a maximum hp rating of 2hp (230v, single-phase). These switches/controls directly control all types of pumps up to 5 hp when used in the control circuit of a magnetic starter. Additionally, some electronic controls have a relay output (example, 3 amps) and can be used in the control circuit of a magnetic starter or control panel for pump control.

Study Guide Questions - Chapter 4

Answers can be found on page 63

Q. What is a constant pressure system?

Q. Where are constant pressure systems used?

Q. Name the two main categories of constant pressure systems:?

1.

2.

Notes

Appendix

Cable Selection Charts 43

Table 1: Single-Phase Two- or Three-Wire Cable, 60 Hz..... 44

Table 2: Three-Phase Three-Lead 60°C Cable, 60 Hz..... 46

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Table 5: Three-Phase Six-Lead 75°C Cable, 60 Hz 51

Metric Standards Table..... 52



Recommended Cable Selections

Single-Phase Submersible Pump Installations

The following tables are recommended for use as a standard water industry reference for the selection of submersible cable size. These tables are based on maximum motor running current rather than on the particular motor characteristic or motor manufacturer's requirements.

NOTE: These charts are applicable only to single-phase (capacitor-start and two-wire) and three-phase submersible motors. Due to their inherent differences in starting characteristics, wire selection method for PSC (permanent split capacitor) and split-phase motors should be handled according to the manufacturer's recommendations.

The following data were used to develop these tables:

- Wire size selection is based on the maximum amperes shown on motor nameplate and assumes a power factor of 80 percent.
- Voltages at the service entrance will be the rated voltage, i.e., 115, 200, 230, 460 or 575 (this is the 60 Hertz voltage assumed to be available at the service entrance).
- Voltage at the motor shall be at least 95 percent of service-entrance voltage with the motor running during normal operating conditions.
- Cable lengths are based on one continuous wire size run from the service entrance to the motor terminals (rather than breaking down into different sizes for supply and drop cable).
- Maximum ampacity for wire was taken from the National Electrical Code (NEC) Table 310-16, Column 1, for wire types TW and UF, having a temperature rating of 60°C. Not more than three current-carrying conductors are used in raceway, cable or direct burial (based on ambient temperature of 30°C).
- Maximum motor amps is the ampacity divided by 1.25 as specified in NEC article 430-22 for motor branch circuits.

VALUES FOR THE TABLES ARE AS FOLLOWS:									
@ 140°F (60°C)									
NEC REFERENCE	AWG WIRE SIZE (COPPER)	#14	#12	#10	#8	#6	#4	#2	#0
NEC 310-16	Max. Conductor Ampacity	20	25	30	40	55	70	95	125
NEC 430-22	Max. Motor Amps	12	16	24	40	52	68	92	120

**Recommended Cable Selections
Single-Phase Submersible Pump Installations**

TABLE 1

Cable selection for SINGLE-PHASE TWO- OR THREE-WIRE CABLE, 60 Hz Service Entrance to Motor – Maximum Length in Feet															
Motor Rating			60°C Insulation - AWG Copper Wire Size												
Volts	HP	KW	14	12	10	8	6	4	3	2	1	0	00	000	0000
115	1/2	.37	100	160	250	390	620	960	1190	1460	1780	2160	2630	3140	3770
230	1/2	.37	400	650	1020	1610	2510	3880	4810	5880	7170	8720			
	3/4	.55	300	480	760	1200	1870	2890	3580	4370	5330	6470	7870		
	1	.75	250	400	630	990	1540	2380	2960	3610	4410	5360	6520		
	1 1/2	1.1	190	310	480	770	1200	1870	2320	2850	3500	4280	5240		
	2	1.5	150	250	390	620	970	1530	1910	2360	2930	3620	4480		
	3	2.2	120	190	300	470	750	1190	1490	1850	2320	2890	3610		
	5	3.7	0	0	180	280	450	710	890	1110	1390	1740	2170	2680	
	7 1/2	5.5	0	0	0	200	310	490	610	750	930	1140	1410	1720	
	10	7.5	0	0	0	0	250	390	490	600	750	930	1160	1430	1760
	15	11	0	0	0	0	170	270	340	430	530	660	820	1020	1260

Motor Rating			75°C Insulation - AWG Copper Wire Size												
Volts	HP	KW	14	12	10	8	6	4	3	2	1	0	00	000	0000
115	1/2	.37	100	160	250	390	620	960	1190	1460	1780	2160	2630	3140	3770
230	1/2	.37	400	650	1020	1610	2510	3880	4810	5880	7170	8720			
	3/4	.55	300	480	760	1200	1870	2890	3580	4370	5330	6470	7870	9380	
	1	.75	250	400	630	990	1540	2380	2960	3610	4410	5360	6520	7780	9350
	1 1/2	1.1	190	310	480	770	1200	1870	2320	2850	3500	4280	5240	6300	7620
	2	1.5	150	250	390	620	970	1530	1910	2360	2930	3620	4480	5470	6700
	3	2.2	120	190	300	470	750	1190	1490	1850	2320	2890	3610	4470	5550
	5	3.7	0	110	180	280	450	710	890	1110	1390	1740	2170	2680	3330
	7 1/2	5.5	0	0	120	200	310	490	610	750	930	1140	1410	1720	2100
	10	7.5	0	0	0	160	250	390	490	600	750	930	1160	1430	1760
	15	11	0	0	0	0	170	270	340	430	530	660	820	1020	1260

1 Foot = .3048 Meter

Lengths **not** in bold type meet the U.S. National Electrical Code ampacity for either individual conductors or jacketed 60°C or 75°C cable.

Lengths in bold type meet the National Electric Code ampacity only for individual conductor 60°C or 75°C cable, in free air or water, not in magnetic enclosure or conduit. If any other cable is used, the National Electric Code as well as the local codes should be observed. Flat molded and web cable is considered jacketed cable.

Cable lengths in Table 1 above allow for a 5% voltage drop running at maximum nameplate amperes. If 3% voltage drop is desired multiply Table 1 lengths by .6 to get maximum cable length.

Continued on next page

Table 1 (page 44) is based on copper wire. If aluminum wire is used, it must be two sizes larger than copper wire and oxidation inhibitors must be used on connectors.

Example: If Table 1 (page 44) calls for #12 copper wire, #10 aluminum wire would be required.

The portion of the total cable length which is between the supply and single-phase control box with a line contactor, should not exceed 25% of total maximum allowable to ensure reliable contactor operation. Single-phase control boxes without line contactors may be connected at any point in the total cable length.

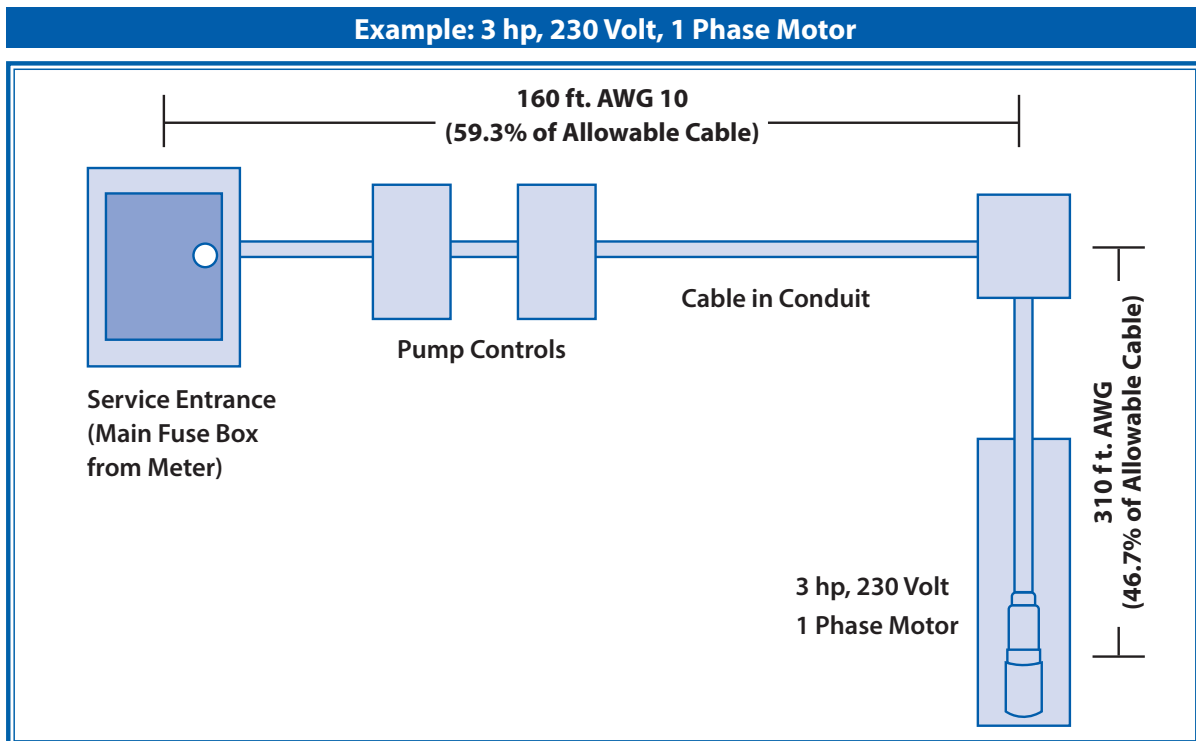
Two different cable sizes can be used.

Depending on the installation, any number of combinations of cable may be used.

For example, in a replacement installation, the well already has 160 feet of buried #10 cable between the service entrance and the well head. The question is: What size cable is required in the well with a 3 hp, 230 volt, single-phase motor setting at 310 feet?

1. From Table 1, a 3 hp motor can use up to 300 feet of #10 AWG cable.
2. The application has 160 feet of buried #10 AWG cable.
3. 160 feet divided by 300 feet (max allowable) is equal to 53.3% of max allowable.
4. $100\% - 53.3\% = 46.7\%$ remaining of another cable size.
5. 310 feet (well head to motor) is 46.7% of max allowable length of another cable size.
6. 310 feet divided by .467 (46.7%) = 664 feet is max allowable.
7. 664 feet is less than or equal to what size cable in Table 1 under the 3 hp listing.

The table shows #8 is good for 470 feet, which is too short. #6 is good for 750 feet, therefore #6 can be used for the remaining 310 feet.



Recommended Cable Selections
Three-Phase Submersible Pump Installations

TABLE 2

Cable selection for THREE-PHASE THREE-LEAD 60°C CABLE, 60Hz (Service entrance to motor) Maximum length in feet																					
Motor Rating			60°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size					
Volts	HP	KW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500	
200V 60HZ Three-Phase 3 - Lead	1/2	0.37	710	1140	1800	2840	4420														
	3/4	0.55	510	810	1280	2030	3160														
	1	0.75	430	690	1080	1710	2670	4140	5140												
	1 1/2	1.1	310	500	790	1260	1960	3050	3780												
	2	1.5	240	390	610	970	1520	2360	2940	3610	4430	5420									
	3	2.2	180	290	470	740	1160	1810	2250	2760	3390	4130									
	5	3.7	110	170	280	440	690	1080	1350	1660	2040	2490	3050	3670	4440	5030					
	7 1/2	5.5	0	0	200	310	490	770	960	1180	1450	1770	2170	2600	3150	3560					
	10	7.5	0	0	0	230	370	570	720	880	1090	1330	1640	1970	2390	2720	3100	3480	3800	4420	
	15	11	0	0	0	160	250	390	490	600	740	910	1110	1340	1630	1850	2100	2350	2570	2980	
	20	15	0	0	0	0	190	300	380	460	570	700	860	1050	1270	1440	1650	1850	2020	2360	
	25	18.5	0	0	0	0	0	240	300	370	460	570	700	840	1030	1170	1330	1500	1640	1900	
30	22	0	0	0	0	0	0	0	250	310	380	470	580	700	850	970	1110	1250	1360	1590	
230V 60 HZ Three-Phase 3 - Lead	1/2	0.37	930	1490	2350	3700	5760	8910													
	3/4	0.55	670	1080	1700	2580	4190	6490	8060	9860											
	1	0.75	560	910	1430	2260	3520	5460	6780	8290											
	1 1/2	1.1	420	670	1060	1670	2610	4050	5030	6160	7530	9170									
	2	1.5	320	510	810	1280	2010	3130	3890	4770	5860	7170	8780								
	3	2.2	240	390	620	990	1540	2400	2980	3660	4480	5470	6690	8020	9680						
	5	3.7	140	230	370	590	920	1430	1790	2190	2690	3290	4030	4850	5870	6650	7560	8460	9220		
	7 1/2	5.5	0	160	260	420	650	1020	1270	1560	1920	2340	2870	3440	4160	4710	5340	5970	6500	7510	
	10	7.5	0	0	190	310	490	760	950	1170	1440	1760	2160	2610	3160	3590	4100	4600	5020	5840	
	15	11	0	0	0	210	330	520	650	800	980	1200	1470	1780	2150	2440	2780	3110	3400	3940	
	20	15	0	0	0	0	250	400	500	610	760	930	1140	1380	1680	1910	2180	2450	2680	3120	
	25	18.5	0	0	0	0	0	320	400	500	610	750	920	1120	1360	1540	1760	1980	2160	2520	
30	22	0	0	0	0	0	260	330	410	510	620	760	930	1130	1280	1470	1650	1800	2110		
380V 60 HZ Three-Phase 3 - Lead	1/2	0.37	2690	4290	6730																
	3/4	0.55	2000	3190	5010	7860															
	1	0.75	1620	2580	4060	6390	9980														
	1 1/2	1.1	1230	1970	3100	4890	7630														
	2	1.5	870	1390	2180	3450	5400	8380													
	3	2.2	680	1090	1710	2690	4200	6500	8020	9830											
	5	3.7	400	640	1010	1590	2490	3870	4780	5870	7230	8830									
	7 1/2	5.5	270	440	690	1090	1710	2640	3260	4000	4930	6010	7290	8780							
	10	7.5	200	320	510	800	1250	1930	2380	2910	3570	4330	5230	6260	7390	8280	9340				
	15	11	0	0	370	590	920	1430	1770	2170	2690	3290	4000	4840	5770	6520	7430	8250	8990		
	20	15	0	0	0	440	700	1090	1350	1670	2060	2530	3090	3760	4500	5110	5840	6510	7120	8190	
	25	18.5	0	0	0	360	570	880	1100	1350	1670	2050	2510	3040	3640	4130	4720	5250	5740	6590	
	30	22	0	0	0	0	470	730	910	1120	1380	1700	2080	2520	3020	3430	3920	4360	4770	5490	
	40	30	0	0	0	0	0	530	660	820	1010	1240	1520	1840	2200	2500	2850	3170	3470	3990	
	50	37	0	0	0	0	0	0	540	660	820	1000	1220	1480	1770	2010	2290	2550	2780	3190	
	60	45	0	0	0	0	0	0	0	560	690	850	1030	1250	1500	1700	1940	2150	2350	2700	
	75	55	0	0	0	0	0	0	0	0	570	700	860	1050	1270	1440	1660	1850	2030	2350	
	100	75	0	0	0	0	0	0	0	0	0	510	630	760	910	1030	1180	1310	1430	1650	
	125	90	0	0	0	0	0	0	0	0	0	0	0	0	620	740	840	950	1060	1160	1330
	150	110	0	0	0	0	0	0	0	0	0	0	0	0	0	620	700	790	880	960	1090
175	130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	650	750	840	920	1070	
200	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	630	700	760	880	

Continued on next page

**Recommended Cable Selections
Three-Phase Submersible Pump Installations**

TABLE 2 (continued)

Cable selection for THREE-PHASE THREE-LEAD 60°C CABLE, 60Hz (Service entrance to motor) Maximum length in feet																					
Motor Rating			60°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size					
Volts	HP	KW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500	
460V 60HZ Three-Phase 3 - Lead	1/2	0.37	3770	6020	9460																
	3/4	0.55	2730	4350	6850																
	1	0.75	2300	3670	5770	9070															
	1 1/2	1.1	1700	2710	4270	6730															
	2	1.5	1300	2070	3270	5150	8050														
	3	2.2	1000	1600	2520	3970	6200														
	5	3.7	590	950	1500	2360	3700	5750													
	7 1/2	5.5	420	680	1070	1690	2640	4100	5100	6260	7680										
	10	7.5	310	500	790	1250	1960	3050	3800	4680	5750	7050									
	15	11	0	340	540	850	1340	2090	2600	3200	3930	4810	5900	7110							
	20	15	0	0	410	650	1030	1610	2000	2470	3040	3730	4580	5530							
	25	18.5	0	0	0	530	830	1300	1620	1990	2450	3010	3700	4470	5430						
	30	22	0	0	0	430	680	1070	1330	1640	2030	2490	3060	3700	4500	5130	5860				
	40	30	0	0	0	0	500	790	980	1210	1490	1830	2250	2710	3290	3730	4250				
	50	37	0	0	0	0	0	640	800	980	1210	1480	1810	2190	2650	3010	3420	3830	4180	4850	
	60	45	0	0	0	0	0	540	670	830	1020	1250	1540	1850	2240	2540	2890	3240	3540	4100	
	75	55	0	0	0	0	0	0	0	680	840	1030	1260	1520	1850	2100	2400	2700	2950	3440	
	100	75	0	0	0	0	0	0	0	0	620	760	940	1130	1380	1560	1790	2010	2190	2550	
	125	90	0	0	0	0	0	0	0	0	0	0	0	740	890	1000	1220	1390	1560	1700	1960
	150	110	0	0	0	0	0	0	0	0	0	0	0	0	760	920	1050	1190	1340	1460	1960
175	130	0	0	0	0	0	0	0	0	0	0	0	0	0	810	930	1060	1190	1300	1510	
200	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	810	920	1030	1130	1310	
575V 60 HZ Three-Phase 3 - Lead	1/2	0.37	5900	9410																	
	3/4	0.55	4270	6810																	
	1	0.75	3630	5800	9120																
	1 1/2	1.1	2620	4180	6580																
	2	1.5	2030	3250	5110	8060															
	3	2.2	1580	2530	3980	6270															
	5	3.7	920	1480	2330	3680	5750														
	7 1/2	5.5	660	1060	1680	2650	4150														
	10	7.5	490	780	1240	1950	3060	4770	5940												
	15	11	330	530	850	1340	2090	3260	4060												
	20	15	0	410	650	1030	1610	2520	3140	3860	4760	5830									
	25	19	0	0	520	830	1300	2030	2530	3110	3840	4710									
	30	22	0	0	430	680	1070	1670	2080	2560	3160	3880	4770	5780	7030	8000					
	40	30	0	0	0	500	790	1240	1540	1900	2330	2860	3510	4230	5140	5830					
	50	37	0	0	0	0	640	1000	1250	1540	1890	2310	2840	3420	4140	4700	5340	5990	6530	7580	
	60	45	0	0	0	0	0	850	1060	1300	1600	1960	2400	2890	3500	3970	4520	5070	5530	6410	
	75	55	0	0	0	0	0	690	860	1060	1310	1600	1970	2380	2890	3290	3750	5220	4610	5370	
	100	75	0	0	0	0	0	0	0	790	970	1190	1460	1770	2150	2440	2790	3140	3430	3990	
	125	90	0	0	0	0	0	0	0	0	770	950	1160	1400	1690	1920	2180	2440	2650	3070	
	150	110	0	0	0	0	0	0	0	0	0	800	990	1190	1440	1630	1860	2080	2270	2640	
175	130	0	0	0	0	0	0	0	0	0	0	870	1050	1270	1450	1650	1860	2030	2360		
200	150	0	0	0	0	0	0	0	0	0	0	0	920	1110	1260	1440	1620	1760	2050		

Recommended Cable Selections
Three-Phase Submersible Pump Installations

TABLE 3

Cable selection for THREE-PHASE SIX-LEAD 60°C CABLE, 60HZ																				
Motor Rating			60°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size				
Volts	HP	KW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500
200V 60HZ Three-Phase 6 - Lead Y -D	5	3.7	160	250	420	660	1030	1620	2020	2490	3060	3730	4570	5500	6660	7540				
	7 1/2	5.5	110	180	300	460	730	1150	1440	1770	2170	2650	3250	3900	4720	5340				
	10	7.5	80	130	210	340	550	850	1080	1320	1630	1990	2460	2950	3580	4080	4650	5220	5700	6630
	15	11	0	0	140	240	370	580	730	900	1110	1360	1660	2010	2440	2770	3150	3520	3850	4470
	20	15	0	0	0	170	280	450	570	690	850	1050	1290	1570	1900	2160	2470	2770	3030	3540
	25	18.5	0	0	0	140	220	360	450	550	690	850	1050	1260	1540	1750	1990	2250	2460	2850
	30	22	0	0	0	0	180	294	370	460	570	700	870	1050	1270	1450	1660	1870	2040	2380
230V 60HZ Three-Phase 6 - Lead Y -D	5	3.7	210	340	550	880	1380	2140	2680	3280	4030	4930	6040	7270	8800	9970				
	7 1/2	5.5	150	240	390	630	970	1530	1900	2340	2880	3510	4300	5160	6240	7060	8010	8950	9750	
	10	7.5	110	180	280	460	730	1140	1420	1750	2160	2640	3240	3910	4740	5380	6150	6900	7530	8760
	15	11	0	0	190	310	490	780	970	1200	1470	1800	2200	2670	3220	3660	4170	4660	5100	5910
	20	15	0	0	140	230	370	600	750	910	1140	1390	1710	2070	2520	2860	3270	3670	4020	4680
	25	18.5	0	0	0	190	300	480	600	750	910	1120	1380	1680	2040	2310	2640	2970	3240	3780
	30	22	0	0	0	150	240	390	490	610	760	930	1140	1390	1690	1920	2200	2470	2700	3160
380V 60HZ Three-Phase 6 - Lead Y -D	5	3.7	600	960	1510	2380	3730	5800	7170	8800										
	7 1/2	5.5	400	660	1030	1630	2560	3960	4890	6000	7390	9010								
	10	7.5	300	480	760	1200	1870	2890	3570	4360	5350	6490	7840	9390						
	15	11	210	340	550	880	1380	2140	2650	3250	4030	4930	6000	7260	8650	9780				
	20	15	160	260	410	660	1050	1630	2020	2500	3090	3790	4630	5640	6750	7660	4260	9760		
	25	18.5	0	210	330	540	850	1320	1650	2020	2500	3070	3760	4560	5460	6190	7080	7870	8610	9880
	30	22	0	0	270	430	700	1090	1360	1680	2070	2550	3120	3780	4530	5140	5880	6540	7150	8230
	40	30	0	0	0	320	510	790	990	1230	1510	1860	2280	2760	3300	3750	4270	4750	5200	5980
	50	37	0	0	0	250	400	630	810	990	1230	1500	1830	2220	2650	3010	3430	3820	4170	4780
	60	45	0	0	0	0	340	540	660	840	1030	1270	1540	1870	2250	2550	2910	3220	3520	4050
	75	55	0	0	0	0	0	450	550	690	855	1050	1290	1570	1900	2160	2490	2770	3040	3520
	100	75	0	0	0	0	0	0	420	520	640	760	940	1140	1360	1540	1770	1960	2140	2470
	125	90	0	0	0	0	0	0	0	400	490	600	730	930	1110	1260	1420	1590	1740	1990
	150	110	0	0	0	0	0	0	0	0	420	510	620	750	930	1050	1180	1320	1440	1630
	175	130	0	0	0	0	0	0	0	0	360	440	540	660	780	970	1120	1260	1380	1600
		200	150	0	0	0	0	0	0	0	0	0	0	480	580	690	790	940	1050	1140
460V 60HZ Three-Phase 6 - Lead Y -D	5	3.7	880	1420	2250	3540	5550	8620												
	7 1/2	5.5	630	1020	1600	2530	3960	6150	7650	9390										
	10	7.5	460	750	1180	1870	2940	4570	5700	7020	8620									
	15	11	310	510	810	1270	2010	3130	3900	4800	5890	7210	8850							
	20	15	230	380	610	970	1540	2410	3000	3700	4560	5590	6870	8290						
	25	18.5	190	310	490	790	1240	1950	2430	2980	3670	4510	5550	6700	8140					
	30	22	0	250	410	640	1020	1600	1990	2460	3040	3730	4590	5550	6750	7690	8790			
	40	30	0	0	300	480	750	1180	1470	1810	2230	2740	3370	4060	4930	5590	6370			
	50	37	0	0	0	370	590	960	1200	1470	1810	2220	2710	3280	3970	4510	5130	5740	6270	7270
	60	45	0	0	0	320	500	810	1000	1240	1530	1870	2310	2770	3060	3810	4330	4860	5310	6150
	75	55	0	0	0	0	420	660	810	1020	1260	1540	1890	2280	2770	3150	3600	4050	4420	5160
	100	75	0	0	0	0	0	500	610	760	930	1140	1410	1690	2070	2340	2680	3010	3280	3820
	125	90	0	0	0	0	0	0	470	590	730	880	1110	1330	1500	1830	2080	2340	2550	2940
	150	110	0	0	0	0	0	0	0	510	630	770	950	1140	1380	1570	1790	2000	2180	2530
	175	130	0	0	0	0	0	0	0	0	550	680	830	1000	1220	1390	1580	1780	1950	2270
		200	150	0	0	0	0	0	0	0	0	0	590	730	880	1070	1210	1380	1550	1690
575V 60HZ Three-Phase 6 - Lead Y -D	5	3.7	1380	2220	3490	5520	8620													
	7 1/2	5.5	990	1590	2520	3970	6220													
	10	7.5	730	1170	1860	2920	4590	7150	8910											
	15	11	490	790	1270	2010	3130	4890	6090											
	20	15	370	610	970	1540	2410	3780	4710	5790	7140	8740								
	25	18.5	300	490	780	1240	1950	3040	3790	4660	5760	7060								
	30	22	240	400	645	1020	1600	2500	3120	3840	4740	5820	7150	8670						
	40	30	0	300	480	750	1180	1860	2310	2850	3490	4290	5260	6340	7710	8740				
	50	37	0	0	380	590	960	1500	1870	2310	2830	3460	4260	5130	6210	7050	8010	8980	9790	
	60	45	0	0	0	500	790	1270	1590	1950	2400	2940	3600	4330	5250	5950	6780	7600	8290	9610
	75	55	0	0	0	420	660	1030	1290	1590	1960	2400	2950	3570	4330	4930	5620	6330	6910	8050
	100	75	0	0	0	0	400	780	960	1180	1450	1780	2190	2650	3220	3660	4180	4710	5140	5980
	125	90	0	0	0	0	0	600	740	920	1150	1420	1740	2100	2530	2880	3270	3660	3970	4600
	150	110	0	0	0	0	0	0	650	800	990	1210	1480	1780	2160	2450	2790	3120	3410	3950
	175	130	0	0	0	0	0	0	0	700	860	1060	1300	1570	1910	2170	2480	2780	3040	3540
		200	150	0	0	0	0	0	0	0	0	760	930	1140	1370	1670	1890	2160	2420	2640

**Recommended Cable Selections
Three-Phase Submersible Pump Installations**

TABLE 4

Cable selection for THREE-PHASE THREE-LEAD 75°C CABLE, 60Hz (Service entrance to motor) Maximum length in feet																				
Motor Rating			75°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size				
Volts	HP	KW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500
200V 60HZ Three-Phase 3 - Lead	1/2	0.37	710	1140	1800	2840	4420													
	3/4	0.55	510	810	1280	2030	3160													
	1	0.75	430	690	1080	1710	2670	4140	5140											
	1 1/2	1.1	310	500	790	1260	1960	3050	3780											
	2	1.5	240	390	610	970	1520	2360	2940	3610	4430	5420								
	3	2.2	180	290	470	740	1160	1810	2250	2760	3390	4130								
	5	3.7	110	170	280	440	690	1080	1350	1660	2040	2490	3050	3670	4440	5030				
	7 1/2	5.5	0	0	200	310	490	770	960	1180	1450	1770	2170	2600	3150	3560				
	10	7.5	0	0	150	230	370	570	720	880	1090	1330	1640	1970	2390	2720	3100	3480	3800	4420
	15	11	0	0	0	160	250	390	490	600	740	910	1110	1340	1630	1850	2100	2350	2570	2980
	20	15	0	0	0	0	190	300	380	460	570	700	860	1050	1270	1440	1650	1850	2020	2360
	25	18.5	0	0	0	0	0	240	300	370	460	570	700	840	1030	1170	1330	1500	1640	1900
	30	22	0	0	0	0	0	200	250	310	380	470	580	700	850	970	1110	1250	1360	1590
230V 60 HZ Three-Phase 3 - Lead	1/2	0.37	930	1490	2350	3700	5760	8910												
	3/4	0.55	670	1080	1700	2580	4190	6490	8060	9860										
	1	0.75	560	910	1430	2260	3520	5460	6780	8290										
	1 1/2	1.1	420	670	1060	1670	2610	4050	5030	6160	7530	9170								
	2	1.5	320	510	810	1280	2010	3130	3890	4770	5860	7170	8780							
	3	2.2	240	390	620	990	1540	2400	2980	3660	4480	5470	6690	8020	9680					
	5	3.7	140	230	370	590	920	1430	1790	2190	2690	3290	4030	4850	5870	6650	7560	8460	9220	
	7 1/2	5.5	0	160	260	420	650	1020	1270	1560	1920	2340	2870	3440	4160	4710	5340	5970	6500	7510
	10	7.5	0	0	190	310	490	760	950	1170	1440	1760	2160	2610	3160	3590	4100	4600	5020	5840
	15	11	0	0	0	210	330	520	650	800	980	1200	1470	1780	2150	2440	2780	3110	3400	3940
	20	15	0	0	0	160	250	400	500	610	760	930	1140	1380	1680	1910	2180	2450	2680	3120
	25	19	0	0	0	0	200	320	400	500	610	750	920	1120	1360	1540	1760	1980	2160	2520
	30	22	0	0	0	0	0	260	330	410	510	620	760	930	1130	1280	1470	1650	1800	2110
380V 60 HZ Three-Phase 3 - Lead	1/2	0.37	2690	4290	6730															
	3/4	0.55	2000	3190	5010	7860														
	1	0.75	1620	2580	4060	6390	9980													
	1 1/2	1.1	1230	1970	3100	4890	7630													
	2	1.5	870	1390	2180	3450	5400	8380												
	3	2.2	680	1090	1710	2690	4200	6500	8020	9830										
	5	3.7	400	640	1010	1590	2490	2870	4780	5870	7230	8830								
	7 1/2	5.5	270	440	690	1090	1710	2640	3260	4000	4930	6010	7290	8780						
	10	7.5	200	320	510	800	1250	1930	2380	2910	3570	4330	5230	6260	7390	8280	9340			
	15	11	0	0	370	590	920	1430	1770	2170	2690	3290	4000	4840	5770	6520	7430	8250	8990	
	20	15	0	0	280	440	700	1090	1350	1670	2060	2530	3090	3760	4500	5110	5840	6510	7120	8190
	25	18.5	0	0	0	360	570	880	1100	1350	1670	2050	2510	3040	3640	4130	4720	5250	5740	6590
	30	22	0	0	0	290	470	730	910	1120	1380	1700	2080	2520	3020	3430	3920	4360	4770	5490
	40	30	0	0	0	0	0	530	660	820	1010	1240	1520	1840	2200	2500	2850	3170	3470	3990
	50	37	0	0	0	0	0	440	540	660	820	1000	1220	1480	1770	2010	2290	2550	2780	3190
	60	45	0	0	0	0	0	370	460	560	690	850	1030	1250	1500	1700	1940	2150	2350	2700
	75	55	0	0	0	0	0	0	0	460	570	700	860	1050	1270	1440	1660	1850	2030	2350
	100	75	0	0	0	0	0	0	0	0	420	510	630	760	910	1030	1180	1310	1430	1650
	125	90	0	0	0	0	0	0	0	0	0	0	0	510	620	740	840	950	1060	1160
	150	110	0	0	0	0	0	0	0	0	0	0	0	0	520	620	700	790	880	960
	175	130	0	0	0	0	0	0	0	0	0	0	0	0	0	560	650	750	840	920
	200	150	0	0	0	0	0	0	0	0	0	0	0	0	0	550	630	700	760	880

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**Recommended Cable Selections
Three-Phase Submersible Pump Installations**

TABLE 4 (continued)

Cable selection for THREE-PHASE THREE-LEAD 75°C CABLE, 60Hz (Service entrance to motor) Maximum length in feet																				
Motor Rating			75°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size				
Volts	HP	KW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500
460V 60HZ Three-Phase 3 - Lead	1/2	0.37	3770	6020	9460															
	3/4	0.55	2730	4350	6850															
	1	0.75	2300	3670	5770	9070														
	1 1/2	1.1	1700	2710	4270	6730														
	2	1.5	1300	2070	3270	5150	8050													
	3	2.2	1000	1600	2520	3970	6200													
	5	3.7	590	950	1500	2360	3700	5750												
	7 1/2	5.5	420	680	1070	1690	2640	4100	5100	6260	7680									
	10	7.5	310	500	790	1250	1960	3050	3800	4680	5750	7050								
	15	11	0	340	540	850	1340	2090	2600	3200	3930	4810	5900	7110						
	20	15	0	0	410	650	1030	1610	2000	2470	3040	3730	4580	5530						
	25	18.5	0	0	330	530	830	1300	1620	1990	2450	3010	3700	4470	5430					
	30	22	0	0	270	430	680	1070	1330	1640	2030	2490	3060	3700	4500	5130	5860			
	40	30	0	0	0	320	500	790	980	1210	1490	1830	2250	2710	3290	3730	4250			
	50	37	0	0	0	0	410	640	800	980	1210	1480	1810	2190	2650	3010	3420	3830	4180	4850
	60	45	0	0	0	0	0	540	670	830	1020	1250	1540	1850	2240	2540	2890	3240	3540	4100
	75	55	0	0	0	0	0	440	550	680	840	1030	1260	1520	1850	2100	2400	2700	2950	3440
	100	75	0	0	0	0	0	0	0	500	620	760	940	1130	1380	1560	1790	2010	2190	2550
	125	90	0	0	0	0	0	0	0	0	0	600	740	890	1000	1220	1390	1560	1700	1960
	150	110	0	0	0	0	0	0	0	0	0	0	630	760	920	1050	1190	1340	1460	1690
175	130	0	0	0	0	0	0	0	0	0	0	0	670	810	930	1060	1190	1300	1510	
200	150	0	0	0	0	0	0	0	0	0	0	0	590	710	810	920	1030	1130	1310	
575V 60 HZ Three-Phase 3 - Lead	1/2	0.37	5900	9410																
	3/4	0.55	4270	6810																
	1	0.75	3630	5800	9120															
	1 1/2	1.1	2620	4180	6580															
	2	1.5	2030	3250	5110	8060														
	3	2.2	1580	2530	3980	6270														
	5	3.7	920	1480	2330	3680	5750													
	7 1/2	5.5	660	1060	1680	2650	4150													
	10	7.5	490	780	1240	1950	3060	4770	5940											
	15	11	330	530	850	1340	2090	3260	4060											
	20	15	0	410	650	1030	1610	2520	3140	3860	4760	5830								
	25	19	0	0	520	830	1300	2030	2530	3110	3840	4710								
	30	22	0	0	430	680	1070	1670	2080	2560	3160	3880	4770	5780	7030	8000				
	40	30	0	0	0	500	790	1240	1540	1900	2330	2860	3510	4230	5140	5830				
	50	37	0	0	0	410	640	1000	1250	1540	1890	2310	2840	3420	4140	4700	5340	5990	6530	7580
	60	45	0	0	0	0	540	850	1060	1300	1600	1960	2400	2890	3500	3970	4520	5070	5530	6410
	75	55	0	0	0	0	0	690	860	1060	1310	1600	1970	2380	2890	3290	3750	5220	4610	5370
	100	75	0	0	0	0	0	0	640	790	970	1190	1460	1770	2150	2440	2790	3140	3430	3990
	125	90	0	0	0	0	0	0	0	630	770	950	1160	1400	1690	1920	2180	2440	2650	3070
	150	110	0	0	0	0	0	0	0	0	660	800	990	1190	1440	1630	1860	2080	2270	2640
175	130	0	0	0	0	0	0	0	0	0	700	870	1050	1270	1450	1650	1860	2030	2360	
200	150	0	0	0	0	0	0	0	0	0	0	760	920	1110	1260	1440	1620	1760	2050	

Recommended Cable Selections Three-Phase Submersible Pump Installations

TABLE 5

Cable selection for THREE-PHASE SIX-LEAD 75°C CABLE, 60Hz																				
Motor Rating			75°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size				
Volts	HP	KW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500
200V 60HZ Three-Phase 6 - Lead Y - D	5	3.7	160	250	420	660	1030	1620	2020	2490	3060	3730	4570	5500	6660	7540				
	7 1/2	5.5	110	180	300	460	730	1150	1440	1770	2170	2650	3250	3900	4720	5340				
	10	7.5	80	130	210	340	550	850	1080	1320	1630	1990	2460	2950	3580	4080	4650	5220	5700	6630
	15	11	0	0	140	240	370	580	730	900	1110	1360	1660	2010	2440	2770	3150	3520	3850	4470
	20	15	0	0	120	170	280	450	570	690	850	1050	1290	1570	1900	2160	2470	2770	3030	3540
	25	18.5	0	0	0	140	220	360	450	550	690	850	1050	1260	1540	1750	1990	2250	2460	2850
	30	22	0	0	0	120	180	294	370	460	570	700	870	1050	1270	1450	1660	1870	2040	2380
230V 60HZ Three-Phase 6 - Lead Y - D	5	3.7	210	340	550	880	1380	2140	2680	3280	4030	4930	6040	7270	8800	9970				
	7 1/2	5.5	150	240	390	630	970	1530	1900	2340	2880	3510	4300	5160	6240	7060	8010	8950	9750	
	10	7.5	110	180	280	460	730	1140	1420	1750	2160	2640	3240	3910	4740	5380	6150	6900	7530	8760
	15	10	0	130	190	310	490	780	970	1200	1470	1800	2200	2670	3220	3660	4170	4660	5100	5910
	20	15	0	0	140	230	370	600	750	910	1140	1390	1710	2070	2520	2860	3270	3670	4020	4680
	15	18.5	0	0	120	190	300	480	600	750	910	1120	1380	1680	2040	2310	2640	2970	3240	3780
	30	22	0	0	0	150	240	390	490	610	760	930	1140	1390	1690	1920	2200	2470	2700	3160
380V 60HZ Three-Phase 6 - Lead Y - D	5	3.7	600	960	1510	2380	3730	5800	7170	8800										
	7 1/2	5.5	400	660	1030	1630	2560	3960	4890	6000	7390	9010								
	10	7.5	300	480	760	1200	1870	2890	3570	4360	5350	6490	7840	9390						
	15	11	210	340	550	880	1380	2140	2650	3250	4030	4930	6000	7260	8650	9780				
	20	15	160	260	410	660	1050	1630	2020	2500	3090	3790	4630	5640	6750	7660	4260	9760		
	25	18.5	0	210	330	540	850	1320	1650	2020	2500	3070	3760	4560	5460	6190	7080	7870	8610	9880
	30	22	0	0	270	430	700	1090	1360	1680	2070	2550	3120	3780	4530	5140	5880	6540	7150	8230
	40	30	0	0	210	320	510	790	990	1230	1510	1860	2280	2760	3300	3750	4270	4750	5200	5980
	50	37	0	0	0	250	400	630	810	990	1230	1500	1830	2220	2650	3010	3430	3820	4170	4780
	60	45	0	0	0	0	340	540	660	840	1030	1270	1540	1870	2250	2550	2910	3220	3520	4050
	75	55	0	0	0	0	290	450	550	690	855	1050	1290	1570	1900	2160	2490	2770	3040	3520
	100	75	0	0	0	0	0	340	420	520	640	760	940	1140	1360	1540	1770	1960	2140	2470
	125	90	0	0	0	0	0	0	340	400	490	600	730	930	1110	1260	1420	1590	1740	1990
	150	110	0	0	0	0	0	0	0	350	420	510	620	750	930	1050	1180	1320	1440	1630
	175	130	0	0	0	0	0	0	0	0	360	440	540	660	780	970	1120	1260	1380	1600
	200	150	0	0	0	0	0	0	0	0	0	410	480	580	690	790	940	1050	1140	1320
4600V 60HZ Three-Phase 6 - Lead Y - D	5	3.7	880	1420	2250	3540	5550	8620												
	7 1/2	5.5	630	1020	1600	2530	3960	6150	7650	9390										
	10	7.5	460	750	1180	1870	2940	4570	5700	7020	8620									
	15	11	310	510	810	1270	2010	3130	3900	4800	5890	7210	8850							
	20	15	230	380	610	970	1540	2410	3000	3700	4560	5590	6870	8290						
	25	18.5	190	310	490	790	1240	1950	2430	2980	3670	4510	5550	6700	8140					
	30	22	0	250	410	640	1020	1600	1990	2460	3040	3730	4590	5550	6750	7690	8790			
	40	30	0	0	300	480	750	1180	1470	1810	2230	2740	3370	4060	4930	5590	6370			
	50	37	0	0	250	370	590	960	1200	1470	1810	2220	2710	3280	3970	4510	5130	5740	6270	7270
	60	45	0	0	0	320	500	810	1000	1240	1530	1870	2310	2770	3360	3810	4330	4860	5310	6150
	75	55	0	0	0	0	420	660	810	1020	1260	1540	1890	2280	2770	3150	3600	4050	4420	5160
	100	75	0	0	0	0	310	500	610	760	930	1140	1410	1690	2070	2340	2680	3010	3280	3820
	125	90	0	0	0	0	0	390	470	590	730	880	1110	1330	1500	1830	2080	2340	2550	2940
	150	110	0	0	0	0	0	0	0	420	510	630	770	950	1140	1380	1570	1790	2000	2180
	175	130	0	0	0	0	0	0	0	0	450	550	680	830	1000	1220	1390	1580	1780	1950
	200	150	0	0	0	0	0	0	0	0	0	480	590	730	880	1070	1210	1380	1550	1690
575V 60HZ Three-Phase 6 - Lead Y - D	5	3.7	1380	2220	3490	5520	8620													
	7 1/2	5.5	990	1590	2520	3970	6220													
	10	7.5	730	1170	1860	2920	4590	7150	8910											
	15	11	490	790	1270	2010	3130	4890	6090											
	20	15	370	610	970	1540	2410	3780	4710	5790	7140	8740								
	25	18.5	300	490	780	1240	1950	3040	3790	4660	5760	7060								
	30	22	240	400	645	1020	1600	2500	3120	3840	4740	5820	7150	8670						
	40	30	0	300	480	750	1180	1860	2310	2850	3490	4290	5260	6340	7710	8740				
	50	37	0	0	380	590	960	1500	1870	2310	2830	3460	4260	5130	6210	7050	8010	8980	9790	
	60	45	0	0	330	500	790	1270	1590	1950	2400	2940	3600	4330	5250	5950	6780	7600	8290	9610
	75	55	0	0	0	420	660	1030	1290	1590	1960	2400	2950	3570	4330	4930	5620	6330	6910	8050
	100	75	0	0	0	0	400	780	960	1180	1450	1780	2190	2650	3220	3660	4180	4710	5140	5980
	125	90	0	0	0	0	0	600	740	920	1150	1420	1740	2100	2530	2880	3270	3660	3970	4600
	150	110	0	0	0	0	0	520	650	800	990	1210	1480	1780	2160	2450	2790	3120	3410	3950
	175	130	0	0	0	0	0	0	0	570	700	860	1060	1300	1570	1910	2170	2480	2780	3040
	200	150	0	0	0	0	0	0	0	500	610	760	930	1140	1370	1670	1890	2160	2420	2640

Appendix

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Length				
Inches	(in)	Millimeters	(mm)	25.400
Inches	(in)	Centimeters	(cm)	2.539
Feet	(ft)	Meters	(m)	0.305
Yards	(yd)	Meters	(m)	0.914
Miles (statute)	(mi)	Kilometers	(km)	1.609
Millimeters	(mm)	Inches	(in)	0.039
Meters	(m)	Feet	(ft)	3.281
Centimeters	(cm)	Inches	(in)	0.394
Meters	(m)	Yards	(yd)	1.094
Kilometers	(km)	Miles (statute)	(mi)	0.621
Area				
Square Inches	(in ²)	Square Centimeters	(cm ²)	6.452
Square Feet	(ft ²)	Square Meters	(m ²)	0.093
Square Yards	(yd ²)	Square Meters	(m ²)	0.836
Square Miles	(mi ²)	Square Kilometers	(km ²)	2.590
Acres	(ac)	Hectares	(ha)	0.405
Square Centimeters	(cm ²)	Square Inches	(in ²)	0.155
Square Meters	(m ²)	Square Feet	(ft ²)	10.764
Square Meters	(m ²)	Square Yards	(yd ²)	1.196
Square Kilometers	(km ²)	Square Miles	(mi ²)	0.386
Hectares	(ha)	Acres	(ac)	2.471
Liquid Volume				
Ounces	(oz)	Milliliters	(ml)	29.574
Pints	(pt)	Liters	(l)	0.473
Quarts	(qt)	Liters	(l)	0.946
Gallons	(gal)	Liters	(l)	3.785
Pounds per Cubic Foot	(lb/ft ³)	Kilograms per Cubic Meter	(kg/m ³)	16.018
Pounds per Gallon	(lb/gal)	Kilograms per Cubic Meter	(kg/m ³)	119.826
Milliliters	(ml)	Ounces	(oz)	0.034
Liters	(l)	Pints	(pt)	2.113
Liters	(l)	Quarts	(qt)	1.057
Liters	(l)	Gallons	(gal)	0.264
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Cubic Foot	(lb/ft ³)	0.062
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Gallon	(lb/gal)	0.008
Mass				
Ounces	(oz)	Grams	(g)	28.350
Pounds	(lb)	Kilograms	(kg)	0.454
Grams	(g)	Ounces	(oz)	0.035
Kilograms	(kg)	Pounds	(lb)	2.205
Flow				
Cubic Meters per Hour	(m ³ /h)	Gallons per Minute	(gpm)	4.400
Gallons per Minute	(gpm)	Cubic Meters per Hour	(m ³ /h)	0.227

