Block C: Rural Water Supply

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Plumbing Apprenticeship Program Level 4

SkilledTradesBC

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Competency C1: Install Rural Water Supply Systems

Private water supply systems are an alternative source of water for many households and businesses across the world. These systems are typically used in rural areas where municipal water systems are not available or are not desirable due to various reasons such as cost, distance, or lack of infrastructure. Private water supply systems can draw water from a variety of sources, including groundwater and surface water, and are designed to provide safe and reliable water to consumers. However, unlike municipal water systems, private water supply systems are the responsibility of the property owner and their plumber, and as such, it is essential to understand their design, installation, operation, and maintenance requirements. In this competency you will lean about private water supply systems, including their types, components, advantages, and disadvantages, as well as important considerations for ensuring adequate water quantity and quality.

Learning Objectives

After completing the learning tasks in this Competency, you will be able to:

- Describe pressure water supply systems
- Size private pressure systems and select a pump.
- Describe the installation of private water supply pressure systems.
- Describe the testing, commissioning and service of private water supply pressure systems.

Learning Task 1

Describe Pressure Water Supply Systems

Private pressure water supply systems rely on pumps and pressure tanks to deliver water to taps and appliances throughout a building. The system typically includes a well or other water source, a pump to extract the water from the source, and a pressure tank to store the water and maintain a consistent pressure in the system. This ensures that there is a consistent flow of water at an appropriate pressure, making it a convenient and reliable source of water for daily use.

Types of Water Supply

Private water supply systems can be classified based on the source of water they use. The two main types of private water supply systems (Figure 1) are surface water systems and groundwater systems .

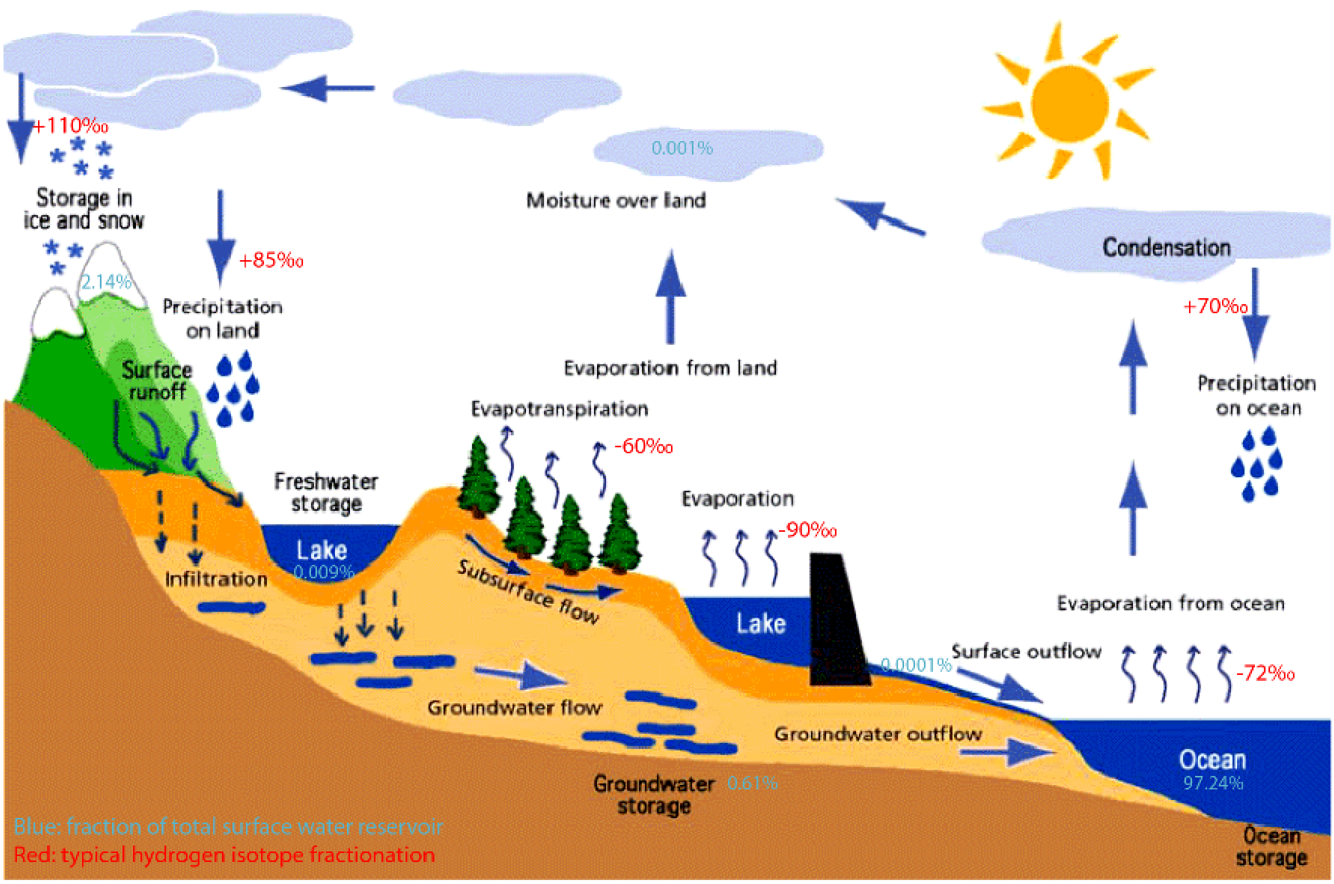

Figure 1. Hydrological cycle

Surface Water Systems

Surface water systems draw water from rivers, lakes, or ponds. They are often used in areas where groundwater is not available or where the surface water source is closer to the property. Surface water systems require different components and treatments than groundwater systems to ensure that the water is safe and reliable. Surface water quality can be affected by various factors, including nutrient runoff, algae blooms, sedimentation, and pollution from industrial discharge, agricultural runoff, or sewage treatment plants.

Groundwater Systems

Groundwater systems draw water from underground aquifers. An aquifer is an underground layer of permeable rock, sand, or soil that contains and transmits water (Figure 2). The water in the aquifer comes from rain and snowmelt that seeps into the ground and is stored in the spaces between soil particles or in the cracks and crevices of rock.

Aquifers can vary in size both vertically and horizontally. They can range from a few meters thick to being as vast as the Ogallala Aquifer, which is equivalent in size to California. Aquifers have different levels of porosity, which refers to the spaces found between rocks, gravel, and sand. However, the foundation of the aquifer is made up of solid rock that doesn't allow water to pass through, known as bedrock. The porosity of the aquifer affects the rate at which water can move through it and how fast the aquifer can be replenished after water has been extracted from them.

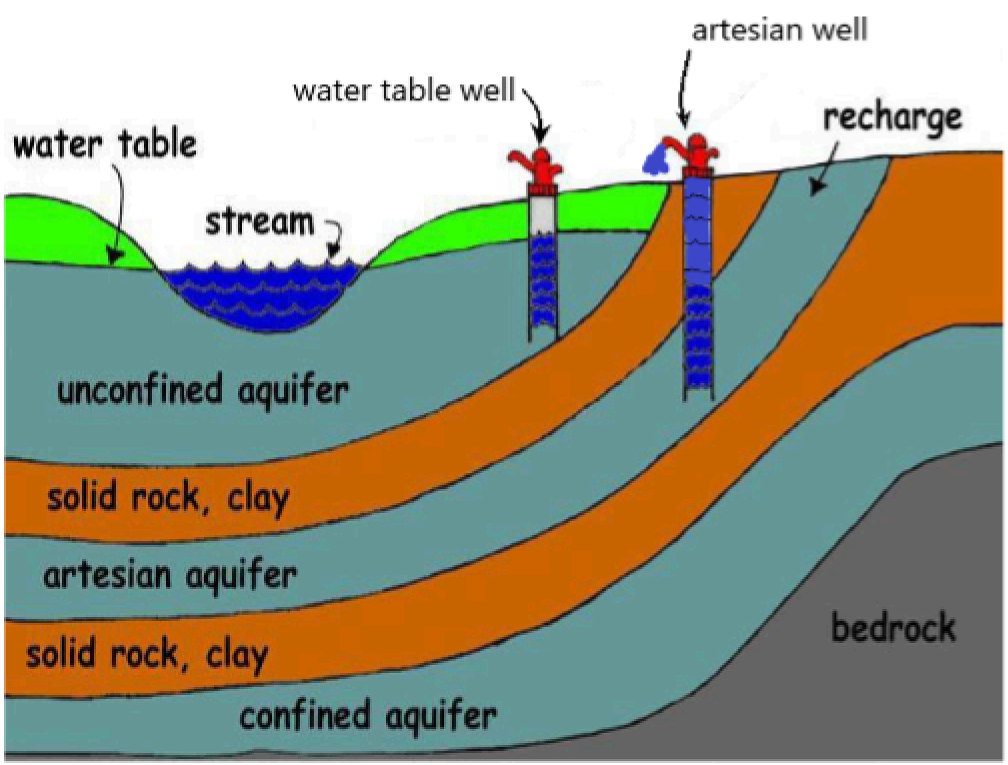

Figure 2. Ground water

Aquifers can be classified as either confined or unconfined. An unconfined aquifer is also known as a shallow well aquifer because its water table, which is the top layer of water, is located near the surface of the ground. This type of aquifer does not have a dense layer of rock or material above it, so its water is not under pressure and can be easily affected by conditions on the surface. This means that any pollution or contamination on the surface can easily seep into the shallow well aquifer and affect the quality of the water. In contrast, a confined aquifer has a layer of dense rock or material above it which keeps the water under pressure and protects it from surface contamination.

Aquifers can be accessed through springs and wells. Although they are naturally replenished, an aquifer can be depleted by overuse or contamination.

Springs

Springs are natural sources of groundwater that flow to the surface. Springs are created when a portion of an underground aquifer reaches the surface and intersects with a stream, lake, or rock formation, resulting in the formation of a small pool due to the natural shape of the land. They are often found in hilly or mountainous areas, where the water table intersects with the surface (Figure 2). Springs are often considered reliable sources of drinking water since they originate from groundwater. However, it is important to note that springs are susceptible to contamination, similar to other surface water sources. As the water from springs flows through the upper layer of soil and collects on the surface, it can be easily influenced by various contaminants.