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Force				
Foot Pound Force	(ft-lbf)	Joules	(J)	1.356
Newtons	(N)	Kilogram Force	(kgf)	0.102
Joules	(J)	Foot Pound Force	(ft-lbf)	0.738
Kilogram Force	(kgf)	Newtons	(N)	9.807
Power				
Horsepower	(hp)	Kilowatts	(kW)	0.746
Horsepower	(hp)	Watts	(W)	745.700
Kilowatts	(kW)	Horsepower	(hp)	1.341
Watts	(W)	Horsepower	(hp)	0.001
Pressure				
Bars	(b)	Pounds per Square Inch	(psi)	14.500
Kilograms per Square Centimeter	(kg/cm²)	Pounds per Square Inch	(psi)	14.500
Pounds per Square Inch	(lb/in²)	Kilograms per Square Meter	(kg/m²)	703.070
Pounds per Square Inch	(lb/in²)	Kilopascals	(kPa)	6.895
Pounds per Square Inch	(lb/in²)	Meters of Water	(m)	0.704
Inches of Mercury	(inHg)	Kilograms per Square Meter	(kg/m²)	345.300
Kilograms per Square Meter	(kg/m²)	Pounds per Square Inch	(lb/in²)	0.001
Kilopascal	(kPa)	Pounds per Square Inch	(lb/in²)	0.145
Meters of Water	(m)	Pounds per Square Inch	(lb/in²)	1.420
Kilograms per Square Meter	(kg/m²)	Inches of Mercury	(inHg)	0.003
1 Atmosphere	14.7 lb/in²	Kilograms per Square Centimeter	(kg/cm²)	1.033
1 Atmosphere	14.7 lb/in²	Kilograms per Square Meter	(kg/m²)	10,335.000
1 Atmosphere	14.7 lb/in²	Kilopascal	(kPa)	101.350
1 Atmosphere	14.7 lb/in²	76.0 Centimeters Mercury	(cmHg)	5.170
1 Atmosphere	29.92 inHg	76.0 Centimeters Mercury	(cmHg)	2.540
Pascal	(Pa)	Newtons per Square Meter	(N/m²)	1.000
Pascal	(Pa)	Kilograms per Square Meter	(kg/m²)	0.102
Temperature				
Degrees Fahrenheit	(°F)	Degrees Celsius	(°C)	(°F-32) 0.556
Degrees Celsius	(°C)	Degrees Fahrenheit	(°F)	(1.8 x °C) + 32
Flow				
Feet per Second	(fps)	Meters per Second	(m/s)	0.305
Miles per Hour	(mph)	Kilometers per Hour	(km/h)	1.609
Gallons per Minute	(gpm)	Liters per Minute	(l/min)	3.785
Gallons per Minute	(gpm)	Cubic Meters per Minute	(m³/min)	0.004
Meters per Second	(m/s)	Feet per Second	(fps)	3.281
Kilometers per Hour	(km/h)	Miles per Hour	(mph)	0.621
Liters per Minute	(l/m)	Gallons per Minute	(gpm)	0.264
Cubic Meters per Minute	(m³/min)	Gallons per Minute	(gpm)	264.172

Notes

Glossary

Air-Release Control: Device used to release excess air from a water tank. (VI-3)

Ammeter: Instrument to measure electrical current flow in amps. (VI-1)

Auxiliary Protection Device (*Also known as Electrical Control*): These devices provide a manual or automatic way to disconnect electricity from a power source in case of excess current. They can also protect equipment from overload, overheating, lack of water, or voltage variations. (VI-3)

Centrifugal Pump: A pumping mechanism that spins water by means of an “impeller,” pushing it out by centrifugal force. (VI-3)

Constant Pressure System: A pumping system designed to maintain a relatively constant source of pressure around a selected pressure setpoint, regardless of demand, by controlling the speed of the motor or operation of other mechanical components based on feedback from a pressure-sensing device. (VI-4)

Contactors (*Also called a Magnetic Motor Starter*): Its contacts open or close the pump circuit to start or stop the motor. (VI-3)

Control: Device used to maintain ideal operating conditions in a pump. (VI-3, VI-4)

Control Bypass Device: A type of mechanical pressure-control device; used to eliminate the pressure switch control from the pump run circuit. There are two types: flow switch controls (flow switch activation of electrical circuits to maintain pump power during flow) and shuttle-type bypass valves (shuttle-type valves that block pressure port flow to the pressure switch). (VI-4)

Cut-In Pressure (*Also called Pump-Start Pressure*): Pressure level at which a pump turns on. (VI-3, VI-4)

Cut-Out Pressure: An electrical pressure switch activated by the pressure in a pressure tank. At a high point, it turns off the pump. (VI-3, VI-4)

Digital Pressure Control: Type of pressure switch that provides a closer pressure differential than a regular pressure switch. Pressure switches are electrical switches activated by the pressure in a pressure tank. (VI-3)

Electrical Control: *See Auxiliary Protection Device.* (VI-3)

Electrical Overpressure Switch: A device used to limit maximum system pressure in conjunction with a relief valve. This device is similar to a pressure switch except that it is used as a pressure-limit control and must be reset manually. (VI-3)

Electronic/Electrical Pressure-Control Products: Products encompassing all systems that utilize a variable frequency drive (VFD) to change the speed of the motor and pump. (VI-4)

Expulsion Arrestor: A type of lightning arrestor consisting of an air gap and a gas-generating material. During normal voltage, the air gap insulates the power lines from the ground. If the line-to-ground voltage exceeds the arrestor’s impulse sparkover voltage, the air gap sparks over and short circuits the line to the ground. The resulting current that flows through the special material in the arrestor produces a gas, which in turn blows out the arc. Designed for outdoor installation only. (VI-2)

Float Switch: A float switch is used to turn a pump on or off in systems with gravity tanks or reservoirs instead of pressure tanks. The float responds to a rise and fall in the water level in the pressure tank rather than to pressure. (VI-3)

Flow Switch Control: A switch that turns a pump on or off in response to a rise or fall in water level in a pressure tank, rather than in response to pressure. Based on water flow. (VI-4)

Frequency: The number of repetitions per unit of time of a complete wave-form, as of an electric current. (VI-2, VI-4)

Fused Disconnect Switch: A disconnecting switch in which a fuse unit forms a part of the blade. It is required by the National Electrical Code in every pump motor installation. It is placed in the circuit before the operating control should be located within easy view while servicing. (VI-3)

Ground Fault Circuit Interrupter (GFCI): A permanently installed circuit protection device that can detect very small amounts of current “leaking” out of its intended path. It can prevent injury in the most common electrical shock situation, the phase-to-ground electrical shock. (VI-1)

Ground Source Heat Pump: A space conditioning system that uses the earth’s relatively constant temperature, whether in the ground, groundwater, or surface water, as both a heat source and sink. These pumps use a reversible refrigeration cycle to provide either heating or cooling. (A heat sink is a body of air or liquid to which heat can be transferred.) (VI-4)

Grounded: Electrical systems that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation. (NFPA 70 – 2014). (VI-1, VI-2, VI-3, VI-4)

Grounding: The connection of one electrical supply line to the earth to eliminate any hazardous voltage. (VI-1, VI-2, VI-3)

Impulse Sparkover Voltage: Set voltage level between a power line and the ground. When lightning causes excessive voltage, it triggers a lightning arrestor, protecting the pump motor. (VI-2)

Inherent Thermal Protection: Method that guards against overheating in air- cooled motors such as jet-pump motors, using a combination thermal switch and over-current protector located in the motor. (VI-2)

Internal Surge Arrestor: Built-in lightning protection used in many small submersible motors, it directly connects motor windings and frames, and offers excellent protection. (VI-2)

Jet Pump: A surface-mounted centrifugal pump that has an ejector (venturi) device to increase suction capacity. (VI-3)

Lightning Arrestor: A device for protecting electrical equipment from damage by lightning or other power surges. (VI-2)

Liquid-Level Control: Mechanical device for low-yield wells, in which a float moves vertically around the riser pipe, adjusting a built-in bypass valve. If a well’s yield declines, the float will drop, opening the regulating valve and allowing water to be recirculated within the well. The valve will adjust the rate of delivery to be equal to well yield. (VI-3)

Lock Out and Tag: Safety procedure used when working on an electrical system. Power is turned off at the disconnecting device or breaker, and a padlock is installed on a breaker or switch to prevent anyone else from turning the circuit back on while work is being done. The lock is marked with a warning tag. (VI-1)

Low-Flow Control: A protective device that starts a time delay circuit that in turn shuts off pump operation in 30 to 90 seconds if water flow becomes inadequate. (VI-3)

Low-Flow Protector: A type of low- water-level protector that opens the circuit if a pump is operating continuously but is pumping less than a predetermined minimum amount of water. (VI-2)

Low-Pressure Cutoff Switch: Detects drop in pressure below the normal cut- in pressure, and shuts down the pump. (VI-3)

Low-Water Cutoff: An electrode-operated device consisting of a relay box and two electrodes suspended in the well. If the water level drops below the lower electrode, the relay will break the electrical circuit to the motor until the water level recovers to submerge the upper electrode, preventing the submersible pump from running or starting dry. (VI-3)

Magnetic Motor Starter: *See Contactor.* (VI-3)

Maximum Pump Head: The pressure at which flow stops. (VI-4)

Mechanical Pressure-Control Products:

Mechanical products are comprised of pressure-control valves and flow-regulating valves typically combined with pressure switches. (VI-4)

Milliampere: 1 milliampere = 1/1000 of an amp. Measurement of electrical current flow. (VI-1)

National Electrical Code (NFPA 70): Electrical standards code that requires the safe grounding of motor-operated water pumps and metal well casings. (VI-1, VI-3)

Open Tank: Type of tank open to the atmosphere. Used instead of a pressure tank in some water systems. Its primary operating control is a float switch. (VI-3)

Operating Control: Type of equipment control that instructs the equipment when to operate and when to cease operation. (VI-3)

OSHA Regulations (29 CFR): The U.S. Occupational Safety and Health Administration (OSHA) regulations that mandate lock out and tagging procedures for electrical work. (VI-1)

Over-Current Protector: Device that guards a pump against overloading and failure to start; only available on motors 6 inches or larger. (VI-2)

Overload Relay: A device designed to prevent an electric motor from drawing too much current and overheating. (VI-3)

Post-Control Regulation: The control of water pressure downstream of the pressure tank and switch. This supplies regulated pressure at a given flow. (VI-4)

Pre-Control Regulation: The control of water pressure in the supply line, with the regulation device set below the pressure switch cut-out pressure. Pre-control regulating devices can offer constant pressure after a single pressure drawdown and a return to the mid set point and continued demand. (VI-4)

Pressure: The force exerted in pounds over one square inch area. (VI-3, VI-4)

Pressure-Control Valve (PCV): Device that allows the pressure to go from the pump cut-in to the set regulated pressure (pressure below pump cut-out) and continues to deliver the preset pressure until the demand ends. When the demand ends, the pump raises the system pressure through the bypass to the cut-out pressure sensed by the pressure switch, allowing the pump to shut off. (VI-4)

Pressure-Relief Valve: Controls maximum pressure in the system. (VI-3, VI-4)

Pressure Switch: An electrical switch activated by system pressure to control starting and stopping of the pump. (VI-3, VI-4)

Pressure Tank: Vessel used to provide cycle control of the pump. (VI-3, VI-4)

Pulse-Width Modulation (PWM): A PWM controls the speed of the motor. (VI-4)

Pump: A mechanical device that moves liquid or gas by pressure or suction; a device that converts mechanical torque and motion into hydraulic fluid power. (VI-1, VI-2, VI-3, VI-4)

Pump Motor: Electrical motor that operates the pump in a water system. (VI-2, VI-3, VI-4)

Reciprocating Pump (*Also called Piston Pump*): Shallow well pump in which the piston travels back and forth in a cylinder to move water. (VI-3, VI-4)

Regulating Device: Device to control pressure or flow in a water system application. (VI-4)

Relay Arrestor: This component directs all voltage surges above approximately 600 volts to a ground wire that is part of the arrestor. (VI-2)

Safety Control: Control designed to prevent damage to equipment in the event of a malfunction. (VI-3)

Solid-State Pressure Control: *See Digital Pressure Switch.* (VI-3)

Starter: *See Contactor.* (VI-2, VI-3, VI-4)

Submersible Motor: A motor subjected to special conditions of cooling and of insulation from the water environment in the well in which they are submerged. The submersible must also fit in the well casing. (VI-2, VI-3)

Submersible Pump: An adapted centrifugal pump and motor designed to be placed completely below the water surface. (VI-1, VI-2, VI-3, VI-4)

Suction Lift: The low pressure generated on the inlet in the suction of a pump that lifts water up into the pump. (VI-3)

System Monitor: Device used in submersible pumps, that incorporates a microcomputer merged with the standard on/off pressure switch to continuously monitor the power factor of the pump's motor for low water and also detect rapid cycling, high or low voltage, and excessively one runs. When one of these abnormal conditions is detected, the microcomputer activates condition indicator lights on top of the enclosure and, in most cases, shuts off the pump motor. The microcomputer is programmed to restart the pump automatically if the condition corrects itself within a reasonable length of time. This device operates with split-phase, capacitor-start and some capacitor-run motors. (VI-3, VI-4)

Tank: A container that stores water from a well before it enters the distribution system. Tanks are installed inside or outside a dwelling, placed in well pits or buried underground. (VI-3)

Thermal Switch: Switch that protects a motor against continuous overload. (VI-2)

Vacuum-Operated Air Control: A type of control used on plain steel tank jet- pump installations that have 5 feet or more of suction lift. (VI-3)

Valve (Pellet) Arrestor: This arrestor consists of many pellets of nonlinear material separated by small air gaps. (VI-2)

Variable Frequency Drive (VFD): A type of motor controller that maintains constant pressure or flow in a water system by changing the speed of the pump to match the variations in demand for water. (VI-4)

Voltage: Electrical "pressure". (VI-1, VI-2, VI-3, VI-4)

Voltage Variation: Voltage that exceeds the power company's rated voltage by more than plus or minus 10 percent. (VI-2, VI-3)

Voltmeter: Device used for measuring electrical voltage. (VI-1, VI-2, VI-3, VI-4)

Wellhead Pressure: Pressure at the top of the well, at ground level. (VI-3)

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Study Guide Answers

Chapter 1

Q. Before working on an electrical circuit, be sure that all power sources are turned off. To ensure that no one else might reenergize the circuit, it is a good practice to “lock out and tag.” What does that mean?

A. To “lock out and tag” the circuit means to disconnect it at the breaker or switch and install a padlock (for which you have the only key) on the breaker or switch to prevent anyone else from turning the circuit back on while you are still working on it. Also mark the lock with a warning tag.

If you missed this question, go back to page 9 for information on working on electrical circuits safely.

Q. What is GFCI and what does it do?

A. Ground fault circuit interrupters (GFCIs) can prevent injury in the most common electrical shock situation, the phase-to-ground electrical shock. They are permanently installed circuit protection devices that can detect very small amounts of current “leaking” out of its intended path. The 2005 National Electrical Code does not require GFCIs on water well pump circuits but their use is good electrical practice and can protect the installer and the customer from possible electrocution.

If you missed this question, go back to page 11 for information on ground fault circuit interrupters.

Q. What is a safe distance to keep between you and any 50,000-volt power lines?

A. OSHA requires maintaining 10 feet for the safe operation of equipment and handling of supplies. However, 35 feet is a much safer distance.

If you missed this question, go back to page 11 for information on overhead power lines.

Chapter 2

Q. Define grounding.

A. Grounding is the connection of one electrical supply line to the earth to eliminate any hazardous voltage.

If you missed this question, go back to page 16 for information on grounding necessary.

Q. What is the primary cause of motor failure and what is its solution?

A. Motor overheating, which destroys the motor insulation. Overheating is caused by overloading, a locked rotor, rapid cycling, loss of cooling, current imbalance, or over/under voltage conditions.

If you missed this question, go back to page 16 for information on types of motor protection needed.

Q. What is a lightning arrestor and what does it do?

A. A lightning arrestor is a protective device connected between the power lines and the ground. It conducts currents of as much as 10,000 amps harmlessly to the ground. In the event of a direct strike, an arrestor will not necessarily protect the motor.

If you missed this question, go back to page 17 for information on lightning arrestors.

Chapter 3

Q. How and why should electrical system controls be grounded?.

A. All electrical controls must be permanently grounded and wired in accordance with the National Electric Code (NEC) and applicable local codes. Failure to properly ground the controls can result in serious or fatal injury.

If you missed this question, go back to page 21 for information on grounding caution.

Q. What does a control do, and what are the two basic categories?

A. Controls regulate the performance and protect the equipment for its intended use. The two categories are operating controls and safety controls.

If you missed this question, go back to page 21 for information on operating and safety controls.

Q. Who is qualified to alter a pressure switch?

A. Pressure switch adjustments of any kind should only be made by qualified personnel. Improper adjustments may result in mechanical damage to the system and/or risk of personal injury.

If you missed this question, go back to page 23 for information on the pressure switch.

Q. Submersible pumps require controls that jet pumps do not require. What are these and why are they necessary?

A. Every submersible should be protected by low-flow protection controls, if there is any possibility that the well might go dry or the intake screen clog. These prevent continued pump operation without normal water flow through the pump and possible damage.

If you missed this question, go back to page 24 for information on accessories and auxiliary protective controls.

Q. Name two devices for handling overpressure.

A. A pressure-relief valve should be used on any system where the pump could develop a greater pressure than the system's rating. An electrical overpressure switch may also be used to limit maximum system pressure in conjunction with a relief valve.

If you missed this question, go back to page 27 for information on overpressure devices.

Chapter 4

Q. What is a constant pressure system?

A. A constant pressure system is defined as: "A pumping system designed to maintain a relatively constant source of pressure around a selected pressure setpoint, regardless of demand by controlling the speed of the motor, reducing the pressure differential of the pressure switch or operation of other mechanical components based on feedback from a pressure-sensing device."

If you missed this question, go back to page 31 for information on constant pressure systems.

Q. Where are constant pressure systems used?

A. They are used in water well applications where there is continuous demand and in which customers desire a more constant supply of water pressure than that offered by typical systems with a pressure switch with a psi spread between turn-on pressure and turn-off pressure. The main purpose of constant pressure systems is to provide an essentially constant pressure in the water system application, limiting pressure fluctuations to only a few psi.

If you missed this question, go back to page 31 for information on constant pressure systems.

Q. Name the two main categories of constant pressure systems.

A. Mechanical and electronic/ electrical.

If you missed this question, go back to page 31 for information on constant pressure systems.



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Community Water Systems, Shared Wells, & Groundwater Heat Pumps

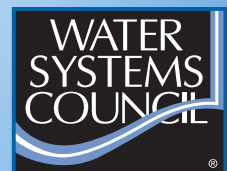


WATER SYSTEMS HANDBOOK

*A complete text on wells:
their design, operation, and maintenance*

13TH EDITION

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BOOK VII

Community Water Systems, Shared Wells, & Groundwater Heat Pumps

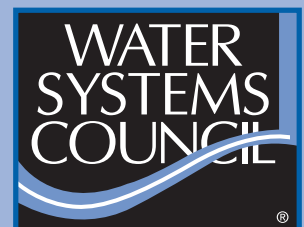
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A Word Of Caution



The products described in this Handbook, including all products using electrical current, can result in serious harm if not used with EXTREME CAUTION and in strict accordance with manufacturers' instructions. Professional assistance is recommended and should always be sought when utilizing unfamiliar equipment.

The products, materials, information, and instructions in this publication are provided for informational purposes only. This publication is not intended to provide instructions or recommendations relating to the selection, adoption, or use of equipment. All information is provided from sources believed to be reliable, accurate, and comprehensive. However, all information, including without limitation product descriptions and functionality is provided "as is" without any express or implied warranty of any kind, including warranties of title, merchantability, noninfringement of intellectual property, compatibility, or fitness for any purpose or use. In no event shall the Water Systems Council or its members, agents, employees, directors, or officers be liable for any damages or other claims whatsoever, including, without limitation, any direct, indirect, special, punitive, or consequential damages, whether from harm, loss of profits, business interruption, loss of information, or related expenses arising out of errors, omissions, or the use of or inability to use the materials, products, information, or services as provided in this Handbook, even if the Water Systems Council or its members have been advised of the possibility of such damages.

Introduction to Wells

Water is life's most vital resource. Through the centuries, people have searched for water, fought for it, and sometimes died for it. No living organism can exist without water.

Consequently, clean and plentiful groundwater is necessary for everyday life. As described in this handbook, groundwater is the reservoir of water that seeps downward through the soil to the water table below the earth's surface. About 98 percent of all fresh water available in the nation at any time is groundwater, which fills the porous beds of rock and sand that make up the earth's crust.

Groundwater is an ideal water supply, for it is pure and wholesome. Filtered by the underground formations through which it passes, groundwater has a degree of purity seldom attained by surface waters.

Natural groundwater reservoirs have many advantages. They have huge capacities, they are relatively inexpensive to tap by means of wells, and they lose little water by evaporation. Above all, they are dependable sources of water.

In the United States alone, more than 115 million people get their drinking water from groundwater every day. More than 23 million American households are supplied from individual, private wells.

A modern well is both flexible and functional. A variety of pumps is available to lift water from all types of wells, from the shallowest to the deepest. These systems are made automatic and dependable by many types of controls and accessories. Groundwater is there when needed. Additional equipment may be added to the system for treatment to ensure better quality of life.

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About this Handbook

The **WATER SYSTEMS HANDBOOK** provides basic information on well design, operation, and maintenance to boost the professional knowledge of well industry personnel.

Before you begin your studies, please take a few moments to familiarize yourself with the format of this handbook. The handbook is divided into eight books. Each includes several chapters that cover the most important aspects of wells. At the end of each chapter, you will find a **Quiz**. You can use this quiz as a learning tool to review the noteworthy points in each chapter. Answers to the quiz can be found at the end of each book. If you miss an answer, follow the directions to take you back to where the information is located in the chapter.

For quick reference, you will find that highlighted text is generally defined in a **Glossary** at the back of each book, where you will also find a topical **Index**. While illustrations appear in each chapter, you will also see tables and charts referenced in text and located in the **Appendix** at the back of each book. A handy metric system reference also appears in each appendix.

We hope that studying the information in this handbook will prepare you for your job as a well professional, charged with the important responsibility of helping to ensure access to pure, plentiful well water for families across America.

Water Systems Council

Dedication

This 13th Edition of Water Systems Handbook is dedicated to the millions of Americans who rely on private water systems to provide safe, sustainable water supply and to the water well professionals in the water well industry.

The 13th Edition is also dedicated in memory of Jeff Wellen for his many years of leadership and service to WSC and the water well industry.

Special thanks to the members of the Water Systems Council Technical Committee, who initiated and completed revisions to this 13th Edition.



The Water Systems Council (WSC) is a national nonprofit organization, dedicated to promoting the wider use of wells as safe, sustainable, and cost-effective drinking water systems; protecting groundwater resources and users of well water, and ensuring a safe drinking water supply for well owners. WSC members include major manufacturers of the integral components of wells and other drinking water systems, leading distributors of these components, and various drinking water professionals.

WSC is the only national nonprofit organization with programs solely focused on private water wells and small, shared wells.

www.watersystemscouncil.org

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Chapter 1

Community Water Systems & Shared Wells

- ✓ Possibilities for small community water systems
- ✓ Planning considerations
- ✓ Shared well system design

Many small communities face the problem of providing an adequate quality and quantity of drinking water, under sufficient pressure and with fire protection in mind, to satisfy the area's needs at an affordable cost. Individual families in these communities may not be able to afford drilled **wells** of their own, and community water supplies may be miles away. In sparsely populated areas, there may be too few connections on a water line to support the capital cost of a water district, and fire protection, in most cases, would require sufficiently sized pipelines and large water pressure tanks, both of which are cost-prohibitive.

Small communities should consider all available water supply options:

There are five typical sources for private water systems:

1. Individual wells – The option for individual household wells should always be considered. In many communities, individual wells are desired for reasons of economics and private ownership rights.
2. Shared wells – **Shared wells** are drilled to serve two or more nearby homes. The shared or cluster system is usually administered by a user-controlled, nonprofit association (similar to condominium management). The association is responsible for the operation and maintenance of the equipment, collection of revenues, and periodic testing to ensure that water quality meets federal and state requirements.
3. Pumping from surface water – If adequate surface water supplies are available, it requires treatment and horizontal piping.
4. Drilling a central community well – For this option, horizontal piping is also required.
5. Extending rural pipelines – If an existing municipal water system has the capacity to expand, rural pipelines may be tied into it, yet the terrain and scatter of homes may make horizontal piping difficult.

A 2005 Water Systems Council study demonstrated that savings of more than 70% are possible by focusing on a decentralized water system using a flexible combination of all of these sources, including the extension of municipal water systems and construction of individual, shared, and community wells, as compared to mandatory connection of all households to a traditional public water system.

In 2016, Congress passed the Water Supply Cost Savings Act in recognition of the cost savings of using wells and well systems for water infrastructure, requiring communities of 500 or fewer to consider wells and well systems for water infrastructure needs. A comprehensive study should therefore be undertaken by any community desiring to ensure its best selection according to cost, water quality, water supply sustainability, and land use perspectives.

Project planning

Complete plans for a water project include a **feasibility study**, **preliminary engineering report**, and **final engineering report**.

✓ **Feasibility study.** The geography of the area and the density and growth rate of the population are examined in a feasibility study because system selection and design depend upon whether the population is relatively scattered or concentrated in definable clusters. The following steps are part of a thorough feasibility study:

1. Use a map of the area to locate homes to be served. Identify potential growth locations.
2. Write a brief description of water supply facilities serving the area.
3. Perform a field survey of local residents to determine interest in a community water project.
4. Write a needs and interest assessment report.
5. Evaluate **groundwater** and **surface water** resources for quality and quantity. Assess the average life expectancy of existing resources, and any possible problems that might arise with wells or surface water in the area.
6. Identify any sources of water pollution such as sewage and industrial waste discharge.
7. Write a report on the feasibility of each potential water resource.

✓ **Preliminary engineering report.** If the findings of the feasibility study indicate potential for a community water system that includes shared wells, secure a consulting engineer to prepare a preliminary engineering report with data that can serve as the basis for system design. Ask for the following information in the report:

1. Quality and quantity of the proposed water supply.
2. Nature of the soil for trenching and drilling.
3. Estimated well depths. Recommended diameter, size and material of casing, well screen type, pumps, tanks, and controls.
4. Recommended type and capacity of the proposed water treatment facilities, type and size of water storage units, and size and layout of water distribution piping.
5. Estimated water demands of potential users.
6. Expected advantages of the proposed water system.
7. Estimated cost for the proposed system(s) compared to the costs of other water resource options. Costs include (a) capital cost, (b) power, (c) water treatment, (d) installation labor, (e) preventive maintenance, (f) equipment repair and replacement, and (g) cost of water if purchased from a rural pipeline. Given these costs, determine estimated user payment per month.

8. If no structure already exists (town or county), recommend legal structure for operating the water system to ensure continuous satisfactory operation, regular maintenance of the system, and a reasonable operating cost.
- ✓ **Final engineering report.** After review of the feasibility study and preliminary engineering report, select a water system design. The final engineering report should contain specific information about the system design, including any necessary revisions of the preliminary engineering report.

Table VII.1.1

Average Water Consumption for Home and Farm Use						
Private Residences						
Outlets	Flow Rate gpm	Total Usage Gallons	Bathrooms in Home			
			1	1 ½	2-2 ½	3-4
Shower or Bathtub	5	35	35	35	53	70
Lavatory	4	2	2	4	6	8
Toilet	4	5	5	10	15	20
Kitchen Sink	5	3	3	3	3	3
Automatic Washer	5	35	-	18	18	18
Dishwasher	2	14	-	-	3	3
Normal seven (7) minute peak demand (gallons)			45	70	98	122
Minimum sized pump required to meet peak demand without supplemental supply		Divide peak demand by 7	7 gpm (420 gph)	10 gpm (600 gph)	14 gpm (840 gph)	17 gpm (1020 gph)
Notes: Values given are average and do not include higher or lower extremes. Peak demand can occur several times during morning and evening hours.						
Yard Fixtures			Farm Use			
Garden Hose - ½"		3 gpm	Horse, Steer		12 gpd	
Garden Hose - ¾"		6 gpm	Dry Cow		15 gpd	
Sprinkler		3-7 gpm	Milking Cow		35 gpd	
Alternate Capacity Methods: Calculate the number of bathrooms x 4 gpm = ? (Note that 1/2 baths are considered as full baths) Count the number of fixtures in a home including outside hose bibs. Supply one gallon per minute each.			Hog		4 gpd	
			Sheep		2 gpd	
			Chicken/100		6 gpd	
			Turkey/100		6 gpd	
			Fire		20-60 gpm	

Shared well design

If a **shared well** system is chosen, there are many decisions to be made, such as the number of required wells and the selection of equipment.

In many cases, the maximum distance between dwellings before another well is required is 1,000 feet. The Federal Housing Administration (FHA) requires that the minimum capacity of the water source be 5 gpm, which is what the pump must deliver, not what the well yields. The average person uses 80 gallons of water per day, so a typical family of four would use 320 gallons daily.

Table VII.1.1 (page 11) is a topographical view of a community that covers several square miles. Four wells are needed to handle this community. The rationale for the number of wells, pump requirements, and sizes of pressure tanks are described here.

Well #1 has only one family, so the **pump** selected for it is determined by counting the number of bathrooms in the dwelling (Table VII.1.1, page 11). Basically, every water-using fixture requires a **capacity** of approximately 2.5 gpm.

The water supply **pressure** required is determined by adding up the pressure requirements for (a) the minimum pressure to operate the highest fixture in the dwelling (12 psig for a shower), (b) elevation, and (c) pipe **friction loss**. The pump must be able to deliver the required flow at its **cut-in pressure** or it will fall short of the required flow or demand.

Well #2 has three dwellings and requires triple the flow for Well #1, or a total of 21 gpm. The well requirement for all three dwellings is 960 gallons per day, which is still less than the daily yield of 1,440.

Using Figure VII.1.1, the total **pressure tank** requirement is determined to be 105 gallons. Each dwelling would have a 35-gallon tank.

The remaining eight dwellings are all within 1,000 feet of one another. Assuming the same minimum well yield of 1 gpm and four persons per dwelling, two wells are required – Wells #3 and #4 – if each well can produce 1,440 gallons a day. Calculate the **total demand** using this formula:

$$\frac{320 \text{ gallons per family} \times \text{number of families (8)}}{2,560 \text{ gallons/day}}$$

The total pumping capacity required is 56 gpm (7 gpm x 8 families). With two wells, the pump capacity for each well is 28 gpm. Each pump will serve four dwellings.

Total tank storage volume needed is 170 gallons (Table VII.1.2, page 13), so a 43-gallon tank is required in each dwelling. Each well requires a pump capable of delivering 28 gpm to four 43-gallon tanks.

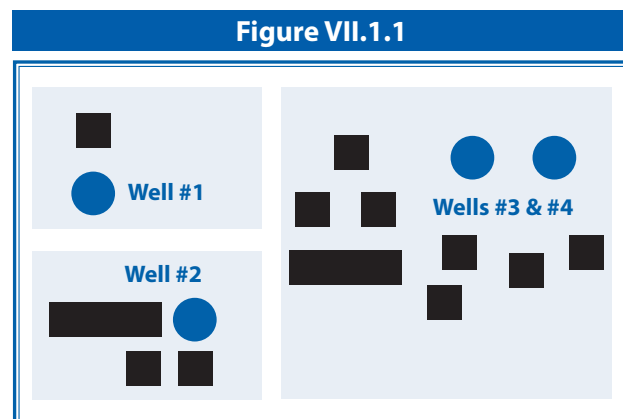


Table VII.1.2

Sample Tank Selection Chart - Minimum Tank Volume for Proper Motor Life
(Based on present industry practices)

Pump Capacity		Maximum Drawdown (1)	Total Tank Volume (Gallons)					
			Switch Setting (Pounds Per Square Inch)					
			20-40		30-50		40-60	
GPH	GPM	(Gallons)	A	B	A	B	A	B
240	4	4	10	25	15	40	15	55
300	5	5	15	30	15	50	20	70
360	6	6	15	40	20	60	20	85
420	7	7	20	45	25	70	25	100
480	8	8	20	50	25	80	30	110
540	9	9	25	60	30	90	35	125
600	10	10	30	65	30	100	40	140
660	11	12	35	80	40	120	45	165
720	12	13	35	85	40	130	50	180
780	13	15	40	100	50	150	55	210
840	14	17	45	110	55	170	65	235
900	15	19	50	125	60	190	70	265
960	16	20	55	130	65	200	75	280
1020	17	23	65	150	75	230	85	320
1080	18	25	70	160	80	250	95	350
1140	19	27	75	175	85	270	100	375
1200	20	30	80	195	95	300	110	415
1260	21	33	90	215	105	330	125	460
1320	22	36	100	235	115	360	135	500
1380	23	38	105	245	125	380	140	530
1440	24	41	110	265	135	410	155	570
1500	25	44	120	285	140	440	165	610
1560	26	47	130	305	150	470	175	655
1620	27	50	135	325	160	500	185	700
1680	28	53	145	345	170	530	200	735
1740	29	57	155	370	185	570	215	790
1800	30	60	165	390	195	600	225	835

A- Bladder or Diaphragm Tank Design B- Plain Steel Tank Design

(1) Note: Actual values may vary somewhat with field conditions.

Rules of thumb for shared wells

- ✓ Average well yields 1,440 gallons a day or more
- ✓ Dwellings using the same well should be within 1,000 feet of each other
- ✓ Each person uses 80 gallons a day
- ✓ Gallons per family x number of families = minimum gallons needed per day
- ✓ Gallons per minute x number of families = minimum pump capacity
- ✓ Gallons per minute x number of fixtures = minimum pump capacity
(Table VII.1.2 for tank capacity recommendations).

Study Guide Questions - Chapter 1

Answers can be found on page 34

Q. What are the five ways a small community can obtain water?

1. _____
2. _____
3. _____
4. _____
5. _____

Q. What are some factors that are examined in a feasibility study?

Q. In a shared well system, what is the maximum distance between dwellings before another well is required?

Q. What is the average number of gallons per day used by one person?

Notes

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Chapter 2

Groundwater Heat Pumps

- ✓ Heat pump basics
- ✓ Groundwater heat pump system design overview
- ✓ Potential problems and solutions

Groundwater heat pumps (GWHP) use energy stored in **groundwater** and the earth during the hydrologic or **water cycle** (Book I, Chapter 1) to provide heat and air-conditioning for homes, commercial buildings, and factories. Groundwater is isolated from wide seasonal and daily temperature fluctuations, so it maintains a steady temperature throughout the year – about 50°F in the Midwestern United States.

When water is drawn out of the ground and coupled to a **heat pump** through a **heat exchanger**, the energy can be extracted and used to raise or lower indoor air temperatures. This heat energy is essentially free and is the key to the high efficiency and low operating cost of groundwater heat pumps when compared to coal, gas, or electric heating units. Most of the added cost of these other heating units is caused by thermal inefficiency. Fuel in coal, oil, and gas furnaces burns at 1,200°F to produce an indoor temperature of 70°F. A large amount of energy is lost in flue gas.

Heat pump basics

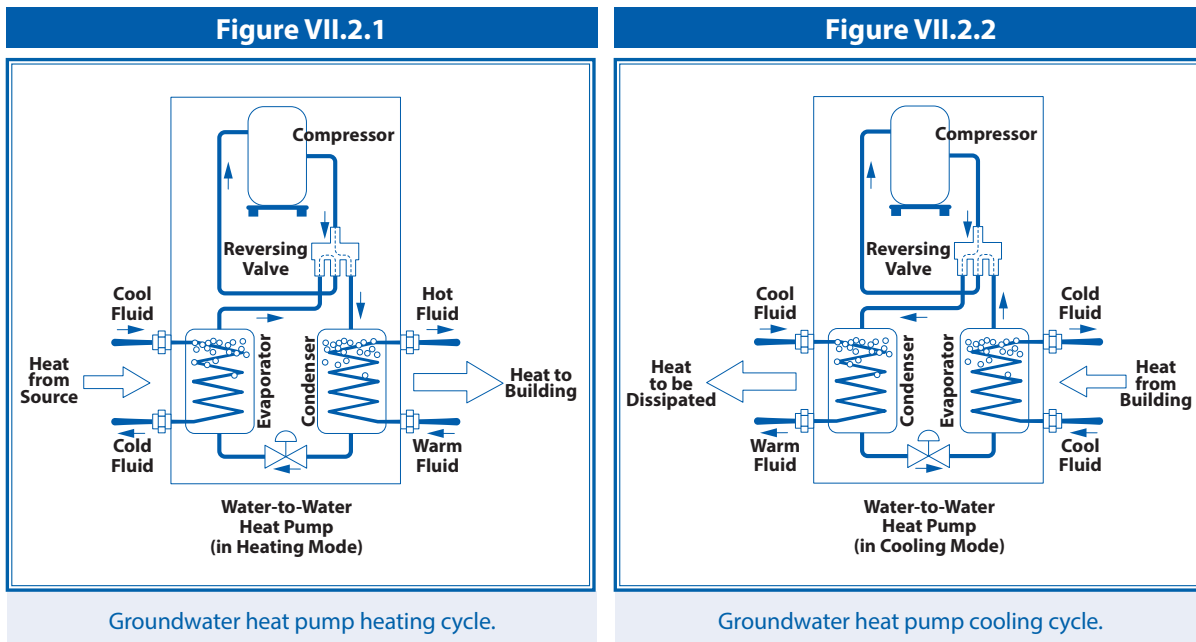
Heat exchanger systems use basic refrigeration technology. Most heat pumps are reversible, meaning they can provide cooling as well as heating by use of a refrigerant-reversing valve that permits the flow of refrigerant in either direction.

The heating cycle for groundwater heat pumps begins when groundwater is pumped through tubes to a heat exchanger. In many designs, these water-carrying tubes are set concentrically within another set of tubes that contain a liquid refrigerant that absorbs heat from the groundwater as it circulates through the inner set of tubes and forms a cool gas, which is 10° to 30°F cooler than the groundwater.

The cool gas is then directed to a compressor, which compresses it to a hot, denser gas (about 180°F and 245 psi). This hot gas then flows through another heat exchanger where heat from the refrigerant is released to the air and moved throughout the building. After this release of heat, the refrigerant condenses to a liquid and flows through an expansion device that reduces the pressure and consequently lowers the temperature. Finally, the refrigerant reenters the first heat exchanger and the cycle is repeated.

For cooling, the process is reversed. A compressor circulates the hot dense gas through tubes located within the groundwater tubes, lowering the refrigerant temperature. The refrigerant then passes through an expansion device that further lowers its temperature and pressure. The cool liquid refrigerant flows through a second heat exchanger and absorbs heat from air in the building. The cooled air is then circulated by a fan or blower. The warmed refrigerant returns to the compressor to repeat the cycle. Figure VII.2.1 and Figure VII.2.2 show diagrams of the heating and cooling cycles.

Some groundwater heat pump systems have an additional small heat exchanger between the reversing valve and the compressor to provide hot water for bathing, cooking, laundry, or other needs.



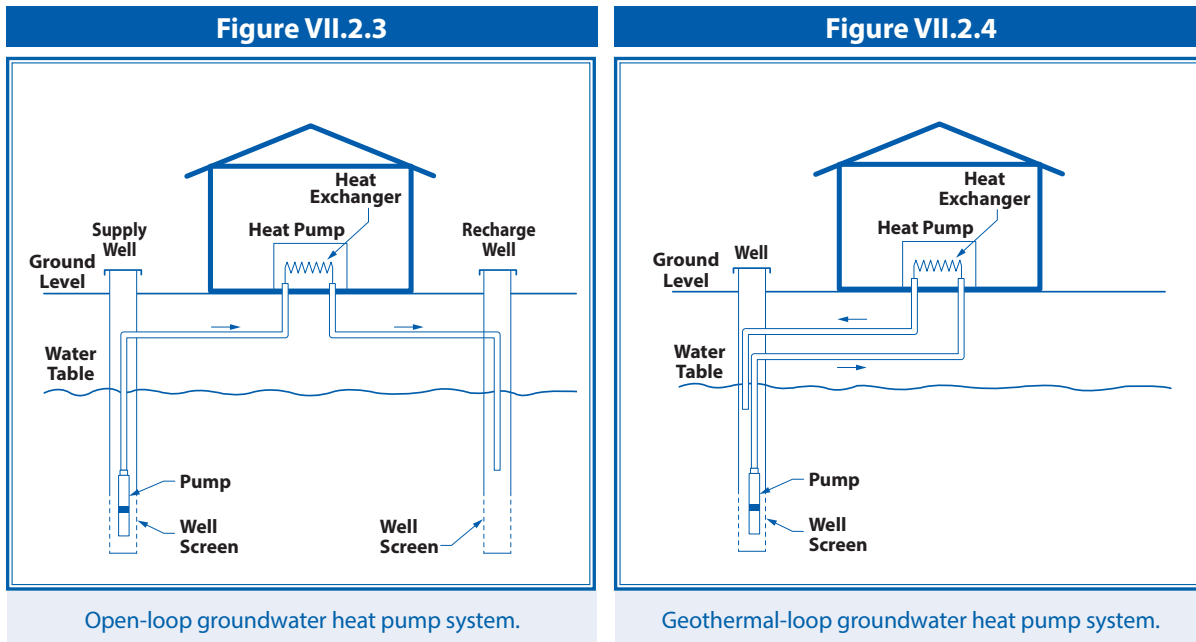
GWHP systems

Many GWHP systems use an **open-loop groundwater** heat pump design (Figure VII.2.3). Water enters the heat pump from a **supply well**, the heat exchange occurs, and water is returned to the ground by a second well called a **recharge well**, also known as a diffusion, dispersion, injection, or return well. After the heat exchange process, water can also be discharged into a lake, stream, or storm sewer, depending on local conditions and environmental regulations.

When there is insufficient water for an open-loop well system, an alternative is a **geothermal-loop groundwater heat pump** (Figure VII.2.4). Because water is never in direct contact with the refrigerant, it does not become contaminated and can be drained back into the supply. Some water may be removed from the system for household use.

Geothermal loops use the earth as a heat source or sink, and must therefore be deep enough to allow the temperature of the return water to stabilize. A rule of thumb calls for about 150 feet of wetted bore hole per ton of heat pump capacity. Geothermal-loop systems are often less efficient than open-loop systems because the source water temperature varies. However, geothermal-loop systems are usually less costly to install than the two-well open-loop system and are still more efficient than conventional heating and cooling systems.

In areas with insufficient water supplies or where open-loop or geothermal-loop systems are prohibited, a **closed-loop groundwater heat pump** may be a good alternative. In closed-loop (also called earth-coupled) systems, water used in the heat pump is circulated through pipes or tubes buried either vertically or horizontally in the ground. Heat is transferred to or from the soil through the pipe walls.



There are two types of closed-loop systems: **vertical earth coil system** and **horizontal earth coil system** (Figures VII.2.5 and VII.2.6). In the vertical earth coil, a bore hole is drilled into the earth and the heat exchange pipe is run down to the bottom and then back up to a level below the frost line. Depending on the depth of the bore hole and size of the heating system, one or more bore holes may be connected in a series to attain the necessary heat exchange capacity. After the loop is in place, bore holes are backfilled to ensure good contact between the pipe and the earth.

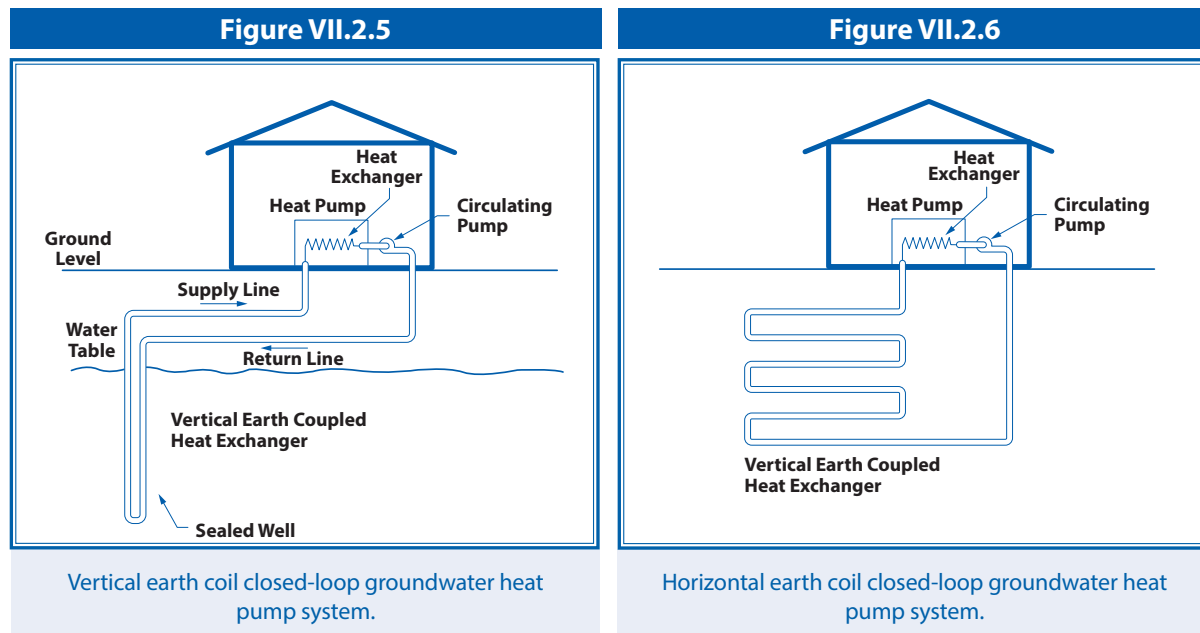
In the horizontal earth coil, plastic pipe is buried below the frost line, usually 4 to 6 feet below the earth's surface. A circulating pump is used to pump water from the heat pump through the loop. The water absorbs heat from the earth and is circulated back to the heat pump. Best performance is achieved when the coil is kept wet by being placed under a septic lateral field, for example. In general, approximately 300 linear feet of wetted pipe is required per ton of heat pump capacity.

In areas of the country where groundwater temperatures are at or lower than 55°F, it is necessary to use a solution of water and 10 to 20 percent propylene glycol by volume in closed-loop systems to prevent freezing and to select heat pumps that can operate with water temperatures in the 30° to 40°F range when heating.

Despite their lower efficiency, closed-loop systems have several inherent advantages over open-loop or geothermal-loop systems. First, no water is drawn from the earth, so there is no danger of overpumping the aquifer. Second, the circulating pump needs only to overcome the friction losses in the piping and heat exchangers, so the pump may be smaller. Third, there are no precipitating minerals that might cause scaling problems.

When returning groundwater to its producing aquifer, water should remain in a closed system. The preferred methods are **alternating two-well system** or **non-alternating two-well system**. Although an alternating system costs more to install, it usually requires less maintenance.

A recharge well is essentially the same as a supply well and should be constructed and developed with the same integrity in mind. If this rule is followed, the well can become a supply well with minimal effort.



System design

This general overview of the considerations involved in the design of a groundwater heat pump system is not intended to be a detailed design guide or manual. Obtain specific information from GWHP manufacturers and contractors.

Just as homeowners depend on an HVAC contractor to provide adequate heating and cooling, HVAC contractors depend on well drillers and pump installers to provide:

1. A well with adequate **capacity**.
2. A **pump** that will supply the required amount of water at proper pressure.
3. A **tank** of adequate size to prevent short cycling.

A groundwater heat pump may run 12 hours a day, so it is extremely important that the well supplies enough water to meet this **demand** day after day during the heating and cooling seasons. It is also necessary that the water pump supplies this required demand at the necessary **pressure**. Success of the installation depends, in large part, on adequate well capacity and proper pump size. If either of these is inadequate, the customer ends up with an ineffective heat pump system.

In sizing a heat pump for an installation, the heat pump installer must consider many factors in determining the heat load of a home, including climate, insulation, window areas, directions of exposure, and size of the home. This exercise, called an **energy audit**, must be performed for each installation to properly size a heating and cooling system.

Accurate sizing of the water well pump for the system is also critical. Not only must the pump be sized accurately, but selection is also important because the pump's operating costs are part of the owner's energy bill.

Typically, a water pump in a GWHP system will consume 10 to 15 percent of the electrical energy used in the heating and cooling system. The heat pump compressor will consume approximately 75 to 80 percent of the operating energy, and the fan will consume approximately 10 to 11 percent. Sizing and selecting a water pump properly to minimize the pumping cost is very important.

Pump capacity for open- or geothermal-loop systems

In some installations, the pump supplies water for household uses as well as for the heat pump. *Common practice is to install a pump with a rated capacity that is a minimum of 5 gpm or 25 percent greater than required for the heat pump alone.*

Heat pump requirements: Heat pump size is based on the manufacturer's data and heat loss and gain calculations for the building in which it will be installed.

To calculate the size of the unit required, the heat pump or HVAC contractor usually determines heat loss and gain. The proper unit is then selected based on the manufacturer's specifications, which also give the flow rate required for the heat pump at these conditions.

Total demand: A pump is selected to supply a minimum of 5 gpm or 25 greater than the total demand, which is the household demand or the heat pump demand, whichever is greater.

Well capacity and design

The water usage of a GWHP differs drastically from that of a household system. For example, the heat pump may run around the clock during the coldest winter periods while household demand varies.

Pump tests

During peak demand, an untested or seasonally inadequate well may run dry, which could damage the water pump and the heat pump unit. Therefore, the contractor must conduct a proper pumping test to establish the well's maximum flow and its specific capacity.

A constant rate test requires that the well be pumped at about three times the required yield. After drawdown in the well has stabilized, the test may continue for as long as 12 more hours. A less costly version of this test is to pump the well at the target rate for 24 hours. Other versions of pump tests are matched to varying aquifer characteristics.

If the test shows that there is insufficient yield to maintain a GWHP, alternative system designs should be considered. These are discussed later in this chapter.

Pressure requirements

After the total pump capacity necessary to meet the system demand has been established, the next step is to determine the pressure or **head** the pump must supply to the system. Book VIII, Chapter 1 and Book VII, Chapter 1 provide all the information necessary to calculate system pressure requirements.

The pressure required by a heat pump is obtained from the HVAC contractor. From the load calculations and groundwater temperature, the flow rate required for the unit can be determined. The manufacturer's data give the heat pump pressure drop for this flow.

If the system requires automatic pressure-regulating valves, the heat pump installer or the water pump installer will have to take this pressure drop into account. If a recharge well is used and a positive head is maintained on the heat pump discharge line, also take this into account. Also consider any pressure losses in piping from the water pump or tank to the heat pump. For proper operation of the heat pump, it must be sized so that the inlet pressure to the heat pump meets the HVAC contractor's requirements.

For the sample system shown in Figure VII.2.1 (page 17), when friction, tank pressure, depth to water, and elevation are added, the required head is 187 feet at an average pressure of 40 psi. The selected tank pressure range, which is 30 to 50 psi, was checked with the heat pump manufacturer and met its requirements.

When installing a water system for a groundwater source heat pump, it is very important to keep pressure drops in the line between the pump and the pressure tank to a minimum to help reduce pumping costs.

Pump selection

With this same example, a pump must supply 15 gpm at 187 feet of head and, in addition, must develop adequate pressure to turn off the **pressure switch**. As indicated earlier, the pumping cost on a heat pump system becomes much more expensive than for a household system only. Seriously consider pump operating costs when making a decision about a heating and cooling system.

Pressure tank sizing

Refer to Book VIII, Chapter 3

Disposal methods

As previously indicated, although groundwater heat pumps are very efficient, they require a large amount of water to operate. Water that has passed through the heat pump must then be disposed. Before any disposal system is considered, find out about state and local regulations.

Recharge wells are the most widely recognized method of disposal. Generally, the area of a recharge well is twice that of a supply well so that if some minerals precipitate out of the water, there is less likelihood of clogging the recharge well formation. Regular maintenance of recharge wells should be performed.

Placement of the recharge well relative to the supply well is important both from a thermal pollution and groundwater movement point of view. Thermal pollution can be avoided on most residential installations if the wells are 75 to 100 feet apart. It is also advantageous to place the recharge well downstream (relative to underground water movement) from the supply well.

Some other ways to dispose of GWHP water are by discharge to a surface water body, a leach field, or a sewer, depending on regulations.

Compensating for a low-yield well

If the well yield (capacity) is not sufficient to supply the required total system demand, there are alternate means to supply a GWHP system:

1. Drill a new well with a larger diameter so that the well provides enough water storage to meet the total demand. In this case, the **well casing** will provide additional storage.
2. Use an intermediate **atmospheric storage tank**. This tank supplies only the heat pump. Household requirements are supplied directly from the well into a pressure tank. The well pump supplies water to both tanks, with a separate pressure pump required to supply water from the intermediate tank to the heat pump. The well pump should be sized so that its capacity at the required head is 10 percent less than the well yield. This is to prevent overdrawing the well. The pressure pump must be sized to supply the heat pump demand at the required pressure. For example:

Heat pump demand = 12 gpm

Well pump yield = 8 gpm

Capacity supplied by tank = heat pump demand - well pump yield (12 gpm - 8 gpm = 4 gpm)

The tank should be large enough to supply water for 8 hours of continuous heat pump usage.

Tank size = 4 gpm x 8 hrs. x 60 min./hr. = 1,920 gallons

At times during this 8-hour period, there will be household usage of water from the well, which will effectively lower the flow rate into the tank. This has to be taken into account, so add 400 to 600 gallons to tank capacity, which results to about a 2,400-gallon tank. This size tank will allow for at least 8 hours of heat pump usage, even with 480 gallons being diverted from the well for household requirements.

Water quality

Groundwater contains minerals, which means that corrosion and scaling can be problems with heat pumps.

Limestone Scaling: Limestone (calcium carbonate) is the most abundant hardness-causing mineral and causes most scaling problems. The amount of calcium carbonate held in solution in the water depends upon the amount of carbon dioxide in solution.

This dissolved carbon dioxide will remain in solution unless there is a change in temperature or pressure. For example, when the pressure in a bottle of carbonated beverage is relieved by removing the cap, the dissolved carbon dioxide begins bubbling out. In groundwater, dissolved carbon dioxide leaves the solution when there is an increase in temperature or a decrease in pressure, causing carbonates to precipitate out to form scale.

Scaling as a result of temperature change is difficult to avoid, but is not a significant problem. If scaling should occur, it can be removed by operating the heat pump in reverse-cycle or cleaning it with chemicals.

Pressure-induced scaling can be minimized by careful water system design. For carbon dioxide to come out of solution, water pressure has to be reduced. In the pipe and system design, make sure that a positive pressure always exists. This pressure should be equal to or greater than the original hydrostatic pressure in the supply well to minimize dissolution of carbon dioxide and accompanying scaling.

Corrosion: Three types of corrosion may occur in groundwater heat pump systems: galvanic, dezincification, and chemical. The higher the temperature, the faster the corrosion rate. In general, fluid velocities above 6 feet per second may result in increased noise, corrosion, and/or erosion.

1. **Galvanic corrosion** occurs when two dissimilar metals are placed together in the presence of an electrolyte, such as groundwater. To avoid galvanic corrosion, use plastic piping. If dissimilar metal piping is connected, use dielectric couplings.
2. **Dezincification** is a form of corrosion in which the zinc in brass is removed from the alloy. Brass is generally only used in valves for heat pumps, so the problem is not too severe and occurs most often in water with high total dissolved solids and dissolved oxygen.
3. **Chemical corrosion** has several possible causes, including the following:

Dissolved oxygen: Dissolved oxygen in water can be extremely corrosive. One source of dissolved oxygen in a water system is the standard hydropneumatic tank where the air and water are in contact. This not only adds oxygen to the water, but also contributes to “red water” or iron oxidation problems. Only precharged diaphragm (or bladder) pressure tanks should be used in groundwater heat pump systems.

Hydrogen sulfide: The familiar rotten-egg odor is a gas that is corrosive to copper and copper-alloy heat exchangers. Treatment is available. Hydrogen sulfide can be treated without the use of chemicals by a pressurized oxidation method and an atmospheric storage tank method. It can also be treated chemically with chlorine.

Total dissolved solids (TDS): The higher the TDS, the more corrosive the water. With a TDS of 1,000 ppm, serious corrosion can occur.

Carbon dioxide: Carbon dioxide in excess of 50 ppm accelerates corrosion.

Chlorides: Chlorides are extremely aggressive and attack most common metals, other than some stainless steels, under certain conditions. Beware of levels in excess of 300 ppm. Plastic pipe is not affected by chlorides.

Troubleshooting recharge or return well problems

The most common problem with a recharge well is that it cannot accept as much water as the same-sized supply well can produce. If the return well is too small, it will overflow. The water will either run off or, in flat areas, create an unplanned mire. The return well must then be oversized by about 30 percent, depending on local conditions. In an alternating two-well system, both wells must be oversized. Or an overflow tube can be installed to direct the overflow to a drainage ditch or storm sewer.

Other problems include these:

- *If yield is too low in the pumping well or if the tube is discharging above the static water level, air can be entrained and will promote well screen incrustation.*
- *If injection capacity is reduced but no scaling or corrosion is found, fine sand or silt may be entering the well. Redevelop both wells to eliminate this problem.*
- *If continued reduction in GWHP efficiency is noted and none of the causes already considered is responsible, there may be thermal interference between the supply and discharge wells. Space the wells at least 100 feet apart, depending on aquifer conditions. Reduction in system efficiency may also occur when water volume through the heat exchanger is not large enough to minimize the temperature drop and subsequent mineral scaling. Reduction in system efficiency may also be caused by mechanical malfunction of the heat pump or other system components.*

System standards

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) maintains the most widely accepted product performance certification procedures and sponsors a groundwater heat pump certification program.

Participation in AHRI programs is voluntary. More than 90 percent of the air-conditioning and refrigeration components manufactured in the United States are produced by AHRI members. Many certified units are specified as water-source heat pumps rather than groundwater-source. When selecting a ground water heat pump (GWHP) system, consider equipment with AHRI certification and contact the manufacturer to make sure the system is suitable for a particular groundwater application. Check www.ahrinet.org.

The International Ground Source Heat Pump Association (IGSHPA) also offers a Ground Source Heat Pump System Registration Program. Check www.igshpa.org.

Study Guide Questions - Chapter 2

Answers can be found on page 34

Q. What are groundwater heat pumps and how do they work?

Q. Name some types of GWHP systems.

Q. List three things HVAC contractors for a GWHP system need from well drillers and pump installers.

Q. What do GWHP systems require in large quantities?

Q. What is the most commonly used disposal method for the used water from a GWHP?

Q. What is a major problem for GWHPs?

Notes

Appendix

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Length				
Inches	(in)	Millimeters	(mm)	25.400
Inches	(in)	Centimeters	(cm)	2.539
Feet	(ft)	Meters	(m)	0.305
Yards	(yd)	Meters	(m)	0.914
Miles (statute)	(mi)	Kilometers	(km)	1.609
Millimeters	(mm)	Inches	(in)	0.039
Meters	(m)	Feet	(ft)	3.281
Centimeters	(cm)	Inches	(in)	0.394
Meters	(m)	Yards	(yd)	1.094
Kilometers	(km)	Miles (statute)	(mi)	0.621
Area				
Square Inches	(in ²)	Square Centimeters	(cm ²)	6.452
Square Feet	(ft ²)	Square Meters	(m ²)	0.093
Square Yards	(yd ²)	Square Meters	(m ²)	0.836
Square Miles	(mi ²)	Square Kilometers	(km ²)	2.590
Acres	(ac)	Hectares	(ha)	0.405
Square Centimeters	(cm ²)	Square Inches	(in ²)	0.155
Square Meters	(m ²)	Square Feet	(ft ²)	10.764
Square Meters	(m ²)	Square Yards	(yd ²)	1.196
Square Kilometers	(km ²)	Square Miles	(mi ²)	0.386
Hectares	(ha)	Acres	(ac)	2.471
Liquid Volume				
Ounces	(oz)	Milliliters	(ml)	29.574
Pints	(pt)	Liters	(l)	0.473
Quarts	(qt)	Liters	(l)	0.946
Gallons	(gal)	Liters	(l)	3.785
Pounds per Cubic Foot	(lb/ft ³)	Kilograms per Cubic Meter	(kg/m ³)	16.018
Pounds per Gallon	(lb/gal)	Kilograms per Cubic Meter	(kg/m ³)	119.826
Milliliters	(ml)	Ounces	(oz)	0.034
Liters	(l)	Pints	(pt)	2.113
Liters	(l)	Quarts	(qt)	1.057
Liters	(l)	Gallons	(gal)	0.264
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Cubic Foot	(lb/ft ³)	0.062
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Gallon	(lb/gal)	0.008
Mass				
Ounces	(oz)	Grams	(g)	28.350
Pounds	(lb)	Kilograms	(kg)	0.454
Grams	(g)	Ounces	(oz)	0.035
Kilograms	(kg)	Pounds	(lb)	2.205
Flow				
Cubic Meters per Hour	(m ³ /h)	Gallons per Minute	(gpm)	4.400
Gallons per Minute	(gpm)	Cubic Meters per Hour	(m ³ /h)	0.227

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Force				
Foot Pound Force	(ft-lbf)	Joules	(J)	1.356
Newtons	(N)	Kilogram Force	(kgf)	0.102
Joules	(J)	Foot Pound Force	(ft-lbf)	0.738
Kilogram Force	(kgf)	Newtons	(N)	9.807
Power				
Horsepower	(hp)	Kilowatts	(kW)	0.746
Horsepower	(hp)	Watts	(W)	745.700
Kilowatts	(kW)	Horsepower	(hp)	1.341
Watts	(W)	Horsepower	(hp)	0.001
Pressure				
Bars	(b)	Pounds per Square Inch	(psi)	14.500
Kilograms per Square Centimeter	(kg/cm²)	Pounds per Square Inch	(psi)	14.500
Pounds per Square Inch	(lb/in²)	Kilograms per Square Meter	(kg/m²)	703.070
Pounds per Square Inch	(lb/in²)	Kilopascals	(kPa)	6.895
Pounds per Square Inch	(lb/in²)	Meters of Water	(m)	0.704
Inches of Mercury	(inHg)	Kilograms per Square Meter	(kg/m²)	345.300
Kilograms per Square Meter	(kg/m²)	Pounds per Square Inch	(lb/in²)	0.001
Kilopascal	(kPa)	Pounds per Square Inch	(lb/in²)	0.145
Meters of Water	(m)	Pounds per Square Inch	(lb/in²)	1.420
Kilograms per Square Meter	(kg/m²)	Inches of Mercury	(inHg)	0.003
1 Atmosphere	14.7 lb/in²	Kilograms per Square Centimeter	(kg/cm²)	1.033
1 Atmosphere	14.7 lb/in²	Kilograms per Square Meter	(kg/m²)	10,335.000
1 Atmosphere	14.7 lb/in²	Kilopascal	(kPa)	101.350
1 Atmosphere	14.7 lb/in²	76.0 Centimeters Mercury	(cmHg)	5.170
1 Atmosphere	29.92 inHg	76.0 Centimeters Mercury	(cmHg)	2.540
Pascal	(Pa)	Newtons per Square Meter	(N/m²)	1.000
Pascal	(Pa)	Kilograms per Square Meter	(kg/m²)	0.102
Temperature				
Degrees Fahrenheit	(°F)	Degrees Celsius	(°C)	(°F-32) 0.556
Degrees Celsius	(°C)	Degrees Fahrenheit	(°F)	(1.8 x °C) + 32
Flow				
Feet per Second	(fps)	Meters per Second	(m/s)	0.305
Miles per Hour	(mph)	Kilometers per Hour	(km/h)	1.609
Gallons per Minute	(gpm)	Liters per Minute	(l/min)	3.785
Gallons per Minute	(gpm)	Cubic Meters per Minute	(m³/min)	0.004
Meters per Second	(m/s)	Feet per Second	(fps)	3.281
Kilometers per Hour	(km/h)	Miles per Hour	(mph)	0.621
Liters per Minute	(l/m)	Gallons per Minute	(gpm)	0.264
Cubic Meters per Minute	(m³/min)	Gallons per Minute	(gpm)	264.172

Glossary

Alternating Two-Well System: In groundwater heat pumps, a system for returning groundwater to its producing aquifer. This type of system costs more to install, but usually requires less maintenance. (VII-2)

Atmospheric Storage Tank: A tank that is open to the atmosphere and not pressurized. (VII-2)

Capacity: Amount of water moving past a given point in a given amount of time. (VII-1, VII-2)

Carbon Dioxide: A naturally occurring gas present in the atmosphere and formed by the decay of organic matter. (VII-2)

Chemical Corrosion: Form of corrosion in groundwater heat pumps, caused by dissolved oxygen, hydrogen sulfide, total dissolved solids, carbon dioxide, arsenic, iron, radon, or chlorides. (VII-2)

Chlorides: Any compound that has chlorine in its chemical compound. (VII-2)

Closed-Loop Groundwater Heat Pump (*Also called an Earth-Coupled System*): In a closed-loop system, water used in the heat pump is circulated through pipes or tubes buried either vertically or horizontally in the ground. Heat is transferred to or from the soil through the pipe walls. (VII-2)

Cut-In Pressure (*Also called Pump-Start Pressure*): Pressure level at which a pump turns on. (VII-1)

Demand: The gallons of water needed within a specific timeframe. (VII-1, VII-2)

Dezincification: A form of corrosion in which the zinc in brass is removed from the alloy. It occurs most often in water with high total dissolved solids and dissolved oxygen. (VII-2)

Dissolved Oxygen: Volume of oxygen in water. (VII-2)

Energy Audit: The consideration of many factors in determining the heat load of a home, including climate, insulation, window areas, directions of exposure, and size of the home, in order to properly size a heating and cooling system. (VII-2)

Feasibility Study: A study of the geography of the area and the density and growth rate of the population needed for system selection and design. (VII-1)

Final Engineering Report: A report that should contain specific information about the system design, including any necessary revisions of the preliminary engineering report. (VII-1)

Friction Loss: Loss of pressure when water flows through a piping system factoring gallons per minute, pipe length, size, and fittings. Measured in feet of head. (VII-1)

Galvanic Corrosion: Corrosion that occurs when two dissimilar metals are placed together in the presence of an electrolyte, such as groundwater. (VII-2)

Geothermal-Loop Groundwater Heat Pump: Used when there is not sufficient water for an open-loop well system. In a geothermal-loop groundwater heat pump, water is never in direct contact with the refrigerant, does not become contaminated, and can be drained back into the supply. Geothermal loops use the earth as a heat source or sink, and must therefore be deep enough to allow the temperature of the return water to stabilize. (VII-2)

Groundwater: Water that flows or seeps downward and is filtered by underground formations to attain a high degree of purity; ideal drinking water supply. Utilized by wells. (VII-1, VII-2)

Groundwater Heat Pump (GWHP): A space conditioning device that uses heat energy stored in groundwater and the earth during the hydrologic or water cycle to provide heat and cooling for homes, commercial buildings, and factories. These heat pumps offer high efficiency and low operating cost when compared to coal, gas, or electric heating units. (VII-2)

Head: Pressure expressed as height in feet. (VII-1, VII-2)

Heat Exchanger: Device that extracts heat energy, using basic refrigeration principles, that can be used to raise or lower indoor air temperatures. (VII-2)

Heat Exchanger System: In a heat exchanger system, groundwater is pumped through tubes to a heat exchanger. In many designs, these water-carrying tubes are set concentrically within another set of tubes that contain a liquid refrigerant that absorbs heat from the groundwater as it circulates through the inner set of tubes and forms a cool gas, which is 10° to 30°F cooler than the groundwater.

The cool gas is then directed to a compressor, which compresses it to a hot, denser gas (about 180°F and 245 psi) that flows through another heat exchanger where its heat is released to the air and moved throughout the building. The refrigerant condenses to a liquid and flows through an expansion device that reduces the pressure and consequently lowers the temperature. Finally, the refrigerant re-enters the first heat exchanger and the cycle is repeated. For cooling, the process is reversed. (VII-2)

Heat Pump: A machine that moves heat from a low temperature reservoir to a higher temperature reservoir; can be used for space heating and cooling. (VII-2)

Horizontal Earth Coil System: A type of closed-loop geothermal heat pump system in which plastic pipe is buried below the frost line, usually 4 to 6 feet below the earth's surface. A circulating pump is used to pump water from the heat pump through the loop. The water absorbs heat from the earth and is circulated back to the heat pump. (VII-2)

Hydrogen Sulfide: A corrosive and flammable gas often found dissolved in well water and often accompanied by iron and low pH values. (VII-2)

Limestone Scaling: The most abundant hardness causing mineral and causes most scaling problems. (VII-2)

Non-Alternating Two-Well System: Closed-loop groundwater heat pump system that uses a single return or recharge well for water emerging from the heat pump system. (VII-2)

Open-Loop Groundwater Heat Pump: A type of groundwater heat pump in which water enters the heat pump from a supply well, the heat exchange occurs, and water is returned to the ground by a second well called a recharge well or return well. (VII-2)

Preliminary Engineering Report: Report prepared by a consulting engineer following completion of a feasibility study; provides data that can serve as the basis for system design. (VII-1)

Pressure: The force exerted in pounds over one square inch area. (VII-1, VII-2)

Pressure Switch: An electrical switch activated by system pressure to control starting and stopping of the pump. (VII-2)

Pressure Tank: Vessel used to provide cycle control of the pump. (VII-1, VII-2)

Pump: A mechanical device that moves liquid or gas by pressure or suction; a device that converts mechanical torque and motion into hydraulic fluid power. (VII-1, VII-2)

Recharge Well (*Also called Diffusion, Dispersion, Injection, or Return Well*): The most commonly used disposal method for the used water from a groundwater heat pump. Requires a large area to avoid clogging. (VII-2)

Shared Well: Wells drilled to serve two or more nearby homes; sometimes referred to as cluster wells. (VII-1)

Supply Well: A well that provides the groundwater needed to operate a groundwater heat pump. (VII-2)

Surface Water: All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors which are directly influenced by surface water. (VII-1)

Tank: A container that stores water from a well before it enters the distribution system. Tanks are installed inside or outside a dwelling, placed in well pits or buried underground. (VII-1, VII-2)

Total Demand: The household water supply demand plus the heat pump water demand. (VII-1, VII-2)

Total Dissolved Solids (TDS): The total weight of the solids that are dissolved in the water, given in ppm per unit volume of water. (VII-2).

Vertical Earth Coil System: Closed-loop heat pump system in which a bore hole is drilled into the earth and the heat exchange pipe is run down to the bottom, then back up to a level below the frost line. (VII-2)

Water Cycle: Water's continuous process of evaporation, condensation, and precipitation. (VII-2)

Well: A deep hole or shaft sunk into the earth to obtain water, oil, gas, or brine. (VII-1, VII-2)

Well Casing: Steel or plastic lining permanently installed in drilled wells to prevent cave-ins or contamination by surface water. (VII-2)

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Study Guide Answers

Chapter 1

Q. What are the five ways a small community can obtain water?

A. Individual wells, shared wells, pumping from surface water, drilling a central community well, or extending rural pipe lines.

If you missed this question, go back to page 9 for information on community water sources.

Q. What are some factors that are examined in a feasibility study?

A. The geography of the area and the density and growth rate of the population, a description of water supply facilities serving the area, the interest of local residents in a community water project, the average life expectancy of (and any possible problems that might arise with) wells or surface water in the area, and sources of water pollution such as sewage and industrial waste discharge.

If you missed this question, go back to page 10 for information on feasibility studies.

Q. In a shared well system, what is the maximum distance between dwellings before another well is required?

A. 1,000 feet.

If you missed this question, go back to page 12 for information on shared well design.

Q. What is the average number of gallons per day used by one person?

A. 80 gallons per day.

If you missed this question, go back to page 12 for information on shared well design.

Chapter 2

Q. What are groundwater heat pumps and how do they work?

A. Groundwater heat pumps (GWHP) use heat energy stored in groundwater and the earth during the hydrologic or water cycle to provide heat for homes, commercial buildings, and factories. They operate using basic refrigeration technology.

If you missed this question, go back to page 16 for information on groundwater heat pumps.

Q. Name some types of GWHP systems.

A. Open-loop, geothermal-loop, and closed-loop systems.

If you missed this question, go back to page 18 for information on GWHP systems.

Q. List three things HVAC contractors for a GWHP system need from well drillers and pump installers.

A. A well with adequate capacity, a pump that will supply the required amount of water at proper pressure and a tank of adequate size to prevent short cycling.

If you missed this question, go back to page 20 for information on system design.

Q. What do GWHP systems require in large quantities?

A. Water.

If you missed this question, go back to page 22 for information on disposal methods.

Q. What is the most commonly used disposal method for the used water from a GWHP?

A. A recharge well, also known as a dispersion, diffusion, injection, or return well.

If you missed this question, go back to page 22 for information on disposal methods.

Q. What is a major problem for GWHPs?

A. Dissolved minerals in the groundwater that can cause corrosion and scaling.

If you missed this question, go back to page 23 for information on water quality.



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Sizing

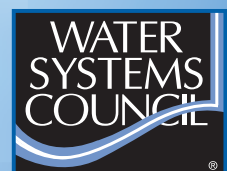


WATER SYSTEMS HANDBOOK

*A complete text on wells:
their design, operation, and maintenance*

13TH EDITION

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WATER SYSTEMS HANDBOOK

BOOK VIII

Sizing

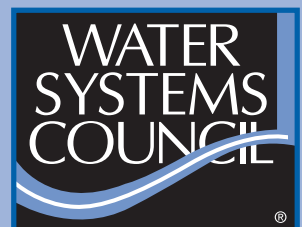
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A Word Of Caution

The products described in this Handbook, including all products using electrical current, can result in serious harm if not used with EXTREME CAUTION and in strict accordance with manufacturers' instructions. Professional assistance is recommended and should always be sought when utilizing unfamiliar equipment.

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Introduction to Wells

Water is life's most vital resource. Through the centuries, people have searched for water, fought for it, and sometimes died for it. No living organism can exist without water.

Consequently, clean and plentiful groundwater is necessary for everyday life. As described in this handbook, groundwater is the reservoir of water that seeps downward through the soil to the water table below the earth's surface. About 98 percent of all fresh water available in the nation at any time is groundwater, which fills the porous beds of rock and sand that make up the earth's crust.

Groundwater is an ideal water supply, for it is pure and wholesome. Filtered by the underground formations through which it passes, groundwater has a degree of purity seldom attained by surface waters.

Natural groundwater reservoirs have many advantages. They have huge capacities, they are relatively inexpensive to tap by means of wells, and they lose little water by evaporation. Above all, they are dependable sources of water.

In the United States alone, more than 115 million people get their drinking water from groundwater every day. More than 23 million American households are supplied from individual, private wells.

A modern well is both flexible and functional. A variety of pumps is available to lift water from all types of wells, from the shallowest to the deepest. These systems are made automatic and dependable by many types of controls and accessories. Groundwater is there when needed. Additional equipment may be added to the system for treatment to ensure better quality of life.

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About this Handbook

The **WATER SYSTEMS HANDBOOK** provides basic information on well design, operation, and maintenance to boost the professional knowledge of well industry personnel.

Before you begin your studies, please take a few moments to familiarize yourself with the format of this handbook. The handbook is divided into eight books. Each includes several chapters that cover the most important aspects of wells. At the end of each chapter, you will find a **Quiz**. You can use this quiz as a learning tool to review the noteworthy points in each chapter. Answers to the quiz can be found at the end of each book. If you miss an answer, follow the directions to take you back to where the information is located in the chapter.

For quick reference, you will find that highlighted text is generally defined in a **Glossary** at the back of each book, where you will also find a topical **Index**. While illustrations appear in each chapter, you will also see tables and charts referenced in text and located in the **Appendix** at the back of each book. A handy metric system reference also appears in each appendix.

We hope that studying the information in this handbook will prepare you for your job as a well professional, charged with the important responsibility of helping to ensure access to pure, plentiful well water for families across America.

Water Systems Council

Dedication

This 13th Edition of Water Systems Handbook is dedicated to the millions of Americans who rely on private water systems to provide safe, sustainable water supply and to the water well professionals in the water well industry.

The 13th Edition is also dedicated in memory of Jeff Wellen for his many years of leadership and service to WSC and the water well industry.

Special thanks to the members of the Water Systems Council Technical Committee, who initiated and completed revisions to this 13th Edition.



The Water Systems Council (WSC) is a national nonprofit organization, dedicated to promoting the wider use of wells as safe, sustainable, and cost-effective drinking water systems; protecting groundwater resources and users of well water, and ensuring a safe drinking water supply for well owners. WSC members include major manufacturers of the integral components of wells and other drinking water systems, leading distributors of these components, and various drinking water professionals.

WSC is the only national nonprofit organization with programs solely focused on private water wells and small, shared wells.

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Chapter 1

Pump Sizing and Selection

- ✓ Well conditions: size, depth, and yield
- ✓ Pump capacities
- ✓ System head and pressure
- ✓ Friction loss calculations
- ✓ Pump selection
- ✓ Pump characteristics and functions

Proper sizing and selection

Proper sizing and selection of a water system is essential to meet a user's water requirements with reliability, operating efficiency, adequate reserve capacity, and reasonable system cost. The system must supply an adequate amount of water during all periods of usage and supply it at high enough pressure to properly operate fixtures and appliances.

Water systems should always be sized with appreciable reserve capacity. Future expansion should be taken into account. The use of additional water-consuming appliances increases each year. For the average new installation, whether it is a home, farm, or commercial establishment, an excess of 50 percent will usually prove to be well worth the small added initial expense.

The well driller should attempt to drill the well deep enough to provide ample water to supply the capacity required for demand. The well driller is creating a storage container that provides cool, fresh, and safe water for the customer. When selecting a pump, it is necessary to use this stored water to meet the capacity requirements of the application. The proper pump should be selected from the performance curves using the required **capacity** (gpm) and the **total dynamic head** (TDH in feet). (Refer to page 27 for a sample Pump Performance Curve).

This chapter explains the procedure for designing a domestic water system based on the type of pumping systems described in Book I, Chapter 2.

It is recommended that a Pump Sizing Selection Worksheet be used to record and document the necessary information for each application (Refer to the appendix for Pump Sizing Selection Worksheets and related Pump Diagrams). This worksheet will serve as a checklist to obtain the needed information and establish a procedure for sizing and selecting a pump system. It may also serve as a quotation sheet for an application. A copy of the worksheet should be kept on file for future review and reference.

Table VIII.1.1

Average Water Consumption for Home and Farm Use						
Private Residences						
Outlets	Flow Rate gpm	Total Usage Gallons	Bathrooms in Home			
			1	1 ½	2-2 ½	3-4
Shower or Bathtub	5	35	35	35	53	70
Lavatory	4	2	2	4	6	8
Toilet	4	5	5	10	15	20
Kitchen Sink	5	3	3	3	3	3
Automatic Washer	5	35	-	18	18	18
Dishwasher	2	14	-	-	3	3
Normal seven (7) minute peak demand (gallons)			45	70	98	122
Minimum sized pump required to meet peak demand without supplemental supply		Divide peak demand by 7	7 gpm (420 gph)	10 gpm (600 gph)	14 gpm (840 gph)	17 gpm (1020 gph)
Notes: Values given are average and do not include higher or lower extremes. Peak demand can occur several times during morning and evening hours.						
Yard Fixtures		Farm Use				
Garden Hose - ½"	3 gpm	Horse, Steer	12 gpd			
Garden Hose - ¾"	6 gpm	Dry Cow	15 gpd			
Sprinkler	3-7 gpm	Milking Cow	35 gpd			
Alternate Capacity Methods: Calculate the number of bathrooms x 4 gpm = ? (Note that 1/2 baths are considered as full baths) Count the number of fixtures in a home including outside hose bibs. Supply one gallon per minute each.		Hog	4 gpd			
		Sheep	2 gpd			
		Chicken/100	6 gpd			
		Turkey/100	6 gpd			
		Fire	20-60 gpm			

I. Pump Sizing

It is important to gather as much information as possible about an application to make a proper **pump** sizing and selection decision. Required information includes:

- well conditions: casing size, well depth, yield, static water level, pumping level, drawdown, and location
- capacity requirement of the system or application expressed in gpm or gph
- pressure requirement expressed in psi or feet of **head**

Information is also needed for the specific type of pump system, whether a **shallow well jet pump**, **deep well jet pump**, or **submersible pump**.

A. Well conditions: Size, depth, and yield

The driller's **well log** is the ideal source of information about a well's condition.

The diameter of the well casing should be given top consideration because this information can quickly narrow down pump choices. Most submersibles require a 4-inch minimum well diameter. Jet pumps, on the other hand, can be used with shallow wells as small as 1-inch in diameter.

The second consideration is depth of the well to the pumping level. This is an important consideration in the selection of any pump because the water level in most wells will drawdown when the pump is in operation. If the drawdown goes below the pump intake, the pump will run dry and may be damaged. A well with a water level deeper than 25 feet would eliminate a shallow well jet pump from consideration. A well should be capable of supplying the required system capacity. If a new well is being constructed, it should be designed to provide adequate capacity. If an existing well is to be used, capacity may be verified by test pumping the well.

When the well yield is not adequate to meet pump capacity as calculated below in Section B, system modifications must be made to meet requirements. These modifications should involve calculating the well storage capacity to anticipate selecting a larger pump that will help meet capacity requirements of the system, including special controls in the installation to protect the pump, motor, and adding tank capacity.

(Refer to the Calculating Well Storage and Maximum Pump Run Time in Section III, page 21).

Location or setting of the pump should also be considered in pump sizing and selection.

B. Capacity requirement of system or application

The capacity requirement of a water system pump may be provided by the user or an engineer's specification. On the other hand, it may be necessary for the installing contractor to determine this requirement.

A pump should be sized to be adequate during a period of peak demand, rather than average usage. The method used for sizing a system also depends on whether usage is for a residential or farm system.

Average daily water usages have been studied by various groups for many years. The Water Systems Council has gathered much of this data. A summary of average values is provided in Table VIII.1.1 (page 10).

Sizing residential water systems

There are several methods available to calculate a residential capacity requirement, but the simplest one is called the outlet or **fixture method**. The number of fixtures is determined and totaled. The total number of fixtures is multiplied by 1 gallon per minute (gpm) to obtain a capacity requirement. Example: 10 fixtures x 1 gpm = 10 gpm. However, using this method requires consideration of what is referred to as the **peak-demand period**, when more than one fixture is in use at the same time. Thus, the number of fixtures being used at the same time is determined and multiplied by 3 gpm to obtain another capacity requirement. Example: 4 fixtures x 3 gpm = 12 gpm. Use the larger (12 gpm) of these two numbers (10 gpm vs. 12 gpm) as the capacity requirement to select the pump for this residence. No one ever complains about having too much water.

Note that the peak-demand period is never a fixed time. It changes with the number of people and the number of bathrooms. For example, a four bedroom home with two baths will have a longer peak-demand period than the same home with three or four bathrooms. The total consumption of water will be the same, but the peak-demand period will be different, thus affecting the pump size requirement.

Typically, the calculation to determine **total usage** is based on the number of bedrooms multiplied by two people at the national average of 80 **gallons per day** (gpd) per person. There are two peak periods every day, morning and evening, each using one-third of a residence's total usage per day.

Furthermore, the number of present occupants does not reflect future use, only the number of bedrooms does. Sizing must therefore be calculated to ensure that the full capabilities of the structure can be met in the future.

Sizing farm water systems

The sizing of a water system for use on a farm should take into account the home usage as determined here, drinking requirements of any animals, water needed for cleaning, and adequate capacity and pressure for firefighting. The time at which the water will be used must be considered to ensure adequate pressure at all times and to avoid delays and inconvenience.

In sizing a farm water system, the pump should be capable of supplying the daily requirements for the animals in a 2-hour period. Therefore, the total gallons per day required should be divided by 120 minutes.

Example: Sizing Farm Water Systems					
Farm has 50 milking cows, 30 dry cows, and 400 chickens. Milk house contains three water-using fixtures and the farmhouse contains 10. The pump capacity requirements would be as follows using Table VIII.1.1 (page 10).					
	# of Animals		Gallons/Animal		Gallons
Milking Cows	50	x	35	=	1750
Dry Cows	30	x	15	=	450
Chickens/100	400	x	6	=	24
Total Daily Usage					2,224
How to Calculate Pump Capacity for 2 Hours	2,224 gal	÷	120 minutes	=	18.6 gpm
	Milk House with 3 Fixtures			=	3.0 gpm
	Farmhouse with 10 Fixtures			=	10.0 gpm
	Required Capacity			=	31.6 gpm
2 hours x 60 minutes = 120 minutes					
This capacity is also suitable for firefighting.					

Schools and hotels have special demand requirements

Schools have special requirements, because practically all the water is used during recess. Demand is continuous for periods of about 15 minutes at a time; therefore, school water systems must have adequate capacity to handle these peak periods.

Hotels also have special requirements. Their peak loads occur from 7 a.m. to 9 a.m. and again from 5 p.m. to 9:30 p.m. In a hotel, a traveler uses up to 50 gallons per day (gpd), half during the morning period and half during the evening.

When well capacity is less than peak consumption

The best and most economical water system results when the rate at which water can be replenished from a source is greater than the requirements. If the maximum rate of water available from the well is less than the peak system demand, the short-time demand must be made up by added storage capacity. In this case, it is important to calculate the well storage capacity and plan for additional storage capacity in advance. (See Calculating Well Storage and Maximum Pump Run Time in Section III, page 21).

There are systems, however, in which the well capacity is so low that a two-pump system may be an option.

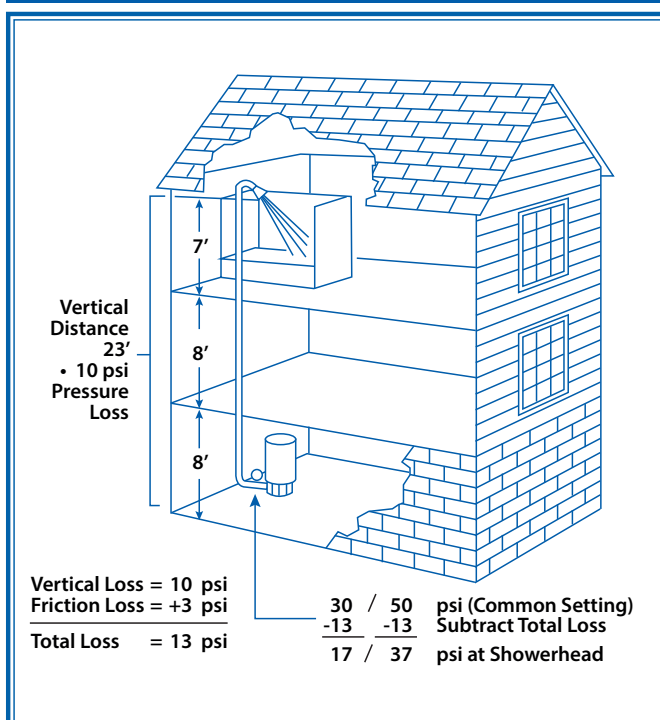
In a two-pump system, the well pump supplies water to an **atmospheric storage tank**. Operation of this pump is controlled by the **float switch** in the atmospheric tank. The switch should be set so that the pump runs for a period of at least 2 minutes each time it is started. This prevents excessive wear on the motor's starting switch and overheating of the motor.

The atmospheric tank should be large enough to take care of the total quantity of water required for peak-demand periods. Be sure the time between demand periods is long enough to have the well pump replenish the supply. In any case, the total daily requirements of the system cannot exceed the 24-hour pumping capacity of the well.

The second pump, which may be a shallow well unit or a submersible installed in the tank, takes water from the atmospheric tank and discharges it into the pressure tank or directly into the system. Its operation is controlled by a **pressure switch**. The pump functions in the same manner as any other water system pump.

The sizes of the second pump and the pressure tank are selected with the same considerations given water systems with adequate well sources.

Figure VIII.1.1



An example of pressure loss in a two-story home. This illustrates a way to calculate system head to meet household demands.

C. System head/pressure requirements

After determining the required water capacity and the well's ability to yield this desired capacity, it is important to determine the **system head** or **pressure** requirements. In Book I Chapter 2, the basics of friction losses that exist in piping, valves, couplings, elbows and the pump, and the components of total head are explained.

The total system head requirement is usually expressed in feet of head or in pounds per square inch (psi), sometimes referred to simply as "pounds". **Suction lift**, or the vertical distance the water is to be pumped, is expressed in feet. Friction loss is also expressed in feet of discharge head lost per 100 feet of pipe. The discharge pressure from the pump, the pressure switch setting, and the friction loss through water-conditioning equipment, such as softeners, filters, and purifiers are expressed in psi. Performance charts of most water system pumps show discharge pressure in psi and lift in feet.

Most water systems use a pressure switch set to operate the pump and to maintain system pressure between 20 and 40, 30 and 50, or 40 and 60 psi. These pressures will provide adequate service for most homes and small commercial establishments, including two-story homes with the pressure tank in the basement and with commonly used water appliances. This assumes, of course, that the piping is sized properly and in reasonably serviceable condition.

System head information may be provided by the user or specified by an engineer. It also may be calculated or a matter of experience and adjustment. For example, referring to Figure VIII.1.2 (page 16), let's say the pressure switch in the basement at the tank is set at 30/50 psi. There is a shower on the second floor at 23 feet of vertical elevation. To determine the pressure loss at this distance, divide 23 feet by 2.31 = 10 psi. The friction loss in the pipe is 3 psi. Adding these two pressures together determine that there is a pressure loss of 13 psi. To calculate the pressure at the shower, subtract 13 psi from the 30/50 psi tank setting and the result is 17/37 psi. If this is not adequate, the pressure switch setting should be changed to 43/63 psi to produce the 30/50 psi at the shower.

If the pressure tank is located a considerable distance from the house, a higher pressure setting may be needed to allow for the pipe friction losses in the longer lengths of pipe.

When selecting a pump, it is recommended to use the cutoff pressure (highest psi) setting. The reason is that pressure and capacity are inversely related. When one increases, the other decreases. This can be seen on pump selection charts or curves. Demand is the greatest on the pump when it first comes on; pressure is the lowest when the pump delivers the highest amount of capacity. As demand decreases or ends, the pump only has to fill the pressure tank and build enough pressure to shut off. It is also important to be able to reach the cut-out pressure that will shut off the pump.

Friction loss calculations

To calculate friction loss, the size (inside diameter or i.d.) length and type of pipe must be known, as well as the number of fittings in the system. The fittings should be converted to an equal length of the same size pipe, with this figure then added to the length of pipe to obtain the total equivalent length of pipe. Refer to the Sample Conversion Chart (Appendix, page 82) for a conversion chart to obtain the equivalent length of pipe for fittings.

To calculate pipe friction loss, use Friction Loss Tables (Appendix - pages 79-81). Friction loss charts are specific to the type of pipe. The size of the pipe is listed at the top of the chart and the pump capacity is listed on the left vertical axis of the chart. The friction loss ratings on the chart are also per 100 feet of pipe, so the total length of pipe in the system is divided by 100 and this result is multiplied by the chart rating to obtain the friction loss for the system. As a rule of thumb, the friction loss rating on the chart should not be more than 5 feet per 100 feet of pipe.

If the rating is higher than this, larger pipe should be used to reduce this rating per 100 feet of pipe.

For example, Steel Pipe Friction Loss Table (Appendix, page 79) shows that 10 gpm flow in a 3/4 -inch steel pipe has a friction loss of 23.0 feet per 100 feet of pipe. In a 1-inch pipe, it would be 6.86 feet per 100 feet of pipe; and in a 1-1/4-inch pipe, it would be only 1.77 feet per 100 feet of pipe.

The Steel Pipe Friction Loss Table is based on the use of new steel pipe. When older steel pipe is used, the friction loss will be greater, and at least 15 percent should be added to the figures in the tables. If there is enough buildup or deposit inside the pipe, the friction loss could be two or three times as great. In some instances, the buildup inside a pipe could be so great that no water can flow.