Artesian springs derive from aquifers where the water is pressurized, resulting in a force that propels the water to the surface. Artesian water sources are typically situated at greater depths and flow beneath a dense layer of clay or rock. When a well is drilled into the aquifer or geological forces create fractures in the clay or rock layer, water may forcefully gush or bubble up to the surface. These types of springs are less vulnerable to contamination and exhibit greater reliability compared to gravity-fed springs, especially during periods of dryness or drought.

Wells

Wells are a vertical shaft that is dug, driven, drilled, bored or jetted into the ground to access groundwater. The diameter of a well is largely dependent on the method used to install it. The length or depth of a well is dependent on where the aquifer is located and how much water is required. Shallow wells are generally thought of as anything less than 7.6 m (25′) deep. Shallow wells are relatively easy and inexpensive to install, but they are more susceptible to contamination from surface water runoff or nearby septic systems.

Choosing a suitable location for a potable water well is crucial for ensuring the availability of safe and clean drinking water. The selection process should consider the proximity to potential sources of contamination, such as septic systems, landfills, and chemical storage facilities. Geological conditions like soil type, depth to bedrock, and the presence of fractures, folds, or faults can influence the water quantity and quality. The distance from the proposed well site to nearby surface water bodies like lakes, streams, or wetlands is also important to prevent contamination from runoff or seepage. You must also consult with local authorities to comply with regulations regarding the minimum setbacks from property lines, structures, and utilities.

A qualified hydrogeologist or well driller will assess the suitability of the site and the construction design to optimize the well's yield and protect the aquifer from potential contamination sources. In British Columbia, all wells are governed by the "Groundwater Protection Regulation." This document covers all aspects of well operation, including well registration.

Well Construction

Well construction is a process that involves drilling, installing and constructing a well to access groundwater. Well construction is a complex process that requires careful planning, design, and construction to ensure that the well is safe, reliable, and provides high-quality water.

The Groundwater Protection Regulation (GWPR) includes a Code of Practice for Construction, Testing, Maintenance, Alteration and Closure of Wells. The Regulation outlines such things as:

- Who is qualified to drill a well and install a well pump?
- How to identify a well.
- How to protect groundwater by installing proper surface seals, how to flood proof wells, how to protect the well head, and how to deactivate and close unused wells.
- That wells are identified by tags through the provincial ID system.
- That well drillers and pump installers must be registered.
- Deactivation of unused wells to protect the aquifer from contaminants entering
- Flood proofing to prevents surface water from entering a well.

Well Types:

There are different types of wells, including:

- dug
- bored
- drilled
- driven

Dug wells

Dug wells are the simplest and oldest type of wells, and are excavated by hand or with a backhoe. They are typically shallow, only reaching depths of 10-30 feet. Dug wells are often lined with bricks, stones, or concrete to prevent collapse and contamination.

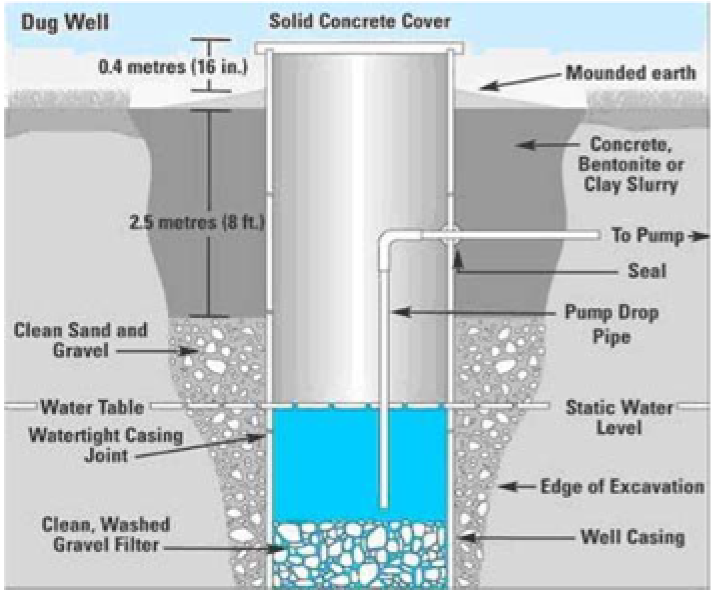

Figure 3. Dug well

Bored wells

Bored wells are a type of well that is similar to a dug well, but instead of being excavated by hand, they are dug using a drilling machine with an auger bit. The typical largest diameter of a bored well is around 1 meter, but this can vary depending on the specific drilling equipment and the needs of the well. For example a larger diameter bore hole can help serve as a storage reservoir during periods of high demand. Bored wells are best installed in clay, silt, and fine sand, as these materials are easily excavated by the auger. They are not suitable for hard rock or soil that contains many large boulders, which can damage the auger and make it difficult to drill the well. When considering a bored well, it's essential to evaluate the soil and rock formations in the area carefully to ensure that the well will be drilled safely and effectively.

Driven wells

Driven wells are another type of shallow well most commonly used in areas with shallow water tables. They can be installed relatively quickly and easily by pounding sections of pipe, tipped with a special drive point-screen assembly, into the earth until the aquifer is reached. This method can be done using a hand-operated maul or a heavy weight supported by a frame that is lifted and lowered by a motor-drive assembly. The purpose of the point-screen assembly is to allow water to enter the pipe while preventing soil and debris from entering.

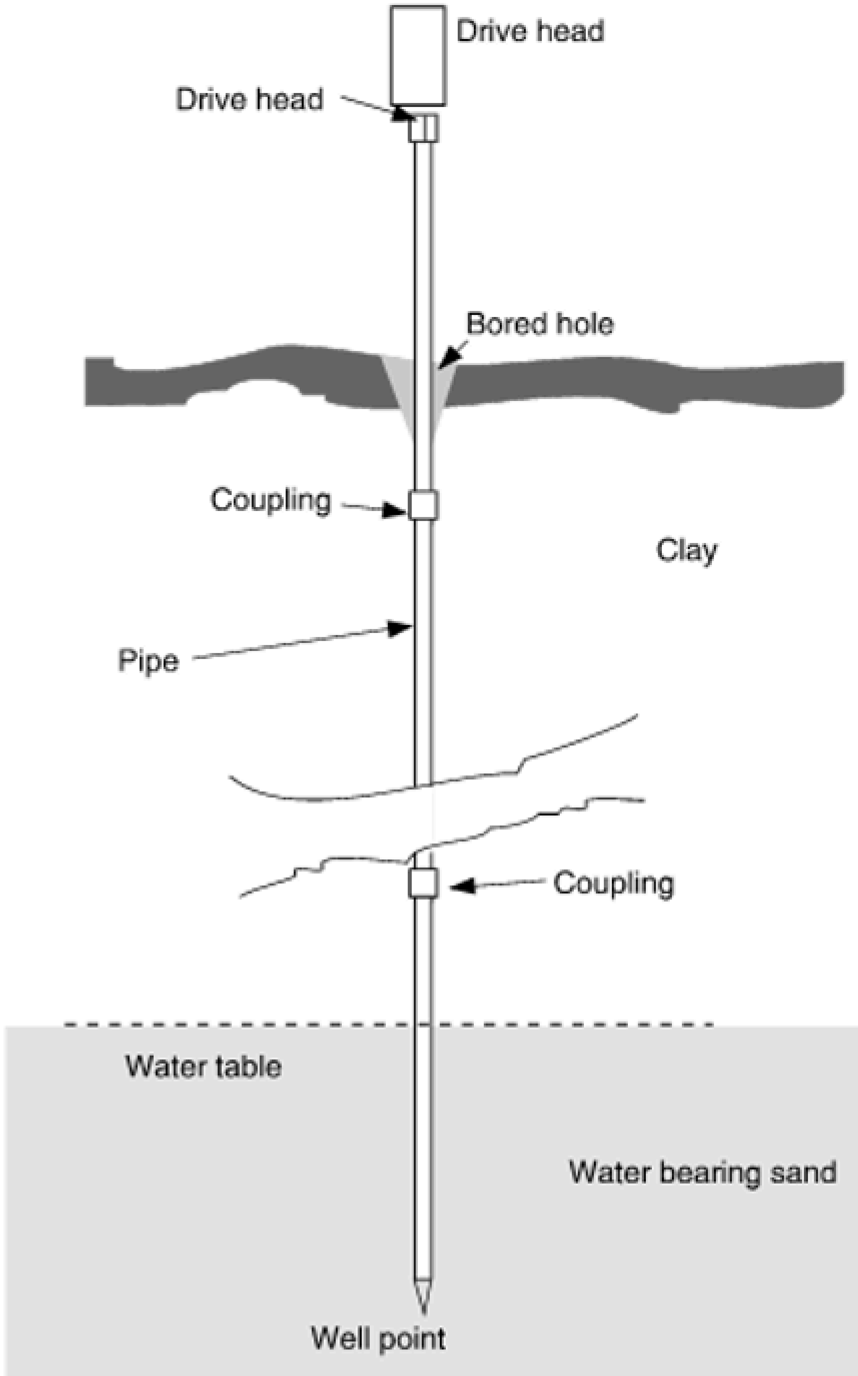

Figure 4. Driven well

Drilled wells

When it comes to establishing a well, drilling a hole may be the most effective option if the soil is dense, contains clay or rocks, or if the water source is deep. Drilling a well also enables penetration of the impervious layers to access the confined aquifers. Drilled water wells usually have a diameter of 101 mm to 152 mm (4″ to 6″) and range from 30 m to 90 m (100′ to 300′) deep.

Lining a drilled well with pipe casing is an essential step in protecting the confined aquifer from contamination. The pipe casing is installed at least all the way down into the impervious layer, which acts as a barrier between the aquifer and any potential sources of contamination. Proper installation of the casing is crucial to prevent any gaps or leaks that could allow contaminants to enter the aquifer.

Well components

The well construction must comply with the provisions of the GWPR. The driller must ensure that the well is built to meet the minimum standards for the casing material, wellhead completion, surface seal, well caps and covers, and proper identification. Figure 5 depicts the crucial components of a well, however, the requirements may vary depending on the geological formation and type of well being constructed.

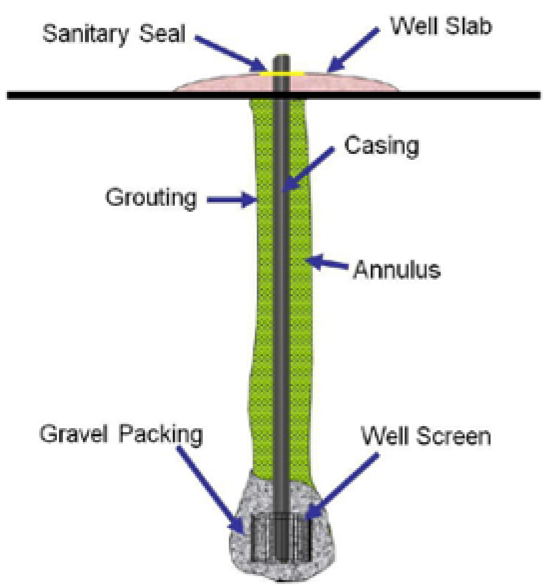

Figure 5. Well components

Sanitary seal

A sanitary seal is a watertight seal that prevents surface water from entering the well. It is typically installed around the top of the well casing. Technically the complete casing seal is made up of both, the above ground penetration point and the below ground grouting.

Well slab

The well slab acts as a surface seal by preventing surface water from entering the well. The slab is usually made of concrete and is placed over the top of the well casing, extending beyond the edge of the casing to form a barrier between the well and the surrounding soil. The slab is typically poured in place on a level, compacted soil surface and reinforced with steel to provide additional strength. The surface of the slab is also sloped away from the well to prevent water from pooling near the wellhead. The combination of the slab and a properly installed well cap help to prevent contamination of the well water from surface sources.

Casing

Casing is a pipe that is installed into the well to prevent the walls from collapsing and to prevent contamination. It is typically made of PVC or steel and is installed during drilling or after the well has been dug. The length of casing varies for different geological formations. For drilled wells the surface casing will be set into the bedrock to maintain the integrity of the impervious layer. Depending on the stability of the rock strata below the initial bedrock, additional production casing or a PVC liner may need to be extended down through the initial surface casing.

The casing diameter must be large enough to accommodate the size of the pump that is required. For residential installations 6” casing is most common, as this will accommodate a liner (if needed) with a 4” submersible pump. The casing must stick-up a minimum of 0.3 m above the well stab or elevated ground.

Annulus

When the initial unconsolidated ground material is being drilled a bit is used that is at least 5 cm larger in diameter than the casing that will be installed. The annulus is the space left between the well casing and the surrounding soil or rock.

Grouting

After the drilling has penetrated the bedrock a minimum of 1 m then the casing is set. Grouting is part of the casing setting process were the space between the well casing and the surrounding soil or rock is filled with a non-toxic sealant to prevent below ground surface water from entering the well. It also helps to stabilize the well casing and prevent contamination.

Type of sealant considerations include; thickness of the annular space and the depth as well as artesian pressures. Commonly used sealants include:

- Bentonite clay mixtures
- Concrete grout
- Sand, cement grout (consisting of sand, cement, and water)

Well screen

Depending on the composition of the water bearing strata a well screen may be required to prevent sediment form entering the well. A well screen is a pipe that has slots or openings that allow water to flow into the well while preventing sediment from entering. It is typically installed onto the bottom of the liner or casing and is surrounded by gravel.

Gravel packing

Gravel packing is often used to fill the annular space between the liner/casing well screen and the borehole wall to help prevent the formation of sediment and improve the flow of water into the well.

Well logs

A well log is a detailed record of the characteristics and conditions encountered during the drilling and construction of a water well. It provides information about the geology, hydrogeology, and properties of the formations encountered, including the depth and thickness of different rock layers, the presence of aquifers and aquitards, and the water-bearing capacity of the well. The details listed on a well log give the plumber a map of important well characteristics necessary to ensure that the water supply system is designed and implemented effectively and in line with the specific characteristics of the well.

Since 2005 the BC Water Sustainability Act has required well drillers to register new wells with the province. This process includes attaching a well identification plate to the well casing and submit the well records to the Ministry of Environment.

Pumps

In a private water system, the primary component responsible for water extraction is the pump. Pumps make it possible to economically lift water from a private water source and make it available where it is desired; Pumps are available in various types and sizes to suit different water sources, including deep wells, shallow wells, and surface water. Pumps can be broadly categorized into two types: positive displacement and non-positive displacement pumps.

Positive Displacement Pumps

Positive displacement pumps, as the name suggests, displace a fixed volume of fluid with each cycle of operation. They work by trapping a specific amount of fluid and then forcing it through the pump’s outlet. The simple manually operated lift pump, that can still be found in parks and campgrounds, is an example of piston type of positive displacement pump, as each stroke delivers a fixed volume water (Figure 6).

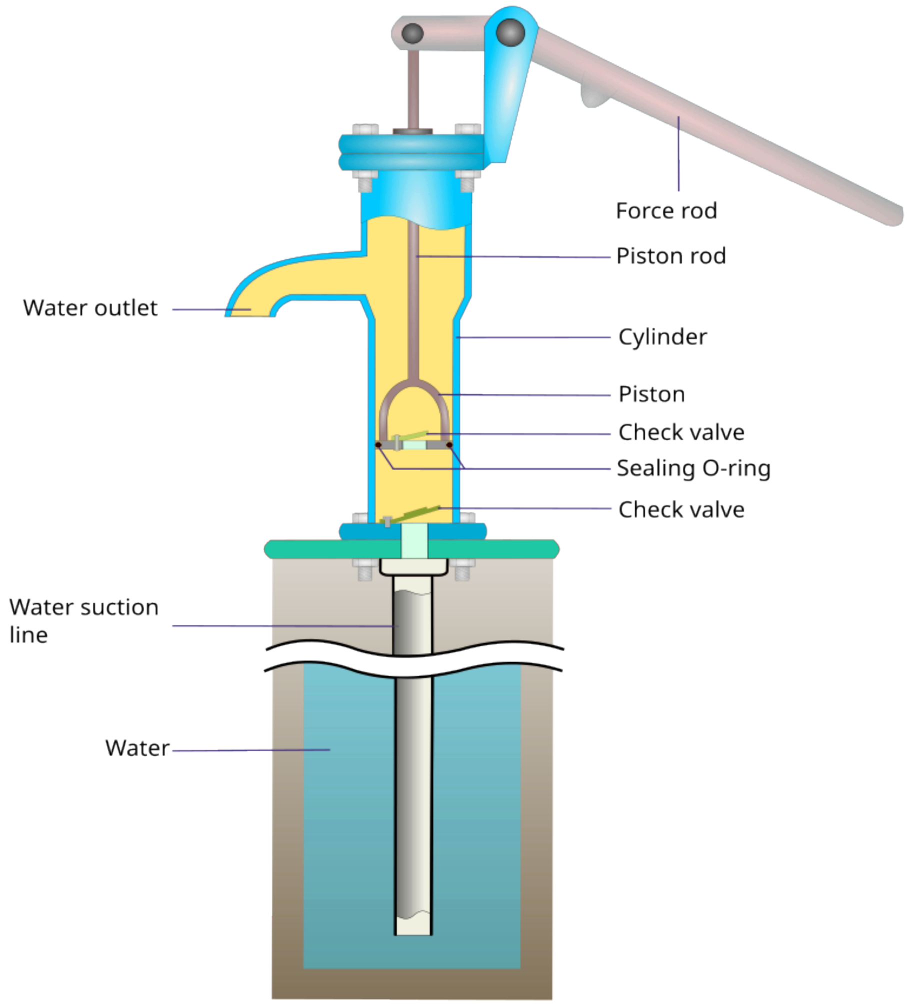

Figure 6. Hand pump

The motorized versions, also known as reciprocating pumps, have a piston that moves inside a cylinder contained in a housing, equipped with check valves. The piston moves back and forth, drawing water from the suction inlet on its back stroke and forcing the water into the discharge outlet as it is pushed forward by the motor (Figure 7).

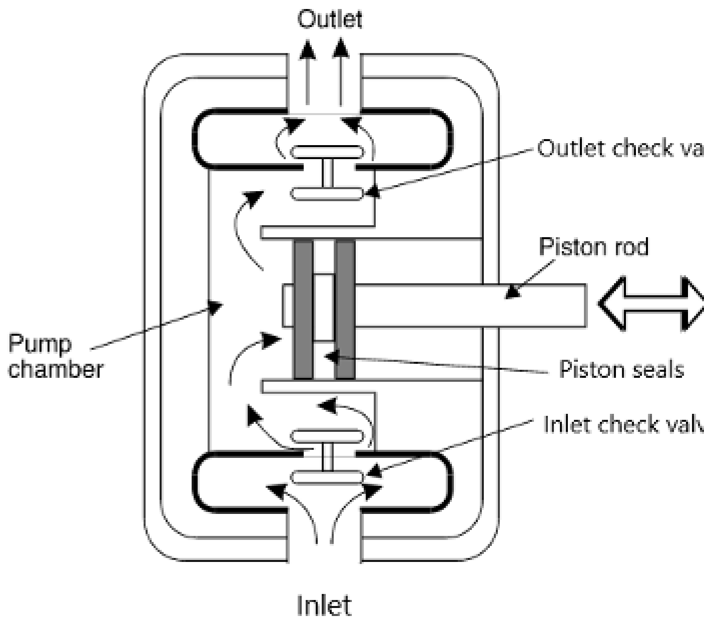

Figure 7. Reciprocating piston pump

Positive displacement pumps are able to fill themselves and the suction pipe with fluid, which is called self priming. Water begins to flow from the well because the backward stroke of the piston lowers the pressure (creates a vacuum) inside the pump and allows the atmospheric pressure that bears on the well water to force the water up the suction pipe.

Although piston pumps were very reliable and tolerant of air that may leak into intake lines they are not generally used anymore for private water supply, as they are more expensive and nosier than other pumps.

Non-Positive Displacement Pumps

Non-positive displacement pumps, such as centrifugal pumps, generate a flow velocity that converts to pressure, pushing fluid out of the pump discharge. They utilize a spinning impeller with angled blades, similar in design to a boat or airplane propeller to create centrifugal force (Figure 8). The pump case must be full of to operate. As the impeller spins the water surrounding it, is thrown to the outside by the rotation of the impeller vanes, creating a low-pressure zone that draws additional water into the eye of the impeller.