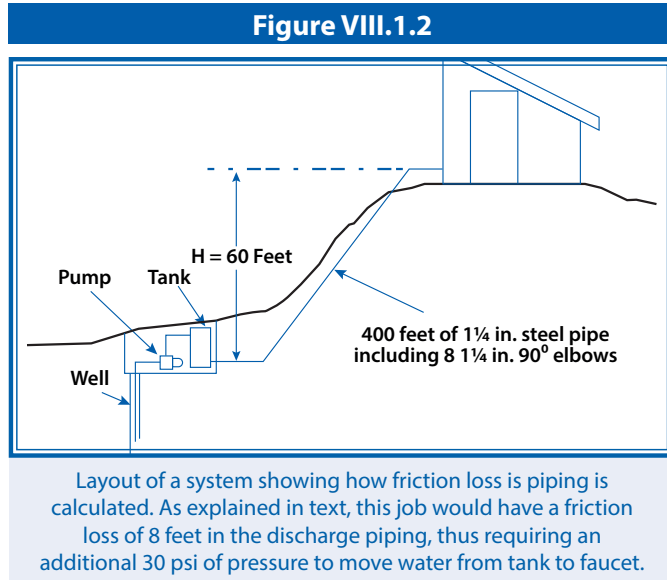
Careful consideration of pipe sizes is important. The use of larger-size pipes, with resultant lower losses, often allows the election of a more economical pump. Pipe sizes and resultant losses must be considered when selecting the pump operating pressure.

Example of how to calculate friction loss

Figure VIII.1.2 illustrates the following example for calculating friction loss.

The pump and tank are located 60 feet below the ground level of a house 400 feet away. Additional pressure will be required to lift the water 60 feet and to force it through the long length of pipe. The pipe size and fittings are given.

In this case, the flow rate is 10 gpm. The Sample Conversion Chart (page 82) shows that the loss through a 1-1/4-inch 90° standard steel elbow is equivalent to 3.5 feet of straight pipe. There are eight elbows. Therefore, they have the equivalent resistance of 28 feet of 1-1/4-inch pipe. The installation has 400 feet of 1-1/4-inch pipe. Adding to this the resistance of the elbows, there is the equivalent of 428 feet of pipe.



The Sample Steel Pipe Friction Loss Table (Appendix, page 79) for 1-1/4-inch steel pipe at 10 gpm shows a friction loss of 1.77 feet per 100 feet of pipe. Divide the total length of pipe (428 ft.) by 100 to obtain 4.28. Then multiply the friction loss of 1.77 feet per 100 feet of pipe $\times 4.28 = 7.58$ feet friction loss in the application. Round this up to 8 feet.

The extra pressure needed at the tank beyond that which is required in a home will therefore be the elevation difference of 60 feet plus the friction loss of 8 feet, or a total of 68 feet. This is equivalent to about 29.4 psi (68 feet divided by 2.31 feet per 1 psi). Round 29.4 psi up to 30 psi. This pressure should be added to the pressure switch setting to obtain the desired pressure in the house. Example: Pressure switch setting is 30/50 psi plus 30 psi = 60/80 psi (new setting).

For most farms, pressure requirements in the various buildings are similar to homes. Take into account the long lengths of pipe and the differences in elevation between the pump and buildings.

For hotel and larger commercial establishments, particular attention must be given to the piping sizes. Friction losses can be great enough in improperly designed piping to render the water system practically useless during high-demand periods.

Higher pressure pumps can overcome the higher friction loss from inadequate pipe sizing. However, these pumps are larger, require more power, and are more expensive to install and operate. An economical balance should be reached between the pump operating costs and the extra cost for larger diameter pipe.

Calculating Friction Loss and Total System Head Requirements				
Step 1 - Determine Friction Loss				
1-1/4" 90° steel elbows: 8 x 3.5 ft. 28 ft.	+	1-1/4" 90° steel pipe 400 ft.	=	428 ft.
428 ft.	÷	100 ft.	=	4.28 ft.
4.28 ft.	x	1.77 ft.	=	7.58 ft.
Round up to 8 ft. friction loss				
Step 2 - Determine Total Head Requirement				
Elevation Difference 60 ft.	+	Friction Loss 8 ft.	=	68 ft.
68 ft.	÷	2.31 ft./psi	=	29.4 psi
Round up to 30 psi				
Step 3				
Add 30 psi to pressure switch setting to achieve correct system pressure.				

Suction lift requirements

Lift requirements – the pressures necessary to get water from the well to ground level must also be taken into account in selecting all pumps, as will be noted in Section II.

II. PUMP SELECTION

In Section II, shallow well, deep well, and submersible pump characteristics and functions are explained in detail. Table VIII.1.2 (page 18) summarizes characteristics of these pumps. Each type of pump has its advantages and limitations.

Shallow well pumps

The factors used to select the **shallow well pump** from the pump selection chart are the capacity requirement, practical suction lift, practical pumping depth, and the cut-in pressure setting. (See selection chart, Table VIII.1.2, page 18.)

Shallow well pumps are located entirely above ground and lift water up through a **suction pipe**. The main characteristic of the shallow well pump is that, regardless of size (hp), it is limited to a maximum **total suction lift** of 25 feet at sea level. The factors that determine the total suction lift are the vertical lift plus the friction loss in the suction pipe and fittings. The vertical lift is basically the distance from the water level in the well while the pump is operating (pumping level) to the top of the well. The friction loss is calculated for all the suction pipe and fittings from the foot valve in the well to the pump. This friction loss is added to the vertical lift to obtain the total suction lift. For each 1,000 feet above sea level, the lift should be reduced by 1 foot.

Several kinds of pumps are used for **shallow well** applications, including **centrifugal pumps, jet pumps, piston pumps, and regenerative turbine pumps**. Performance charts for these pumps usually separate the suction lift from the discharge pressure. Therefore, this vertical distance must be known. The distance should be from maximum drawdown level of the water in the well to the pump inlet.

The suction lift will be greater if the suction piping is long, has many pipe fittings, or is smaller than the pump suction fitting size. In all such cases, friction loss in the suction piping must be calculated (as described previously) and added to the vertical distance between the pump and water level to obtain total suction lift.

Table VIII.1.2

Types and Characteristics of Pumps Used in Private Water Supply Systems

Type of Well	Type of Pump	Normal Capacity Range (gph)	Practical Suction Lift (feet)	Maximum Practical Pumping Depth (feet)	Usual Dis-charge Pressure Range (psi)	Remarks
Shallow Well	Jet	200-1,500	20-25	25	20-40 30-50	1. Simple in construction
						2. Easy to Service
						3. Can be used with 1" & larger wells
						4. Less efficient hydraulics
	Piston or Reciprocating	200-800	20-25	25	20-40 30-50 40-60	1. Adaptable to low capacity & high head
						2. Handles air without losing prime
						3. No longer widely used
						4. Can be used with 1" & larger wells
	Straight Centrifugal (Single & Multi-Stage)	500-2,000	15-25	25	20-40 30-50	1. Suitable for high capacities
						2. Efficient hydraulics
						3. Can be used with 1" & larger wells
						4. Simple and easy to service
Deep Well	Jet (Single & Multi-Stage) (Jet in Well)	200-600	15-20 Feet Below Ejector	200	20-40 30-50 40-60	1. Simple in construction & operation
						2. No moving parts in well
						3. Less efficient hydraulics
						4. Can be used with 2" or 3" wells
						5. Can be located away from well
	Submersible	200-3,000	Pump & Motor Submerged	1000	20-40 30-50 40-60	1. Suitable for deep settings
						2. Adaptable to frost proof installations
						3. Efficient hydraulics
						4. Available in wide range of heads & capacities
						5. Only available for 3" or larger wells
	Piston or Reciprocating	200-800	20-25	150	20-40 30-50 40-60	1. Suitable for deep settings
						2. Adaptable to frost proof installations
						3. Efficient hydraulics (no longer widely used)

Note: Practical suction at sea level. Reduce 1 foot for each 1,000 feet above sea level.

Deep well pumps

A **deep well pump** needs to be used when the water level in the well is deeper than 25 ft. A main difference of a deep well pump from a shallow well pump is that its nozzle and venturi is located in the well rather than at the front of the pump. Deep well pumps force water upward from this pumping element below the well water level and are not restricted by suction-lift limitations. Units for deep wells include **deep well jet pumps** and **submersible pumps**. Deep well jet pumps can go down to about 200 feet; submersible pumps go deeper.

There are two types of deep well jet pump systems. One is called a **twin-pipe system**; the other, a **packer system**. The main factor that determines which one is used is the well casing size. The twin-pipe system requires a 4-inch or larger well casing, and has two pipes running from the pump to the jet assembly in the well. The packer system requires 2-inch or 3-inch well casings, and has one pipe down in the well to the jet assembly. Both systems have the jet assembly at the end of the pipes in the well.

Total suction lift is not calculated in deep well jet pump applications. Capacity charts for jet pumps usually separate the depth to water (in feet) from the discharge pressure.

Therefore, when the depth is known and the suction and drive pipe sizes recommended by the manufacturer are used, the selection chart may be used directly, without considering friction loss in the suction and drive piping.

One factor that is important in deep well jet pump applications is the location of the pump to the well. This is called pump offset. The pump should be located as close to the well as possible. A **pump offset** of 50 ft. or more will reduce the capacity rating by 25%.

Considerations for Proper Pump Selection

The following are some considerations for determining the best pump for a given installation.

1. Adequate capacity (gpm) for present and future use.
2. Adequate pressure for present and future use and for the possibility of a lower water level in the well.
3. Cost of the pump.
4. Cost of labor to install the pump.
5. Cost of materials to install the pump (such as piping, fittings, accessories, well pit).
6. Power supply.
7. Space needed to install the pump. Is space available?
8. Reliability of the pump.
9. Cost of servicing the pump.
10. Ease of servicing the pump. Can it be repaired in the field, or in the dealer's repair shop, or does it have to be returned to the factory?
11. Cost of operating the pump (power and parts).
12. Flexibility of the pump for various types of installations common in a given area.

Submersible pumps

Submersible pumps can be used in considerably deeper well applications than jet pumps. Submersible pumps can be installed more than 1,000 ft. into a well and still provide a usable capacity and adequate pressure.

Submersible deep well pumps are usually rated on the basis of their pressure at different pumping levels. Thus, if the vertical distance to the water is known, the pump capacities can be found for various pressures at ground level. Two types of performance charts can be used to select a submersible pump. One is the performance curve; the other, the selection chart.

Performance curves and selections charts

To use the performance curve to make the pump selection requires the pump capacity (gpm) and the **total dynamic head** (TDH). TDH (or pressure expressed in feet) is the vertical elevation (for example, vertical distance from the water level in the well while the pump is operating to the highest point to which the water will be pumped, expressed in feet), plus the friction loss (calculated for the pipe and fittings from the pump to the pressure tank), plus the pressure (psi) in the tank converted to feet by multiplying it by 2.31 ft. Example: 200 ft. vertical elevation + 10 ft. friction loss + (50 psi x 2.31 ft.) = 210 ft. + 116 ft. = 326 ft. TDH.

These three factors added together make up the TDH, which is usually on the left vertical axis of the curve. The pump capacity (gpm) is usually on the horizontal axis of the graph. So if the system requirements are 20 gpm at 326 ft. TDH, the selection would be the pump where these two factors intersect on the performance curve. NOTE: A Performance Curve may also have metric scales with TDH expressed in meters and capacity in cubic meters per hour. Be sure to read the correct scales on the curve.

Refer to the Appendix for Pump Sizing and Selection Guides that include Performance Curves for Submersible Pumps.

Most times today, pump selection is done using the Selection Chart. To use the Selection Chart, the capacity requirement (gpm), the **cutoff pressure** (psi), and the **depth to water** need to be available. Depth to water is the vertical elevation (from the water pumping level in the well to the highest point) plus the friction loss in the discharge pipe and fittings from the pump to the pressure tank. Note that the depth to water is different from TDH. In most cases today, the pump setting (location of the pump in the well) is used as the depth to water factor to make a submersible selection. When this is done, the actual capacity performance of the pump is higher than the required amount because the pump is operating with the water at a higher level in the well, for example, when the pump is placed in the well at 200 feet and the water is being pumped from 100 feet. Refer to the Appendix for Pump Sizing and Selection Guides that include Pump Selection Charts for Shallow Well Jet Pump, Deep Well Twin-Pipe Jet Pump System, Deep Well Jet Pump Packer System, and Submersible Pump.

Note that it is also important to select the proper pressure tank for the application.

III. CALCULATING WELL STORAGE AND MAXIMUM PUMP RUN TIME

It is also very important to calculate the amount of water that is stored in the well casing. This is a fairly simple, but often neglected, calculation using the application information that includes the well conditions, the pump capacity, and a chart providing the gallons per ft. of storage for different size well casing. (Refer to the Appendix for Storage of Water in Various Sizes of Wells Chart.) Once the amount of water stored in the well is calculated, the maximum amount of time the pump may be operated can be determined.

Example: Calculating Well Storage and Maximum Pump Run Time					
Customer had a low yielding well with 6-inch casing and drilled to 120 feet. The static water level is 20 feet prior to pumping operations and the 10 gpm pump is set at 100 feet. The well system is producing 5 gallons per minute. Customer would like to get 7 gpm to 10 gpm.					
Calculating for 7 Gallons Per Minute (gpm)					
1	100 ft. Pump Setting	–	20 ft. Static Water Level	=	80 ft. Water Storage
2	80 ft. Water Storage	x	1.4 gal/ft.	=	112 gal of Water Storage
3	112 gal of Water Storage	÷	7 gpm	=	16 Minutes of Run Time
4	16 Minutes of Run Time	x	5 gpm Well Yield	=	80 gal (additional water production)
5	112 gal of Water Storage	+	80 gal (additional water production)	=	192 Total usable gal
6	192 Total usable gal	÷	7 Pump Capacity (gpm)	=	27.4 Minutes Maximum Run Time
Calculating for 10 Gallons Per Minute (gpm)					
1	100 ft. Pump Setting	–	20 ft. Static Water Level	=	80 ft. Water Storage
2	80 ft. Water Storage	x	1.4 gal/ft.	=	112 gal of Water Storage
3	112 gal of Water Storage	÷	10 gpm	=	11.2 Minutes of Run Time
4	11 Minutes of Run Time	x	5 gpm Well Yield	=	55 gal (additional water production)
5	112 gal of Water Storage	+	55 gal (additional water production)	=	167 Total usable gal
6	167 Total usable gal	÷	10 Pump Capacity (gpm)	=	16.7 Minutes Maximum Run Time
<i>Always round down the minutes.</i>					

IV. PROCEDURE FOR USING THE SELECTION DIAGRAMS AND WORKSHEETS

To select the correct pump to meet the capacity requirements of an application, it is recommended to use Pump Sizing and Selection Diagrams and Worksheets in conjunction with related Performance Curves. The Appendix offers basic diagrams and worksheets for your use.

The diagrams illustrate basic installations, with room for you to apply the details of your specific installation. The worksheets guide you to obtain all information needed to make the proper equipment selection for your specific installation. Completing these sheets for each installation is important to ensure accuracy and provide basic documentation for any future application needs.

To complete the diagram sheet:

1. Fill in the “well conditions” information as requested.
2. Fill in the horizontal well offset distance, from well to pressure tank (in feet).
3. Record the static water level in the well (in feet).
4. Record the vertical elevation (distance from the pumping level to the highest level the water must be pumped).
5. Record the pump setting in the well (in feet).

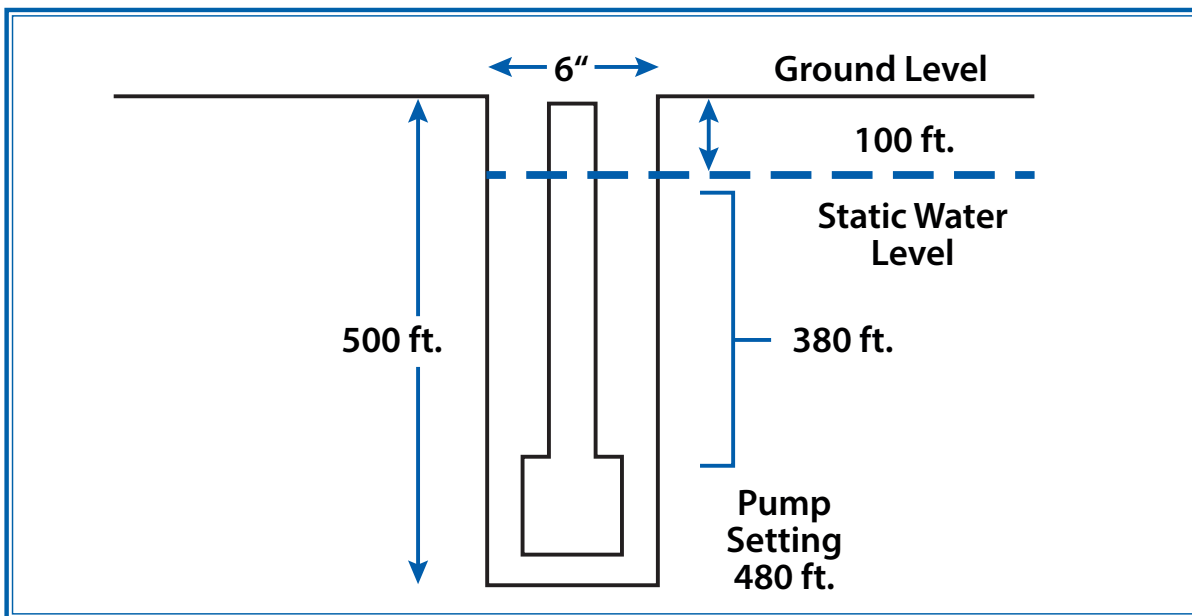
Avoid overpumping low-yield wells

Pump selection should not always be based on well yield. (Figure VIII.1.3)

Low-yield well conditions are often the reason wells are drilled to deeper depths or why the well casing is made larger (6 in. vs. 4 in.) to store more water to meet the demand. To avoid low-yield well conditions, calculate well storage capacity in advance of pump installation to determine how much water is available and how long a particular pump that meets the capacity requirements of the application can operate.

Low-yield wells (1 gpm or less) may also result from overpumping where the pump has created excessive drawdown. In deep well jet installations, this can cause loss of prime, reduced capacity, and/or damage to the pump. There are controls that can be used in these applications to protect the equipment.

FIGURE VIII.1.3



$$480\text{-ft.} - 100\text{-ft.} = 380\text{-ft. OF WATER} \times 1.4 \text{ gal/ft.} = 532 \text{ gal}$$

Example of a well with a 12 gpm requirement: 6-in. well, 500-ft. deep, 2 gpm yield, 100-ft. static water level.

There are 532 gallons of water in the well. The application requires 12 gpm. A 5 gpm pump would have been installed based on concern for the low-yield condition, but a 5 gpm pump would be the wrong selection for this application. The 5 gpm pump, which only has a maximum capacity of 7.5 to 8 gpm, would not meet the application requirement.

If instead a pump capable of meeting the 12 gpm capacity requirement is used, it could run for 44.3 minutes before it used all 532 gallons of water in the well. With the 2 gpm well yield, there are 88.6 gallons of additional water coming into the well while the pump is running (2 gpm x 44.3 min. = 88.6 gallons). In most cases, the correct pump (12 gpm) would never pump the well down under normal operations.

Pump selection should not always be based on well yield.

To complete the worksheet:

STEP ONE: CAPACITY NEEDED

Use the largest gpm number derived from calculations:

1. Fixture/Outlet Method: Fill in the number of fixtures or outlets. Calculate the capacity (number of fixtures/outlets x 1 gpm = ?). Record number of fixtures/outlets used at peak-demand period. Calculate the capacity (number of fixtures/outlets x 3 gpm = ?).
2. Alternate Capacity Method: Calculate the number of bathrooms x 4 gpm = ?
(NOTE: 1/2 baths are considered full baths.)

STEP TWO: CALCULATING DEPTH TO WATER / TOTAL DYNAMIC HEAD (TDH)

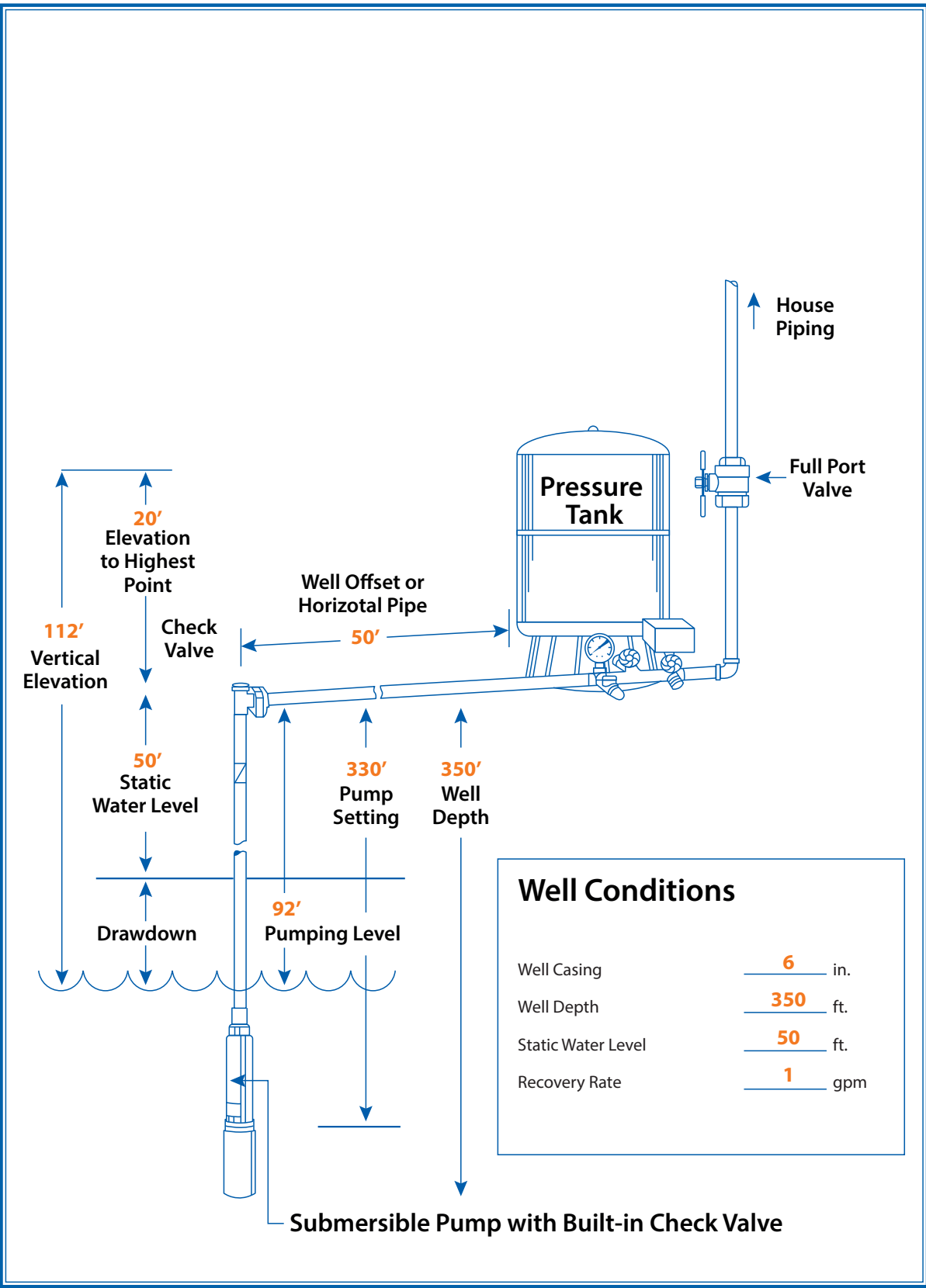
1. Calculating Friction Loss: Record fittings and pipe in system.
2. Check the Equivalency Chart (Appendix, page 82) and record the length of pipe value for each fitting.
3. Determine the equivalency calculation and record the conversion value.
4. Record pipe size and length from the pump to the pressure tank.
5. Determine the total pipe length equivalent by adding all converted fitting values and pipe.
6. Determine the number of 100's by dividing the total pipe length equivalent number by 100.
(NOTE: This must be done because the Friction Loss Charts are per 100 ft. of pipe.)
7. Record the friction loss per 100 ft. of pipe from the proper pipe friction loss chart.
8. Determine the friction loss by multiplying the number of 100's by the friction loss value and record on line provided. Also, record the vertical elevation on the line provided, then add these two numbers together. NOTE: Use the Total Depth to Water figure to make a pump selection from the Pump Selection Charts. See Appendix for Sample Selection Charts.
9. To calculate TDH, convert the pressure at the pressure tank to feet by multiplying it by 2.31 ft. and adding the result to the total depth to water number. Use the TDH to make a pump selection using the pump performance curves.

STEP THREE: PRESSURE NEEDED

1. Record the cut-in and cut-out pressures.
(NOTE: Check the maximum shut-off pressure on the chart for the pump selected.)
2. Record the pressure tank precharge setting.
3. Electrical: Record the electrical service and motor information.
4. Selection Information: Record the equipment selected for the system and application.

Sample Diagrams, worksheets, and performance curves follow for your reference. Check the Appendix for diagrams, worksheets, and performance curves that you can print a copy of to use for your own applications.

Example #1 - Submersible Pump Diagram



Example #1 - Submersible Pump Worksheet**Step 1****FLOW CAPACITY NEEDED****Fixtures Method:**

Bathtub/Shower	<u>2</u>
Toilet	<u>3</u>
Lavatory	<u>3</u>
Kitchen Sink	<u>1</u>
Dishwasher	<u>1</u>
Washing Machine	<u>1</u>
Hose Bib	<u>1</u>
Other	
(E.g., sprinklers, swimming pool)	

Total Outlets 12
x 1 gpm = 12 gpm

Peak Demand Period¹:

No. of Outlets Being
Used at Same Time 4
x 3 gpm = 12 gpm

Bathrooms: 3 x 4 gpm 12 gpm

Step 2**CALCULATING DEPTH TO WATER****Calculating Friction Loss:**

8' (Check Valve equivalent) x 2 (Quantity) = 16 ft.
 Pitless Adapter/Side Out Tee (1) 5.7' = 6 ft.
1 " Pipe (total length) **PVC** = 380 ft.
 Other = ft.
 Total Pipe Length Equivalent = 402 ft.
 Divide by 100 ft. = 4 ft.
 x 11 (Friction loss per 100 ft. from chart)² = 44 ft.
 (Friction Loss)

Calculating Depth to Water:

Vertical Elevation (Example using elevation to highest point) = 112 ft.
 Friction Loss = 44 ft.
 Total Depth to Water = 156 ft.

To calculate Total Dynamic Head add in Pressure

(30) psi x 2.31 = 69 ft.
 TDH = 225 ft. **PT#1**
50 psi = 272 ft. **PT#2**

See Pump Curve on Page 26

Step 3**FLOW CAPACITY NEEDED****Tank Pressure Switch Setting:**

TDH
 Cut-In 30 psi **69'**
 Cut-Out 50 psi **116'**
 (Check Max. Shut-Off psi from Bulletin)
 Tank Precharge
 Set @ 2 psi
 Less Than Cut-In = 28 psi
 Electrical:
1 Phase/ 230 Volt/ 3 Wire Motor

Step 4**SELECTION**

Pump Model 10 gpm / 1 hp
 Wire Size _____
 Pressure Tank _____
 Relief Valve _____
 Motor _____
 Control Box (3-Wire) _____
 Magnetic Starter (3 Ø) _____
 Motor Protection Device _____

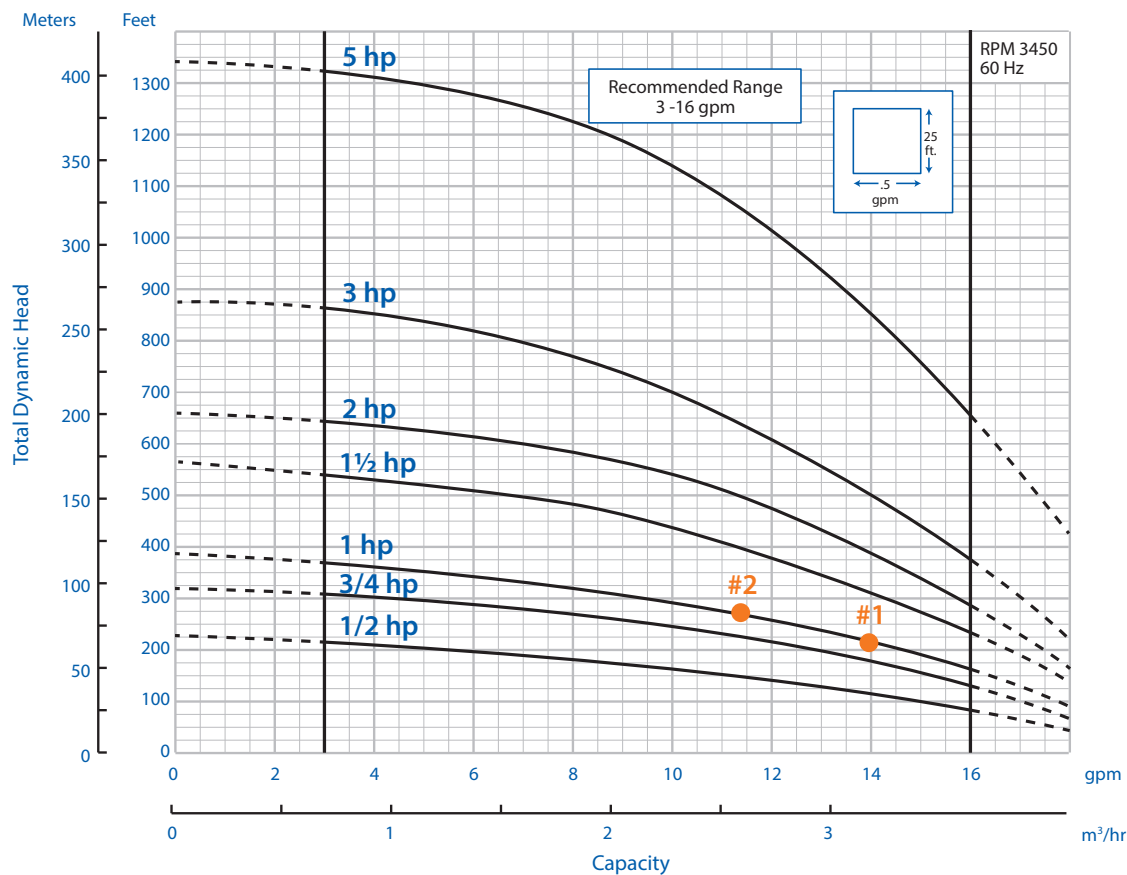
¹ The peak demand period is never a fixed time. It changes with the number of people and the number of bathrooms.

² It was approximated by extrapolating the values between 10 gpm (6.88') and 15 gpm (14.63') Reference the Appendix - Plastic Pipe Friction Loss Chart (page 80).

Use Table VIII.1.1 (page 10) to complete this worksheet.

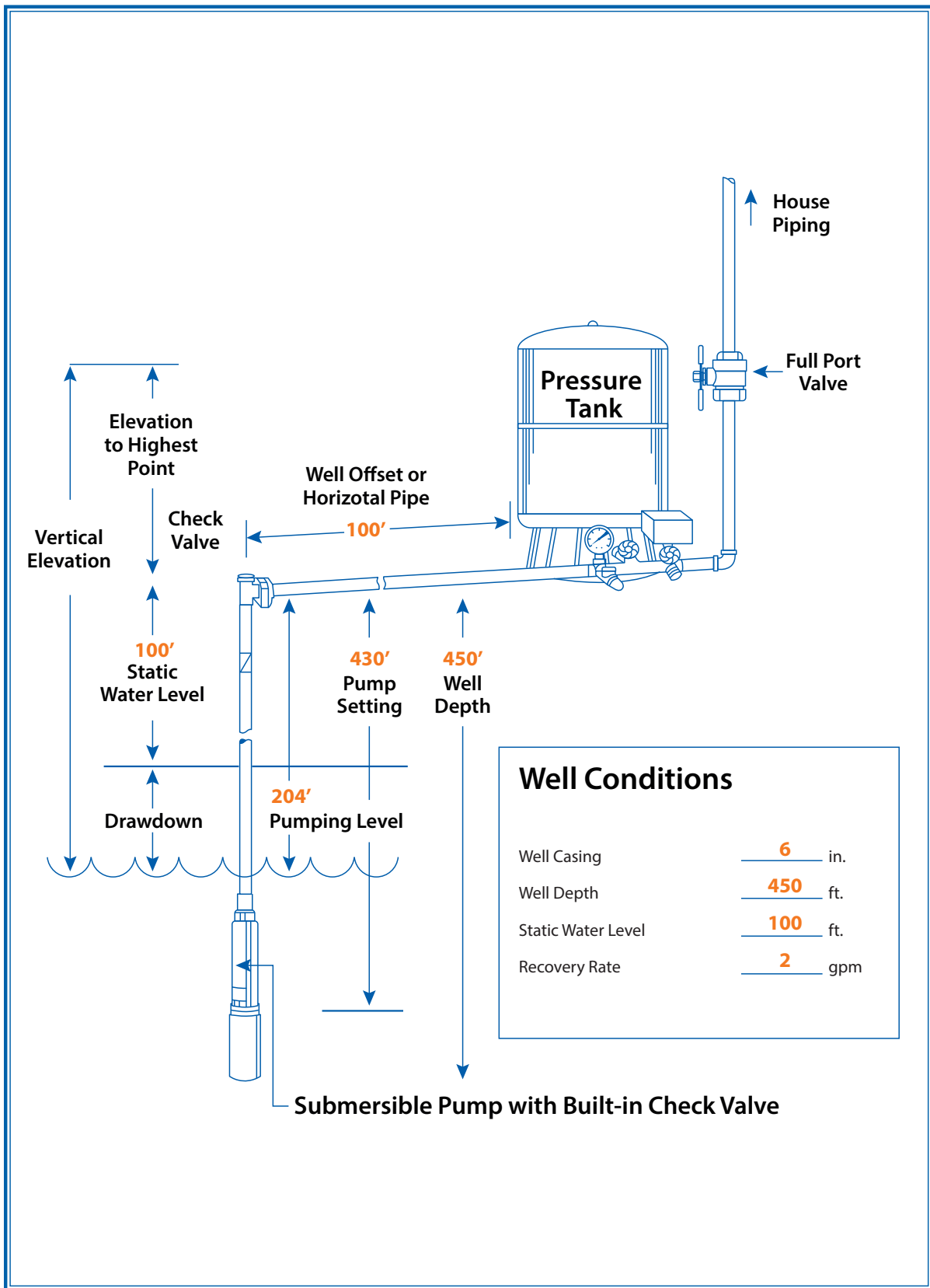
Example #1 - Submersible Pump Performance Curve

10 gpm Pump



Horsepower Range 1 hp, Recommended Range 3-16 gpm, 60 Hz, 3450 RPM																		
Pump Model	hp	psi	Depth to Water in Feet/Ratings in gpm (Gallons per Minute)															
			20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	340
	1	0								15.8	15.2	14.5	13.7	12.8	12.0	11.0	10.0	6.7
		20						15.7	14.9	14.3	13.5	12.7	11.7	10.6	9.6	8.1	6.5	
		30				16.0	15.6	14.8	14.2	13.3	12.5	11.6	10.4	9.4	7.8	5.5	3.0	
		40			16.0	15.5	14.7	14.1	13.2	12.4	11.5	10.3	9.1	7.4	5.0	3.0		
		50			15.3	14.6	13.9	13.0	12.3	11.3	10.1	8.9	7.0	4.3				
		60	15.8	15.2	14.5	13.7	12.8	12.0	11.0	10.0	8.6	6.7	4.0					
Shut-off psi			158	150	141	132	124	115	106	98	89	81	72	63	55	46	37	20

Example #2 - Submersible Pump Diagram



Example #2 - Submersible Pump Worksheet**Step 1****FLOW CAPACITY NEEDED****Fixtures Method:**

Bathtub/Shower	<u>3</u>
Toilet	<u>3</u>
Lavatory	<u>3</u>
Kitchen Sink	<u>1</u>
Dishwasher	<u>1</u>
Washing Machine	<u>1</u>
Hose Bib	<u>2</u>
Other	<u> </u>
(e.g., sprinklers, swimming pool)	<u> </u>

Total Outlets 14
x 1 gpm = 14 gpm

Peak Demand Period¹:

No. of Outlets Being
Used at Same Time 4
x 3 gpm = 12 gpm

Bathrooms: 3 x 4 gpm 12 gpm

Step 2**CALCULATING DEPTH TO WATER****Calculating Friction Loss:**

8' (Check Valve equivalent) x 3 (Quantity) = 24 ft.
 Pitless Adapter/Side Out Tee (1.25) 7.6' = 8 ft.
1.25" Pipe (total length) **PVC** = 530 ft.
 Other = ft.
 Total Pipe Length Equivalent = 562 ft.
 Divide by 100 ft. = 6 ft.
 x 4 (Friction loss per 100 ft. from chart) = 24 ft.
 (Friction Loss)

Calculating Depth to Water:

Vertical Elevation (Example using elevation to highest point) = 204 ft.
 Friction Loss = 24 ft.
 Total Depth to Water = 228 ft.

To calculate Total Dynamic Head add in Pressure

(40) psi x 2.31 = 92 ft.

TDH = 320 ft. **PT#1**

60 psi = 367 ft. **PT#2**

See Pump Curve on Page 28

Step 1**FLOW CAPACITY NEEDED****Tank Pressure Switch Setting:**

		TDH
Cut-In	<u>40</u> psi	<u>92'</u>
Cut-Out	<u>60</u> psi	<u>139'</u>

(Check Max. Shut-Off psi from Bulletin)
 Tank Precharge
 Set @ 2 psi
 Less Than Cut-In = 38 psi

Electrical:

1 Phase/ 230 Volt/ 3 Wire Motor

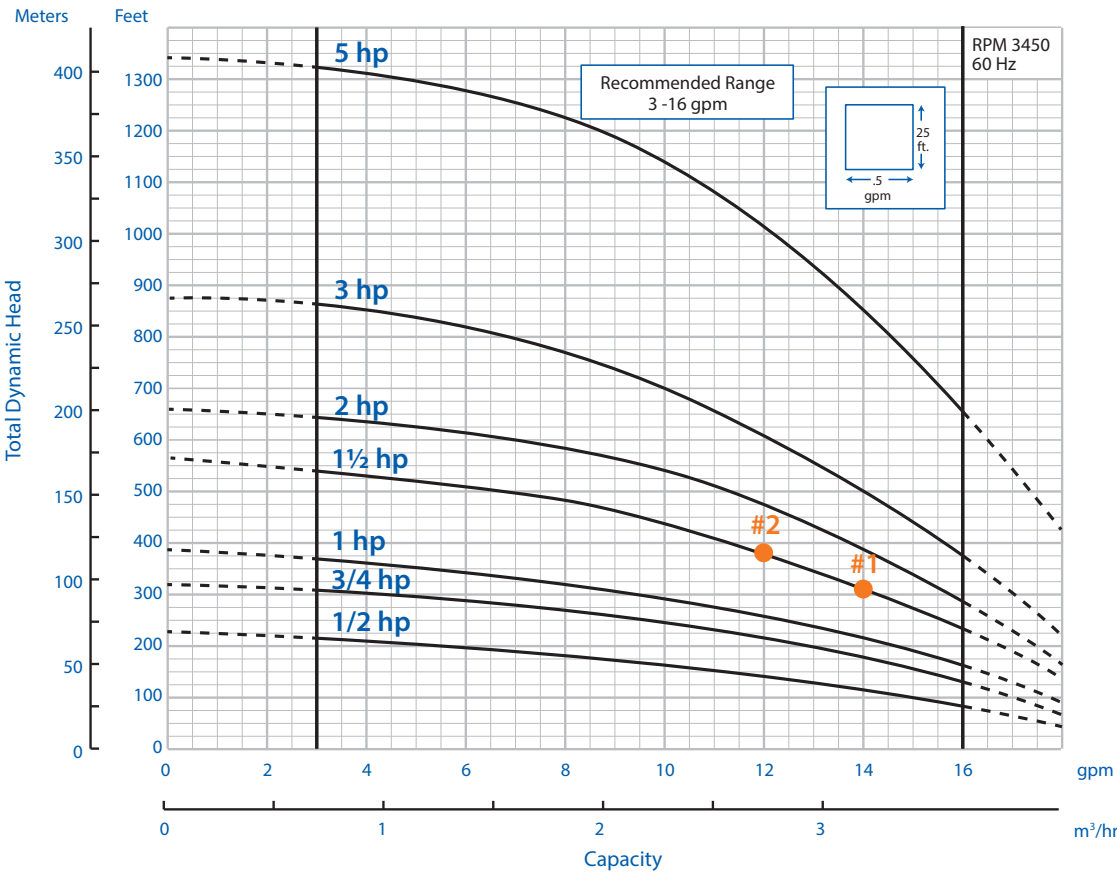
Step 4**SELECTION**

Pump Model	<u>10 gpm/1.5 hp</u>
Wire Size	<u> </u>
Pressure Tank	<u> </u>
Relief Valve	<u> </u>
Motor	<u> </u>
Control Box (3-Wire)	<u> </u>
Magnetic Starter (3 Ø)	<u> </u>
Motor Protection Device	<u> </u>

¹ The peak demand period is never a fixed time. It changes with the number of people and the number of bathrooms.

Example #2 - Submersible Pump Performance Curve

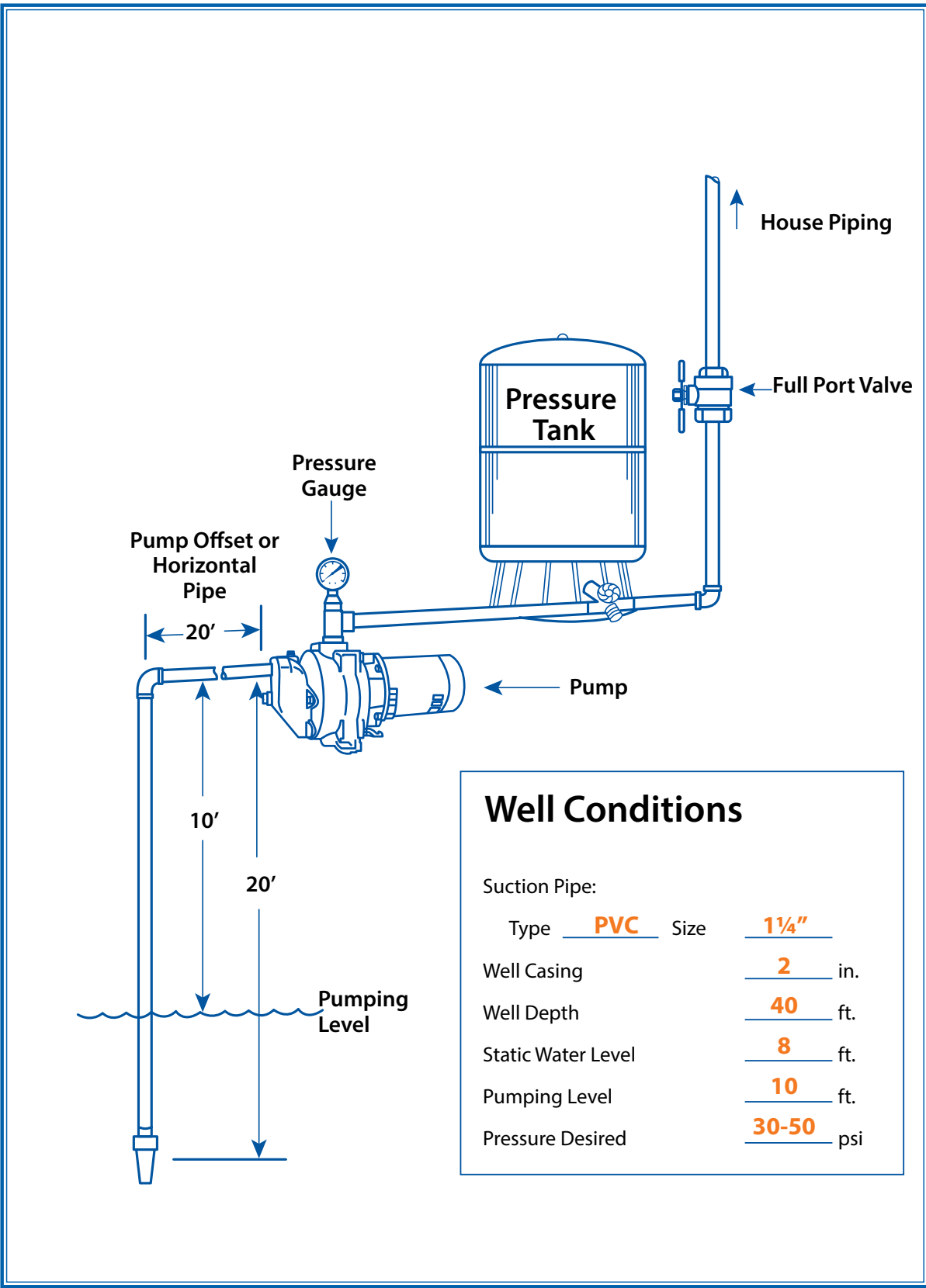
10 gpm Pump



Horsepower Range 1 1/2 hp, Recommended Range 3-16 gpm, 60 Hz, 3450 RPM

Pump Model	hp	psi	Depth to Water in Feet/Ratings in gpm (Gallons per Minute)																				
			20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	340	380	420	460	500	540
	1½	0												15.7	15.3	14.8	14.4	13.3	12.2	10.9	9.3	7.1	3.0
		20								16.0	15.6	15.2	14.7	14.3	13.7	13.2	11.9	10.6	9.0	6.5			
		30							15.9	15.5	15.1	14.6	14.2	13.5	13.1	12.6	11.3	9.7	7.6	4.0			
		40						15.8	15.5	15.1	14.6	14.2	13.5	13.0	12.5	11.8	10.3	8.8	6.0				
		50					15.7	15.4	14.9	14.5	14.0	13.4	12.8	12.3	11.7	11.0	9.4	7.4	3.4				
		60				15.7	15.3	14.8	14.4	3.9	13.3	12.8	12.2	11.6	10.9	10.1	8.1	5.6					
Shut-off psi							197	188	180	171	162	154	144	136	128	119	110	93	76	58	41	24	6

Example #3 - Shallow Well Jet Pump Diagram



Example #3 - Shallow Well Jet Pump Worksheet

Step 1

CAPACITY NEEDED

Fixtures Method:

Bathtub/Shower	<u>1</u>
Toilet	<u>1</u>
Lavatory	<u>1</u>
Kitchen Sink	<u>1</u>
Dishwasher	<u>0</u>
Washing Machine	<u>1</u>
Hose Bib	<u>1</u>
Other	<u>0</u>

Total Outlets 6
x 1 gpm = 6 gpm

Peak Demand:

No. of Outlets Being
Used at Same Time 2
x 3 gpm = 6 gpm

Step 2

SUCTION CONDITIONS

Friction Loss Calculator:

1 90° Elbow = 3.5 ft.
1 Foot Valve = 12.0 ft.
Pipe = 40.0 ft.
Total = 55.5 ft.