The velocity of the water at the casing's outside depends on the impeller's speed and diameter. The high-speed water is accepted by the outlet portion of the casing, called the volute. This gradually widening area of the casing slows the water down and converts its velocity into usable pressure for the distribution system.

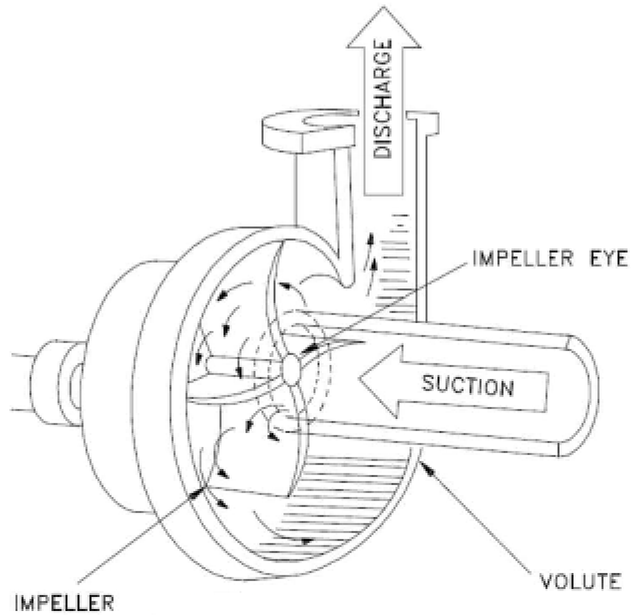

Figure 8. Centrifugal pump

Centrifugal pumps can have multiple impeller designs, where each impeller in the series adds to the work of the previous impeller by directing the water leaving its rim to the next impeller's eye. However, it's important to note that these additional impeller stages do not increase the flow rate of the fluid leaving the pump, but only increase its pressure. The flow rate of a centrifugal pump is determined by several factors, including the design of the impeller, the pump case, the size of the impeller, its rim speed, the size of the waterways through the impeller, and the pump's elevation relative to its water supply.

When a centrifugal pump operates, it creates negative pressure in its casing. This negative pressure, along with atmospheric pressure acting on the water surface in the well or lake, causes water to flow up the drop pipe and through the pump casing. However, the pump's lift capability is influenced by several factors such as atmospheric pressure, friction resistance (loss) in the supply pipe, and the pump's condition.

Centrifugal pumps have a theoretical suction lift capability of approximately 34 feet at sea level (Figure 9), based on atmospheric pressure (14.7 psia) and the weight of water per foot of height (0.433 psi/ ft.hd.). However, the pump's actual lift capability is lower due to factors such as friction loss in the suction pipe, the pump's efficiency, and the elevation above sea level. The maximum practical suction lift for a centrifugal pump installed at sea level is typically around 25 feet.

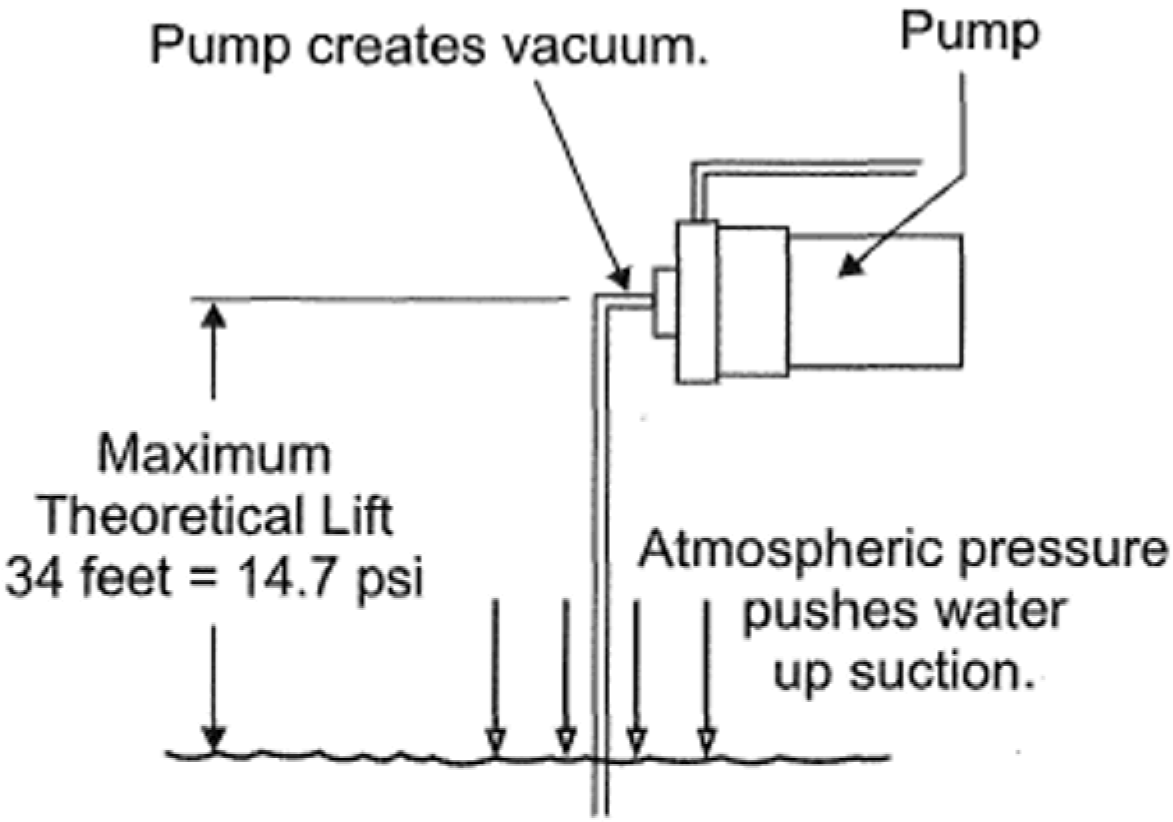

Figure 9. Theoretical suction lift

The resistance caused by flow pressure in the opposite direction of the centrifugal pump reduces its flow output capacity. If there is excessive backpressure, it can surpass the pump's ability to move fluid. This property is significant in centrifugal pumps, and it's essential to understand that they are considered variable displacement pumps due to this. Variable displacement indicates that the amount of water discharged from the centrifugal pump decreases as it is asked to do more work, such as raising the height of fluid lift or increasing output pressure.

Centrifugal pumps, unlike positive displacement pumps, do not have the ability to self-prime and provide a variable flow rate that changes based on the discharge pressure. However, despite these limitations, the design and engineering of centrifugal pumps make them highly suitable for the water supply industry. In fact, they are commonly used in private water supply systems, with jet pumps and submersible pumps being the two most prevalent types. Jet pumps are surface-mounted and use suction to draw water, while submersible pumps are installed underwater and push water to the surface. Both types are reliable and efficient, making them popular choices for private water supply applications.

Jet pump

The jet pump is a type of centrifugal pump that uses the venturi effect to boost its suction. The pump incorporates a nozzle, (also known as an injector or ejector), and venturi into the inlet of the impeller housing (Figure 10). The impeller case is designed so that some of the impeller output water is diverted to a nozzle through a passage built into the pump case and the jet assembly. As the diverted water travels through the venturi tube, it creates a low-pressure zone which boosts the inlet suction. This is a continual cycle that increases the volume of water traveling to the impeller.

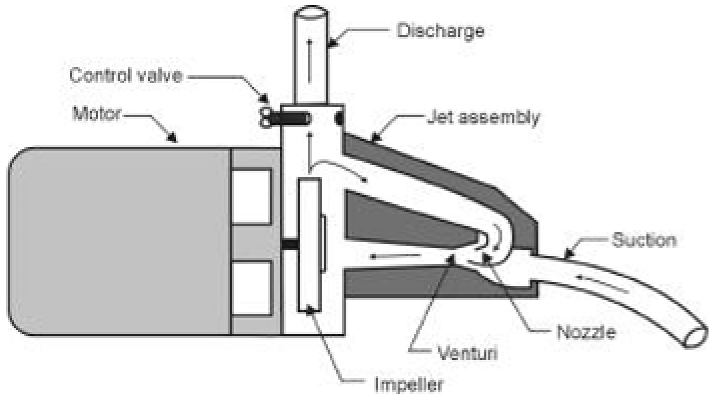

Figure 10. Shallow well jet pump operating principle

The flow control valve ensures enough water is diverted from the impeller to the jet assembly by restricting the amount of water that can flow from the outlet of the pump to achieve good pumping performance. Some manufacturers may require a separate flow control fitting to be installed on the outlet of the case. Shallow well jet pumps provide a good supply of water but they are limited to lifting no more than about 7.6 m (25′) below the pump.

Jet pumps are also available in deep well designs were the jet assembly is located in the water source. Two pipes are connected from the pump to the ejector housing (Figure 11). One delivers water to the pump and is called the suction or delivery line. The other, which recirculates water back to the ejector, is called the pressure or return line. The pump pressure supplied by the return line actually helps push water up through the suction line to the pump. The control valve must be adjusted to match the depth of the installation to ensure there is sufficient water diverted to the pressure line while still maximizing the discharge volume.

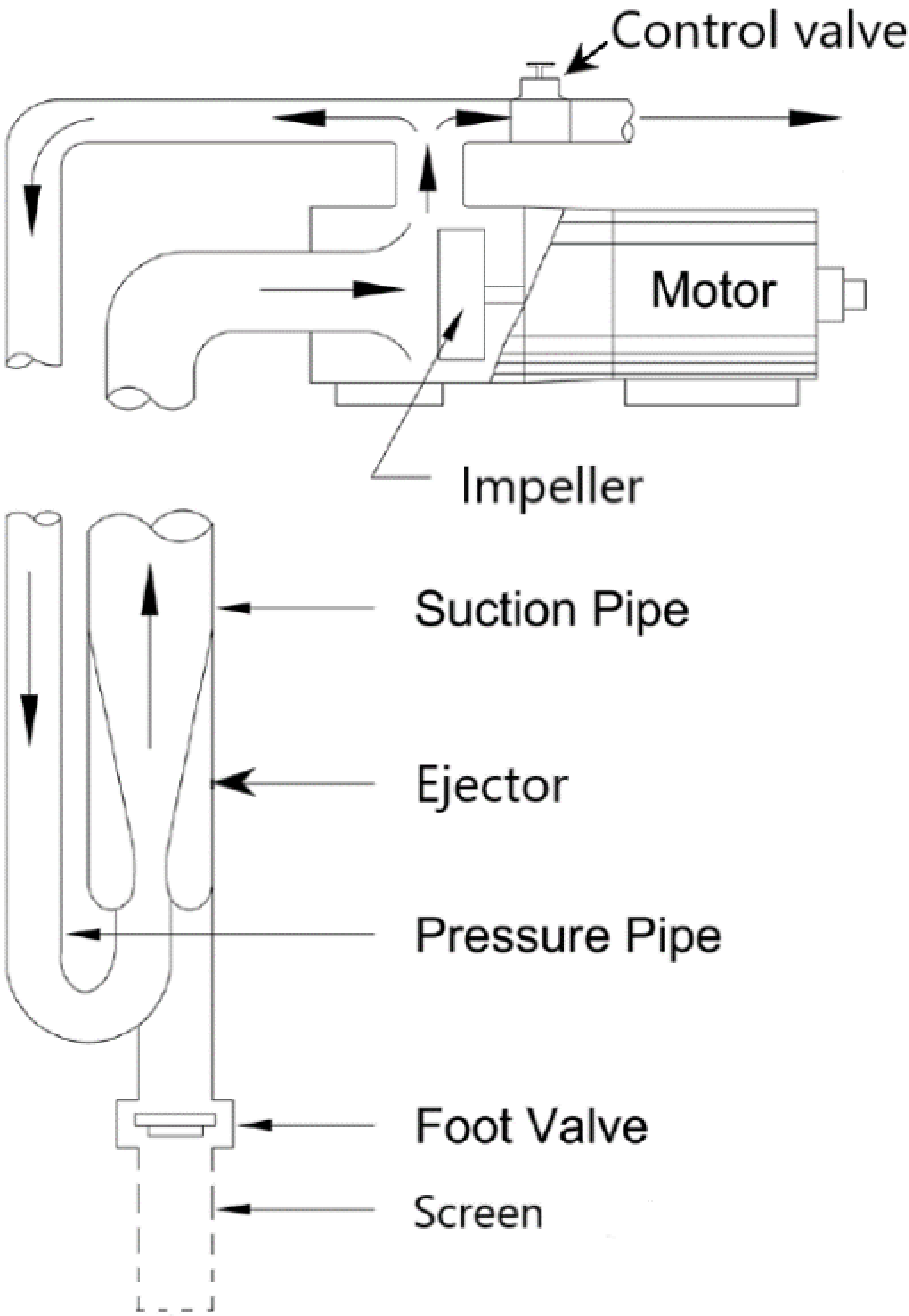

Figure 11. Deep well jet pump principle

Although this combination of atmospheric and pump pressure is very effective at lifting water long distances, up to 36.7 m (120′), it results in efficiency losses at the discharge side of the pump. For the most part the use of jet pumps for deep well applications has been replaced by submersible pumps.

Submersible pumps

Submersible pumps are a type of multi-stage centrifugal pump designed to be fully submerged in the water or other fluid it is pumping. Submersible pumps commonly employed in residential wells are typically designed with a diameter of 3 5/8″ to fit comfortably within a 4″ well casing. The motor is positioned at the bottom of the pump and is housed within a stainless steel cylinder that is attached beneath the pump assembly (Figure 12). Located just above the motor is the inlet screen, which serves as the point of entry for water into the pump from the well. When the pump is turned on, the motor drives a series of impellers stacked on top of each other within a stainless steel housing . The impellers are hydraulically connected in series each one is designed to increase the pressure of the water as it passes through and into the next. A typical impeller section for this type of pump will generally increase water pressure available from the impeller by approximately 9 psi per stage. The pump is supplied with a discharge check valve to hold pressure in the system when the pump stops.

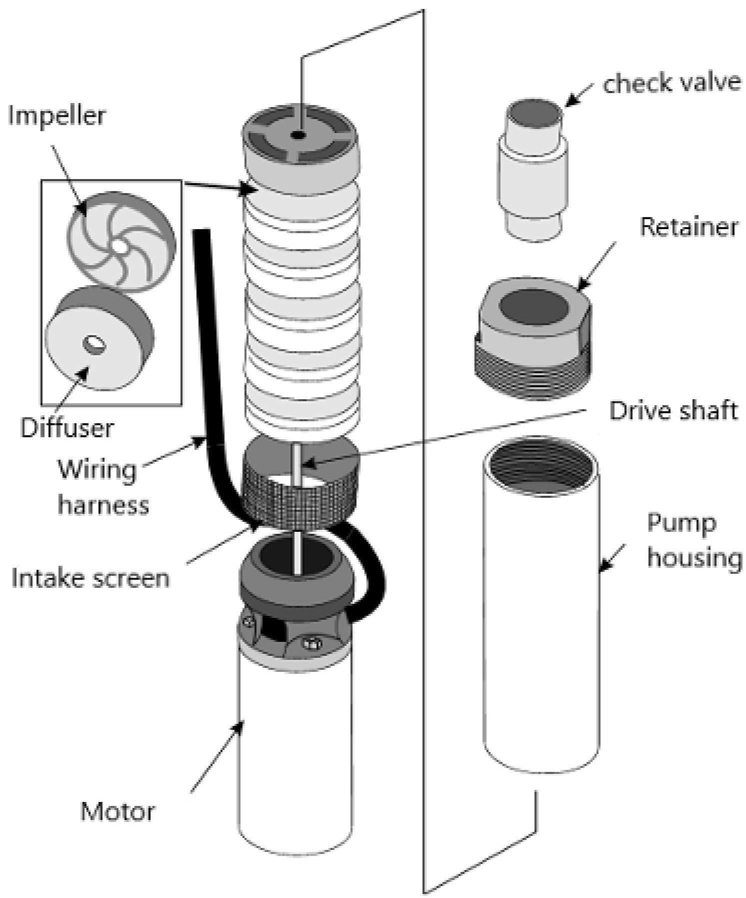

Figure 12. Submersible pump parts diagram

The multiple impeller design of submersible pumps enables many design options to match a wide range of applications. They can be designed with more impellers to create more pressure or impellers with a different design to deliver more volume. The horsepower of a submersible pump's motor and the number of impellers will indicate the potential capacity and the pressure it can deliver.

Additionally, submersible pumps are compact, highly efficient, quiet, and require minimal maintenance. They are also less prone to issues such as pump cavitation and are not affected by changes in atmospheric pressure, as they are completely submerged in water.

Pump Motors

The alternating current (AC) electric motor is one of the most common drivers used on water supply pumps. Alternating current power may be single-phase or three-phase electricity, but is generally single-phase for residences and three-phase for commercial or industrial use.

Unlike three-phase motors, single-phase induction motors cannot generate their own starting torque. To overcome this issue, two sets of windings are used. The “start or auxiliary windings” create a phase shift in the magnetic fields and produce an artificial second phase, allowing the motor to generate starting torque. As soon as the motor attains a sufficient speed, the starting means may be removed depending on the type of the motor.

Single-phase induction motors are classified and named based on their starting method. There are various types of such motors, which include capacitor start/Induction run (CSIR) motors, capacitor start/capacitor run (CSCR) motors, split-phase induction motors, and permanent split capacitor motors. Each of these motor types has different abilities in terms of horsepower, efficiency, starting torque, and starting current. The manufacturer chooses the motor type based on the pump requirements for the specific application. For residential above-ground rural water supply the pump and motor typically comes as part of a coupled package (Figure 13). Considering the proper electrical supply requirements are provided, the starting method holds minimal significance during installation since all the necessary circuitry is self-contained within the pump motor. Jet pumps are often supplied with a dual voltage motor. They are easily switch between 115V and 230V with a change plug or dial on the motor terminal board located under the motor end cover. It is essential that the setting is checked before the power is connected to the pump.

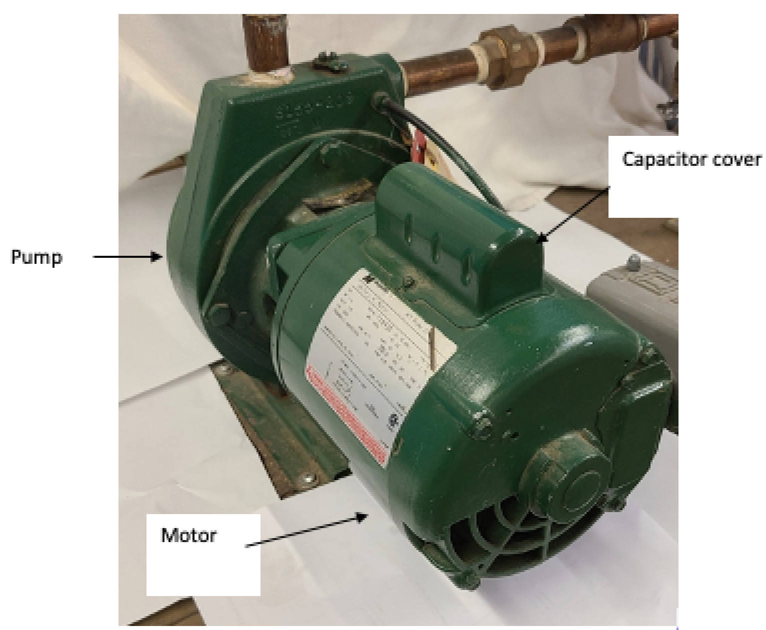

Figure 13. CSIR motor and pump package

Frequent cycling of the pump can lead damage to both the pump motor and the pressure switch contacts. This pump cycling not only causes potential harm but also creates significant disturbance for occupants within the building. To mitigate wear and tear on the pump motor, motor manufacturers recommend a minimum run cycle of two minutes for centrifugal pumps. This duration allows the pump to dissipate waste heat generated by the motor and motor starter mechanism, preventing premature failure of these delicate components. It is advisable to limit the pump cycling to no more than 25 times per hour.

Furthermore, when centrifugal pumps are installed indoors, it is crucial to ensure sufficient airflow around the motor. Maintaining proper ventilation and airflow around the motor will prevent overheating and ensure reliable pump operation. Insufficient airflow may cause the motor to overheat, activating its thermal overload motor protection.