0.56 Numbers of hundreds of feet
x 0.71 Friction loss / 100 ft. of pipe
= 0.40 Ft. (Friction Loss)

Vertical Lift = 10 ft.
+ Friction Loss (rounded up) = 1 ft.
Total Lift = 11 ft.
(Maximum 25 Ft.)

Step 3

PRESSURE NEEDED

Tank Pressure Switch Setting:

Cut-On 30 psi
Cut-Off 50 psi

Step 4

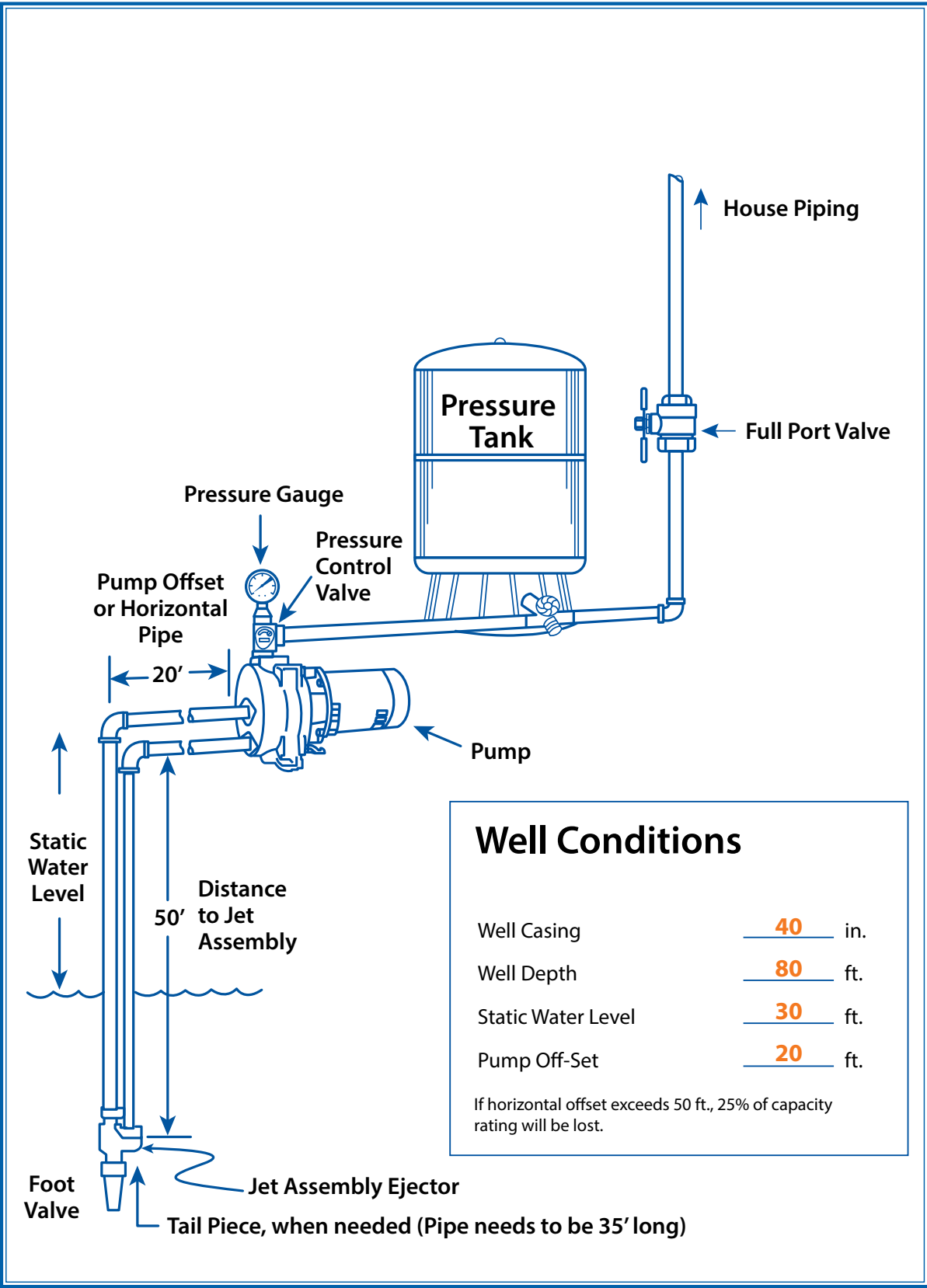
SELECTION

Pump Model 1/2 hp Jet Pump

Sample Selection Chart: Shallow Well Jet Pump

Shallow Well Performance Ratings																								
Horsepower (hp)	½						¾						1						1½					
Total Suction Lift (feet)	Discharge Pressure — psi																							
	20	30	40	50	60	Max. Shut off (psi)	30	40	50	60	Max. Shut off (psi)	30	40	50	60	Max. Shut off (psi)	30	40	50	60	Max. Shut off (psi)			
	Gallons per minute						Gallons per minute					Gallons per minute					Gallons per minute							
5	11.5	11.3	11.0	7.7	48.0	83	21.3	18.3	12.5	6.6	70	24.8	24.4	16.6	9.9	74	26.6	26.3	25.0	15.6	80			
10	10.3	10.0	9.6	7.0	4.2	81	18.8	17.3	11.3	5.0	68	22.9	22.2	15.8	8.6	72	24.7	24.3	22.6	13.9	77			
15	8.8	8.6	8.3	6.3	3.7	79	16.4	15.5	9.6	3.7	66	19.8	19.5	13.8	6.9	70	21.6	21.5	20.4	12.9	75			
20	7.0	7.0	6.8	5.8	3.2	76	13.6	13.2	8.3	2.0	63	16.6	16.6	12.2	5.6	67	18.1	18.0	17.6	12.0	73			
25	5.3	5.2	5.2	5.0	2.8	73	10.0	9.9	6.4	1.0	59	12.5	12.4	10.4	3.6	65	14.0	14.0	14.0	10.1	71			

Example #4 - Deep Well Twin-Pipe Jet Pump Diagram



Example #4: Deep Well Twin-Pipe Jet Pump Worksheet

Step 1

FLOW CAPACITY NEEDED Fixtures Method:

Bathtub/Shower	<u>1</u>
Toilet	<u>1</u>
Lavatory	<u>1</u>
Kitchen Sink	<u>1</u>
Dishwasher	<u>0</u>
Washing Machine	<u>1</u>
Hose Bib	<u>1</u>
Other	<u>0</u>
(e.g., sprinklers, swimming pool)	
Total Outlets	<u>6</u>
x 1 gpm =	<u>6</u> gpm

Peak Demand Period¹:

No. of Outlets Being Used at Same Time	<u>2</u>	
x 3 gpm =	<u>6</u>	gpm
Bathrooms	<u>1</u>	
x 4 gpm =	<u>4</u>	gpm

Step 2

Jet Assembly Setting 50 ft.
(See Diagram)

Step 3

PRESSURE NEEDED Tank Pressure Switch Setting:

Cut-In	<u>30</u>	psi
Cut-Out	<u>50</u>	psi
Tank Precharge		
Set @ 2 psi		
Less Than Cut-In =	<u>28</u>	psi

Step 4

SELECTION

Pump Model	<u>1/2 hp Jet Pump</u>
Jet Assembly	
Pressure-Control Valve	
PCV Setting (psi)	
Pressure Tank	
(Refer to your manufacturer for selections)	

¹ Note that the peak demand period is never a fixed time. It changes with the number of people and the number of bathrooms.

Sample Selection Chart: Deep Well Twin-Pipe Jet Pump System

Two-Pipe or Twin-Pipe Performance Ratings																		
Horsepower (hp)		½				¾				1				1 ½				
Well Casing Minimum Inside Diameter		4		4½		4		4½		4		4½		4½				
Pressure	Pipe Size (in.)	1		1¼		1		1¼		1		1¼		1¼				
Suction		1¼		1½		1¼		1½		1¼		1½		1½				
	Feet	Gallons Per Minute (gpm) 30-50 psi Pressure Switch Setting																
Depth to Jet Assembly (based on submergence of 5 feet)	30	13.0	11.0			15.8			16.6	17.0			19.3		21.2			
	40	11.8	9.0			15.7			16.0		16.6			18.0		20.0		
	50		7.6		6.9	13.2			15.0		14.4			16.0		16.1		
	60		7.0	5.2	6.4	10.2			13.0		11.5	11.2		14.3		15.0		
	70				4.7	5.6		8.2		11.0	10.0		9.3		12.6		14.0	11.2
	80				3.8	4.8		6.5			8.6		7.3	6.2	10.0	10.0		10.6
	90				3.1	4.1		3.5			7.3			6.1		8.7		9.0
	100									6.0			5.4		7.0			7.6
	110									5.0			4.5		5.7			6.2
	120														4.5			5.2
	130																	4.0
	140																	2.8
150																	1.5	

NOTE: The user should reference the manufacturer's product literature.

Chapter 2

Wire Sizing

- ✓ Single-Phase Two- or Three-Wire Cable, 60 Hz
- ✓ Three-Phase Three-Lead 60°C Cable, 60 Hz
- ✓ Three-Phase Six-Lead 60°C Cable, 60 Hz
- ✓ Three-Phase Three-Lead 75°C Cable, 60 Hz
- ✓ Three-Phase Six-Lead 75°C Cable, 60 Hz

Select proper wire size

In the final step involving electrical work, be sure to use wire of the proper size. The greater the distance from the pump to the electrical service connection, the heavier the wire needed. Local codes should be checked to confirm proper selection.

Wire sizing charts differ based on each manufacturer. Be sure to refer to the manufacturer's manual, and follow federal, state, and local codes.

Recommended Cable Selections

Single-Phase Submersible Pump Installations

The following tables are recommended for use as a standard water industry reference for the selection of submersible cable size. These tables are based on maximum motor running current rather than on the particular motor characteristic or motor manufacturer's requirements.

NOTE: These charts are applicable only to single-phase (capacitor-start and two-wire) and three-phase submersible motors. Due to their inherent differences in starting characteristics, wire selection method for permanent split capacitor (PSC) and split-phase motors should be handled according to the manufacturer's recommendations.

The following data were used to develop these tables:

- Wire size selection is based on the maximum amperes shown on motor nameplate and assumes a power factor of 80 percent.
- Voltages at the service entrance will be the rated voltage, i.e., 115, 200, 230, 460, or 575 (this is the 60 Hertz voltage assumed to be available at the service entrance).
- Voltage at the motor shall be at least 95 percent of service-entrance voltage with the motor running during normal operating conditions.
- Cable lengths are based on one continuous wire size run from the service entrance to the motor terminals (rather than breaking down into different sizes for supply and drop cable). Refer to your motor manufacturer's wire sizing charts.
- Maximum ampacity for wire was taken from the **National Electrical Code (NEC)** Table 310-16, Column 1, for wire types TW and UF, having a temperature rating of 60°C. Not more than three current-carrying conductors are used in raceway, cable, or direct burial (based on ambient temperature of 30°C).

VALUES FOR THE TABLES ARE AS FOLLOWS:									
@ 140°F (60°C)									
NEC Reference	AWG Wire Size (Copper)	#14	#12	#10	#8	#6	#4	#2	#1
NEC 310-16	Maximum Conductor Ampacity	15	20	30	40	55	70	95	110

Source: National Electric Code 2023

Refer to your motor manufacturer's wire sizing charts.

**Table VIII.2.1: Recommended Cable Selections
Single-Phase Submersible Pump Installations**

Cable selection for SINGLE-PHASE TWO- OR THREE-WIRE CABLE, 60 Hz Service Entrance to Motor – Maximum Length in Feet															
Motor Rating			60°C Insulation - AWG Copper Wire Size												
Volts	hp	kW	14	12	10	8	6	4	3	2	1	0	00	000	0000
115	1/2	.37	100	160	250	390	620	960	1190	1460	1780	2160	2630	3140	3770
230	1/2	.37	400	650	1020	1610	2510	3880	4810	5880	7170	8720			
	3/4	.55	300	480	760	1200	1870	2890	3580	4370	5330	6470	7870		
	1	.75	250	400	630	990	1540	2380	2960	3610	4410	5360	6520		
	1 1/2	1.1	190	310	480	770	1200	1870	2320	2850	3500	4280	5240		
	2	1.5	150	250	390	620	970	1530	1910	2360	2930	3620	4480		
	3	2.2	120	190	300	470	750	1190	1490	1850	2320	2890	3610		
	5	3.7	0	0	180	280	450	710	890	1110	1390	1740	2170	2680	
	7 1/2	5.5	0	0	0	200	310	490	610	750	930	1140	1410	1720	
	10	7.5	0	0	0	0	250	390	490	600	750	930	1160	1430	1760
15	11	0	0	0	0	170	270	340	430	530	660	820	1020	1260	

Motor Rating			75°C Insulation - AWG Copper Wire Size												
Volts	hp	kW	14	12	10	8	6	4	3	2	1	0	00	000	0000
115	1/2	.37	100	160	250	390	620	960	1190	1460	1780	2160	2630	3140	3770
230	1/2	.37	400	650	1020	1610	2510	3880	4810	5880	7170	8720			
	3/4	.55	300	480	760	1200	1870	2890	3580	4370	5330	6470	7870	9380	
	1	.75	250	400	630	990	1540	2380	2960	3610	4410	5360	6520	7780	9350
	1 1/2	1.1	190	310	480	770	1200	1870	2320	2850	3500	4280	5240	6300	7620
	2	1.5	150	250	390	620	970	1530	1910	2360	2930	3620	4480	5470	6700
	3	2.2	120	190	300	470	750	1190	1490	1850	2320	2890	3610	4470	5550
	5	3.7	0	110	180	280	450	710	890	1110	1390	1740	2170	2680	3330
	7 1/2	5.5	0	0	120	200	310	490	610	750	930	1140	1410	1720	2100
	10	7.5	0	0	0	160	250	390	490	600	750	930	1160	1430	1760
	15	11	0	0	0	0	170	270	340	430	530	660	820	1020	1260

1 Foot = .3048 Meter

Lengths not in bold type meet the U.S. NEC ampacity for either individual conductors or jacketed 60°C or 75°C cable.

Lengths in bold type meet the NEC ampacity only for individual conductor 60°C or 75°C cable, in free air or water, not in magnetic enclosure or conduit. If any other cable is used, the NEC as well as the local codes should be observed. Flat molded and web cable is considered jacketed cable.

Cable lengths in above allow for a 5% voltage drop running at maximum nameplate amperes. If 3% voltage drop is desired, multiply lengths by 0.6 to get maximum cable length.

Continued on next page

Continued from previous page

Table VIII.2.1 (page 37) is based on copper wire. If aluminum wire is used, it must be two sizes larger than copper wire and oxidation inhibitors must be used on connectors.

Example: If Table VIII.2.1 (page 37) calls for #12 copper wire, #10 aluminum wire would be required.

The portion of the total cable length which is between the supply and single-phase control box with a line contactor should not exceed 25% of total maximum allowable to ensure reliable contactor operation. Single-phase control boxes without line contactors may be connected at any point in the total cable length.

Two different cable sizes can be used.

Depending on the installation, any number of combinations of cable may be used.

For example, in a replacement installation, the well already has 160 feet of buried #10 cable between the service entrance and the well head. The question is: What size cable is required in the well with a 3 hp, 230 volt, single-phase motor setting at 310 feet?

1. From Table VIII.2.1 (page 37), a 3 hp motor can use up to 300 feet of #10 AWG cable.
2. The application has 160 feet of buried #10 AWG cable.
3. 160 feet divided by 300 feet (max allowable) is equal to 53.3% of max allowable.
4. $100\% - 53.3\% = 46.7\%$ remaining of another cable size.
5. 310 feet (well head to motor) is 46.7% of max allowable length of another cable size.
6. $310 \text{ feet} \div .467 (46.7\%) = 664 \text{ feet}$ is max allowable.
7. 664 feet is less than or equal to what size cable in Table VIII.2.1 (page 37) under the 3 hp cable run.

The table shows #8 is good for 470 feet, which is too short. #6 is good for 750 feet, and therefore #6 can be used for the remaining 310 feet.

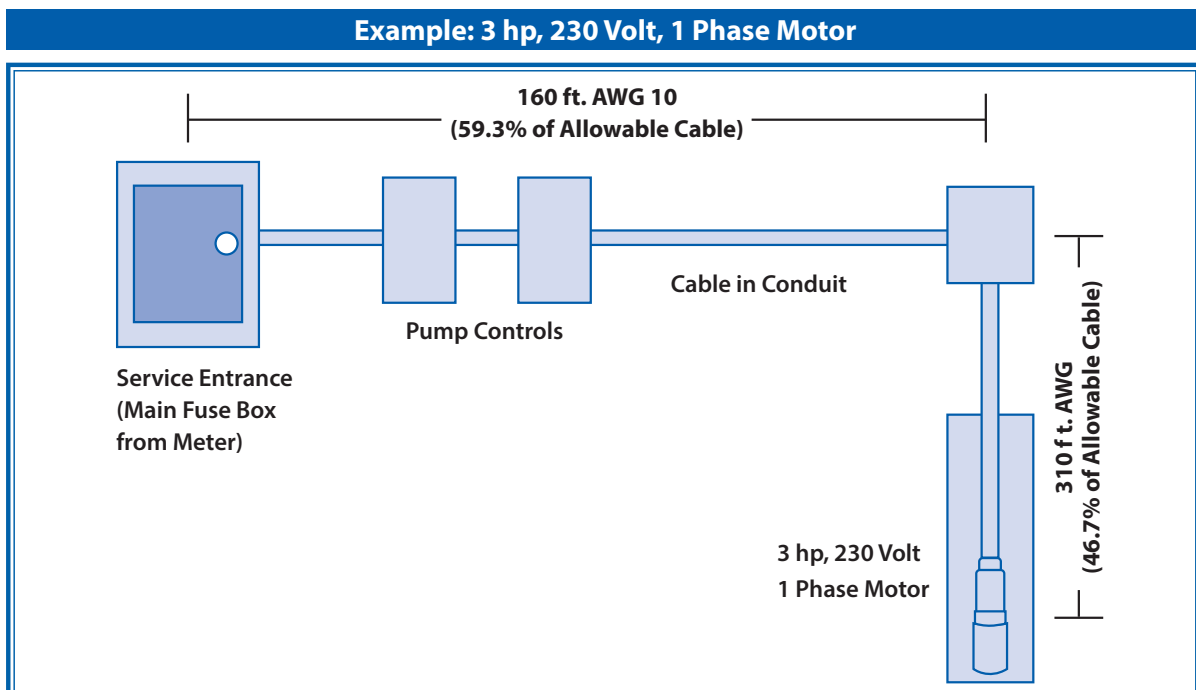


**Table VIII.2.2: Recommended Cable Selections
Three-Phase Submersible Pump Installations**

**Cable selection for THREE-PHASE THREE-LEAD 60°C CABLE, 60Hz
(Service entrance to motor) Maximum length in feet**

Motor Rating			60°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size				
Volts	hp	kW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500
200V 60HZ Three Phase 3 - Lead	1/2	0.37	710	1140	1800	2840	4420													
	3/4	0.55	510	810	1280	2030	3160													
	1	0.75	430	690	1080	1710	2670	4140	5140											
	1 1/2	1.1	310	500	790	1260	1960	3050	3780											
	2	1.5	240	390	610	970	1520	2360	2940	3610	4430	5420								
	3	2.2	180	290	470	740	1160	1810	2250	2760	3390	4130								
	5	3.7	110	170	280	440	690	1080	1350	1660	2040	2490	3050	3670	4440	5030				
	7 1/2	5.5	0	0	200	310	490	770	960	1180	1450	1770	2170	2600	3150	3560				
	10	7.5	0	0	0	230	370	570	720	880	1090	1330	1640	1970	2390	2720	3100	3480	3800	4420
	15	11	0	0	0	160	250	390	490	600	740	910	1110	1340	1630	1850	2100	2350	2570	2980
	20	15	0	0	0	0	190	300	380	460	570	700	860	1050	1270	1440	1650	1850	2020	2360
	25	18.5	0	0	0	0	0	240	300	370	460	570	700	840	1030	1170	1330	1500	1640	1900
	30	22	0	0	0	0	0	0	250	310	380	470	580	700	850	970	1110	1250	1360	1590
230V 60 HZ Three Phase 3 - Lead	1/2	0.37	930	1490	2350	3700	5760	8910												
	3/4	0.55	670	1080	1700	2580	4190	6490	8060	9860										
	1	0.75	560	910	1430	2260	3520	5460	6780	8290										
	1 1/2	1.1	420	670	1060	1670	2610	4050	5030	6160	7530	9170								
	2	1.5	320	510	810	1280	2010	3130	3890	4770	5860	7170	8780							
	3	2.2	240	390	620	990	1540	2400	2980	3660	4480	5470	6690	8020	9680					
	5	3.7	140	230	370	590	920	1430	1790	2190	2690	3290	4030	4850	5870	6650	7560	8460	9220	
	7 1/2	5.5	0	160	260	420	650	1020	1270	1560	1920	2340	2870	3440	4160	4710	5340	5970	6500	7510
	10	7.5	0	0	190	310	490	760	950	1170	1440	1760	2160	2610	3160	3590	4100	4600	5020	5840
	15	11	0	0	0	210	330	520	650	800	980	1200	1470	1780	2150	2440	2780	3110	3400	3940
	20	15	0	0	0	0	250	400	500	610	760	930	1140	1380	1680	1910	2180	2450	2680	3120
	25	18.5	0	0	0	0	0	320	400	500	610	750	920	1120	1360	1540	1760	1980	2160	2520
	30	22	0	0	0	0	0	260	330	410	510	620	760	930	1130	1280	1470	1650	1800	2110
380V 60 HZ Three Phase 3 - Lead	1/2	0.37	2690	4290	6730															
	3/4	0.55	2000	3190	5010	7860														
	1	0.75	1620	2580	4060	6390	9980													
	1 1/2	1.1	1230	1970	3100	4890	7630													
	2	1.5	870	1390	2180	3450	5400	8380												
	3	2.2	680	1090	1710	2690	4200	6500	8020	9830										
	5	3.7	400	640	1010	1590	2490	3870	4780	5870	7230	8830								
	7 1/2	5.5	270	440	690	1090	1710	2640	3260	4000	4930	6010	7290	8780						
	10	7.5	200	320	510	800	1250	1930	2380	2910	3570	4330	5230	6260	7390	8280	9340			
	15	11	0	0	370	590	920	1430	1770	2170	2690	3290	4000	4840	5770	6520	7430	8250	8990	
	20	15	0	0	0	440	700	1090	1350	1670	2060	2530	3090	3760	4500	5110	5840	6510	7120	8190
	25	18.5	0	0	0	360	570	880	1100	1350	1670	2050	2510	3040	3640	4130	4720	5250	5740	6590
	30	22	0	0	0	0	470	730	910	1120	1380	1700	2080	2520	3020	3430	3920	4360	4770	5490
	40	30	0	0	0	0	0	530	660	820	1010	1240	1520	1840	2200	2500	2850	3170	3470	3990
	50	37	0	0	0	0	0	0	540	660	820	1000	1220	1480	1770	2010	2290	2550	2780	3190
	60	45	0	0	0	0	0	0	0	560	690	850	1030	1250	1500	1700	1940	2150	2350	2700
	75	55	0	0	0	0	0	0	0	0	570	700	860	1050	1270	1440	1660	1850	2030	2350
	100	75	0	0	0	0	0	0	0	0	0	510	630	760	910	1030	1180	1310	1430	1650
	125	90	0	0	0	0	0	0	0	0	0	0	0	620	740	840	950	1060	1160	1330
	150	110	0	0	0	0	0	0	0	0	0	0	0	0	620	700	790	880	960	1090
	175	130	0	0	0	0	0	0	0	0	0	0	0	0	0	650	750	840	920	1070
	200	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	630	700	760	880

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**Table VIII.2.2: Recommended Cable Selections
Three-Phase Submersible Pump Installations**

**Cable selection for THREE-PHASE THREE-LEAD 60°C CABLE, 60Hz
(Service entrance to motor) Maximum length in feet**

Motor Rating			60°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size				
Volts	hp	kW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500
460V 60HZ Three Phase 3 - Lead	1/2	0.37	3770	6020	9460															
	3/4	0.55	2730	4350	6850															
	1	0.75	2300	3670	5770	9070														
	1 1/2	1.1	1700	2710	4270	6730														
	2	1.5	1300	2070	3270	5150	8050													
	3	2.2	1000	1600	2520	3970	6200													
	5	3.7	590	950	1500	2360	3700	5750												
	7 1/2	5.5	420	680	1070	1690	2640	4100	5100	6260	7680									
	10	7.5	310	500	790	1250	1960	3050	3800	4680	5750	7050								
	15	11	0	340	540	850	1340	2090	2600	3200	3930	4810	5900	7110						
	20	15	0	0	410	650	1030	1610	2000	2470	3040	3730	4580	5530						
	25	18.5	0	0	0	530	830	1300	1620	1990	2450	3010	3700	4470	5430					
	30	22	0	0	0	430	680	1070	1330	1640	2030	2490	3060	3700	4500	5130	5860			
	40	30	0	0	0	0	500	790	980	1210	1490	1830	2250	2710	3290	3730	4250			
	50	37	0	0	0	0	0	640	800	980	1210	1480	1810	2190	2650	3010	3420	3830	4180	4850
	60	45	0	0	0	0	0	540	670	830	1020	1250	1540	1850	2240	2540	2890	3240	3540	4100
	75	55	0	0	0	0	0	0	0	680	840	1030	1260	1520	1850	2100	2400	2700	2950	3440
	100	75	0	0	0	0	0	0	0	0	620	760	940	1130	1380	1560	1790	2010	2190	2550
	125	90	0	0	0	0	0	0	0	0	0	0	740	890	1000	1220	1390	1560	1700	1960
	150	110	0	0	0	0	0	0	0	0	0	0	0	760	920	1050	1190	1340	1460	1960
	175	130	0	0	0	0	0	0	0	0	0	0	0	0	810	930	1060	1190	1300	1510
	200	150	0	0	0	0	0	0	0	0	0	0	0	0	0	810	920	1030	1130	1310
575V 60 HZ Three Phase 3 - Lead	1/2	0.37	5900	9410																
	3/4	0.55	4270	6810																
	1	0.75	3630	5800	9120															
	1 1/2	1.1	2620	4180	6580															
	2	1.5	2030	3250	5110	8060														
	3	2.2	1580	2530	3980	6270														
	5	3.7	920	1480	2330	3680	5750													
	7 1/2	5.5	660	1060	1680	2650	4150													
	10	7.5	490	780	1240	1950	3060	4770	5940											
	15	11	330	530	850	1340	2090	3260	4060											
	20	15	0	410	650	1030	1610	2520	3140	3860	4760	5830								
	25	19	0	0	520	830	1300	2030	2530	3110	3840	4710								
	30	22	0	0	430	680	1070	1670	2080	2560	3160	3880	4770	5780	7030	8000				
	40	30	0	0	0	500	790	1240	1540	1900	2330	2860	3510	4230	5140	5830				
	50	37	0	0	0	0	640	1000	1250	1540	1890	2310	2840	3420	4140	4700	5340	5990	6530	7580
	60	45	0	0	0	0	0	850	1060	1300	1600	1960	2400	2890	3500	3970	4520	5070	5530	6410
	75	55	0	0	0	0	0	690	860	1060	1310	1600	1970	2380	2890	3290	3750	5220	4610	5370
	100	75	0	0	0	0	0	0	0	790	970	1190	1460	1770	2150	2440	2790	3140	3430	3990
	125	90	0	0	0	0	0	0	0	0	770	950	1160	1400	1690	1920	2180	2440	2650	3070
	150	110	0	0	0	0	0	0	0	0	0	800	990	1190	1440	1630	1860	2080	2270	2640
	175	130	0	0	0	0	0	0	0	0	0	0	870	1050	1270	1450	1650	1860	2030	2360
	200	150	0	0	0	0	0	0	0	0	0	0	0	920	1110	1260	1440	1620	1760	2050

**Table VIII.2.3: Recommended Cable Selections
Three-Phase Submersible Pump Installations**

Cable selection for THREE-PHASE SIX-LEAD 60°C CABLE, 60Hz																				
Motor Rating			60°C Insulation - AWG Copper Wire Size												MCM Copper Wire Size					
Volts	hp	kW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500
200V 60HZ Three Phase 6 - Lead Y-D	5	3.7	160	250	420	660	1030	1620	2020	2490	3060	3730	4570	5500	6660	7540				
	7 1/2	5.5	110	180	300	460	730	1150	1440	1770	2170	2650	3250	3900	4720	5340				
	10	7.5	80	130	210	340	550	850	1080	1320	1630	1990	2460	2950	3580	4080	4650	5220	5700	6630
	15	11	0	0	140	240	370	580	730	900	1110	1360	1660	2010	2440	2770	3150	3520	3850	4470
	20	15	0	0	0	170	280	450	570	690	850	1050	1290	1570	1900	2160	2470	2770	3030	3540
	25	18.5	0	0	0	140	220	360	450	550	690	850	1050	1260	1540	1750	1990	2250	2460	2850
	30	22	0	0	0	0	180	294	370	460	570	700	870	1050	1270	1450	1660	1870	2040	2380
230V 60HZ Three Phase 6 - Lead Y-D	5	3.7	210	340	550	880	1380	2140	2680	3280	4030	4930	6040	7270	8800	9970				
	7 1/2	5.5	150	240	390	630	970	1530	1900	2340	2880	3510	4300	5160	6240	7060	8010	8950	9750	
	10	7.5	110	180	280	460	730	1140	1420	1750	2160	2640	3240	3910	4740	5380	6150	6900	7530	8760
	15	11	0	0	190	310	490	780	970	1200	1470	1800	2200	2670	3220	3660	4170	4660	5100	5910
	20	15	0	0	140	230	370	600	750	910	1140	1390	1710	2070	2520	2860	3270	3670	4020	4680
	25	18.5	0	0	0	190	300	480	600	750	910	1120	1380	1680	2040	2310	2640	2970	3240	3780
	30	22	0	0	0	150	240	390	490	610	760	930	1140	1390	1690	1920	2200	2470	2700	3160
380V 60HZ Three Phase 6 - Lead Y-D	5	3.7	600	960	1510	2380	3730	5800	7170	8800										
	7 1/2	5.5	400	660	1030	1630	2560	3960	4890	6000	7390	9010								
	10	7.5	300	480	760	1200	1870	2890	3570	4360	5350	6490	7840	9390						
	15	11	210	340	550	880	1380	2140	2650	3250	4030	4930	6000	7260	8650	9780				
	20	15	160	260	410	660	1050	1630	2020	2500	3090	3790	4630	5640	6750	7660	4260	9760		
	25	18.5	0	210	330	540	850	1320	1650	2020	2500	3070	3760	4560	5460	6190	7080	7870	8610	9880
	30	22	0	0	270	430	700	1090	1360	1680	2070	2550	3120	3780	4530	5140	5880	6540	7150	8230
	40	30	0	0	0	320	510	790	990	1230	1510	1860	2280	2760	3300	3750	4270	4750	5200	5980
	50	37	0	0	0	250	400	630	810	990	1230	1500	1830	2220	2650	3010	3430	3820	4170	4780
	60	45	0	0	0	0	340	540	660	840	1030	1270	1540	1870	2250	2550	2910	3220	3520	4050
	75	55	0	0	0	0	0	450	550	690	855	1050	1290	1570	1900	2160	2490	2770	3040	3520
	100	75	0	0	0	0	0	0	420	520	640	760	940	1140	1360	1540	1770	1960	2140	2470
	125	90	0	0	0	0	0	0	0	400	490	600	730	930	1110	1260	1420	1590	1740	1990
	150	110	0	0	0	0	0	0	0	0	420	510	620	750	930	1050	1180	1320	1440	1630
	175	130	0	0	0	0	0	0	0	0	360	440	540	660	780	970	1120	1260	1380	1600
	200	150	0	0	0	0	0	0	0	0	0	0	480	580	690	790	940	1050	1140	1320
460V 60HZ Three Phase 6 - Lead Y-D	5	3.7	880	1420	2250	3540	5550	8620												
	7 1/2	5.5	630	1020	1600	2530	3960	6150	7650	9390										
	10	7.5	460	750	1180	1870	2940	4570	5700	7020	8620									
	15	11	310	510	810	1270	2010	3130	3900	4800	5890	7210	8850							
	20	15	230	380	610	970	1540	2410	3000	3700	4560	5590	6870	8290						
	25	18.5	190	310	490	790	1240	1950	2430	2980	3670	4510	5550	6700	8140					
	30	22	0	250	410	640	1020	1600	1990	2460	3040	3730	4590	5550	6750	7690	8790			
	40	30	0	0	300	480	750	1180	1470	1810	2230	2740	3370	4060	4930	5590	6370			
	50	37	0	0	0	370	590	960	1200	1470	1810	2220	2710	3280	3970	4510	5130	5740	6270	7270
	60	45	0	0	0	320	500	810	1000	1240	1530	1870	2310	2770	3060	3810	4330	4860	5310	6150
	75	55	0	0	0	0	420	660	810	1020	1260	1540	1890	2280	2770	3150	3600	4050	4420	5160
	100	75	0	0	0	0	0	500	610	760	930	1140	1410	1690	2070	2340	2680	3010	3280	3820
	125	90	0	0	0	0	0	0	470	590	730	880	1110	1330	1500	1830	2080	2340	2550	2940
	150	110	0	0	0	0	0	0	0	510	630	770	950	1140	1380	1570	1790	2000	2180	2530
	175	130	0	0	0	0	0	0	0	0	550	680	830	1000	1220	1390	1580	1780	1950	2270
	200	150	0	0	0	0	0	0	0	0	0	590	730	880	1070	1210	1380	1550	1690	1970
575V 60HZ Three Phase 6 - Lead Y-D	5	3.7	1380	2220	3490	5520	8620													
	7 1/2	5.5	990	1590	2520	3970	6220													
	10	7.5	730	1170	1860	2920	4590	7150	8910											
	15	11	490	790	1270	2010	3130	4890	6090											
	20	15	370	610	970	1540	2410	3780	4710	5790	7140	8740								
	25	18.5	300	490	780	1240	1950	3040	3790	4660	5760	7060								
	30	22	240	400	645	1020	1600	2500	3120	3840	4740	5820	7150	8670						
	40	30	0	300	480	750	1180	1860	2310	2850	3490	4290	5260	6340	7710	8740				
	50	37	0	0	380	590	960	1500	1870	2310	2830	3460	4260	5130	6210	7050	8010	8980	9790	
	60	45	0	0	0	500	790	1270	1590	1950	2400	2940	3600	4330	5250	5950	6780	7600	8290	9610
	75	55	0	0	0	420	660	1030	1290	1590	1960	2400	2950	3570	4330	4930	5620	6330	6910	8050
	100	75	0	0	0	0	400	780	960	1180	1450	1780	2190	2650	3220	3660	4180	4710	5140	5980
	125	90	0	0	0	0	0	600	740	920	1150	1420	1740	2100	2530	2880	3270	3660	3970	4600
	150	110	0	0	0	0	0	0	650	800	990	1210	1480	1780	2160	2450	2790	3120	3410	3950
	175	130	0	0	0	0	0	0	0	700	860	1060	1300	1570	1910	2170	2480	2780	3040	3540
	200	150	0	0	0	0	0	0	0	0	760	930	1140	1370	1670	1890	2160	2420	2640	3070

**Table VIII.2.4: Recommended Cable Selections
Three-Phase Submersible Pump Installations**

Cable selection for THREE-PHASE THREE-LEAD 75°C CABLE, 60Hz (Service entrance to motor) Maximum length in feet																				
Motor Rating			75°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size				
Volts	hp	kW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500
200V 60HZ Three Phase 3 - Lead	1/2	0.37	710	1140	1800	2840	4420													
	3/4	0.55	510	810	1280	2030	3160													
	1	0.75	430	690	1080	1710	2670	4140	5140											
	1 1/2	1.1	310	500	790	1260	1960	3050	3780											
	2	1.5	240	390	610	970	1520	2360	2940	3610	4430	5420								
	3	2.2	180	290	470	740	1160	1810	2250	2760	3390	4130								
	5	3.7	110	170	280	440	690	1080	1350	1660	2040	2490	3050	3670	4440	5030				
	7 1/2	5.5	0	0	200	310	490	770	960	1180	1450	1770	2170	2600	3150	3560				
	10	7.5	0	0	150	230	370	570	720	880	1090	1330	1640	1970	2390	2720	3100	3480	3800	4420
	15	11	0	0	0	160	250	390	490	600	740	910	1110	1340	1630	1850	2100	2350	2570	2980
	20	15	0	0	0	0	190	300	380	460	570	700	860	1050	1270	1440	1650	1850	2020	2360
	25	18.5	0	0	0	0	0	240	300	370	460	570	700	840	1030	1170	1330	1500	1640	1900
30	22	0	0	0	0	0	200	250	310	380	470	580	700	850	970	1110	1250	1360	1590	
230V 60 HZ Three Phase 3 - Lead	1/2	0.37	930	1490	2350	3700	5760	8910												
	3/4	0.55	670	1080	1700	2580	4190	6490	8060	9860										
	1	0.75	560	910	1430	2260	3520	5460	6780	8290										
	1 1/2	1.1	420	670	1060	1670	2610	4050	5030	6160	7530	9170								
	2	1.5	320	510	810	1280	2010	3130	3890	4770	5860	7170	8780							
	3	2.2	240	390	620	990	1540	2400	2980	3660	4480	5470	6690	8020	9680					
	5	3.7	140	230	370	590	920	1430	1790	2190	2690	3290	4030	4850	5870	6650	7560	8460	9220	
	7 1/2	5.5	0	160	260	420	650	1020	1270	1560	1920	2340	2870	3440	4160	4710	5340	5970	6500	7510
	10	7.5	0	0	190	310	490	760	950	1170	1440	1760	2160	2610	3160	3590	4100	4600	5020	5840
	15	11	0	0	0	210	330	520	650	800	980	1200	1470	1780	2150	2440	2780	3110	3400	3940
	20	15	0	0	0	160	250	400	500	610	760	930	1140	1380	1680	1910	2180	2450	2680	3120
	25	19	0	0	0	0	200	320	400	500	610	750	920	1120	1360	1540	1760	1980	2160	2520
380V 60 HZ Three Phase 3 - Lead	1/2	0.37	2690	4290	6730															
	3/4	0.55	2000	3190	5010	7860														
	1	0.75	1620	2580	4060	6390	9980													
	1 1/2	1.1	1230	1970	3100	4890	7630													
	2	1.5	870	1390	2180	3450	5400	8380												
	3	2.2	680	1090	1710	2690	4200	6500	8020	9830										
	5	3.7	400	640	1010	1590	2490	2870	4780	5870	7230	8830								
	7 1/2	5.5	270	440	690	1090	1710	2640	3260	4000	4930	6010	7290	8780						
	10	7.5	200	320	510	800	1250	1930	2380	2910	3570	4330	5230	6260	7390	8280	9340			
	15	11	0	0	370	590	920	1430	1770	2170	2690	3290	4000	4840	5770	6520	7430	8250	8990	
	20	15	0	0	280	440	700	1090	1350	1670	2060	2530	3090	3760	4500	5110	5840	6510	7120	8190
	25	18.5	0	0	0	360	570	880	1100	1350	1670	2050	2510	3040	3640	4130	4720	5250	5740	6590
	30	22	0	0	0	290	470	730	910	1120	1380	1700	2080	2520	3020	3430	3920	4360	4770	5490
	40	30	0	0	0	0	0	530	660	820	1010	1240	1520	1840	2200	2500	2850	3170	3470	3990
	50	37	0	0	0	0	0	440	540	660	820	1000	1220	1480	1770	2010	2290	2550	2780	3190
	60	45	0	0	0	0	0	370	460	560	690	850	1030	1250	1500	1700	1940	2150	2350	2700
	75	55	0	0	0	0	0	0	0	460	570	700	860	1050	1270	1440	1660	1850	2030	2350
	100	75	0	0	0	0	0	0	0	0	420	510	630	760	910	1030	1180	1310	1430	1650
	125	90	0	0	0	0	0	0	0	0	0	0	0	510	620	740	840	950	1060	1160
	150	110	0	0	0	0	0	0	0	0	0	0	0	0	520	620	700	790	880	960
175	130	0	0	0	0	0	0	0	0	0	0	0	0	0	560	650	750	840	920	
200	150	0	0	0	0	0	0	0	0	0	0	0	0	0	550	630	700	760	880	

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**Table VIII.2.4: Recommended Cable Selections
Three-Phase Submersible Pump Installations**

Cable selection for THREE-PHASE THREE-LEAD 75°C CABLE, 60Hz (Service entrance to motor) Maximum length in feet																				
Motor Rating			75°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size				
Volts	hp	kW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500
460V 60HZ Three Phase 3 - Lead	1/2	0.37	3770	6020	9460															
	3/4	0.55	2730	4350	6850															
	1	0.75	2300	3670	5770	9070														
	1 1/2	1.1	1700	2710	4270	6730														
	2	1.5	1300	2070	3270	5150	8050													
	3	2.2	1000	1600	2520	3970	6200													
	5	3.7	590	950	1500	2360	3700	5750												
	7 1/2	5.5	420	680	1070	1690	2640	4100	5100	6260	7680									
	10	7.5	310	500	790	1250	1960	3050	3800	4680	5750	7050								
	15	11	0	340	540	850	1340	2090	2600	3200	3930	4810	5900	7110						
	20	15	0	0	410	650	1030	1610	2000	2470	3040	3730	4580	5530						
	25	18.5	0	0	330	530	830	1300	1620	1990	2450	3010	3700	4470	5430					
	30	22	0	0	270	430	680	1070	1330	1640	2030	2490	3060	3700	4500	5130	5860			
	40	30	0	0	0	320	500	790	980	1210	1490	1830	2250	2710	3290	3730	4250			
	50	37	0	0	0	0	410	640	800	980	1210	1480	1810	2190	2650	3010	3420	3830	4180	4850
	60	45	0	0	0	0	0	540	670	830	1020	1250	1540	1850	2240	2540	2890	3240	3540	4100
	75	55	0	0	0	0	0	440	550	680	840	1030	1260	1520	1850	2100	2400	2700	2950	3440
100	75	0	0	0	0	0	0	0	500	620	760	940	1130	1380	1560	1790	2010	2190	2550	
125	90	0	0	0	0	0	0	0	0	0	600	740	890	1000	1220	1390	1560	1700	1960	
575V 60 HZ Three Phase 3 - Lead	1/2	0.37	5900	9410																
	3/4	0.55	4270	6810																
	1	0.75	3630	5800	9120															
	1 1/2	1.1	2620	4180	6580															
	2	1.5	2030	3250	5110	8060														
	3	2.2	1580	2530	3980	6270														
	5	3.7	920	1480	2330	3680	5750													
	7 1/2	5.5	660	1060	1680	2650	4150													
	10	7.5	490	780	1240	1950	3060	4770	5940											
	15	11	330	530	850	1340	2090	3260	4060											
	20	15	0	410	650	1030	1610	2520	3140	3860	4760	5830								
	25	19	0	0	520	830	1300	2030	2530	3110	3840	4710								
	30	22	0	0	430	680	1070	1670	2080	2560	3160	3880	4770	5780	7030	8000				
	40	30	0	0	0	500	790	1240	1540	1900	2330	2860	3510	4230	5140	5830				
	50	37	0	0	0	410	640	1000	1250	1540	1890	2310	2840	3420	4140	4700	5340	5990	6530	7580
	60	45	0	0	0	0	540	850	1060	1300	1600	1960	2400	2890	3500	3970	4520	5070	5530	6410
	75	55	0	0	0	0	0	690	860	1060	1310	1600	1970	2380	2890	3290	3750	5220	4610	5370
	100	75	0	0	0	0	0	0	640	790	970	1190	1460	1770	2150	2440	2790	3140	3430	3990
	125	90	0	0	0	0	0	0	0	630	770	950	1160	1400	1690	1920	2180	2440	2650	3070
	150	110	0	0	0	0	0	0	0	0	660	800	990	1190	1440	1630	1860	2080	2270	2640
175	130	0	0	0	0	0	0	0	0	0	700	870	1050	1270	1450	1650	1860	2030	2360	
200	150	0	0	0	0	0	0	0	0	0	0	760	920	1110	1260	1440	1620	1760	2050	

**Table VIII.2.5: Recommended Cable Selections
Three-Phase Submersible Pump Installations**

Cable selection for THREE-PHASE SIX-LEAD 75°C CABLE, 60Hz																				
Motor Rating			75°C Insulation - AWG Copper Wire Size													MCM Copper Wire Size				
Volts	hp	kW	14	12	10	8	6	4	3	2	1	0	00	000	0000	250	300	350	400	500
200V 60HZ Three Phase 6 - Lead Y-D	5	3.7	160	250	420	660	1030	1620	2020	2490	3060	3730	4570	5500	6660	7540				
	7 1/2	5.5	110	180	300	460	730	1150	1440	1770	2170	2650	3250	3900	4720	5340				
	10	7.5	80	130	210	340	550	850	1080	1320	1630	1990	2460	2950	3580	4080	4650	5220	5700	6630
	15	11	0	0	140	240	370	580	730	900	1110	1360	1660	2010	2440	2770	3150	3520	3850	4470
	20	15	0	0	120	170	280	450	570	690	850	1050	1290	1570	1900	2160	2470	2770	3030	3540
	25	18.5	0	0	0	140	220	360	450	550	690	850	1050	1260	1540	1750	1990	2250	2460	2850
	30	22	0	0	0	120	180	294	370	460	570	700	870	1050	1270	1450	1660	1870	2040	2380
230V 60HZ Three Phase 6 - Lead Y-D	5	3.7	210	340	550	880	1380	2140	2680	3280	4030	4930	6040	7270	8800	9970				
	7 1/2	5.5	150	240	390	630	970	1530	1900	2340	2880	3510	4300	5160	6240	7060	8010	8950	9750	
	10	7.5	110	180	280	460	730	1140	1420	1750	2160	2640	3240	3910	4740	5380	6150	6900	7530	8760
	15	10	0	130	190	310	490	780	970	1200	1470	1800	2200	2670	3220	3660	4170	4660	5100	5910
	20	15	0	0	140	230	370	600	750	910	1140	1390	1710	2070	2520	2860	3270	3670	4020	4680
	15	18.5	0	0	120	190	300	480	600	750	910	1120	1380	1680	2040	2310	2640	2970	3240	3780
	30	22	0	0	0	150	240	390	490	610	760	930	1140	1390	1690	1920	2200	2470	2700	3160
380V 60HZ Three Phase 6 - Lead Y-D	5	3.7	600	960	1510	2380	3730	5800	7170	8800										
	7 1/2	5.5	400	660	1030	1630	2560	3960	4890	6000	7390	9010								
	10	7.5	300	480	760	1200	1870	2890	3570	4360	5350	6490	7840	9390						
	15	11	210	340	550	880	1380	2140	2650	3250	4030	4930	6000	7260	8650	9780				
	20	15	160	260	410	660	1050	1630	2020	2500	3090	3790	4630	5640	6750	7660	4260	9760		
	25	18.5	0	210	330	540	850	1320	1650	2020	2500	3070	3760	4560	5460	6190	7080	7870	8610	9880
	30	22	0	0	270	430	700	1090	1360	1680	2070	2550	3120	3780	4530	5140	5880	6540	7150	8230
	40	30	0	0	210	320	510	790	990	1230	1510	1860	2280	2760	3300	3750	4270	4750	5200	5980
	50	37	0	0	0	250	400	630	810	990	1230	1500	1830	2220	2650	3010	3430	3820	4170	4780
	60	45	0	0	0	0	340	540	660	840	1030	1270	1540	1870	2250	2550	2910	3220	3520	4050
	75	55	0	0	0	0	290	450	550	690	855	1050	1290	1570	1900	2160	2490	2770	3040	3520
	100	75	0	0	0	0	0	340	420	520	640	760	940	1140	1360	1540	1770	1960	2140	2470
	125	90	0	0	0	0	0	0	340	400	490	600	730	930	1110	1260	1420	1590	1740	1990
	150	110	0	0	0	0	0	0	0	350	420	510	620	750	930	1050	1180	1320	1440	1630
	175	130	0	0	0	0	0	0	0	0	360	440	540	660	780	970	1120	1260	1380	1600
		200	150	0	0	0	0	0	0	0	0	410	480	580	690	790	940	1050	1140	1320
4600V 60HZ Three Phase 6 - Lead Y-D	5	3.7	880	1420	2250	3540	5550	8620												
	7 1/2	5.5	630	1020	1600	2530	3960	6150	7650	9390										
	10	7.5	460	750	1180	1870	2940	4570	5700	7020	8620									
	15	11	310	510	810	1270	2010	3130	3900	4800	5890	7210	8850							
	20	15	230	380	610	970	1540	2410	3000	3700	4560	5590	6870	8290						
	25	18.5	190	310	490	790	1240	1950	2430	2980	3670	4510	5550	6700	8140					
	30	22	0	250	410	640	1020	1600	1990	2460	3040	3730	4590	5550	6750	7690	8790			
	40	30	0	0	300	480	750	1180	1470	1810	2230	2740	3370	4060	4930	5590	6370			
	50	37	0	0	250	370	590	960	1200	1470	1810	2220	2710	3280	3970	4510	5130	5740	6270	7270
	60	45	0	0	0	320	500	810	1000	1240	1530	1870	2310	2770	3360	3810	4330	4860	5310	6150
	75	55	0	0	0	0	420	660	810	1020	1260	1540	1890	2280	2770	3150	3600	4050	4420	5160
	100	75	0	0	0	0	310	500	610	760	930	1140	1410	1690	2070	2340	2680	3010	3280	3820
	125	90	0	0	0	0	0	390	470	590	730	880	1110	1330	1500	1830	2080	2340	2550	2940
	150	110	0	0	0	0	0	0	420	510	630	770	950	1140	1380	1570	1790	2000	2180	2530
	175	130	0	0	0	0	0	0	0	450	550	680	830	1000	1220	1390	1580	1780	1950	2270
		200	150	0	0	0	0	0	0	0	0	480	590	730	880	1070	1210	1380	1550	1690
575V 60HZ Three Phase 6 - Lead Y-D	5	3.7	1380	2220	3490	5520	8620													
	7 1/2	5.5	990	1590	2520	3970	6220													
	10	7.5	730	1170	1860	2920	4590	7150	8910											
	15	11	490	790	1270	2010	3130	4890	6090											
	20	15	370	610	970	1540	2410	3780	4710	5790	7140	8740								
	25	18.5	300	490	780	1240	1950	3040	3790	4660	5760	7060								
	30	22	240	400	645	1020	1600	2500	3120	3840	4740	5820	7150	8670						
	40	30	0	300	480	750	1180	1860	2310	2850	3490	4290	5260	6340	7710	8740				
	50	37	0	0	380	590	960	1500	1870	2310	2830	3460	4260	5130	6210	7050	8010	8980	9790	
	60	45	0	0	330	500	790	1270	1590	1950	2400	2940	3600	4330	5250	5950	6780	7600	8290	9610
	75	55	0	0	0	420	660	1030	1290	1590	1960	2400	2950	3570	4330	4930	5620	6330	6910	8050
	100	75	0	0	0	0	400	780	960	1180	1450	1780	2190	2650	3220	3660	4180	4710	5140	5980
	125	90	0	0	0	0	0	600	740	920	1150	1420	1740	2100	2530	2880	3270	3660	3970	4600
	150	110	0	0	0	0	0	520	650	800	990	1210	1480	1780	2160	2450	2790	3120	3410	3950
	175	130	0	0	0	0	0	0	570	700	860	1060	1300	1570	1910	2170	2480	2780	3040	3540
		200	150	0	0	0	0	0	0	500	610	760	930	1140	1370	1670	1890	2160	2420	2640

Chapter 3

Tank Sizing

- ✓ Tank operation
- ✓ Sizing a tank
- ✓ Other considerations

Most domestic water systems have a well tank for the system to operate properly. In this chapter, we will look at how **pressure tanks** work, the importance of having a pressure tank, and how to properly size a pressure tank.