Submersible pumps will often have some of the circuit components supplied separately in an above ground mounted control box. Control boxes contain starting capacitors, a starting relay, and, in some sizes, overload protectors, running capacitors, and contactors (Figure 14).

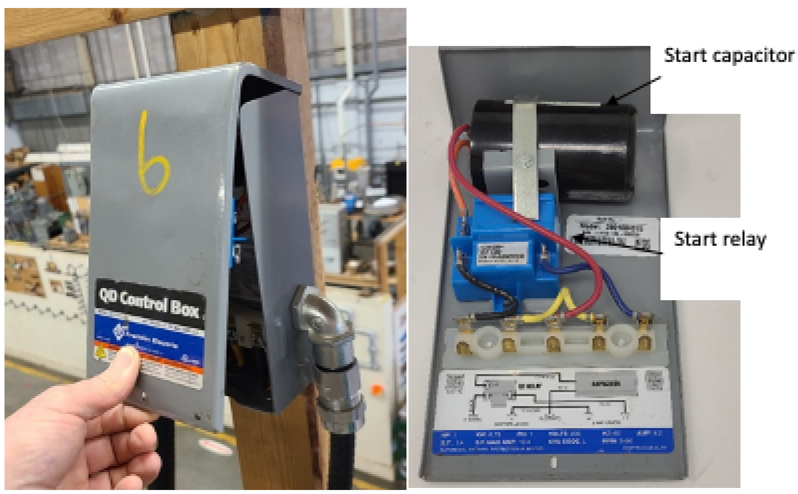

Figure 14. Submersible pump control box

Submersible motors

Submersible pumps typically used for residential wells are usually 3 5/ 8″ in diameter to fit inside a 4″ well casing. The motor, which looks like a stainless-steel cylinder is attached below the pump. Just above it is a screen of some type; many are made from plastic and some are made from stainless steel. This is the inlet screen of the pump and the point at which water comes into the pump from the well. Submersible motors have waterproof features to ensure that the motor winding conductors and motor leads are protected from water damage. Submersible motors come in 2 and 3-wire types. Both types have a green ground wire, which is not included in the wire count. Two-wire pumps have two black wires and a green wire, while three-wire pumps have a black, red, yellow, and green wire. (Figure 15).

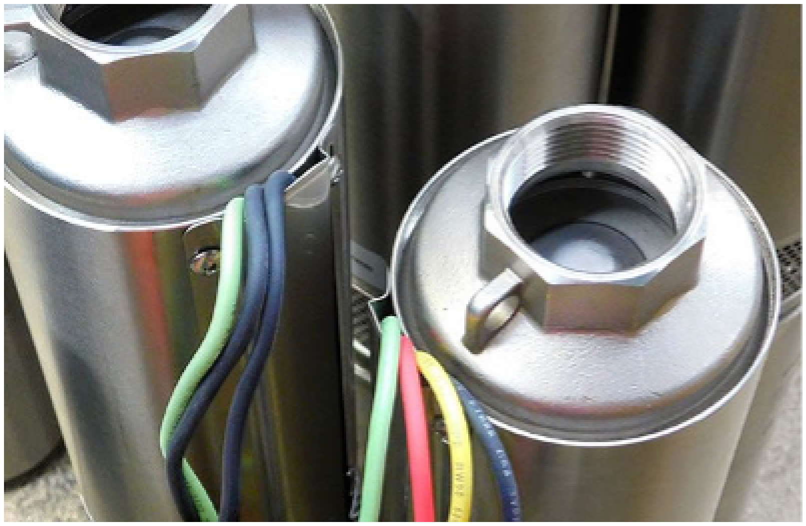

Figure 15. Two wire and three wire submersible pumps

Three-wire well pumps are either of the CSIR or CSCR types and have all of their starting components housed in the above ground control box. Two-wire well pumps, on the other hand, are of the permanent split capacitor or split phase types and do not use a separate control box because all the starting elements are built within the motor or pump housing. However, the horsepower rating of 2-wire motors is limited to around 1 ½ hp because larger horsepower motors require more capacitance to operate. While manufacturers indicate there is little difference in failure rates between the different types, 3-wire types seem to be preferred by industry because the starting components are located outside of the well, making them easily accessible for testing and replacement.

Permanent Magnet Synchronous Motors (PMSMs)

A Permanent Magnet Synchronous Motor (PMSM) generates a magnetic field using permanent magnets, as opposed to traditional electromagnets in the rotor. The rotor runs synchronously to the switching AC current due to the permanently magnetized magnets. Since induction motor slippage is not necessary, PMSMs can provide more accurate speed control and consume less energy. Unlike induction motors, PMSMs do not require separate start windings but rather rely on an electronic variable frequency drive for operation.

Variable Frequency Drives (VFDs)

A VFD is an electronic device that controls the speed of an AC motor by varying the frequency of the power supplied to the motor. Decreasing a pumps speed has a huge impact on the required motor output. By adjusting the frequency of the power supplied to the motor, a VFD can vary the speed of the motor, allowing it to operate at a more efficient level. VFDs also allow the motor to gradually ramp up to meet the actual flow and pressure demand, this soft start capability increases the motor life. Rural water supply pumps with VFDs are often referred to as constant pressure pump systems (Figure 16) because they have the capability to slow down the motor and the pump speed according to the required demand, leading to increased efficiency and reduced energy consumption.

Figure 16. Franklin Electric SubDrive (VFD) with phone app

Although VFDs can enhance the efficiency of single-phase induction motors, Permanent Magnet Synchronous motors (PMSMs) are entirely reliant on VFDs for operation. The use of PMSMs in conjunction with VFDs is not a new concept, and more design engineers and equipment owners are installing permanent magnet motor systems for well and booster applications due to their smaller size and superior efficiencies.

Pressure System Components

The pressure system components encompass the entirety of equipment, fittings, and piping employed to convey water from the well or water source to the household water supply lines. The specific components utilized depend on the type of pump and the requirements of the particular installation. Familiarizing oneself with the functionality of each part within the complete pump system and exploring the available alternatives, assists in selecting the appropriate equipment, pipe, and fittings required for the task.

Foot Valve

A foot valve is a type of vertical lift check valve with NPT connection on the outlet side and a strainer on the inlet side. The addition of the strainer prevents large pieces of debris from clogging the foot valve while it's in the open position, also avoiding damage to the water pump. (Figure 17).

Foot valves are used in shallow well jet pump and deep well jet pump installations. They are installed onto the end of a pump suction line to hold water in the suction line so that the pump remains primed while not in operation. When the pump starts, and a vacuum is created inside the suction piping, the valve opens and water from the well or lake flows into the pipe. When the pump stops, and pressures equalize across the pump, the valve closes. Some foot valves have a lightly spring-loaded disc and others are simply a weighted disc, it is best to install the foot valve in the vertical position for most efficient operation.

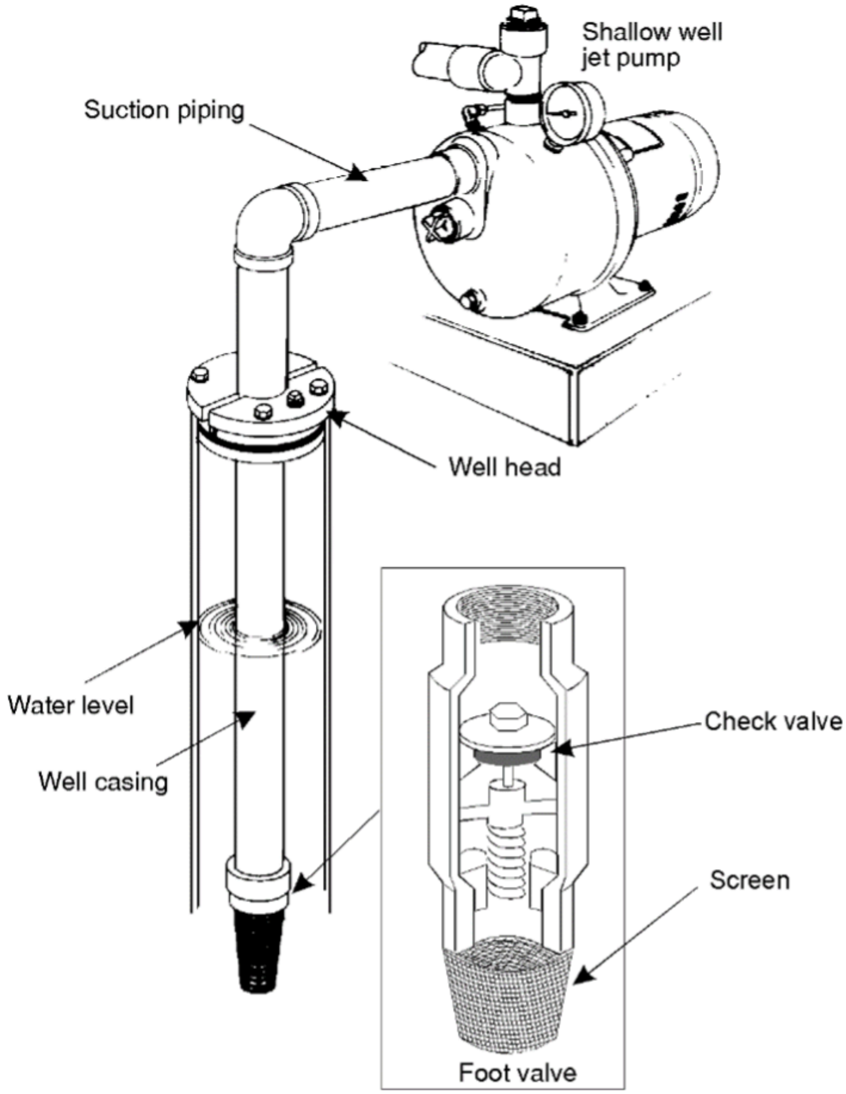

Figure 17. Foot valve

Inline Check Valves

Submersible pumps do not use foot valves; instead a check valve is usually built into the discharge side of the pumps. If the pump does not have a built-in check valve, a spring-loaded inline check valve should be installed in the discharge line within 7.6 m (25 ft) of the pump and below the drawdown level of the water supply (Figure 18). The check valves on a submersible pump is used to hold pressure when the pump stops. They are also used to prevent backspin, water hammer and upthrust. Any of these or a combination of them can lead to immediate pump or motor failure, a shortened service life or operating problems in the system.