The primary functions of a pressure tanks in a water system are to protect the pump and pressure switch by allowing the pump to run long enough to cool the motor and to prevent rapid cycling of the pump and pressure switch. Additionally, the pressure tank can supply water at pressure while the pump is not on. Finally, the pressure tank can provide additional water under pressure to assist in meeting the total demand for the system.

This chapter will provide an outlook at the physics principal behind how pressure tanks work, how to size both non-bladder/diaphragm tanks as well as bladder/diaphragm tanks, and how to size tanks to specific applications.

How tanks work

Boyle's Law

A physics law that states:

One of the best known characteristics of a gas is its compressibility...its ability to be forced into a smaller volume by the application of pressure.

Fact #1: Air IS compressible

Fact #2: Water IS NOT compressible

By compressing the air in a **hydropneumatic tank**, we are in effect creating a giant spring to provide a range of pressure within which a usable amount of water can be withdrawn

The formula

$$\frac{P_a}{P_1} - \frac{P_a}{P_2} = \text{Acceptance Factor}$$

Total tank volume (required) = **Drawdown** (in **gpm**)

Drawdown Factor

P_a = Pressure in tank when empty

P_1 = **Pump cut-in pressure**

P_2 = **Pump cut-out pressure**

(must include atmospheric pressure – 14.7 at sea level)

Things needed to size a tank.

<u>Pump Flow Rate:</u>	Nominal gpm output at intended pressure range
<u>Minute Run Time:</u>	Desired minimum pump operating time in minutes
<u>Cut-In Pressure:</u>	Pump on, diaphragm empty
<u>Cut-Out Pressure:</u>	Pump off, diaphragm full
<u>Drawdown:</u>	Diaphragm water capacity between cut-in and cut-out

Pump flow rate

The pump output is the first step in determining the tank size required.

Run time

A pump supplying 10 gallons per minute (gpm) would require 10 gallons of drawdown to achieve a 1-minute run time.

Importance of run time

The most important function of a pressure tank is to protect the pump. Adequate run time will prevent rapid cycling of the pump motor and will prolong the life of the pump. To determine the pump run time, it is necessary to know the pump flow rate (gpm), how much run time is required, pressure settings, and amount of drawdown to the tank.

If not specified by the manufacturer:

Pumps up to $\frac{3}{4}$ hp = 1 minute minimum
Pumps 1hp and larger = 2 minutes minimum

Pressure settings

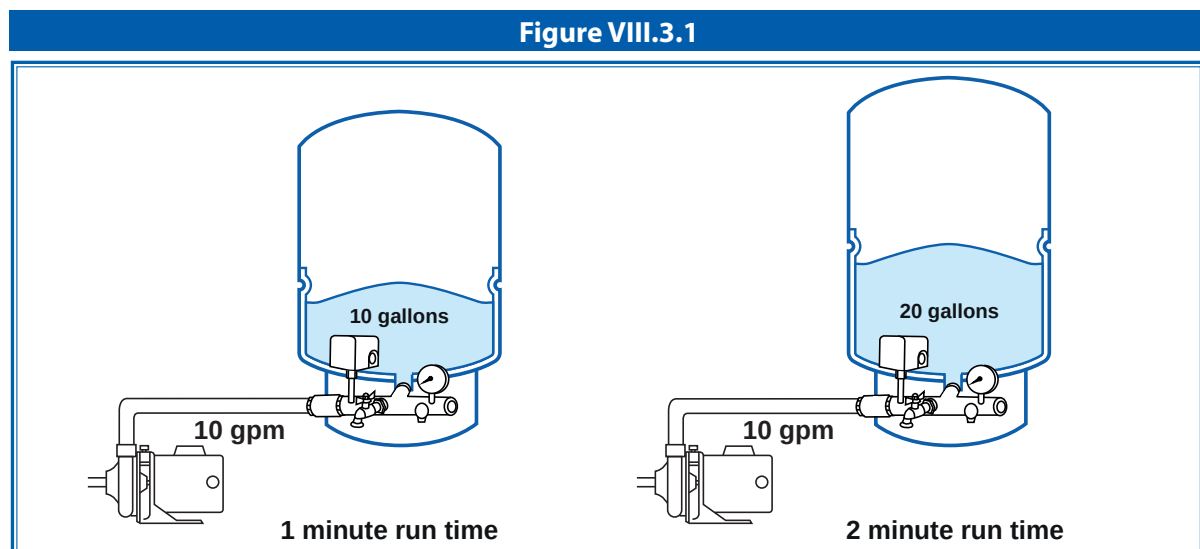
The pressure settings on the system will determine the amount of drawdown you need for the desired pump run time.

The cut-in pressure is the minimum pressure of the system and where the pump switch will activate the pump.

The cut-out pressure is the maximum pressure of the system and where the pump switch will deactivate the pump. There is commonly a 20 psi differential between the cut-in and cut-out.

Controlling run time

At 10 gpm, a tank storing 10 gallons of drawdown (stored water) will create a 1-minute pump run time.



Sizing procedure for diaphragm/bladder tanks

How to calculate acceptance factor (AF), using 30/50 as an example.

$$1 - [(\text{Pump cut-in } 30 + 14.7) \div (\text{Pump cut-out } 50 + 14.7)] = 0.31 \text{ AF}$$

Atmospheric Pressure = 14.7 psi

Diaphragm/Bladder Tanks Common Pressure Switch Settings		
Pump cut-in psi	Pump cut-out psi	Acceptance Factor (AF)
20	40	0.37
30	50	0.31
40	60	0.27
50	70	0.24
Drawdown = Acceptance Factor x Total volume of the tank		

Once the AF is determined, use the below formula to calculate the drawdown for any pressure setting.

Example: Sizing a Diaphragm/Bladder Tank				
10 gpm, 1 hp pump requiring 2 minutes run time with 30/50 pressure switch.				
Sizing Criteria				
10 gpm Pump Size	x	2 Minutes Run Time	=	20 Gallons of Minimum Drawdown
Total Tank Volume Required				
20 Gallons of Minimum Drawdown	÷	0.31 AF	=	64.5 Volume Gallons
Always round up to the next tank size.				

Sizing procedure for non-diaphragm/bladder tanks

How to calculate acceptance factor (AF), using 30/50 as an example.

$$[(14.7) \div (\text{Pump cut-in } 30 + 14.7)] - [(14.7) \div (\text{Pump cut-out } 50 + 14.7)] = 0.102 \text{ AF}$$

Atmospheric Pressure = 14.7 psi

Non-Diaphragm/Bladder Tanks Common Pressure Switch Settings		
Pump cut-in psi	Pump cut-out psi	Acceptance Factor (AF)
20	40	0.155
30	50	0.102
40	60	0.073
50	70	0.054
Drawdown = Acceptance Factor x Total volume of the tank		

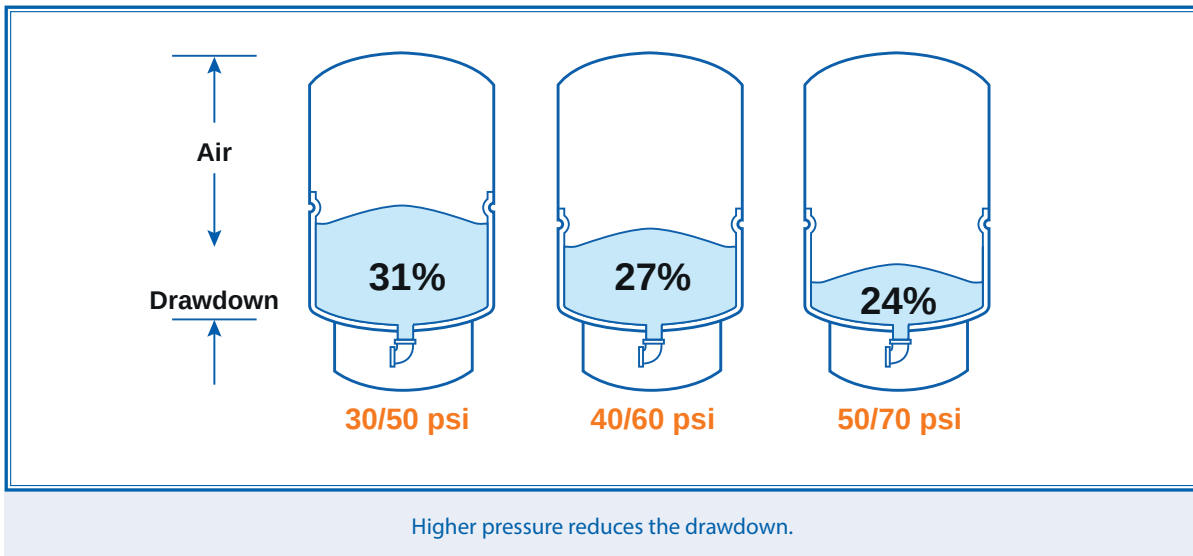
Once the AF is determined, use the below formula to calculate the drawdown for any pressure setting.

Example: Sizing a Non-Diaphragm/Bladder Tank				
10 gpm, 1 hp pump requiring 2 minutes run time with 30/50 pressure switch.				
Sizing Criteria				
10 gpm Pump Size	x	2 Minutes Run Time	=	20 Gallons of Minimum Drawdown
Total Tank Volume Required				
20 Gallons of Minimum Drawdown	÷	0.102 AF	=	196.1 Volume Gallons
Always round up to the next tank size.				

Pressure range sets the drawdown

Drawdown: Because a precharged tank utilizes a compressed air cushion, drawdown is only part of the total tank volume: the other portion is the precharge. Drawdown is expressed as a percent of total tank volume, determined by the operating pressure range. It is typically 1/4 to 1/3 of the total tank volume (Figure VIII.3.2).

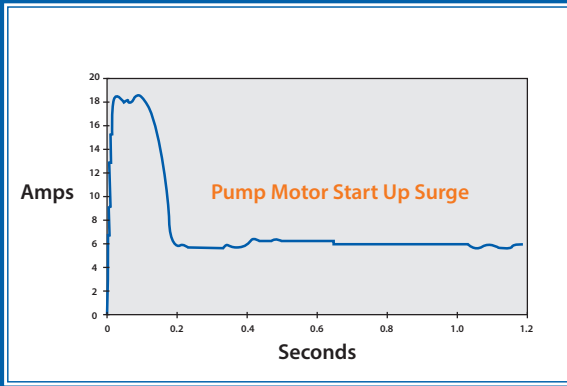
Figure VIII.3.2



Benefits of a larger tank

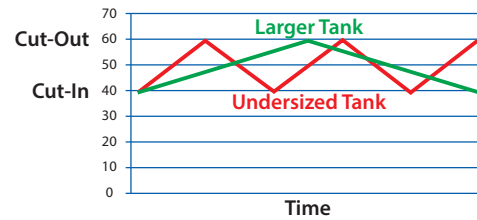
- Helps prolong pump life.
- Improves performance.
- Provides energy savings.
- Offers emergency water storage.

Figure VIII.3.3



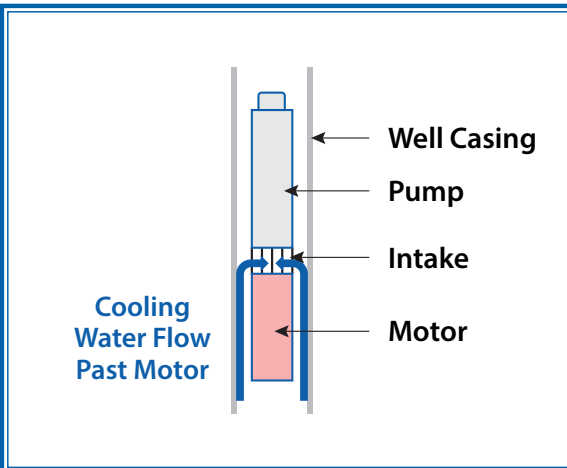
Rapid pump cycling accelerates wear on the pump, tank and pressure switch. A larger tank reduces the number of pump cycles, extending system life while also saving energy.

Figure VIII.3.4



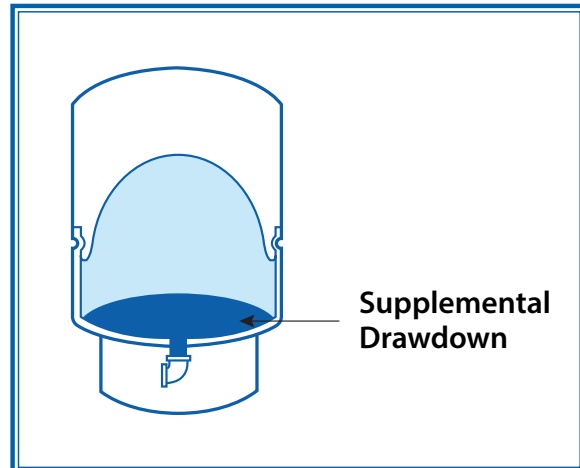
A small tank promotes rapid variation between cut-in and cut-out; a larger tank spreads these cycles out for improved pressure consistency.

Figure VIII.3.5



Once it has started, a pump motor is cooled by water flow and requires a minimum run time to avoid damaging heat buildup. A larger tank increases run time to promote motor cooling.

Figure VIII.3.6



During a power outage, a larger tank provides greater potential for water reserve. A larger tank also permits a supplemental drawdown strategy to maximize storage.

Supplemental drawdown

A reserve tank for your well tank

When to Use:

- Systems requiring flow assistance during peak draws.
- Emergency storage for power outages.

Information needed:

Peak Flow & Reserve Applications

- Supplemental storage requirement in gallons (gpm x minutes)
- Normal operating pressure range (psi)
- Minimum desired delivery pressure (psi)

Flow Assist & Water Reserve in VFD Applications

- Desired storage requirement in gallons (gpm x minutes)
- VFD control set point (psi)
- Minimum desired Delivery Pressure (psi)

Flow Assist in Municipal Systems

- Supplemental storage requirement in gallons (gpm x minutes)
- Static water supply pressure (no flow)
- Minimum allowable delivery pressure (psi)

Peak demand

Example: Sizing for Supplemental Drawdown				
System has a intermittent 15 gpm demand but can only supply 10 gpm continuously.				
Sizing Criteria				
15 gpm Peak Demand	-	10 gpm Flow	=	5 gpm Flow Shortage
5 gpm Flow Shortage	x	3 Minutes Demand Period	=	15 gal Supplemental Drawdown

How it works

Supplemental drawdown is a sizing strategy that provides reserve tank storage beyond the normal pump operating range. A supplemental configuration operates differently from a traditional set-up.

- Additional water volume is provided below the pump cut-in setting
- The tank can continue to supply water while the pump is operating
- Supplemental flow continues until the precharge is reached

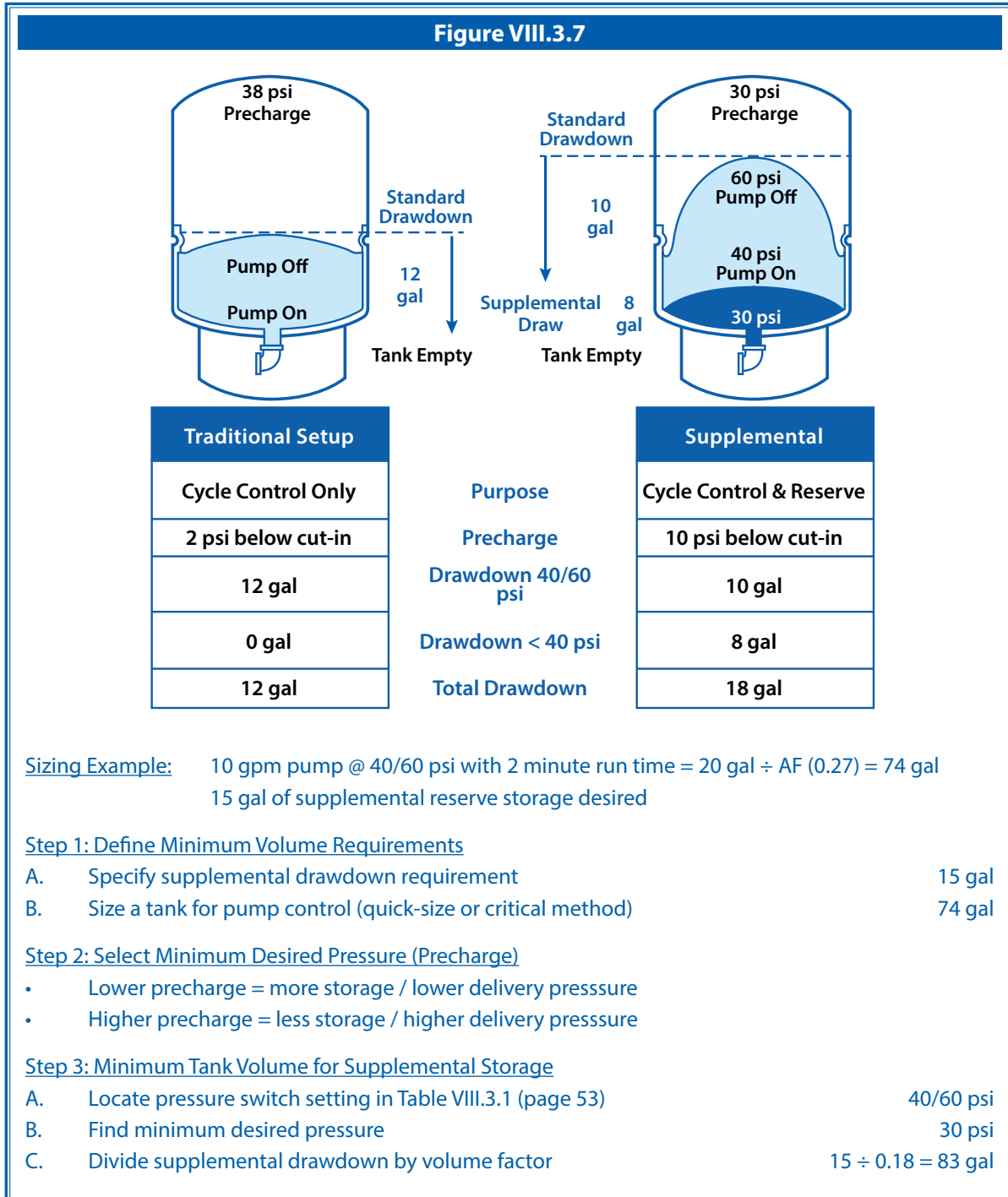


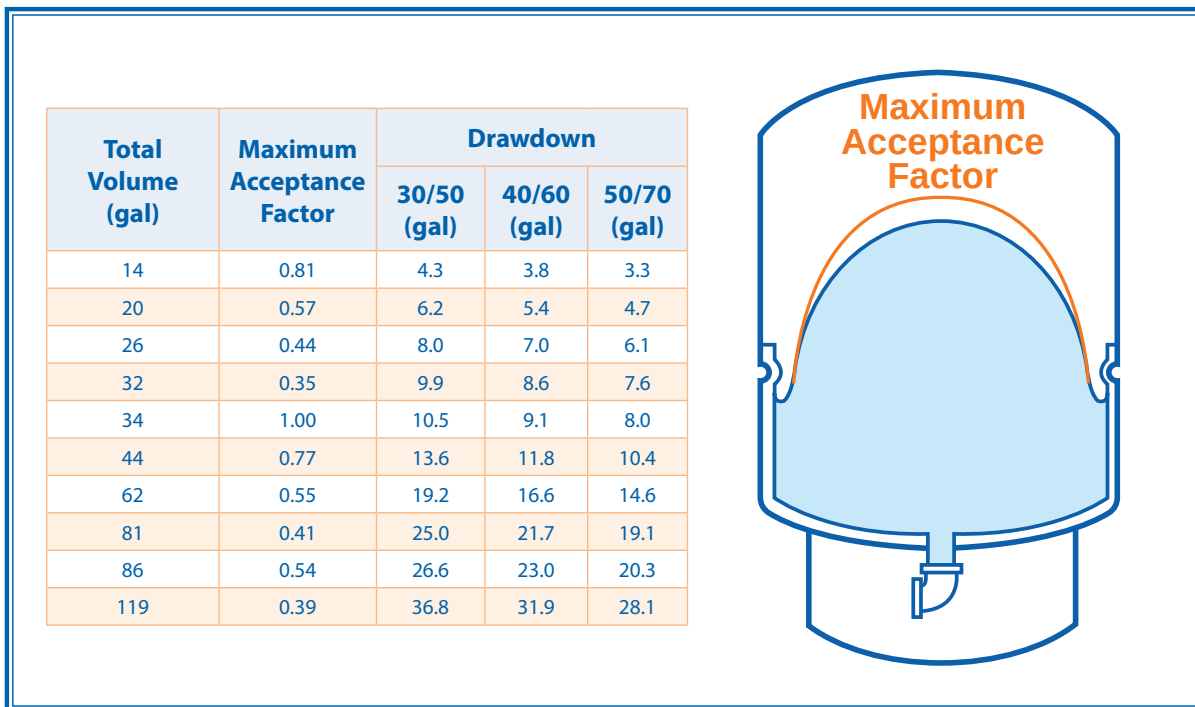
Table VIII.3.1: Supplemental Volume						
Pressure Switch Settings						
	30/50 psi		40/60 psi		50/70 psi	
Minimum Desired Pressure	20 psi	25 psi	30 psi	35 psi	40 psi	45 psi
Supplemental Volume Factor	0.22	0.11	0.18	0.09	0.15	0.08

Maximum acceptance factor

The **acceptance factor** indicates the percent of total tank volume occupied by water filling the diaphragm. Wide pressure differentials like those used in supplemental drawdown can exceed a tank's **maximum acceptance factor**, causing diaphragm over-extension and damage. The Tank Sizing Acceptance Factor charts can be found in the Appendix on pages 90-91.

Ensure the acceptance factor does not exceed the rating for the selected tank model. (See Appendix pages 90-91)

Figure VIII.3.8



Motor Starting Frequency Recommendation				
hp	Single Phase		Three-Phase	
	Starts/hr.	Starts/24 hr.	Starts/hr.	Starts/24 hr.
1/2 - 3/4	12.50	300	12.50	300
1 - 5	4.20	100	12.50	300
7.5 - 30	2.09	50	4.20	100
40 and over	-	-	4.20	100
• Motor, pressure switch, tank, and pump life may be extended by limiting starts per hour and starts per day. • Proper tank sizing is critical to control pump cycle times. • Excessive or rapid cycling creates heat which can prematurely damage motors, switches, and controls.				
A one (1) minute run time for pumps and motors up to 3/4 hp and two (2) minutes for 1 hp and larger motors is recommended to dissipate heat build-up from starting current.				

Pressure tanks with variable speed controllers

There is a major difference between constant pressure systems and traditional pump systems. In constant pressure systems, the pressure tank does not control the operation of the pump as it does in traditional pump systems where the pressure tank is utilized for storage and to minimize pump cycling and provide adequate drawdown for minimum pump run time. Since all VFDs are soft starters, the start up amps are significantly reduced. This eliminates the need to run the motor a specified period of time after start up to dissipate the heat.

In constant pressure applications, the pump starts almost immediately and continues to run while there is demand, so that the drawdown in the pressure tank is minimal. Variable speed pump control systems act primarily to minimize pressure fluctuations and provide enough water to meet initial flow and pressure demands until the pump satisfies demand – typically in a matter of a few seconds.

Since constant pressure systems do not rely on drawdown capacity, these systems can use a smaller pressure tank. Pressure tank requirements vary by product and manufacturer, so refer to the manufacturer's recommendations to ensure proper operation.

Pressure tanks with heat pumps

The **pressure tank** must be of the correct type and size to adequately function in a heat pump system. A **precharged diaphragm pressure tank** (or **precharged bladder pressure tank**) is essential so that air cannot contact the water, which keeps corrosion to a minimum and prevents fouling of the heat pump heat exchanger.

When sizing a pressure tank, first determine the pump capacity and the operating pressure range. The tank is then sized using the Tank Selection Chart (Appendix, page 88). When sizing the tank, relate the amount of tank acceptance (drawdown) to the pump discharge (flow).

The tank drawdown should be equal to the pump capacity up to 10 gpm. For situations with more than 10 gpm, the tank drawdown should be as much as twice the pump capacity. This will prevent the pump from shortcycling and will extend pump and control life. To continue with the example used earlier, one tank is used for both the heat pump and household requirements.

Pump flow requirements = total demand = 15 gpm

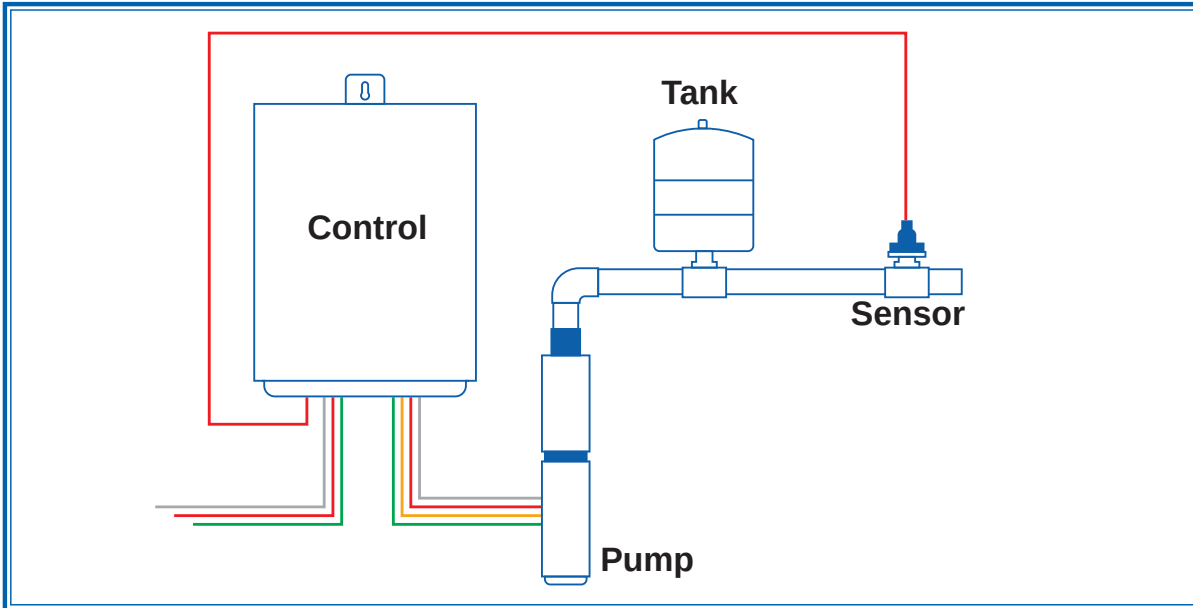
System pressure = 30 to 50 psi drawdown required = 19 gal

$\text{gpm} \div \text{AF} = \text{Tank Size}$

$19 \div 0.31 = 61.29$ (nearest tank size is 65 gal)

Tank sizing for variable frequency drive pump

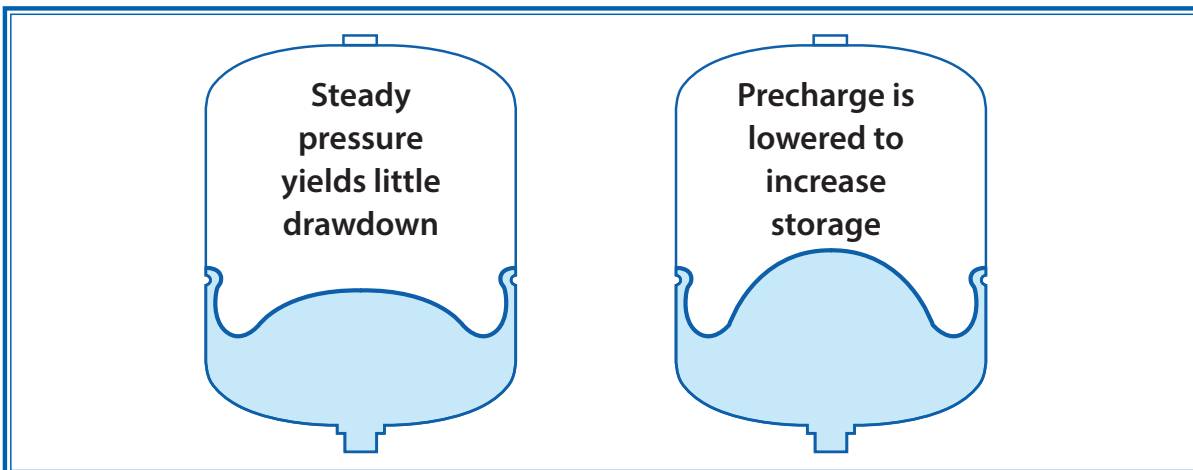
Figure VIII.3.9



Tank Sizing for VFD application differs from traditional pressure switch systems. A minimum pressure differential yields a drawdown of 5% or less. Rather than controlling pump cycling, the tank performs two functions:

- Provides initial flow while pump spools up.
- Buffers pressure fluctuations to assist VFD in maintaining smooth control of supply pressure.

Figure VIII.3.10



Minimum tank size is equal to 20% of system maximum flow.
 A 100 gpm pump maximum flow rate would require a minimum 20 gallon tank.
 Tank precharge pressure starting point must be set 25% below static pressure.
 A system static pressure of 50 psi would required a tank charge of 37.5 psi.

Tank sizing procedure when using variable frequency drive (VFD) systems

Information needed:

- Manufacturer's tank size requirement
- Nominal pump flow in gallons per minute (gpm)

Tank sizing for VFD applications differs from traditional pressure switch systems. A minimal pressure differential yields drawdown of 5% or less. Rather than controlling pump cycling, the tank performs two functions:

- Provides initial flow while pump spools up.
- Buffers pressure fluctuations to assist VFD in maintaining smooth control of supply pressure.

Procedure:

- Tank size is normally specified by the VFD manufacturer
- If not specified, select a total tank volume that is at least 20% of the nominal pump flow (4 gallons at 20 gpm)
- A larger tank is recommended by most manufacturers.
- To increase the volume of stored water, the precharge is set 15-20 psi below the VFD control setpoint.

Chapter 4

Water Treatment Sizing

- ✓ Media based water treatment sizing
- ✓ Water softener brining
- ✓ Water treatment system pressure drops
- ✓ Multiport valve pressure drops
- ✓ Media tank pressure drop

The purpose of media-based water treatment equipment and systems is to modify the quality of the **source water**. As noted in Book V, Chapter 4, a system is designed with a specific media which will have the effect of changing the quality of the source water to an acceptable quality. Once the media has been selected, the system must be sized so that it provides the required flow rate and pressure required of this **product water**. Essentially, the water treatment system will receive the source water flow and pressure from the well system at the point of entry of the home or facility, modify the quality of this water, and then provide the treated water to the home or facility at the necessary flow and pressure requirements of the home. It matters little if the system improves the **water quality** but cannot provide the water service (flow and pressure) necessary for its use in the home.

In the sizing of media-based systems, there are three primary variables which will be important in sizing the system: (1) the specification for the effects of the selected media on the flow and pressure, (2) the media tank size, and (3) the **multiport control valves**. This chapter is intended to introduce the important concepts and relationships which affect the flow and pressure of the product water for media-based water treatment systems.

In this chapter, four important topics will be addressed in the sizing of media-based systems: the important specifications of media tanks, the steps used in sizing the media tank, the effects of brining for water softener media systems, and the steps to estimate the total **pressure drop** for a media-based system.

The two standard terms used by manufacturers to qualify the flow rate of water through a water treatment system:

- **Continuous flow rate:** This generates a pressure drop of 15 psi. This flow rate will ensure that the system will perform at its specified function consistently over extended periods of time. This is the normal service flow expected by the manufacturer.
- **Peak flow rate:** This generates a pressure drop of 25 psi. This flow rate is the maximum flow rate that will still ensure adequate performance of the specified function of the system. It is intended by the manufacturer to be applied for only short periods.

1. Media tank specifications

The most important specification for a media tank is the diameter. It is essential in determining the effectiveness of the media inside and the projected pressure drop it will cause in the flow of water.

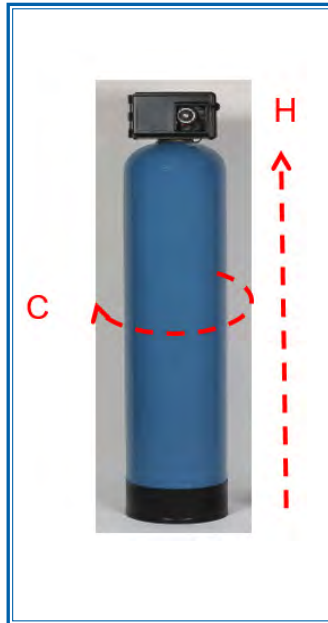
- a. How to determine the media tank diameter when unknown.

i. PROCEDURE

1. STEP ONE: Measure the tank circumference with a tape measure.
2. STEP TWO: Refer to Table VIII.4.1 and enter the measured circumference to determine the tank diameter.

ii. EXAMPLE

1. Media tank circumference = **32"**.
2. Tank diameter = **10"**
(Refer to Table VIII.4.1).



Outside Circumference (in.)	Tank Diameter (in.)
19	6
22	7
25	8
28	9
32	10
38	12
41	13
44	14
50	16
57	18
63	20
66	21
76	24
95	30
114	36

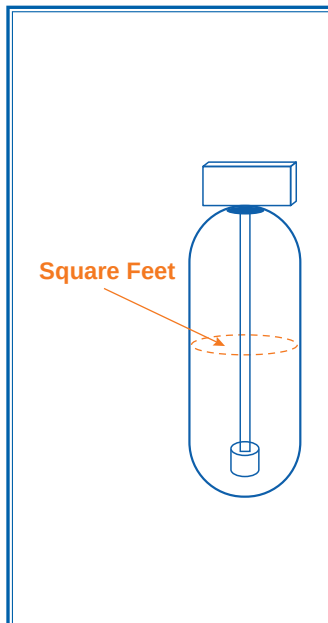
- b. How to determine the surface area of the media inside the media tank.

i. PROCEDURE

1. STEP ONE: Determine the tank diameter.
2. STEP TWO: Enter the tank diameter to determine the surface area of the media in the tank.
(Refer to Table VIII.4.2).

ii. EXAMPLE

1. Media tank diameter = **14"**.
2. **1.07 sq. ft.**



Tank Diameter (in.)	Inside (sq. ft.)
6	0.196
7	0.267
8	0.350
9	0.440
10	0.540
12	0.780
13	0.920
14	1.070
16	1.390
18	1.770
20	2.180
21	2.410
24	3.140
30	4.910
36	7.070

- c. How to determine the volume of media within a media tank. This procedure is helpful in determining the amount of neutralizer media which needs to be replaced within a neutralizer filter as noted in Book V, Chapter 4, Page 31.

i. PROCEDURE

1. STEP ONE: Using a straightedge in the neutralizer dome hole, measure the distance in inches which needs to be replaced.
2. STEP TWO: Enter the tank diameter to determine the media volume per inch of height. (Refer to Table VIII.4.3).
3. STEP THREE: Multiply the measured media replacement in inches from Step 1 by the media per volume from step 2.

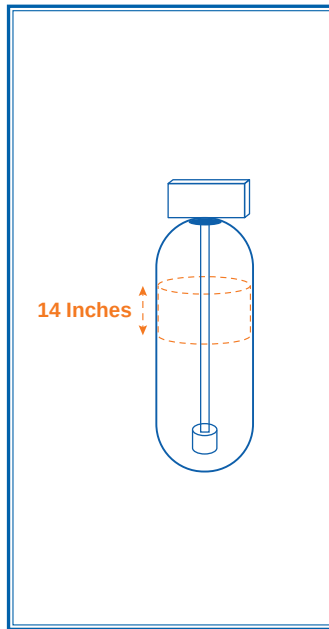


Table VIII.4.3	
Tank Diameter (in.)	Tank Volume per Inch
6	0.016
7	0.022
8	0.029
9	0.040
10	0.045
12	0.065
13	0.077
14	0.089
16	0.116
18	0.147
20	0.182
21	0.200
24	0.261
30	0.409
36	0.589

ii. EXAMPLE

1. Media tank diameter = 9".
2. By measurement with a straight edge, 14" of this media bed needs to be replaced.
3. Volume per inch for **9" tank = 0.04 cu. ft. per inch** (Refer to Table VIII.4.3).
4. Multiplying 14" by 0.04 cu. ft. per inch results in **0.56 cu. ft.** of media needs to be replaced.

2. Media tank sizing

As the result of water treatment analysis, two factors are determined: the type of media necessary to improve the condition of the feed water, and the service flow necessary to satisfy the water flow requirements of the application. These two factors can be used to determine the size of media tank necessary for the application.

a. Recommended media tank service flow

Media manufacturers recommend a range of service flows, a maximum and a minimum, for their media based upon the service water flow per square foot of the media bed. These service flows vary with different media types. As a rule, it is best to select a service flow rate midway within the manufacturer's range of service flows.

i. PROCEDURE

1. STEP ONE: Refer to the manufacturer's recommended service flow range for the media type or refer to the specific media in Table VIII.4.4.
2. STEP TWO: Identify the recommended service flow range for the required media type. Specify the service flow midway between the maximum and minimum service flows.
3. STEP THREE: Divide the service flow necessary for the application by the service flow specified in step two. The result is the number of square feet of media necessary for the treatment of the service flow.
4. STEP FOUR: Refer to Table VIII.4.2 (page 58) and identify the tank diameter which satisfies the required square feet of media bed. Always round up.

ii. EXAMPLE

1. The water analysis has determined that carbon filtration is required, and the required service flow is 7 gpm.
2. From Table VIII.4.4, adequate carbon filtration requires no more than 5 gpm/sq. ft. of media bed (midway between **3 and 8 gpm**).
3. A service flow of 7 gpm will therefore require **1.4 sq. ft. of media bed** (7 gpm/5 gpm per sq. ft.)
4. From Table VIII.4.2 (page 58), a **media tank of 18" diameter (1.77 sq. ft.)** will satisfy this water treatment requirement.

b. Selecting multiple media tanks

In many media tank applications, a single large media tank will not be appropriate due to either space limitations or to the resulting backwash flow requirements. In these cases, multiple media tanks installed in series will be a better solution.

i. PROCEDURE

1. STEP ONE: Divide the number of square feet of media determined in STEP THREE above by 2.
2. STEP TWO: Refer to Table VIII.4.2 (page 58) and identify the tank diameter which satisfies this new flow per sq. ft. This alternate solution will be two of these mineral tanks operating in parallel.

ii. EXAMPLE

1. Using the example from above, the service flow will require either one mineral tank with a media surface of **1.4 sq. ft.** or two mineral tanks, each with a surface area of **0.7 sq. ft.**
2. From Table VIII.4.2 (page 58), **two (2) media tanks of 12" diameter** will satisfy this water treatment requirement.

Media	Service Flow Range gpm / sq. ft.
Filter Sand	3 to 7
Multimedia	7 to 10
Calcite	3 to 6
Carbon	3 to 8
Birm	5 to 8
Pyrolox	5 to 8
Greensand	3 to 5
Resins:	
Softening	4 to 16
Nitrate	5 to 11
Dealkalize	5 to 11

Tank Diameter (in.)	Inside (sq. ft.)
6	0.196
7	0.267
8	0.350
9	0.440
10	0.540
12	0.780
13	0.920
14	1.070
16	1.390
18	1.770
20	2.180
21	2.410
24	3.140
30	4.910
36	7.070

Tank Diameter (in.)	Inside (sq. ft.)
6	0.196
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13	0.920
14	1.070
16	1.390
18	1.770
20	2.180
21	2.410
24	3.140
30	4.910
36	7.070

3. Water softener brining

The effects of various brining levels upon the softening capacity of water softeners are discussed in Book V, Chapter 4, Table V.4.1. Consequently, the selection of brining level for a water softener will determine the frequency of required regeneration. Typical brining levels range from 6 pounds to 20 pounds per cubic foot of resin. Higher brining levels result in higher softening capacity after each regeneration cycle.



a. BRINE VOLUME

How to determine the volume of brine necessary to achieve the desired softening capacity during the regeneration cycle.

i. **PROCEDURE**

1. STEP ONE: Determine the total volume of water softening resin inside the water softener tank.
2. STEP TWO: Enter the cu. ft. of resin and read across to the desired salting level. The result is the brine volume required to achieve the desired salting level (Refer to Table VIII.4.7).

ii. **EXAMPLE**

1. The water softener contains 1.5 cu. ft. of resin media.
2. The desired brining level is 10 lbs. of salt per cu. ft. of resin.
3. This will require **6 gal** of brine.

b. BRINE REFILL TIME

How to determine the "Brine Refill" time setting necessary to achieve the desired brine volume for the regeneration cycle.

i. **PROCEDURE**

1. STEP ONE: Determine the desired brine volume in gallons as in procedure 3a.
2. STEP TWO: Identify the brine refill flow control rating in gallons per minute.
3. STEP THREE: Divide the desired brine volume by the brine refill flow control rating. The result in minutes should be entered in the timer setting for brine refill.

ii. **EXAMPLE**

1. The desired brine volume for regeneration is 6 gal.
2. The brine refill flow control is 1.2 gpm.
3. The timer setting for "Brine Refill" should be 5 minutes ($6 \div 1.2 = 5$).

Table VIII.4.7						
Resin	Gallons of Brine required for Salting Levels					
(cu. ft.)	6 lbs.	8 lbs.	10 lbs.	12 lbs.	15 lbs.	20 lbs.
0.5	1.2	1.6	2	2.4	3	4
1	2.4	3.2	4	5	6	8
1.5	3	5	6	7.2	9	12
2	5	6.4	8	9.6	12	18
3	7.2	9.6	12	14.4	18	24
4	10	13	16	19	24	32
5	12	16	20	24	30	40
6	14	19	24	29	36	48
8	19	26	32	38	48	64
10	24	32	40	48	60	80
12	29	38	48	58	72	96
15	36	48	60	72	90	120
20	48	64	80	96	120	160
25	60	80	100	120	150	200
30	72	96	120	144	180	240
35	84	112	140	168	210	280
40	96	128	160	192	240	320
45	108	144	180	216	270	360
50	120	160	200	240	300	400

4. Water treatment system pressure drop

The total pressure drop caused by a media-based water treatment system consists in a combination of the individual pressure drops associated with the multiport valve, the media within the media tank, and the distributor system inside the tank. These components are described in Book V, Chapter 4. As the source water flows through each of these three components, a pressure drop is created by the resistance to the flow of water caused by the component.

a. Multiport valve pressure drop

Multiport valve manufacturers specify a flow coefficient (Cv) for each of their products based upon their flow testing. The Cv is defined as the flow rate for which there is a pressure drop of 1 psi in water flowing through the product. The Cv formula allows the calculation of the pressure drop for water flowing at different rates through the product.

Table VIII.4.8		
Valve Model	Valve Size In/Out	Cv
Valve A	1"	7.00
Valve B	1" MPT	6.80
Valve C	1"	5.00
Valve D	1"	3.99
Valve E	1"	6.50
Valve F	1.25"	8.80
Valve G	1.25"	7.10
Valve H	1.5"	18.10

i. PROCEDURE

1. STEP ONE: Find the manufacturer's flow coefficient (Cv) for the multiport valve.
2. STEP TWO: Use the flow coefficient formula to calculate the pressure drop for any flow rate through the valve.

ii. EXAMPLE

1. For Valve D, find the pressure drop at a flow rate of 12 gpm, which is 3.99 (Refer to Table VIII.4.7, page 61).
2. Use the Cv formula: $dP = [Q \div Cv]^2$
3. $dP = [12 \div 3.99]^2 = [3.00]^2 = 9.0$ psi
4. **The pressure drop will be 9 psi**

b. Determining the peak flow rate for a multiport valve

The Cv may also be used to calculate the peak (manufacturer's recommended maximum) flow rate for a multiport valve at a specified pressure drop. The pressure drop at the *peak flow rate* is specified as 25 psi.

i. PROCEDURE

1. STEP ONE: Find the manufacturer's Cv for the multiport valve.
2. STEP TWO: Use the modified flow coefficient formula to calculate the flow rate for a specified pressure drop.

ii. EXAMPLE

1. For Valve A, find the peak flow rate for a multiport valve (Refer to Table VIII.4.8).
2. Use the Cv modified formula: $Q = Cv[dP]^{1/2}$
3. Flow rate $Q = 7[25]^{1/2} = 7 [5] = 35$ gpm
4. **The peak flow rate for Valve A (at 25 psi pressure drop) will be 35 gpm**

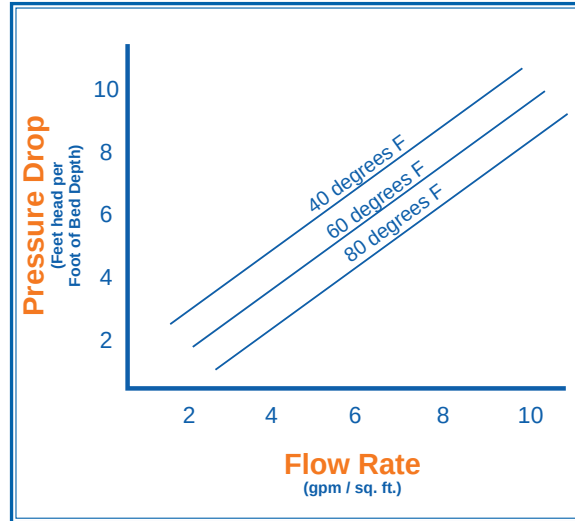
$dP = [Q \div Cv]^2$ $Q = Cv [dP]^{1/2}$			
dP	Pressure Drop (psi)	Cv	Flow Coefficient
Q	Flow Rate (gpm)	$\sqrt{2}$	Square Root
Flow Coefficient (Cv)			

c. Media tank pressure drop

Media manufacturers publish pressure drop charts for their products. These charts can be used to determine the pressure drop caused by the media bed at a specified flow rate.

i. **PROCEDURE**

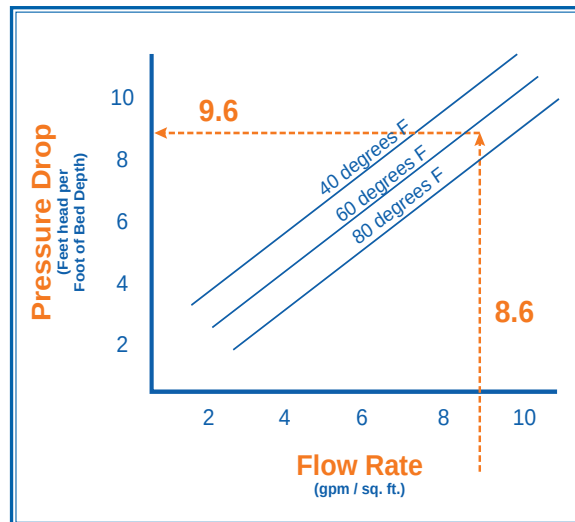
1. STEP ONE: Determine the media surface area for the tank and estimate the temperature of the service water that will be flowing through the media. Normally, this temperature will be about 60 degrees F.
2. STEP TWO: Calculate the flow rate per square foot of media surface area.
3. STEP THREE: Enter the manufacturer's media chart at the flow rate per square foot, read up to the 60-degree temperature line, and then across to the pressure drop. Note that this is the pressure drop in feet of head per foot of media bed depth. Most media beds are about three feet deep.
4. STEP FOUR: Calculate the media bed pressure drop by multiplying the pressure drop per foot by three.
5. STEP FIVE: Calculate the pressure drop for the media bed in psi by dividing the pressure drop in STEP FOUR by 2.31 psi/foot head.



Typical Media Pressure Drop Chart

ii. **EXAMPLE**

1. For media X, calculate the pressure drop for a 16" diameter media tank and a flow rate of 12 gpm.
2. From Table VIII.4.9 (page 64), the surface area for a **16" media tank is 1.39 sq. ft.**
3. The resulting media flow rate is 8.6 gpm per sq. ft. ($12 \text{ gpm} \div 1.39 \text{ sq. ft.}$)
4. From the manufacturer's chart for Media X, read up from 8.6 to the 60-degree temperature line, then across to the chart reading of **9.6 ft. of head per foot of media depth.**
5. Multiply this pressure drop by three to account for 3 ft. of media bed, for a media bed pressure drop of 28.8 ft. of head.
6. Divide the pressure drop in head by 2.31 psi/ft., to the result of 12.5 psi.
7. The pressure drop for a 16" media tank with Media X at a flow rate of 12 gpm will be **12.5 psi**



Media X Pressure Drop Chart

d. Distributor pressure drop

The pressure drop for tank distributors is typically extremely low relative to the valve and media bed. For small residential treatment systems with mineral tanks less than 14" in diameter, use an estimate of 1 psi for the distributor pressure drop. For water treatment systems media tanks 14" diameter and larger, distributor manufacturers provide simple pressure drop graphs, indicating flow with pressure drop. These charts are like Table VIII.4.9.

i. **PROCEDURE**

1. STEP ONE: For media tanks larger than 14" diameter, consult the manufacturer's pressure drop for the specific distributor.
2. STEP TWO: Read up from the flow rate to the curve, then across to read the pressure drop in psi.

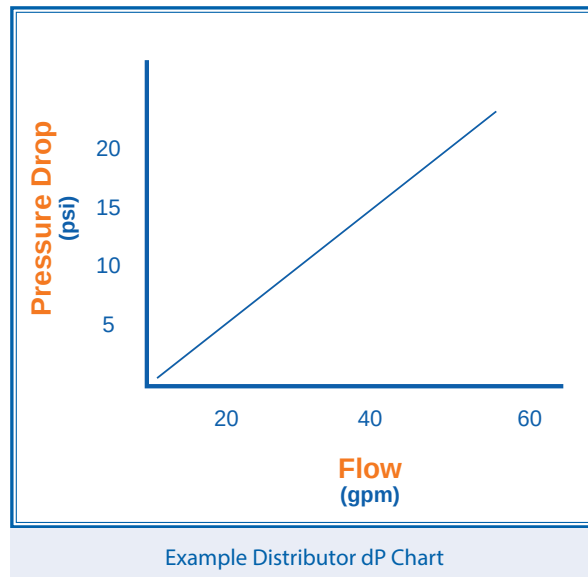
ii. **EXAMPLE**

1. For a hub and lateral type distributor on a 16" media tank, find the pressure drop caused by the distributor at a flow rate of 30 gpm.
2. Using the specification sheet for the specific 16" distributor, enter the chart at 35 gpm, read up to the pressure curve, then across to the pressure drop of 10 psi.
3. The pressure drop for the hub and lateral distributor on a **16" media tank at a flow rate of 35 gpm will be 5 psi.**

Tank Diameter (in.)	Inside (sq. ft.)
6	0.196
7	0.267
8	0.35
9	0.44
10	0.54
12	0.78
13	0.92
14	1.07
16	1.39
18	1.77
20	2.18
21	2.41
24	3.14
30	4.91
36	7.07

e. Total pressure drop for a media tank water treatment system

The total pressure drop for a complete media tank water treatment system is the numerical sum of the pressure drops caused by the multiport valve, plus the pressure drop caused by the media bed, plus the pressure drop caused by the distributor.



Water Treatment System Pressure Drop

Service Flow _____ gpm

1. Multiport Valve

Model _____ Cv _____

Pressure Drop dP = [Flow ÷ Cv]

Pressure Drop = [_____ ÷ _____] = _____ psi

2. Media

Tank Size _____ Media Surface Area _____ sq. ft.

Service Flow per sq. ft. = _____ gpm ÷ _____ sq. ft.

= _____ gpm/sq. ft.

Media _____

Chart Plot for _____ gpm/sq.ft.

= _____ ft. Head / Foot of Bed

Bed Depth (X 3) = _____ ft. Head

for psi (÷ 2.31 psi ÷ ft. Head) = _____ psi

3. Distributor

Model _____

Chart Plot for _____ gpm Service Flow = _____ psi

Total System Pressure Drop = _____ psi

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Tank Sizing

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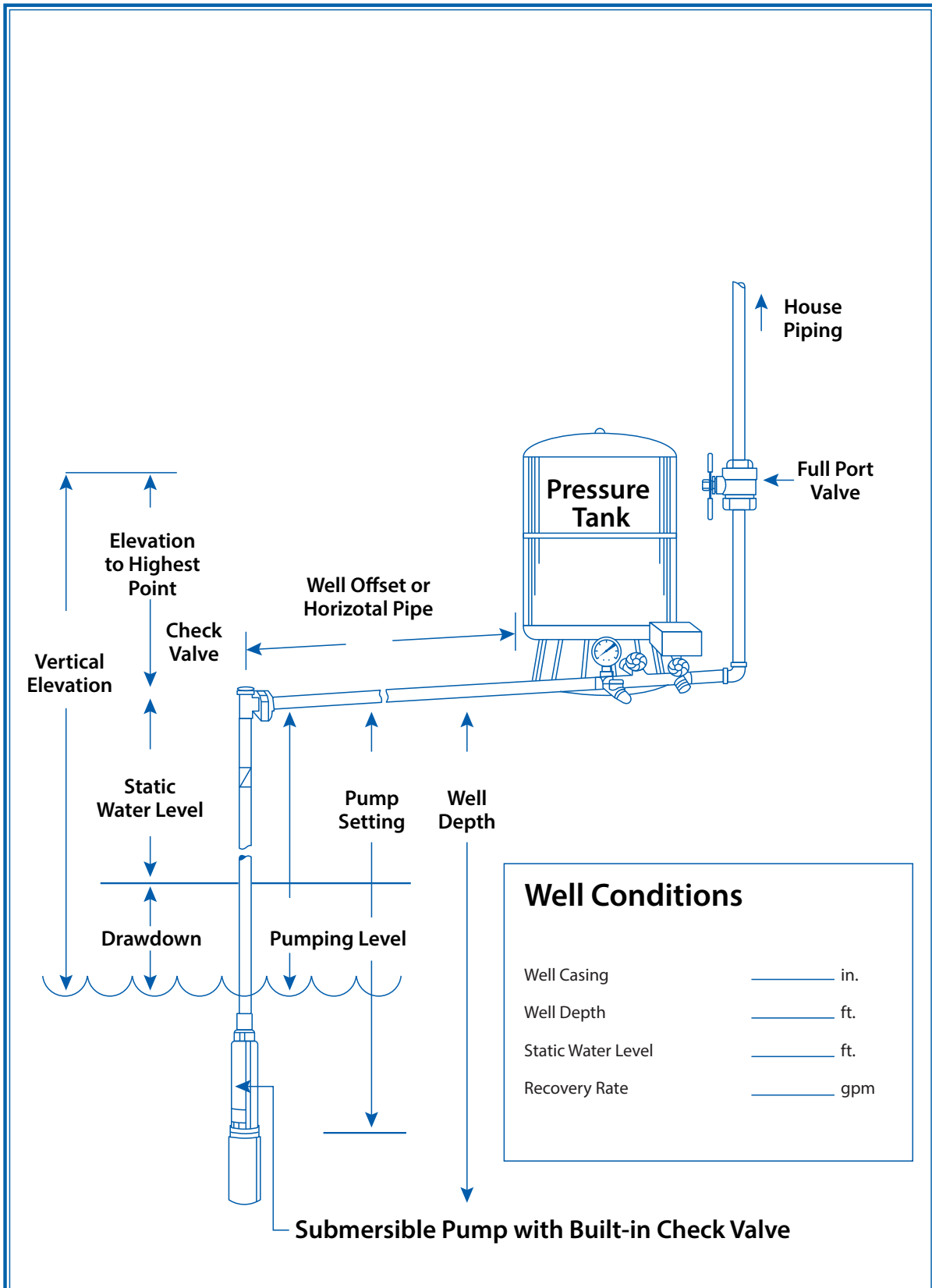
Metric Standards Table

When You Know		You Can Find		If You Multiply By
Length				
Inches	(in)	Millimeters	(mm)	25.400
Inches	(in)	Centimeters	(cm)	2.539
Feet	(ft)	Meters	(m)	0.305
Yards	(yd)	Meters	(m)	0.914
Miles (statute)	(mi)	Kilometers	(km)	1.609
Millimeters	(mm)	Inches	(in)	0.039
Meters	(m)	Feet	(ft)	3.281
Centimeters	(cm)	Inches	(in)	0.394
Meters	(m)	Yards	(yd)	1.094
Kilometers	(km)	Miles (statute)	(mi)	0.621
Area				
Square Inches	(in ²)	Square Centimeters	(cm ²)	6.452
Square Feet	(ft ²)	Square Meters	(m ²)	0.093
Square Yards	(yd ²)	Square Meters	(m ²)	0.836
Square Miles	(mi ²)	Square Kilometers	(km ²)	2.590
Acres	(ac)	Hectares	(ha)	0.405
Square Centimeters	(cm ²)	Square Inches	(in ²)	0.155
Square Meters	(m ²)	Square Feet	(ft ²)	10.764
Square Meters	(m ²)	Square Yards	(yd ²)	1.196
Square Kilometers	(km ²)	Square Miles	(mi ²)	0.386
Hectares	(ha)	Acres	(ac)	2.471
Liquid Volume				
Ounces	(oz)	Milliliters	(ml)	29.574
Pints	(pt)	Liters	(l)	0.473
Quarts	(qt)	Liters	(l)	0.946
Gallons	(gal)	Liters	(l)	3.785
Pounds per Cubic Foot	(lb/ft ³)	Kilograms per Cubic Meter	(kg/m ³)	16.018
Pounds per Gallon	(lb/gal)	Kilograms per Cubic Meter	(kg/m ³)	119.826
Milliliters	(ml)	Ounces	(oz)	0.034
Liters	(l)	Pints	(pt)	2.113
Liters	(l)	Quarts	(qt)	1.057
Liters	(l)	Gallons	(gal)	0.264
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Cubic Foot	(lb/ft ³)	0.062
Kilograms per Cubic Meter	(kg/m ³)	Pounds per Gallon	(lb/gal)	0.008
Mass				
Ounces	(oz)	Grams	(g)	28.350
Pounds	(lb)	Kilograms	(kg)	0.454
Grams	(g)	Ounces	(oz)	0.035
Kilograms	(kg)	Pounds	(lb)	2.205
Flow				
Cubic Meters per Hour	(m ³ /h)	Gallons per Minute	(gpm)	4.400
Gallons per Minute	(gpm)	Cubic Meters per Hour	(m ³ /h)	0.227

Metric Standards Table

When You Know		You Can Find		If You Multiply By
Force				
Foot Pound Force	(ft-lbf)	Joules	(J)	1.356
Newtons	(N)	Kilogram Force	(kgf)	0.102
Joules	(J)	Foot Pound Force	(ft-lbf)	0.738
Kilogram Force	(kgf)	Newtons	(N)	9.807
Power				
Horsepower	(hp)	Kilowatts	(kW)	0.746
Horsepower	(hp)	Watts	(W)	745.700
Kilowatts	(kW)	Horsepower	(hp)	1.341
Watts	(W)	Horsepower	(hp)	0.001
Pressure				
Bars	(b)	Pounds per Square Inch	(psi)	14.500
Kilograms per Square Centimeter	(kg/cm²)	Pounds per Square Inch	(psi)	14.500
Pounds per Square Inch	(lb/in²)	Kilograms per Square Meter	(kg/m²)	703.070
Pounds per Square Inch	(lb/in²)	Kilopascals	(kPa)	6.895
Pounds per Square Inch	(lb/in²)	Meters of Water	(m)	0.704
Inches of Mercury	(inHg)	Kilograms per Square Meter	(kg/m²)	345.300
Kilograms per Square Meter	(kg/m²)	Pounds per Square Inch	(lb/in²)	0.001
Kilopascal	(kPa)	Pounds per Square Inch	(lb/in²)	0.145
Meters of Water	(m)	Pounds per Square Inch	(lb/in²)	1.420
Kilograms per Square Meter	(kg/m²)	Inches of Mercury	(inHg)	0.003
1 Atmosphere	14.7 lb/in²	Kilograms per Square Centimeter	(kg/cm²)	1.033
1 Atmosphere	14.7 lb/in²	Kilograms per Square Meter	(kg/m²)	10,335.000
1 Atmosphere	14.7 lb/in²	Kilopascal	(kPa)	101.350
1 Atmosphere	14.7 lb/in²	76.0 Centimeters Mercury	(cmHg)	5.170
1 Atmosphere	29.92 inHg	76.0 Centimeters Mercury	(cmHg)	2.540
Pascal	(Pa)	Newtons per Square Meter	(N/m²)	1.000
Pascal	(Pa)	Kilograms per Square Meter	(kg/m²)	0.102
Temperature				
Degrees Fahrenheit	(°F)	Degrees Celsius	(°C)	(°F-32) 0.556
Degrees Celsius	(°C)	Degrees Fahrenheit	(°F)	(1.8 x °C) + 32
Flow				
Feet per Second	(fps)	Meters per Second	(m/s)	0.305
Miles per Hour	(mph)	Kilometers per Hour	(km/h)	1.609
Gallons per Minute	(gpm)	Liters per Minute	(l/min)	3.785
Gallons per Minute	(gpm)	Cubic Meters per Minute	(m³/min)	0.004
Meters per Second	(m/s)	Feet per Second	(fps)	3.281
Kilometers per Hour	(km/h)	Miles per Hour	(mph)	0.621
Liters per Minute	(l/m)	Gallons per Minute	(gpm)	0.264
Cubic Meters per Minute	(m³/min)	Gallons per Minute	(gpm)	264.172

Example #1 - Submersible Pump Diagram



Example #1 - Submersible Pump Worksheet**Step 1****FLOW CAPACITY NEEDED****Fixtures Method:**

Bathtub/Shower _____
 Toilet _____
 Lavatory _____
 Kitchen Sink _____
 Dishwasher _____
 Washing Machine _____
 Hose Bib _____
 Other _____
 (E.g., sprinklers, _____
 swimming pool) _____

Total Outlets

x 1 gpm = _____ gpm

Peak Demand Period¹:

No. of Outlets Being _____
 Used at Same Time _____
 x 3 gpm = _____ gpm

Bathrooms: x 4 gpm _____ gpm

Step 1**FLOW CAPACITY NEEDED****Tank Pressure Switch Setting:**

Cut-In _____ psi
 Cut-Out _____ psi
 (Check Max. Shut-Off psi from Bulletin)

Tank Precharge

Set @ 2 psi

Less Than Cut-In = _____ psi

Electrical:

____ Phase/ ____ Volt/ ____ Wire Motor

Step 2**CALCULATING DEPTH TO WATER****Calculating Friction Loss:**

____ (Check Valve equivalent) x ____ (Quantity) = _____ ft.
 Pitless Adapter/Side Out Tee (____) = _____ ft.
 ____ " Pipe (total length) = _____ ft.
 ____ Other = _____ ft.
 Total Pipe Length Equivalent = _____ ft.
 Divide by 100 ft.
 Number of 100 = _____ ft.
 x ____ (Friction loss per 100 ft. from chart)² = _____ ft.
 (Friction Loss)

Calculating Depth to Water:

Vertical Elevation (Example using elevation to highest point) = _____ ft.
 Friction Loss = _____ ft.
 Total Depth to Water = _____ ft.
 To calculate Total Dynamic Head add in Pressure
 (____) psi x 2.31 = _____ ft.
 TDH = _____ ft.
 psi = _____ ft.

Step 4**SELECTION**

Pump Model _____
 Wire Size _____
 Pressure Tank _____
 Relief Valve _____
 Motor _____
 Control Box (3-Wire) _____
 Magnetic Starter (3 Ø) _____
 Motor Protection Device _____

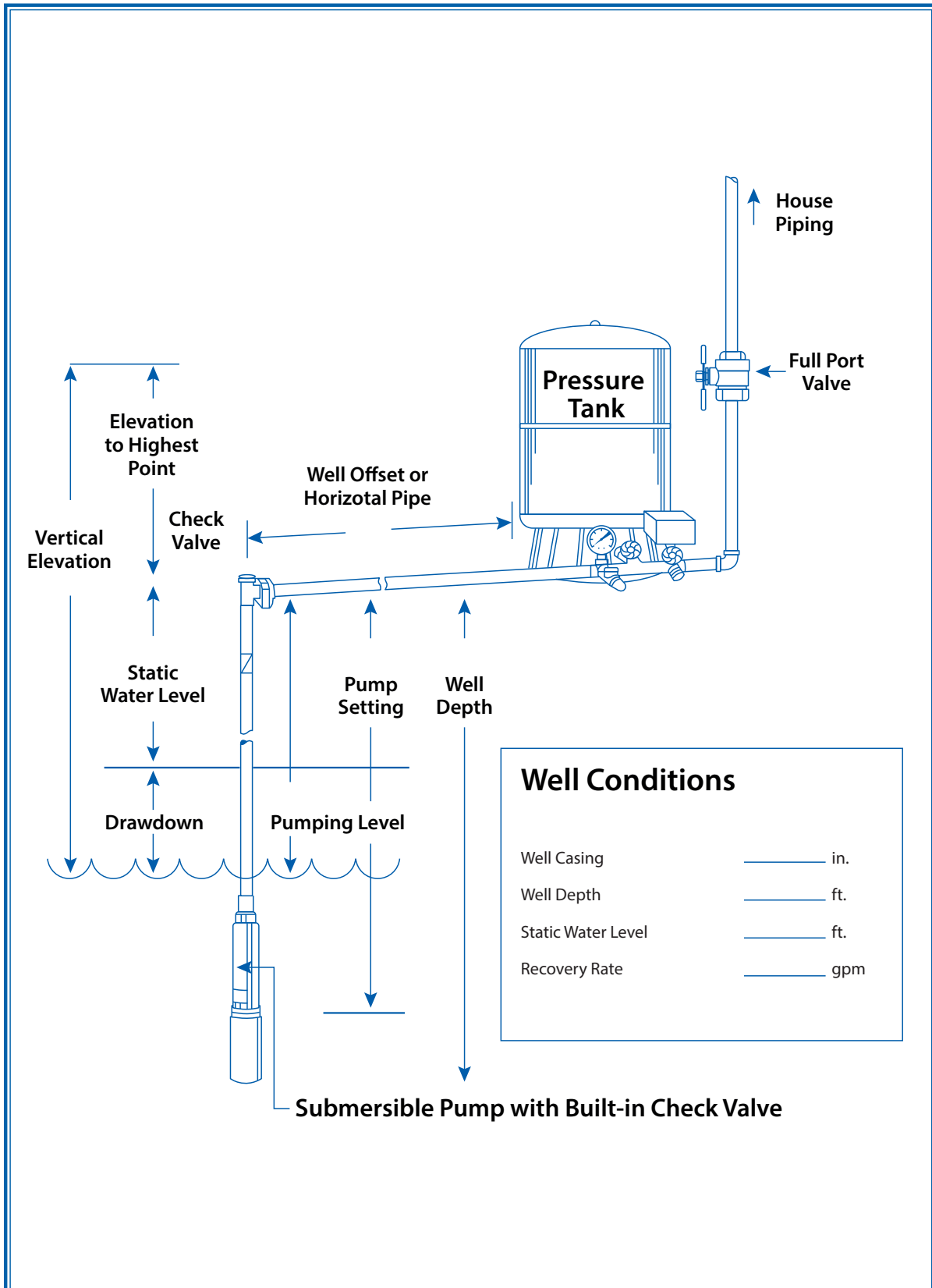
¹ The peak demand period is never a fixed time. It changes with the number of people and the number of bathrooms.

² It was approximated by extrapolating the values between 10 gpm (6.88') and 15 gpm (14.63') Reference the Appendix - Plastic Pipe Friction Loss Chart.

Use Table VIII.1.1 (page 10) to complete this worksheet.

See manufacturer's manual for pump curve. For example of pump curve, see page 26.

Example #2 - Submersible Pump Diagram



Example #2 - Submersible Pump Worksheet

Step 1

FLOW CAPACITY NEEDED

Fixtures Method:

Bathtub/Shower _____
 Toilet _____
 Lavatory _____
 Kitchen Sink _____
 Dishwasher _____
 Washing Machine _____
 Hose Bib _____
 Other _____
 (E.g., sprinklers, _____
 swimming pool) _____

Total Outlets

x 1 gpm = _____ gpm

Peak Demand Period¹:

No. of Outlets Being _____
 Used at Same Time _____

x 3 gpm = _____ gpm

Bathrooms: x 4 gpm _____ gpm

Step 1

FLOW CAPACITY NEEDED

Tank Pressure Switch Setting:

Cut-In _____ psi
 Cut-Out _____ psi

(Check Max. Shut-Off psi from Bulletin)

Tank Precharge

Set @ 2 psi

Less Than Cut-In = _____ psi

Electrical:

____ Phase/ ____ Volt/ ____ Wire Motor

Step 2

CALCULATING DEPTH TO WATER

Calculating Friction Loss:

____ (Check Valve equivalent) x ____ (Quantity) = _____ ft.
 Pitless Adapter/Side Out Tee (____) = _____ ft.
 ____ " Pipe (total length) = _____ ft.
 ____ Other = _____ ft.
 Total Pipe Length Equivalent = _____ ft.
 Divide by 100 ft.
 Number of 100 = _____ ft.
 x ____ (Friction loss per 100 ft. from chart)² = _____ ft.
 (Friction Loss)

Calculating Depth to Water:

Vertical Elevation (Example using elevation to highest point) = _____ ft.
 Friction Loss = _____ ft.
 Total Depth to Water = _____ ft.
 To calculate Total Dynamic Head add in Pressure
 (____) psi x 2.31 = _____ ft.
 TDH = _____ ft.
 psi = _____ ft.

Step 4

SELECTION

Pump Model _____
 Wire Size _____
 Pressure Tank _____
 Relief Valve _____
 Motor _____
 Control Box (3-Wire) _____
 Magnetic Starter (3 Ø) _____
 Motor Protection Device _____

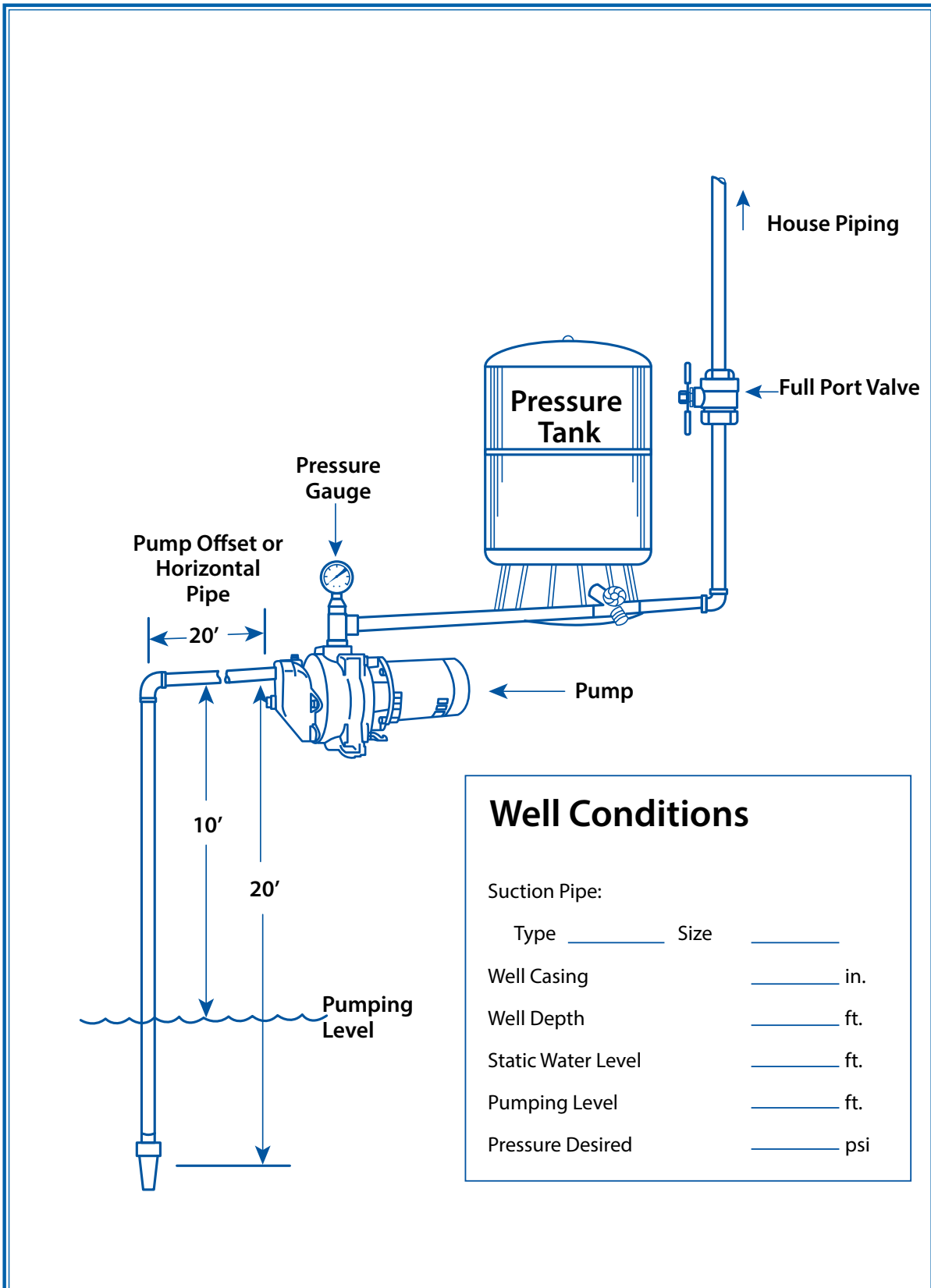
¹ The peak demand period is never a fixed time. It changes with the number of people and the number of bathrooms.

² It was approximated by extrapolating the values between 10 gpm (6.88') and 15 gpm (14.63') Reference the Appendix - Plastic Pipe Friction Loss Chart.

Use Table VIII.1.1 (page 10) to complete this worksheet.

See manufacturer's manual for pump curve. For example of pump curve, see page 29.

Example #3 - Shallow Well Jet Pump Diagram



Example #3 - Shallow Well Jet Pump Worksheet

Step 1

CAPACITY NEEDED

Fixtures Method:

Bathtub/Shower _____
 Toilet _____
 Lavatory _____
 Kitchen Sink _____
 Dishwasher _____
 Washing Machine _____
 Hose Bib _____
 Other _____

Total Outlets

x 1 gpm = _____ gpm

Peak Demand:

No. of Outlets Being
 Used at Same Time _____
 x 3 gpm = _____ gpm

Step 2

SUCTION CONDITIONS

Friction Loss Calculator:

1 90° Elbow = _____ ft.
 1 Foot Valve = _____ ft.
 Pipe = _____ ft.
 Total = _____ ft.

_____ Numbers of hundreds of feet
 x _____ Friction loss / 100 ft. of pipe
 = _____ Ft. (Friction Loss)

Vertical Lift = _____ ft.
 + Friction Loss (rounded up) = _____ ft.
 Total Lift = _____ ft.
 (Max. 25 Ft.)

Step 3

PRESSURE NEEDED

Tank Pressure Switch Setting:

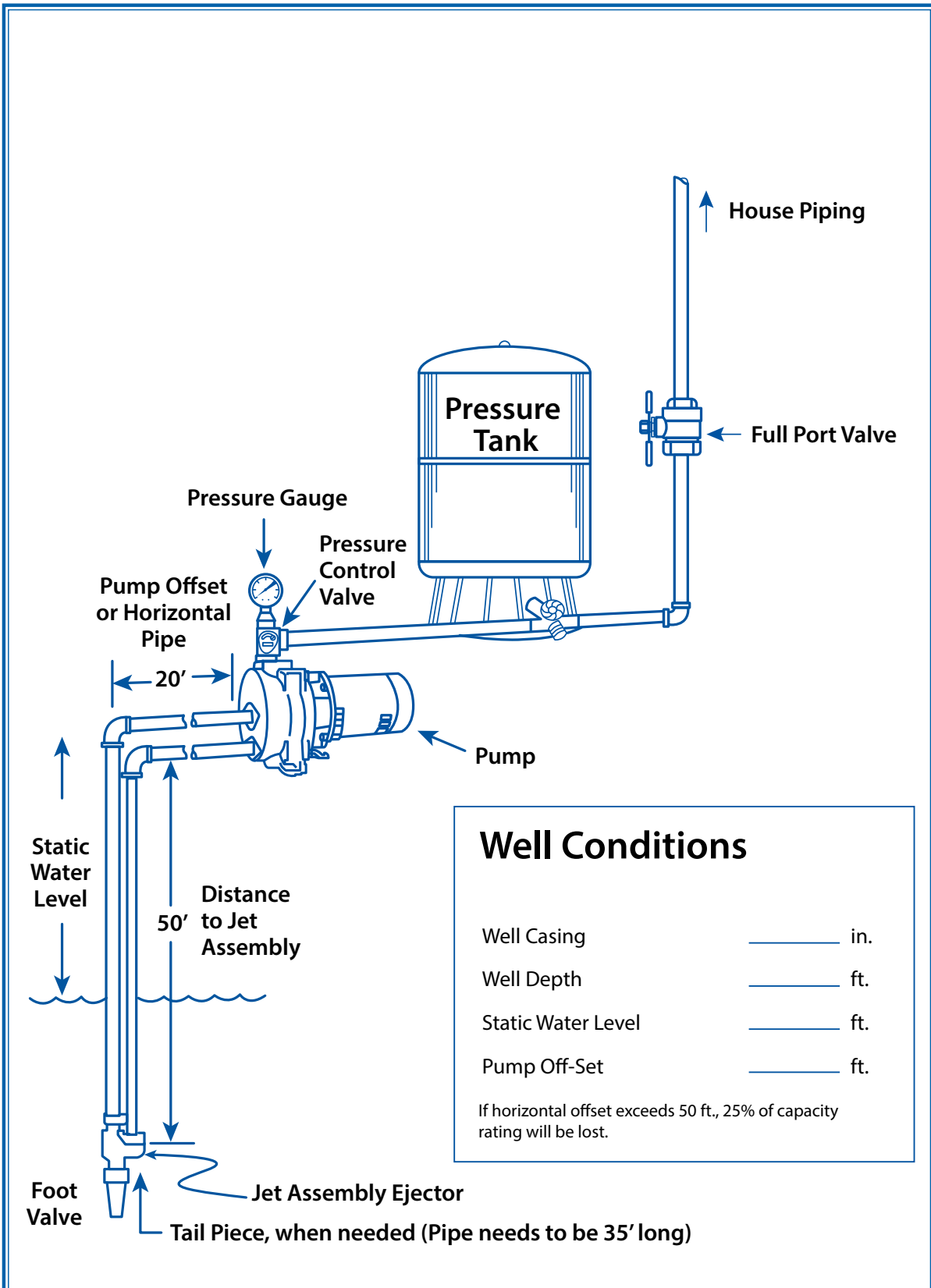
Cut-On _____ psi
 Cut-Off _____ psi

Step 4

SELECTION

Pump Model _____

Example #4 - Deep Well Twin-Pipe Jet Pump Diagram



Example #4 - Deep Well Twin-Pipe Jet Pump Worksheet

Step 1

FLOW CAPACITY NEEDED Fixtures Method:

Bathtub/Shower _____
 Toilet _____
 Lavatory _____
 Kitchen Sink _____
 Dishwasher _____
 Washing Machine _____
 Hose Bib _____
 Other _____
 (e.g., sprinklers,
 swimming pool) _____

Total Outlets

x 1 gpm = _____ gpm

Peak Demand Period¹:

No. of Outlets Being
 Used at Same Time _____
 x 3 gpm = _____ gpm
 Bathrooms _____
 x 4 gpm = _____ gpm

Step 2

Jet Assembly Setting _____ ft.
 (See Diagram)

Step 3

PRESSURE NEEDED

Tank Pressure Switch Setting:

Cut-In _____ psi
 Cut-Out _____ psi
 Tank Precharge
 Set @ 2 psi
 Less Than Cut-In = _____ psi

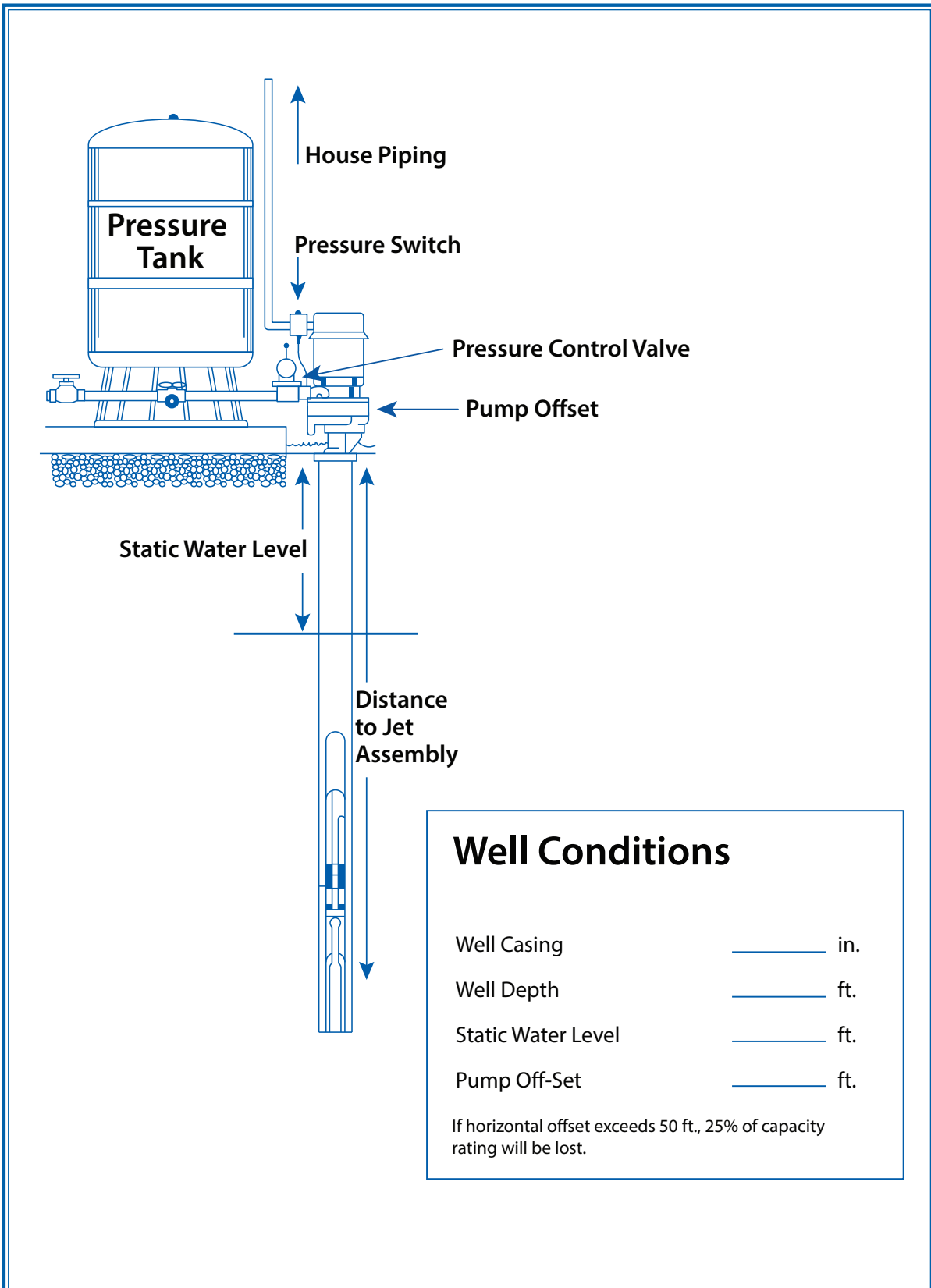
Step 4

SELECTION

Pump Model _____
 Jet Assembly _____
 Pressure-Control Valve _____
 PCV Setting (psi) _____
 Pressure Tank _____
 Alternate Pump _____

¹ Note that the peak demand period is never a fixed time. It changes with the number of people and the number of bathrooms.

Example #5 -Deep Well Packer-System Jet Pump Diagram



Example #5 -Deep Well Packer-System Jet Pump Worksheet

Step 1

FLOW CAPACITY NEEDED Fixtures Method:

Bathtub/Shower _____
 Toilet _____
 Lavatory _____
 Kitchen Sink _____
 Dishwasher _____
 Washing Machine _____
 Hose Bib _____
 Other _____
 (e.g., sprinklers,
 swimming pool) _____

Total Outlets

x 1 gpm = _____ gpm

Peak Demand Period¹:

No. of Outlets Being
 Used at Same Time _____
 x 3 gpm = _____ gpm
 Bathrooms _____
 x 4 gpm = _____ gpm

Step 2

Jet Assembly Setting _____ ft.
 (See Diagram)

Step 3

PRESSURE NEEDED

Tank Pressure Switch Setting:

Cut-In _____ psi
 Cut-Out _____ psi
 Tank Precharge
 Set @ 2 psi
 Less Than Cut-In = _____ psi

Step 4

SELECTION

Pump Model _____
 Jet Assembly _____
 Pressure-Control Valve _____
 PCV Setting (psi) _____
 Pressure Tank _____
 Alternate Pump _____

¹ Note that the peak demand period is never a fixed time. It changes with the number of people and the number of bathrooms.