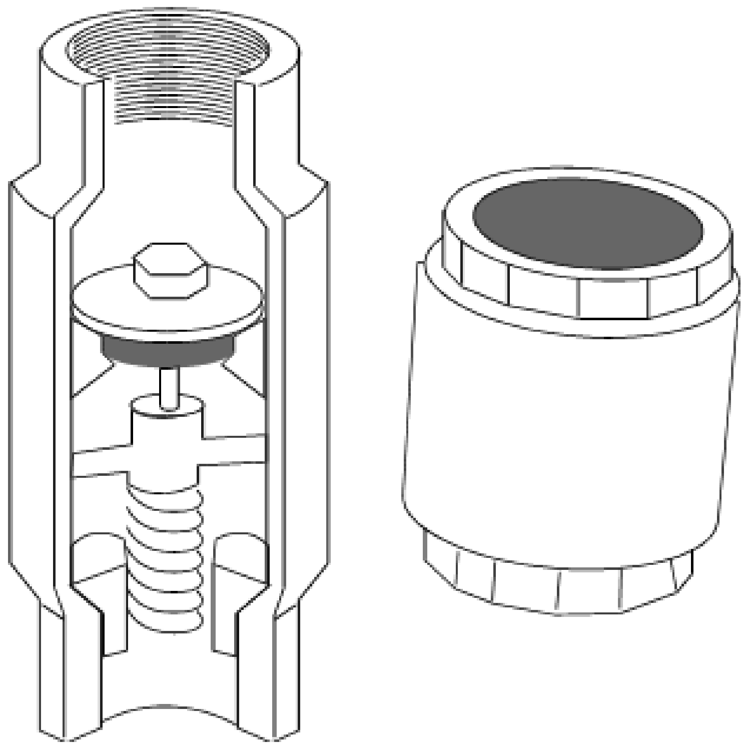

Figure 18. Inline check valve

For pump settings 60 m (200 ft) or deeper, manufacturers often recommend the installation of additional spring-loaded inline check valves at regular 60 m (200 ft) intervals towards the wellhead. This setup helps reduce hydraulic shock on the system caused by starts and stops. Incorporating multiple check valves enables the system to absorb and diminish shock effects both above and below each check valve, thereby safeguarding the lifespan of valves, pump, and pipes. Furthermore, some manufacturers may require an extra check valve positioned above ground, typically near the pressure tank. Strict adherence to the manufacturer's specifications regarding check valve requirements is of utmost importance. However, exceeding the recommended number of check valves must be avoided, as it can result in unforeseen complications.

Riser Pipe (Pump Drop)

Different materials are used for well pump pipe risers, each with its own characteristics and suitability for specific applications. One of the greatest variable costs that a well owner has is the labor paid for the installation and removal of their well pump and motor. To minimize this cost over time, it is important to choose drop pipe that will last while also considering the ease of installation and removal.

The main factors to consider are weight limitations, depth limitations, flow restriction, water composition, ease of installation, and ease of removal. The deeper the pump setting, the more important it is to pay attention to the pipe manufacturer's recommendations as to the maximum depth allowable for the size and schedule of the riser pipe, the maximum horsepower allowable, and the type of couplings and check valves to use.

Here are some commonly used materials and their characteristics:

Polyethylene pipe is a durable and flexible material often used for well pump pipe risers. It has excellent resistance to corrosion, abrasion, and chemicals. Polyethylene risers are one of the most popular materials used for pump risers as they are a lightweight, continuous section without any connections, making them easy to install by hand. Polyethylene pump drop is sold in 160 psi or 200 psi pressure ratings, and size ranges from 1" -2 IPS to fit barb insert fittings. It is available in 100 -1000 ft coil lengths. Due to its maximum pressure rating, polyethylene pipe is not recommended for installation over 300 ft. in depth.

Polyvinyl Chloride (PVC) is widely chosen for well pump pipe risers due to its cost-effectiveness, resistance to corrosion, and ease of installation. It is a lightweight and durable material with excellent chemical resistance. Pre-threaded PVC drop pipes are available in various sizes, ranging from 1″ NPT to 2″ NPT, and come in 20 ft lengths of Sch 80 and Sch 120. This versatility enables their use in different pump setting depths, system pressures ranges, and pump ratings. Be sure to following the manufactures guidelines for instance; PVC Sch 120 1 ¼" drop pipe is generally recommended for systems with a maximum depth of 520′ and a pump rating of up to 2.0 HP. It is important to be aware that PVC can gradually become brittle over time and may be prone to damage from extreme temperatures or physical impact. Care should be taken to protect PVC risers from such factors to ensure their longevity and reliable performance.

Galvanized steel risers offer good strength and durability, making them suitable for greater well depths and environments. Galvanized steel risers can handle high pressures and temperatures. However, over time, the zinc coating may degrade, leading to corrosion also their rigidity makes installation more challenging than PVC or HDPE.

Stainless steel risers offer superior strength, durability, and resistance to corrosion. They are highly suitable for corrosive environments or wells with high mineral content. Stainless steel risers are available in different grades and can withstand high pressures and temperatures. They have a long lifespan and require minimal maintenance and are suitable for greater well depths. However, stainless steel risers tend to be more expensive compared to other materials.

Stainless steel and Galvanized drop pipes are capable of going to almost any depth as they have the highest pressure ratings. In fact, the check valves used will normally be the first thing to limit the depth in the system. For example, a commonly used brass check valve is rated for about 600 feet and a ductile iron check valve is rated for about 1500 feet.

Torque Arrestors

All plastic drop pipes for a submersible pump should be equipped with a torque arrestor (Figure 19) to keep the submersible pump centred and control flexing movement of the pipe caused by the pump starting and stopping. As the pipe flexes, it may contact the interior of the well casing and cause premature wear of the drop pipe. The torque arrestor controls this movement to keep the pipe from wearing against the casing.

Figure 19. Torque arrestor

Follow the manufacturer's instructions for arrestor spacing, number required and method of attachment to the drop pipe. Usually, installations using galvanized or stainless pipe do not require a torque arrestor since the pipe does not flex due to the torque, but pump manufactures still recommend the use a torque arrestor at the pump, as a centralizer for the pump to ensure proper motor cooling and reduce inlet turbulence.

Safety Rope

A safety rope is connected directly to the submersible pump and secured at the well head. The safety rope provides a backup to enable the installer to pull the pump from the well if the riser pipe fails. Every pump should have a safety rope secured to it before hanging it in the well.

Pitless Adapter

If the well head is not equipped with a well house to protect it from the elements then a pitless adapter should be installed (Figure 20). A pitless adapter is a special type of fitting that allows supply piping to connect to the well casing below the frost level. Its main purpose is to allow access to the water supply from the well without the need for a traditional well pit or underground chamber.

Figure 20. Pitless adapter

It allows the water pipe to pass through the well casing sidewall horizontally. This horizontal connection eliminates the need for a vertical pipe extending above the ground, which is a common feature in traditional well pits. It provides a watertight seal between the well casing and the drop pipe.

The second major advantage of these adapters is they provide ease of installation and removal of pumps or lines from the well. The inner well portion of the adapter has removeable elbow with a dead end threaded tapping on the top. This enables a lift out pipe to be connected to the adapter, to reach into the well and lift the riser pipe and pump assembly. The saddle clamp is designed to fit and seal the full range of casing sizes.

Well Caps and Seals

The top of the water well must be protected from debris and contaminants entering the well. Both well caps and seals are designed to cover the top of a water well and, in effect, enclose the well casing so that the well is protected. They provide an access point where supply piping and pumps can be attached and enable access to the well for maintenance and repairs . There are a variety of caps and seals to match the different applications.

Caps

A well cap is cover that sits on top of a well casing, like a lid it is seated along the top and outer edges of a well casing (Figure 21 left). Caps are used when a pitless adapter is installed below the frost line and do not support the pump. Well caps provide venting for the well are often designed with the ability to allow pump wire to pass through underneath the lid (most often via conduit) and there is often a grounding bolt also included. For exposed applications there are watertight types (Figure 21 right) that are sealed all the way around the casing and conduit with a separate vent screens added, to allow the well to breath but keeps vermin out.

Figure 21. Well caps

Seals

A well seal is utilized when the drop pipe can extend above ground level, providing several functions beyond those of a well cap. Positioned on top of a well casing, the well seal enables the passage of pump wire and water supply through designated holes in its design. Figure 22 displays a single-hole well seal on the left, suitable for installing either a shallow well jet pump or a submersible pump. In addition to the centre drop pipe hole it features two threaded tappings; one for venting and the other for accommodating cables in submersible pump installations. The image on the right shows a double-hole well seal designed for deep well jet pump setups, enabling two pipes to descend into the well. Notably, the double-hole variant only includes a vent tapping, as a power cable tapping is unnecessary for jet pump installations.

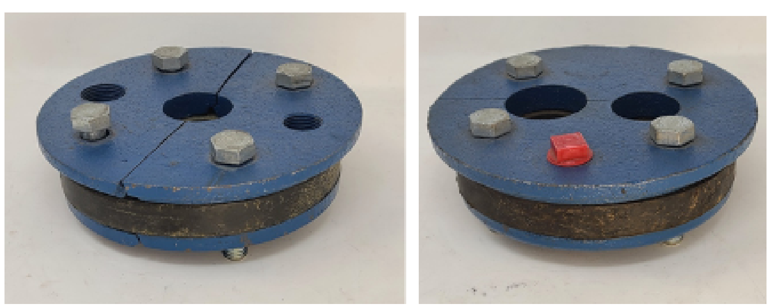

Figure 22. Well seals

The top plate of a well seal is seated along the top and inside edges of a well casing. When the bolts are tightened the two halves draw together causing the rubber seal to expand out towards the inside of the well casing and the outside of the discharge pipe creating a watertight seal.

Well seals are commonly constructed from materials such as cast iron, plastic, cast aluminum, and steel. The selection of materials is contingent upon the depth and size of the pump, ensuring that the seal possesses the necessary strength to support the estimated weight of the pump, drop pipe, cable, and water column.

Pressure Tanks

A pressure tank is a vital component in pumped water supply systems, designed to maintain consistent water pressure and reduce the frequency of pump operation. Because water is noncompressible, there needs to be some method in place to provide usable pressure without the pump running, when small amounts of water are drawn from the system. The pressure tank acts as a buffer or reservoir, storing pressurized water for immediate use when the demand arises.