Sample Steel Pipe Friction Loss

STEEL PIPE: FRICTION LOSS (IN100 FEET OF HEAD) PER 100 ft. Schedule 40 Galvanized															
gpm	gph	3/8"	1/2"	3/4"	1"	1¼"	1½"	2"	2½"	3"	4"	5"	6"	8"	10"
		ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
1	60	4.30	1.86	0.26	-	-	-	-	-	-	-	-	-	-	-
2	120	15.00	4.78	1.21	0.38	-	-	-	-	-	-	-	-	-	-
3	180	31.80	10.00	2.50	0.77	-	-	-	-	-	-	-	-	-	-
4	240	54.90	17.10	4.21	1.30	0.34	-	-	-	-	-	-	-	-	-
5	300	83.50	25.80	6.32	1.93	0.51	0.24	-	-	-	-	-	-	-	-
6	360	-	36.50	8.87	2.68	0.70	0.33	0.10	-	-	-	-	-	-	-
7	420	-	48.70	11.80	3.56	0.93	0.44	0.13	-	-	-	-	-	-	-
8	480	-	62.70	15.00	4.54	1.18	0.56	0.17	-	-	-	-	-	-	-
9	540	-	-	18.80	5.65	1.46	0.69	0.21	-	-	-	-	-	-	-
10	600	-	-	23.00	6.86	1.77	0.83	0.25	0.11	0.04	-	-	-	-	-
12	720	-	-	32.60	9.62	2.48	1.16	0.34	0.15	0.05	-	-	-	-	-
15	900	-	-	49.70	14.70	3.74	1.75	0.52	0.22	0.08	-	-	-	-	-
20	1,200	-	-	86.10	25.10	6.34	2.94	0.87	0.36	0.13	-	-	-	-	-
25	1,500	-	-	-	38.60	9.65	4.48	1.30	0.54	0.19	-	-	-	-	-
30	1,800	-	-	-	54.60	13.60	6.26	1.82	0.75	0.26	-	-	-	-	-
35	2,100	-	-	-	73.40	18.20	8.37	4.42	1.00	0.35	-	-	-	-	-
40	2,400	-	-	-	95.00	23.50	10.79	3.10	1.28	0.44	-	-	-	-	-
45	2,700	-	-	-	-	30.70	13.45	3.85	1.60	0.55	-	-	-	-	-
70	4,200	-	-	-	-	68.80	31.30	8.86	3.63	1.22	0.35	-	-	-	-
100	6,000	-	-	-	-	-	62.20	17.40	7.11	2.39	0.63	-	-	-	-
150	9,000	-	-	-	-	-	-	38.00	15.40	5.14	1.32	-	-	-	-
200	12,000	-	-	-	-	-	-	66.30	26.70	8.90	2.27	0.74	0.30	0.08	-
250	15,000	-	-	-	-	-	-	-	42.80	14.10	3.60	1.20	0.49	0.13	-
300	18,000	-	-	-	-	-	-	-	58.50	19.20	4.89	1.58	0.64	0.15	0.05
350	21,000	-	-	-	-	-	-	-	79.20	26.90	6.72	2.18	0.88	0.23	0.07
400	24,000	-	-	-	-	-	-	-	103.00	33.90	8.47	2.72	1.09	0.28	0.09
450	27,000	-	-	-	-	-	-	-	130.00	42.75	10.65	3.47	1.36	0.35	0.11
500	30,000	-	-	-	-	-	-	-	160.00	52.50	13.00	4.16	1.66	0.42	0.14
550	33,000	-	-	-	-	-	-	-	193.00	63.20	15.70	4.98	1.99	0.51	0.16
600	36,000	-	-	-	-	-	-	-	230.00	74.80	18.60	5.88	2.34	0.60	0.19
650	39,000	-	-	-	-	-	-	-	-	87.50	21.70	6.87	2.73	0.69	0.22
700	42,000	-	-	-	-	-	-	-	-	101.00	25.00	7.93	3.13	0.80	0.26
750	45,000	-	-	-	-	-	-	-	-	116.00	28.60	9.05	3.57	0.91	0.29
800	48,000	-	-	-	-	-	-	-	-	131.00	32.40	10.22	4.03	1.02	0.33
850	51,000	-	-	-	-	-	-	-	-	148.00	36.50	11.50	4.53	1.15	0.37
900	54,000	-	-	-	-	-	-	-	-	165.00	40.80	12.90	5.05	1.27	0.41
950	57,000	-	-	-	-	-	-	-	-	184.00	45.30	14.30	5.60	1.41	0.46
1000	60,000	-	-	-	-	-	-	-	-	204.00	50.20	15.80	6.17	1.56	0.50

Sample Plastic Pipe Friction Loss

PLASTIC PIPE: FRICTION LOSS (IN FEET OF HEAD) PER 100 ft.														
gpm	gph	3/8"	1/2"	3/4"	1"	1¼"	1½"	2"	2½"	3"	4"	6"	8"	10"
		ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
1	60	4.25	1.38	0.36	0.11	-	-	-	-	-	-	-	-	-
2	120	15.13	4.83	1.21	0.38	0.10	-	-	-	-	-	-	-	-
3	180	31.97	9.96	2.51	0.77	0.21	0.10	-	-	-	-	-	-	-
4	240	54.97	17.07	4.21	1.30	0.35	0.16	-	-	-	-	-	-	-
5	300	84.41	25.76	6.33	1.92	0.51	0.24	-	-	-	-	-	-	-
6	360	-	26.34	8.83	2.69	0.71	0.33	0.10	-	-	-	-	-	-
8	480	-	63.71	15.18	4.58	1.19	0.55	0.17	-	-	-	-	-	-
10	600	-	97.52	25.98	6.88	1.78	0.83	0.25	0.11	-	-	-	-	-
15	900	-	-	49.68	14.63	3.75	1.74	0.52	0.22	-	-	-	-	-
20	1,200	-	-	86.94	25.07	6.39	2.94	0.86	0.36	0.13	-	-	-	-
25	1,500	-	-	-	38.41	9.71	4.44	1.29	0.54	0.19	-	-	-	-
30	1,800	-	-	-	-	13.62	6.26	1.81	0.75	0.26	-	-	-	-
35	2,100	-	-	-	-	18.17	8.37	2.42	1.00	0.35	0.09	-	-	-
40	2,400	-	-	-	-	23.55	10.70	3.11	1.28	0.44	0.12	-	-	-
45	2,700	-	-	-	-	29.44	13.46	3.84	1.54	0.55	0.15	-	-	-
50	3,000	-	-	-	-	-	16.45	4.67	1.93	0.66	0.17	-	-	-
60	3,600	-	-	-	-	-	23.48	6.60	2.71	0.93	0.25	-	-	-
70	4,200	-	-	-	-	-	-	8.83	3.66	1.24	0.33	-	-	-
80	4,800	-	-	-	-	-	-	11.43	4.67	1.58	0.41	-	-	-
90	5,400	-	-	-	-	-	-	14.26	5.82	1.98	0.52	-	-	-
100	6,000	-	-	-	-	-	-	-	7.11	2.42	0.63	0.08	-	-
125	7,500	-	-	-	-	-	-	-	10.83	3.80	0.95	0.13	-	-
150	9,000	-	-	-	-	-	-	-	-	5.15	1.33	0.18	-	-
175	10,500	-	-	-	-	-	-	-	-	6.90	1.78	0.23	-	-
200	12,000	-	-	-	-	-	-	-	-	8.90	2.27	0.30	-	-
250	15,000	-	-	-	-	-	-	-	-	-	3.36	0.45	0.12	-
300	18,000	-	-	-	-	-	-	-	-	-	4.85	0.63	0.17	-
350	21,000	-	-	-	-	-	-	-	-	-	6.53	0.84	0.22	-
400	24,000	-	-	-	-	-	-	-	-	-	-	1.08	0.28	-
500	30,000	-	-	-	-	-	-	-	-	-	-	1.66	0.42	0.14
550	33,000	-	-	-	-	-	-	-	-	-	-	1.98	0.50	0.16
600	36,000	-	-	-	-	-	-	-	-	-	-	2.35	0.59	0.19
700	42,000	-	-	-	-	-	-	-	-	-	-	-	0.79	0.26
800	48,000	-	-	-	-	-	-	-	-	-	-	-	1.02	0.33
900	54,000	-	-	-	-	-	-	-	-	-	-	-	1.27	0.41
950	57,000	-	-	-	-	-	-	-	-	-	-	-	-	0.46
1000	60,000	-	-	-	-	-	-	-	-	-	-	-	-	0.50

Sample Copper Pipe Friction Loss

COPPER PIPE: FRICTION LOSS (IN FEET OF HEAD) PER 100 ft.											
gpm	gph	3/8"	1/2"	3/4"	1"	1¼"	1½"	2"	2½"	3"	4"
		ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
1	60	6.20	1.80	0.39	-	-	-	-	-	-	-
2	120	19.60	6.00	1.20	-	-	-	-	-	-	-
5	300	-	30.00	5.80	1.60	-	-	-	-	-	-
7	420	-	53.00	11.00	3.20	2.20	-	-	-	-	-
10	600	-	-	19.60	5.30	3.90	-	-	-	-	-
15	900	-	-	37.00	9.90	6.20	2.10	-	-	-	-
18	1080	-	-	55.40	16.10	6.90	3.20	-	-	-	-
20	1200	-	-	-	18.50	10.40	3.90	-	-	-	-
25	1500	-	-	-	27.70	14.30	5.30	1.50	-	-	-
30	1,800	-	-	-	39.30	18.70	7.60	2.10	-	-	-
35	2,100	-	-	-	48.50	25.40	10.20	2.80	-	-	-
40	2,400	-	-	-	-	30.00	13.20	3.50	1.20	-	-
45	2,700	-	-	-	-	39.30	16.20	4.20	1.60	-	-
50	3,000	-	-	-	-	-	19.40	5.10	1.80	-	-
60	3,600	-	-	-	-	-	27.70	6.90	2.50	1.10	-
70	4,200	-	-	-	-	-	40.00	9.20	3.50	1.40	-
75	4,500	-	-	-	-	-	41.60	9.90	3.70	1.60	-
80	4,800	-	-	-	-	-	45.00	11.60	4.20	1.80	-
90	5,400	-	-	-	-	-	50.80	13.90	4.80	2.20	-
100	6,000	-	-	-	-	-	-	16.90	6.20	2.80	-
125	7,500	-	-	-	-	-	-	25.40	8.60	3.70	-
150	9,000	-	-	-	-	-	-	32.30	11.60	4.80	1.20
175	10,500	-	-	-	-	-	-	41.60	16.20	6.90	1.70
200	12,000	-	-	-	-	-	-	57.80	20.80	9.00	2.20
250	15,000	-	-	-	-	-	-	-	32.30	13.90	3.50
300	18,000	-	-	-	-	-	-	-	41.60	18.50	4.60
350	21,000	-	-	-	-	-	-	-	-	32.30	5.80
400	24,000	-	-	-	-	-	-	-	-	39.30	7.20
450	27,000	-	-	-	-	-	-	-	-	44.00	9.20
500	30,000	-	-	-	-	-	-	-	-	-	11.10
750	45,000	-	-	-	-	-	-	-	-	-	23.10
1000	60,000	-	-	-	-	-	-	-	-	-	37.00

Sample Conversion Chart: Fittings to Equivalent Length of Pipe

EQUIVALENT NUMBER OF FEET STRAIGHT PIPE FOR DIFFERENT FITTINGS													
Size of fittings, inches	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	5"	6"	8"	10"
90° Ell	1.5	2.0	2.7	3.5	4.3	5.5	6.5	8.0	10.0	14.0	15	20	25
45° Ell	0.8	1.0	1.3	1.7	2.0	2.5	3.0	3.8	5.0	6.3	7.1	9.4	12
Long Sweep Ell	1.0	1.4	1.7	2.3	2.7	3.5	4.2	5.2	7.0	9.0	11.0	14.0	-
Close Return Bend	3.6	5.0	6.0	8.3	10.0	13.0	15.0	18.0	24.0	31.0	37.0	39.0	-
Tee-Straight Run	1	2	2	3	3	4	5	-	-	-	-	-	-
Tee-Side Inlet or Outlet or Pitless Adpter	3.3	4.5	5.7	7.6	9.0	12.0	14.0	17.0	22.0	27.0	31.0	40.0	-
Ball or Globe Valve Open	17.0	22.0	27.0	36.0	43.0	55.0	67.0	82.0	110.0	140.0	160.0	220.0	-
Angle Valve Open	8.4	12.0	15.0	18.0	22.0	28.0	33.0	42.0	58.0	70.0	83.0	110.0	-
Gate Valve-Fully Open	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.7	2.3	2.9	3.5	4.5	-
Check Valve (Swing)	4	5	7	9	11	13	16	20	26	33	39	52	65
In Line Check Valve (Spring) or Foot Valve	4	6	8	12	14	19	23	32	43	58	-	-	-

Example

Step 1:

100 ft. of 2-inch plastic pipe with one (1) 90° elbow and one (1) swing check valve

90° elbow — equivalent to 5.5 ft. of straight pipe

Swing check — equivalent to 13.0 ft. of straight pipe

100 ft. of pipe — equivalent to 100.0 ft. of straight pipe
 118.5 ft. = Total equivalent pipe

Figure friction loss for 118.5 ft. of pipe.

Step 2:

Assume flow to be 80 gpm through 2-inch plastic pipe.

- Friction loss table shows 11.43 ft. loss per 100 ft. of pipe
- In step (1) above we have determined total ft. of pipe to be 118.5 ft.
- Convert 118.5 ft. to percentage $118.5 \div 100 = 1.185$
- Multiply

11.43	
x 1.185	
13.54455	or 13.5 ft. = Total friction loss in this system

Sample Selection Chart: Shallow Well Jet Pump

Shallow Well Performance Ratings																				
Horsepower (hp)	½					¾					1					1½				
Total Suction Lift (feet)	Discharge Pressure — psi					Discharge Pressure — psi					Discharge Pressure — psi					Discharge Pressure — psi				
	20	30	40	50	Max. Shut off (psi)	30	40	50	60	Max. Shut off (psi)	30	40	50	60	Max. Shut off (psi)	30	40	50	60	Max. Shut off (psi)
	Gallons per minute					Gallons per minute					Gallons per minute					Gallons per minute				
5	17.5	16.5	10.2	5.0	63	21.3	18.3	12.5	6.6	70	24.8	24.4	16.6	9.9	74	26.6	26.3	25.0	15.6	80
10	15.7	14.4	9.2	4.3	61	18.8	17.3	11.3	5.0	68	22.9	22.2	15.8	8.6	72	24.7	24.3	22.6	13.9	77
15	13.7	12.5	8.0	3.6	59	16.4	15.5	9.6	3.7	66	19.8	19.5	13.8	6.9	70	21.6	21.5	20.4	12.9	75
20	11.5	10.4	7.1	2.3	57	13.6	13.2	8.3	2.0	63	16.6	16.6	12.2	5.6	67	18.1	18.0	17.6	12.0	73
25	8.7	8.6	6.2	1.3	54	10.0	9.9	6.4	1.0	59	12.5	12.4	10.4	3.6	65	14.0	14.0	14.0	10.1	71

Sample Selection Chart: Deep Well Twin-Pipe Jet Pump System

Twin-Pipe or Two-Pipe Performance Ratings																	
Horsepower (hp)		½				¾				1				1 ½			
Well Casing Minimum Inside Diameter		4		4½		4		4½		4		4½		4½			
Pressure	Pipe Size (in.)	1		1¼		1		1¼		1		1¼		1¼			
Suction		1¼		1½		1¼		1½		1¼		1½		1½			
	Feet	Gallons Per Minute (gpm) 30-50 psi Pressure Switch Setting															
Depth to Jet Assembly (based on submergence of 5 feet)	30	13.0	11.0			15.8			16.6		17.0		19.3		21.2		
	40	11.8	9.0			15.7			16.0		16.6		18.0		20.0		
	50		7.6		6.9	13.2			15.0		14.4		16.0		16.1		
	60		7.0	5.2	6.4	10.2			13.0		11.5	11.2	14.3		15.0		
	70			4.7	5.6		8.2		11.0	10.0		9.3		12.6		14.0	11.2
	80			3.8	4.8		6.5			8.6		7.3	6.2	10.0	10.0		10.6
	90			3.1	4.1		3.5			7.3			6.1		8.7		9.0
	100									6.0			5.4		7.0		7.6
	110									5.0			4.5		5.7		6.2
	120													4.5		5.2	
	130															4.0	
	140															2.8	
	150															1.5	
	160																
	170																

NOTE: The user should reference the manufacturer's product literature.

Sample Selection Chart: Deep Well Jet Pump Packer System

Packer System Performance Ratings																		
Horsepower (hp)		½ hp				¾ hp				1 hp				1 ½ hp				
Well Casing		2		3		2		3		2		3		3				
Suction Pipe Size (in.)		1¼		1½		1¼		1½		1¼		1½		1½				
Control valve Setting (psi)		30	30	30	30	30	32	27	30	35	36	28	32	34	34	34	34	39
Feet		Gallons Per Minute (gpm) 30-50 psi Pressure Switch Setting																
Depth to Jet Assembly (based on submergence of 5 feet)	30	11.9	9.5		13.1		13.8		16.8		16.7		19.3		24.4			
	40	10.6	7.9		12.6		13.5		16.8		14.6		19.3		23.1			
	50		7.6		10.7	6.9	11.5		15.3		13.5		18.0		20.2			
	60		6.7	4.8	8.8	6.5	9.0	7.8	13.5		11.0	9.2	15.3		16.9	15.0		
	70			4.3	7.3	5.6		7.1	11.5	9.8		9.0	12.7			14.4		
	80			3.5		4.8		5.1		8.6		7.3	10.2	10.3		12.9		
	90							4.3		7.3		5.6		8.8		10.9	10.3	
	100									6.2		4.2		7.2			9.6	7.3
	110									5.0				5.8			8.2	6.5
	120													4.5			6.9	5.8
	130																5.8	5.0
	140																4.7	4.5
	150																3.4	4.0
	160																	3.3
	170																	2.8

Sample Submersible Pump Selection Chart

Horsepower Range ½ - 3, Recommended Range 3 -16 gpm, 60 Hz, 3450 RPM																														
Pump Model	hp	psi	Depth to Water in Feet/Ratings in gpm (Gallons per Minute)																											
			20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	340	380	420	460	500	540	580	620	660	700	740	780	820
	½	0			15.6	14.0	12.4	10.4	6.5																					
		20	15.4	13.5	11.5	9.2	6.0																							
		30	13.0	11.1	8.0	4.0																								
		40	11.0	7.9	3.0																									
		50	7.0																											
		60																												
Shut-off psi			61	53	44	34	26	18	10																					
	½	0				16.0	15.3	14.3	12.8	11.3	9.0	6.4																		
		20		15.9	14.9	13.8	12.5	10.8	8.3	4.8																				
		30	15.7	14.6	13.5	12.3	10.5	7.8	4.0																					
		40	14.5	13.4	12.0	10.3	7.5	3.0																						
		50	13.0	11.5	9.8	7.2																								
		60	11.3	9.0	6.4																									
Shut-off psi			89	81	72	63	55	46	37	29	20	11																		
	¾	0						16.0	15.2	14.3	13.4	12.5	11.5	10.3	9.0	7.0	4.0													
		20				15.8	15.0	14.0	13.0	12.3	11.2	10.2	8.5	6.0																
		30			15.7	14.8	13.9	12.8	12.0	11.0	9.8	8.2	5.5																	
		40		15.6	14.7	13.8	12.7	11.9	10.8	9.7	8.1	5.2																		
		50	15.3	14.4	13.5	12.6	11.6	10.5	9.4	7.5	4.8																			
		60	14.3	13.4	12.5	11.5	10.3	9.0	7.0	4.0																				
Shut-off psi			130	121	113	104	95	87	78	69	61	52	43	35	26	17	9													
	1	0								15.8	15.2	14.5	13.7	12.8	12.0	11.0	10.0	6.7												
		20						15.7	14.9	14.3	13.5	12.7	11.7	10.6	9.6	8.1	6.5													
		30				16.0	15.6	14.8	14.2	13.3	12.5	11.6	10.4	9.4	7.8	5.5	3.0													
		40			16.0	15.5	14.7	14.1	13.2	12.4	11.5	10.3	9.1	7.4	5.0	3.0														
		50			15.3	14.6	13.9	13.0	12.3	11.3	10.1	8.9	7.0	4.3																
		60	15.8	15.2	14.5	13.7	12.8	12.0	11.0	10.0	8.6	6.7	4.0																	
Shut-off psi			158	150	141	132	124	115	106	98	89	81	72	63	55	46	37	20												
	1½	0												15.7	15.3	14.8	14.4	13.3	12.2	10.9	9.3	7.1	3.0							
		20									16.0	15.6	15.2	14.7	14.3	13.7	13.2	11.9	10.6	9.0	6.5									
		30									15.9	15.5	15.1	14.6	14.2	13.5	13.1	12.6	11.3	9.7	7.6	4.0								
		40									15.8	15.5	15.1	14.6	14.2	13.5	13.0	12.5	11.8	10.3	8.8	6.0								
		50									15.7	15.4	14.9	14.5	14.0	13.4	12.8	12.3	11.7	11.0	9.4	7.4	3.4							
		60						15.7	15.3	14.8	14.4	3.9	13.3	12.8	12.2	11.6	10.9	10.1	8.1	5.6										
Shut-off psi							197	188	180	171	162	154	144	136	128	119	110	93	76	58	41	24	6							
	2	0														16.0	15.7	14.2	14.2	13.4	12.4	11.4	10.0	8.2	5.8					
		20													15.9	15.5	15.3	14.8	14.1	13.2	12.2	11.0	9.9	8.0	5.2					
		30												15.8	15.4	15.1	14.7	14.4	13.5	12.7	11.7	10.3	8.8	6.5						
		40										15.8	15.4	15.1	14.7	14.4	14.0	12.9	12.2	10.9	9.5	7.8	3.9							
		50										16.1	15.7	15.3	15.0	14.6	14.2	14.0	13.4	12.5	11.5	10.1	8.5	6.0						
		60							16.0	15.7	15.3	14.9	14.5	14.2	13.8	13.4	12.8	11.8	10.7	9.1	7.2	3.4								
Shut-off psi								225	216	208	199	190	182	173	164	156	139	121	104	87	69	52	35	17						
	3	0																15.8	15.2	14.6	14.0	13.3	12.6	11.9	11.0	10.0	9.0	7.5	5.8	
		20																15.7	15.1	14.5	13.9	13.2	12.5	11.8	10.9	9.9	8.8	7.2	5.4	
		30																15.9	15.4	14.8	14.2	13.4	12.8	12.0	11.3	10.3	9.3	8.1	6.2	3.8
		40															15.9	15.6	15.0	14.4	13.8	13.1	12.4	11.5	10.8	9.7	8.6	7.1	4.7	
		50												16.0	15.8	15.6	15.3	14.7	14.1	13.3	12.7	11.9	11.0	10.2	9.1	7.8	6.0	3.0		
		60											16.0	15.8	15.5	15.2	14.8	14.3	13.7	12.9	12.3	11.4	10.6	9.6	8.3	6.8	4.5			
Shut-off psi												284	275	267	258	249	232	215	197	180	163	145	128	111	94	76	59	42	24	

Sample Submersible Pump Selection Chart

Horsepower Range 5, Recommended Range 3 -16 gpm, 60 Hz, 3450 RPM																									
Pump Model	hp	psi	Depth to Water in Feet/Ratings in gpm (Gallons per Minute)																						
			440	480	520	560	600	640	680	720	760	800	840	880	950	960	1000	1040	1080	1120	1160	1200	1240	1280	1320
	5	0						16	15.5	15.2	14.9	14.5	14	13.5	13	12.5	12	11.5	10.8	10.2	9.5	8.5	7	5.2	
		20					15.9	15.4	15.1	14.8	14.5	13.9	13.4	12.9	12.4	11.9	11.3	10.7	10.1	9.4	8.2	6.8	4.3		
		30					15.6	15.2	14.9	14.6	14.2	13.7	13.1	12.6	12.1	11.6	11.0	10.4	9.8	8.8	7.5	6.0	3.0		
		40				15.8	15.3	15.1	14.7	14.4	13.8	13.3	12.8	12.3	11.8	11.2	10.6	10.0	9.2	7.9	6.6	4.1			
		50				15.5	15.2	14.9	14.6	14.1	13.6	13.0	12.5	12.1	11.5	10.9	10.3	9.7	8.6	7.3	5.6				
		60			15.7	15.3	15.0	14.7	14.36	13.7	13.2	12.7	12.2	11.7	11.1	10.5	9.9	9.0	7.7	6.5	3.2				
Shut-off psi					346	329	312	294	277	260	242	228	208	191	173	156	139	121	104	87	69	52	35	17	

Storage of Water in Various Sizes of Wells Chart

Well Casing Size	Gallons of Water Storage per Foot
2"	0.16
3"	0.37
4"	0.65
5"	1.02
6"	1.47
8"	2.61
10"	4.08
12"	5.88
14"	8.00
16"	10.45

$$D^2 \div 24.5 = \text{Gallons of water storage per foot}$$

Where: D = Inside diameter of well casing in inches

Sample Tank Selection Chart - Minimum Tank Volume for Proper Motor Life
(Based on present industry practices)

Pump Capacity		Maximum Drawdown *	TOTAL TANK VOLUME (Gallons)					
			Switch Setting (Pounds Per Square Inch)					
			20-40		30-50		40-60	
gph	gpm	(Gallons)	A	B	A	B	A	B
240	4	4	10	25	15	40	15	55
300	5	5	15	30	15	50	20	70
360	6	6	15	40	20	60	20	85
420	7	7	20	45	25	70	25	100
480	8	8	20	50	25	80	30	110
540	9	9	25	60	30	90	35	125
600	10	10	30	65	30	100	40	140
660	11	12	35	80	40	120	45	165
720	12	13	35	85	40	130	50	180
780	13	15	40	100	50	150	55	210
840	14	17	45	110	55	170	65	235
900	15	19	50	125	60	190	70	265
960	16	20	55	130	65	200	75	280
1020	17	23	65	150	75	230	85	320
1080	18	25	70	160	80	250	95	350
1140	19	27	75	175	85	270	100	375
1200	20	30	80	195	95	300	110	415
1260	21	33	90	215	105	330	125	460
1320	22	36	100	235	115	360	135	500
1380	23	38	105	245	125	380	140	530
1440	24	41	110	265	135	410	155	570
1500	25	44	120	285	140	440	165	610
1560	26	47	130	305	150	470	175	655
1620	27	50	135	325	160	500	185	700
1680	28	53	145	345	170	530	200	735
1740	29	57	155	370	185	570	215	790
1800	30	60	165	390	195	600	225	835

A- Bladder or Diaphragm Tank Design B- Plain Steel Tank Design

Note: * Actual values may vary somewhat with field conditions.

Example: Sizing a Diaphragm/Bladder Tank				
___ gpm pump requiring ___ minutes run time with ___ pressure switch.				
Sizing Criteria				
___ gpm Pump Size	x	___ Minutes Run Time	=	gal of Minimum Drawdown
Total Tank Volume Required				
gal of Minimum Drawdown	÷	___ AF	=	___ Volume gal
<i>Always round up to the next tank size.</i>				

Example: Sizing a Non-Diaphragm/Bladder Tank				
___ gpm pump requiring ___ minutes run time with ___ pressure switch.				
Sizing Criteria				
___ Pump Size	x	___ Run Time	=	gal of Minimum Drawdown
Total Tank Volume Required				
gal of Minimum Drawdown	÷	___ AF	=	___ Volume gal
<i>Always round up to the next tank size.</i>				

Example: Sizing for Supplemental Drawdown				
System has a intermittent 15 gpm demand but can only supply 10 gpm continuously.				
Sizing Criteria				
___ Peak Demand	-	___ Flow	=	___ Flow Shortage
___ Flow Shortage	x	___ Demand Period	=	___ Supplemental Drawdown

Tank Sizing Acceptance Factors

Initial Tank Pressure psi (Cut-In)																										
Final Tank Pressure psi	CUT-OUT	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125
	10	0.202																								
	15	0.337	0.168																							
	20	0.432	0.288	0.144																						
	25	0.504	0.378	0.252	0.126																					
	30	0.559	0.447	0.336	0.224	0.112																				
	35	0.604	0.503	0.402	0.302	0.201	0.101																			
	40	0.640	0.548	0.457	0.366	0.274	-0.810	0.091																		
	45	0.670	0.586	0.503	0.419	0.335	0.251	0.168	0.084																	
	50	0.696	0.618	0.541	0.464	0.386	0.309	0.232	0.155	0.077																
	55	0.717	0.646	0.574	0.502	0.430	0.359	0.287	0.215	0.143	0.072															
	60	0.736	0.669	0.602	0.535	0.469	0.402	0.335	0.268	0.201	0.134	0.067														
	65	0.753	0.690	0.627	0.565	0.502	0.439	0.376	0.314	0.251	0.188	0.125	0.063													
	70	0.767	0.708	0.649	0.590	0.531	0.472	0.413	0.354	0.295	0.236	0.177	0.118	0.059												
	75	0.780	0.725	0.669	0.613	0.557	0.502	0.446	0.390	0.334	0.279	0.223	0.167	0.111	0.056											
	80		0.739	0.686	0.634	0.581	0.528	0.475	0.422	0.370	0.317	0.264	0.211	0.158	0.106	0.053										
	85		0.752	0.702	0.652	0.602	0.552	0.502	0.451	0.401	0.351	0.301	0.251	0.201	0.150	0.100	0.050									
	90			0.716	0.669	0.621	0.573	0.525	0.478	0.430	0.382	0.334	0.287	0.239	0.191	0.143	0.096	0.048								
	95			0.729	0.684	0.638	0.593	0.547	0.501	0.456	0.410	0.365	0.319	0.273	0.228	0.182	0.137	0.091	0.046							
	100				0.697	0.654	0.610	0.567	0.523	0.480	0.436	0.392	0.349	0.305	0.262	0.218	0.174	0.131	0.087	0.044						
	115				0.732	0.694	0.655	0.617	0.578	0.540	0.501	0.463	0.424	0.386	0.347	0.308	0.270	0.231	0.193	0.154	0.116					
	120				0.742	0.705	0.668	0.631	0.594	0.557	0.520	0.483	0.445	0.408	0.371	0.334	0.297	0.260	0.223	0.186	0.148	0.111				
	125					0.716	0.680	0.644	0.608	0.573	0.537	0.501	0.465	0.429	0.394	0.358	0.322	0.286	0.251	0.215	0.179	0.143	0.107			
	130					0.726	0.691	0.657	0.622	0.587	0.553	0.518	0.484	0.449	0.415	0.380	0.346	0.311	0.276	0.242	0.207	0.173	0.138	0.104		
	135						0.701	0.668	0.635	0.601	0.568	0.534	0.501	0.468	0.434	0.401	0.367	0.334	0.301	0.267	0.234	0.200	0.167	0.134	0.100	
	140						0.711	0.679	0.646	0.614	0.582	0.549	0.517	0.485	0.452	0.420	0.388	0.356	0.323	0.291	0.259	0.226	0.194	0.162	0.129	0.097
	145							0.689	0.657	0.626	0.595	0.564	0.532	0.501	0.470	0.438	0.407	0.376	0.344	0.313	0.282	0.250	0.219	0.188	0.157	0.125
	150							0.698	0.668	0.638	0.607	0.577	0.546	0.516	0.486	0.455	0.425	0.395	0.364	0.334	0.304	0.273	0.243	0.213	0.182	0.152
	155								0.678	0.648	0.619	0.589	0.560	0.530	0.501	0.471	0.442	0.412	0.383	0.354	0.324	0.295	0.265	0.236	0.206	0.177
	160								0.687	0.658	0.630	0.601	0.572	0.544	0.515	0.487	0.458	0.429	0.401	0.372	0.343	0.315	0.286	0.258	0.229	0.200
	165									0.668	0.640	0.612	0.584	0.556	0.529	0.501	0.473	0.445	0.417	0.390	0.362	0.334	0.306	0.278	0.250	0.223
	170									0.677	0.650	0.623	0.596	0.568	0.541	0.514	0.487	0.460	0.433	0.406	0.379	0.352	0.325	0.298	0.271	0.244
	175										0.659	0.633	0.606	0.580	0.554	0.527	0.501	0.474	0.448	0.422	0.395	0.369	0.343	0.316	0.290	0.264
180										0.668	0.642	0.616	0.591	0.565	0.539	0.514	0.488	0.462	0.437	0.411	0.385	0.360	0.334	0.308	0.282	
185											0.651	0.626	0.601	0.576	0.551	0.526	0.501	0.476	0.451	0.426	0.401	0.376	0.351	0.325	0.300	
190											0.660	0.635	0.611	0.586	0.562	0.537	0.513	0.489	0.464	0.440	0.415	0.391	0.366	0.342	0.318	
195												0.644	0.620	0.596	0.572	0.548	0.525	0.501	0.477	0.453	0.429	0.405	0.381	0.358	0.334	
200												0.652	0.629	0.605	0.582	0.559	0.536	0.512	0.489	0.466	0.442	0.419	0.396	0.373	0.349	
205													0.637	0.614	0.592	0.569	0.546	0.523	0.501	0.478	0.455	0.432	0.410	0.387	0.364	
210														0.645	0.623	0.601	0.579	0.556	0.534	0.512	0.490	0.467	0.445	0.423	0.401	0.378
215															0.631	0.609	0.588	0.566	0.544	0.522	0.501	0.479	0.457	0.435	0.414	0.392
220															0.639	0.618	0.597	0.575	0.554	0.533	0.511	0.490	0.469	0.447	0.426	0.405
225																0.626	0.605	0.584	0.563	0.542	0.521	0.501	0.480	0.459	0.438	0.417
230																0.633	0.613	0.593	0.572	0.552	0.531	0.511	0.490	0.470	0.450	0.429
235																	0.621	0.601	0.581	0.561	0.541	0.521	0.501	0.481	0.461	0.441
240																		0.609	0.589	0.569	0.550	0.530	0.510	0.491	0.471	0.452
245																			0.597	0.578	0.558	0.539	0.520	0.501	0.481	0.462
250																				0.586	0.567	0.548	0.529	0.510	0.491	0.472
255																					0.575	0.556	0.538	0.519	0.501	0.482
260																						0.564	0.546	0.528	0.510	0.491

Tank Sizing Acceptance Factors

Initial Tank Pressure psi (Cut-In)																									
Final Tank Pressure psi	CUT-OUT	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245
	145	0.094																							
	150	0.121	0.091																						
	155	0.147	0.118	0.088																					
	160	0.172	0.143	0.114	0.086																				
	165	0.195	0.167	0.139	0.111	0.083																			
	170	0.217	0.189	0.162	0.135	0.108	0.081																		
	175	0.237	0.211	0.185	0.158	0.132	0.105	0.079																	
	180	0.257	0.231	0.205	0.180	0.154	0.128	0.103	0.077																
	185	0.275	0.250	0.225	0.200	0.175	0.150	0.125	0.100	0.075															
	190	0.293	0.269	0.244	0.220	0.195	0.171	0.147	0.122	0.098	0.073														
	195	0.310	0.286	0.262	0.238	0.215	0.191	0.167	0.143	0.119	0.095	0.072													
	200	0.326	0.932	0.279	0.256	0.233	0.210	0.186	0.163	0.140	0.116	0.093	0.070												
	205	0.341	0.319	0.296	0.273	0.250	0.228	0.205	0.182	0.159	0.137	0.114	0.091	0.068											
	210	0.356	0.334	0.312	0.289	0.267	0.245	0.223	0.200	0.178	0.156	0.134	0.111	0.089	0.067										
	215	0.370	0.348	0.327	0.305	0.283	0.261	0.239	0.218	0.196	0.174	0.152	0.131	0.109	0.087	0.065									
	220	0.383	0.362	0.341	0.320	0.298	0.277	0.256	0.234	0.213	0.192	0.170	0.149	0.128	0.107	0.085	0.064								
	225	0.396	0.375	0.355	0.334	0.313	0.292	0.271	0.250	0.229	0.209	0.188	0.167	0.146	0.125	0.104	0.083	0.063							
	230	0.409	0.388	0.368	0.347	0.327	0.306	0.286	0.266	0.245	0.225	0.204	0.184	0.163	0.143	0.123	0.102	0.082	0.061						
	235	0.421	0.400	0.380	0.360	0.340	0.320	0.300	0.280	0.260	0.240	0.220	0.200	0.180	0.160	0.140	0.120	0.100	0.080	0.060					
	240	0.432	0.412	0.393	0.373	0.353	0.334	0.314	0.294	0.275	0.255	0.236	0.216	0.196	0.177	0.157	0.137	0.118	0.098	0.079	0.059				
	245	0.443	0.424	0.404	0.385	0.366	0.347	0.327	0.308	0.289	0.270	0.250	0.231	0.212	0.193	0.173	0.154	0.135	0.116	0.096	0.077	0.058			
	250	0.453	0.434	0.416	0.397	0.378	0.359	0.340	0.321	0.302	0.283	0.264	0.246	0.227	0.208	0.189	0.170	0.151	0.132	0.113	0.094	0.076	0.039		
	255	0.463	0.445	0.426	0.408	0.389	0.371	0.352	0.334	0.315	0.297	0.278	0.260	0.241	0.222	0.204	0.185	0.167	0.148	0.130	0.111	0.093	0.057	0.038	
	260	0.473	0.455	0.437	0.419	0.400	0.382	0.364	0.346	0.328	0.309	0.291	0.273	0.255	0.237	0.218	0.200	0.182	0.164	0.146	0.127	0.109	0.074	0.056	0.037

Example: Water Treatment System Pressure Drop

Service Flow _____ gpm

Multiport Valve

Model _____ Cv _____
 Pressure Drop dp = (Flow ÷ Cv)
 Pressure Drop dp = (_____ ÷ _____) = psi

Media

Tank Size _____
 Media Surface Area _____
 Service Flow per sq. ft. = _____ gpm ÷ _____ sq. ft.
 = _____ gpm ÷ sq. ft.

Media

Chart Plot for _____ gpm ÷ sq. ft.
 = _____ ft. Head ÷ Foot of Bed
 Bed Depth (x3) = _____ ft. Head
 For psi (÷ 2.31 psi ÷ ft. Head) = _____ psi

Distributor

Model _____
 Chart Plot for _____ gpm Service Flow = _____ psi
 Total System Pressure Drop = _____ psi

Glossary

Acceptance Factor: The percentage of tank volume storing water, expressed as a decimal. (VIII-3)

Atmospheric Pressure: The pressure exerted by the atmosphere on the earth (14.7 per square inch). (VIII-3)

Atmospheric Storage Tank: A tank that is open to the atmosphere and not pressurized. (VIII-1)

Boyle's Law: Air is compressible, and water is not compressible. (VIII-3)

Capacity: As relates to softening or ion exchange:

1. the expected number of days the equipment will be in service;
 2. the expected number of gallons of product water delivered; or
 3. the grains of total hardness removed.
- (VIII-1, VIII-3, VIII-4)

Centrifugal Pump: A pumping mechanism that spins water by means of an "impeller," pushing it out by centrifugal force. (VIII-1)

Continuous Flow Rate: For water treatment systems, that flow which generates a pressure drop of 15 psi when water is passed through the system. For system manufacturers, it is that flow rate which will ensure that the system will perform at its specified function consistently over extended periods of time. This is the normal service flow expected by the manufacturer. (VIII-4)

Cut-In and Cut-Out: An electrical pressure switch activated by the pressure in a pressure tank. When the pressure drops to a low set point (cut-in), it turns on the pump. At a high point (cut-out), it turns off the pump. (VIII-1, VIII-3)

Cut-In Pressure *(Also called Pump-Start Pressure):* Pressure level at which a pump turns on. (VIII-3)

Cut-In Setting: Set point at which water pressure causes a pump to turn on. (VIII-3)

Cut-Out Pressure: An electrical pressure switch activated by the pressure in a pressure tank. At a high point, it turns off the pump. (VIII-3)

Deep Well Jet Pump: Any pump capable of producing water from deeper than 25 feet. (VIII-1)

Deep Well Pump: Any pump capable of producing water from deeper than 25 feet. (VIII-1)

Depth to Water: Measurement of distance between static water level and ground level. (VIII-1)

Discharge Head: All the losses on the discharge side of the pump. These include pressure, elevation, and friction loss. (VIII-1)

Drawdown: Reduction in water level during pumping (measured in feet); the amount of water delivered by the pressure tank between pump shutdown and pump precharge pressure. (VIII-3)

Ejector *(Also Called a Jet):* A water pressure-making device with three parts: body, nozzle, and venturi. Atmospheric pressure forces water into a partial vacuum at the nozzle throat, then into the pumping system where the venturi slows water velocity and converts it into water pressure. (VIII-1)

Fixture Method Multiply the total number of water fixtures on the property by one gallon per minute to determine demand. (VIII-1)

Float Switch: A float switch is used to turn a pump on or off in systems with gravity tanks or reservoirs instead of pressure tanks. The float responds to a rise and fall in the water level in the pressure tank rather than to pressure. (VIII-1)

Flow: Measure of water volume moved in a given length of time. (VIII-1, VIII-3, VIII-4)

Flow Coefficient: The volume of water at 60°F (in U.S. gallons) that will flow through a valve per minute with a pressure drop of 1 psi across the valve. (VIII-4)

Friction Loss: Loss of pressure when water flows through a piping system factoring gallons per minute, pipe length, size, and fittings. Measured in feet of head. (VIII-1)

Gallons Per Hour (gph): Unit of flow measurement, expressed in gallons per hour. (VIII-1)

Gallons Per Minute (gpm): Unit of flow measurement, expressed in gallons per minute. (VIII-1, VIII-3)

Head: Pressure expressed as height of feet. (VIII-1, VIII-4)

Hydropneumatic Tank: A vessel that holds water and air under pressure in which the compressed air creates a cushion that can absorb or apply pressure as needed. (VIII-3)

Jet: *See Ejector.*

Jet Pump: A surface-mounted centrifugal pump that has an ejector (venturi) device to increase suction capacity. (VIII-1)

Maximum Acceptance Factor: The maximum amount of water inside the tank before stretching the bladder/diaphragm. (VIII-3)

Multiport Control Valve: A master control valve used in a filter, deionizer, or water softener to control all the necessary steps in the regeneration process or the backwashing and rinse down of filters. (VIII-4)

National Electric Code (NEC): Electrical standards code that requires the safe grounding of motor-operated water pumps and metal well casings. (VIII-2)

Packer: The space between a single pipe and the well casing serves as the pressure pipe. A deep well jet pump system that requires 2-inch or 3-inch well casing and has one pipe down in the well to the jet assembly. (VIII-1)

Peak-Demand Period: The time period during which the greatest amount of water is consumed by the users of various household fixtures. (VIII-1)

Peak Flow Rate: For water treatment systems, that flow which generates a pressure drop of 25 psi when water passes through the system. For system manufacturers, it is the maximum flow rate that will still ensure adequate performance of the specified function of the system. It is intended by the manufacturer to be applied for only short periods. (VIII-4)

Performance Curve: Method of selecting a submersible pump; requires knowing the pump capacity (gpm) and the total dynamic head (TDH). (VIII-1)

Piston Pump: *(Also called a Reciprocating Pump):* A shallow well reciprocating pump. No longer used for domestic well systems. Shallow well pump in which the piston reciprocates from one end of the cylinder to the other. (VIII-1)

Pounds per Square Inch (PSI): A unit of pressure or force. (VIII-1, VIII-3, VIII-4)

Pressure: The force exerted in pounds over one square inch area. (VIII-1, VIII-3, VIII-4)

Pressure Drop:

1. A decrease in the water pressure (in psi) which occurs as the water flows.
2. The difference between the inlet and outlet water pressure during water flow through a water treatment device such as a water conditioner. (VIII-4)

Pressure Range: A 20 psi differential within the pressure switch settings, controlled by the pressure switch setting, that works with the precharge air in the pressure tank. (VIII-1, VIII-3)

Pressure Switch: An electrical switch activated by system pressure to control starting and stopping of the pump. (VIII-1)

Pressure Tank: Vessel used to provide cycle control of the pump. (VIII-3)

Product Water: Water that has been through the total treatment process and meets the quality standards required for the intended use. (VIII-4)

Pump: A mechanical device that moves liquid or gas by pressure or suction; a device that converts mechanical torque and motion into hydraulic fluid power. (VIII-1)

Pump Cut-In Pressure: A predetermined low pressure in the water systems that activates the pressure switch to energize the motor and start the pump. (VIII-3)

Pump Cut-Out Pressure: High pressure that turns off the pump. (VIII-3)

Pump Offset: The horizontal distance from the pump to the well head should be minimal for optimal performance.

Regenerative Turbine Pump: A pump that uses a rotating wheel or impeller with a series of blades or fins to develop high pressures. (VIII-1)

Service Flow: The rate in U.S. gallons per minute (gpm) or liters per minute (L/min) at which a given water processing system can deliver product water. The rating may be for intermittent peak flow or constant flow. (VIII-4)

Shallow Well: Well that goes down only to the first water-bearing formation (less than 25 feet), where the water table is exposed to atmospheric pressure. (VIII-1)

Shallow Well Jet Pump: A pump that produces lower than atmospheric pressure at its inlet and lifts water with a suction pipe. Limited to wells with depths of 25 feet or less. (VIII-1)

Shallow Well Pump: A centrifugal pump with the ejector mounted to the housing that has a maximum total suction lift of 25 feet. (VIII-1)

Source Water:

1. Water, usually from wells or surface sources, which has had no previous treatment and is entering a water processing system or device.
2. Water at the inlet side of any water treatment system or device. (VIII-4)

Submersible Pump: An adapted centrifugal pump and motor designed to be placed completely below the water surface. (VIII-1)

Suction Lift: The low pressure generated on the inlet in the suction of a pump that lifts water up into the pump. (VIII-3)

Suction Pipe: A pipe through which well water is drawn to the surface. (VIII-1)

Supplemental Drawdown: A sizing strategy that provides reserve tank storage beyond the normal pump operating range. (VIII-3)

System Head: Operating pressure at discharge of tank. Measured in feet or psi. (VIII-1)

Total Dynamic Head (TDH): The amount of pressure the pump is capable of building. Expressed in feet. (VIII-1)

Total Head: Determined by adding the friction head and static head; governs pump pressure selection. (VIII-1)

Total Suction Lift: Determined by vertical lift plus friction loss in the suction pipe and fittings. (VIII-1)

Total Usage: Capacity requirement for sizing a residential water system, in gallons per day (gpd). (VIII-1)

Twin-Pipe System: A two-pipe system has a pressure pipe and a suction pipe connecting the pump and the jet. (VIII-1)

Valve: Any device used to control flow in a water system. (VIII-1, VIII-4)

Water Quality: The definition of the contaminant levels in a specific body of water, whether it is the water available in a particular well or the contaminant level within a lake or reservoir. Water quality may include some obvious characters such as taste, odor, or clarity. (VIII-4)

Well Casing: Steel or plastic lining permanently installed in drilled wells to prevent cave-ins or contamination by surface water. (VIII-1, VIII-3)

Well Log: A written form on which the driller lists well characteristics; required in many states. (VIII-1)

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