The primary purpose of a pressure tank is to prevent rapid cycling of the pump, known as short cycling, which can cause premature wear and tear, and affect the system's efficiency. When a pump starts, it rapidly builds up pressure and delivers water to the tank until a predetermined level is reached. This level is typically controlled by a pressure switch. As water is drawn from the system, the pressure drops, triggering the pump to restart, refilling the tank while also pushing some water to the system to meet any momentary fixture demand. By storing a reserve of pressurized water, the pressure tank reduces the frequency of pump cycling, allowing the pump to run less frequently and for longer durations, which increases its lifespan.

The operation of a pressure tank is based on the principles of air and water separation. Inside the tank, there is a flexible bladder or diaphragm that divides the tank into two compartments: one for water and the other for compressed air (Figure 23). When the pump fills the tank with water, the air inside the tank is compressed further, increasing the pressure. This compressed air acts as a cushion, exerting pressure on the water and maintaining a consistent pressure in the system even when the pump is not running.

As water is drawn from the tank, the compressed air expands, pushing the water out and maintaining a steady flow until the pressure drops to a specific low-pressure threshold. At this point, the pressure switch signals the pump to restart and refill the tank to the predetermined pressure point.

Notice on the diaphragm pressure tank shown in Figure 23 the flexible diaphragm attached to the inner sides of the tank. A bladder pressure tank uses a balloon-type flexible membrane that is attached to the inlet/outlet connection to the tank, essentially creating a bag that that the water is stored in. The advantage of a bladder tank is that no water comes in contact with the tank itself. This is particularly helpful if the water has corrosive properties.

Both bladder and diaphragm tanks are precharged and have an air charging (Schrader, Snifter) valve, at the top. Tanks are made of steel or a light weight fibreglass composite.

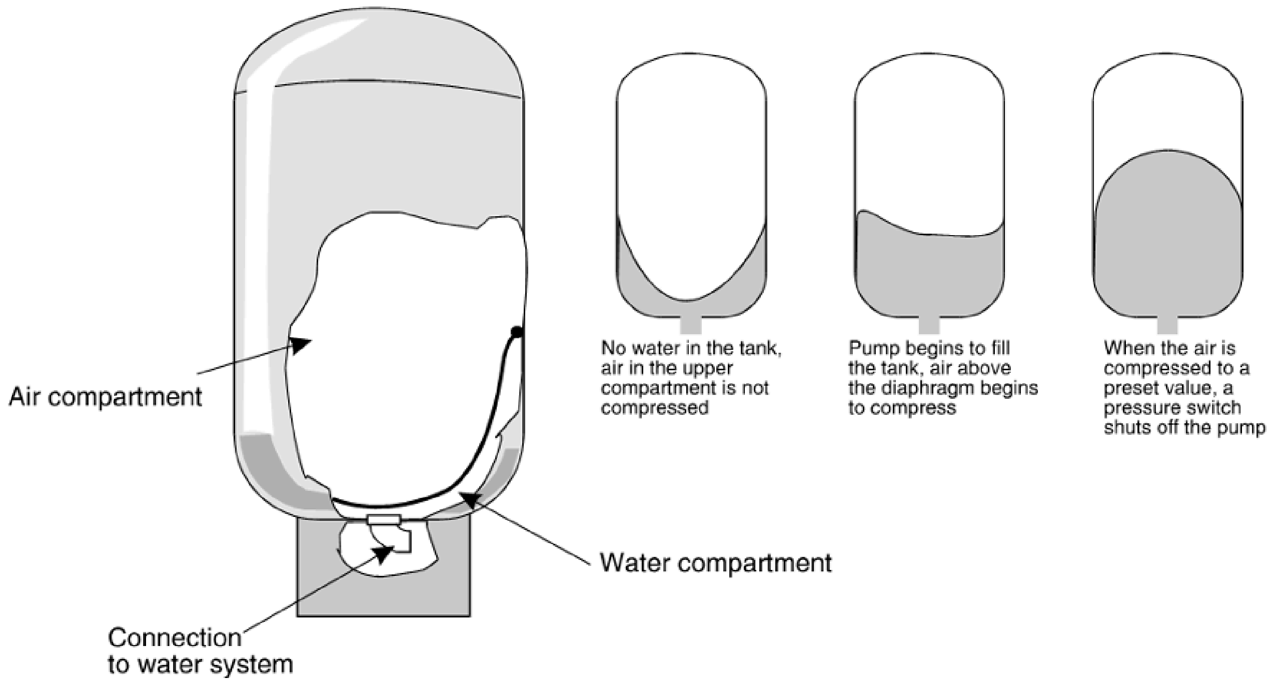

Figure 23. Diaphragm pressure tank operation

Traditional pressure tanks of older designs lacked a bladder or diaphragm, resulting in direct contact between air and water within the tank (Figure 24). This direct contact causes a gradual absorption of air molecules by the water over time, a phenomenon known as waterlogging. Waterlogging leads to increased pump cycling, with more frequent cut-ins and cut-outs. Although some tanks incorporated a plastic disk to separate the air and water, its effectiveness varied. Pressure tanks with air-water contact necessitate periodic air injections to maintain the required air volume. Various air-volume control mechanisms are available, which introduce fresh air into the system during pump operation. Additionally, such tanks have the drawback of being incapable of being pre-charged with compressed air. Consequently, they require larger tank sizes compared to pre-charged diaphragm or bladder style tanks to achieve an equivalent reserve of usable water, also known as drawdown capacity.

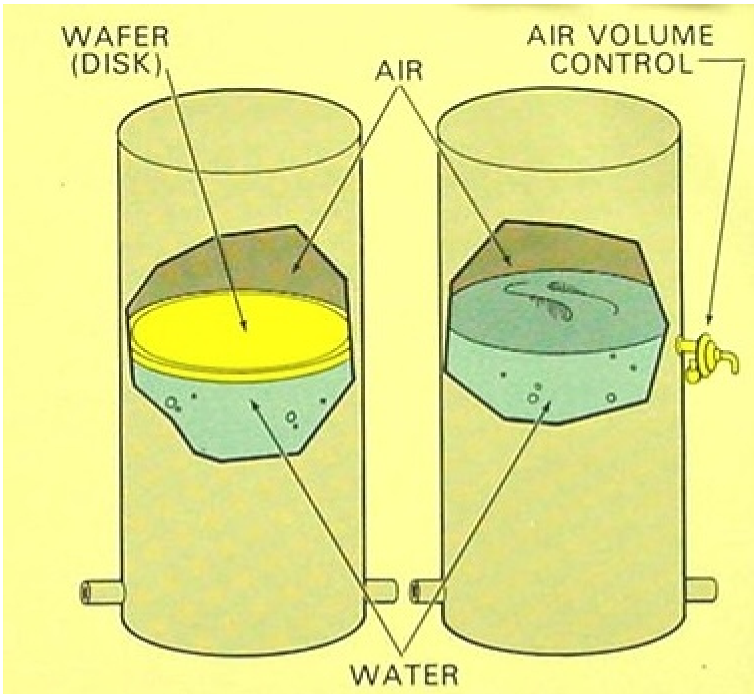

Figure 24. Standard pressure tanks

Without a pressure tank the pump would have to tum on every time there is even the slightest demand on the system, even to fill a small glass of water. It can be inferred that the size of the pressure tank directly impacts the availability of usable water and the frequency of pump operation. Larger tanks provide a greater water supply while minimizing pump cycling, but they come at a higher cost and require more space. Conversely, smaller tanks offer cost and space advantages, but they may lack sufficient water reserve. Undersized tanks exhibit undesirable characteristics such as frequent pump cycling, leading to pump wear and unnecessary energy consumption. Additionally, they may fail to meet peak load demands when multiple faucets are in use simultaneously. Achieving a reliable and practical system necessitates a careful balance of these factors. In Learning Task 2, we will explore methods to calculate the optimal tank size, considering variables such as the pump's flow rate, desired pressure range, and usage patterns.

In VFD constant pressure systems, the pumps are specifically designed to handle frequent starts and stops without harming the motor. Consequently, the pressure tank does not need to provide extensive water storage or manage extended periods of demand. Instead, its role is primarily to dampen sudden pressure surges and compensate for any slight delay in pump shutoff and the initial start-up. Due to the reduced requirements for water storage and demand management, the pressure tank in VFD constant pressure systems can be compact in size. Its purpose is more focused on maintaining system stability and preventing pressure fluctuations rather than providing a significant reserve of water. VFD water systems will operate at a very low pressure differential therefore the water within the pressure is not completely flushed each cycle like a conventional system. The water that can remains in the pressure tank for extended periods of time can stagnate. This stagnate water may get drawn out of the tank and noticed by the users at times when there is a large initial flow surge or a power outage. To eliminate stagnate water accumulation within a pressure tank, serving a constant pressure VFD system, there are specially designed pressure tanks in which the water will continuously flow through them. These tanks have a special tank tee that diverts system water into, and more importantly out of the tank while the pump is running (Figure 25). This constant flushing action ensures that the water in the tank remains fresh.

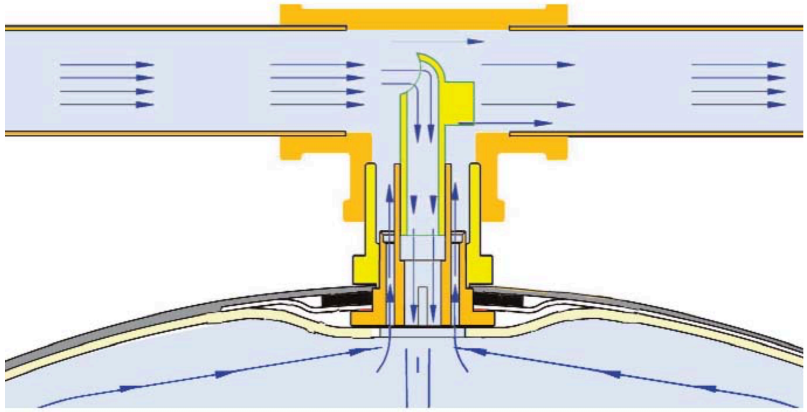

Figure 25. Flow-Thru pressure tank connection

Pressure Switch

A pressure switch monitors the pump discharge pressure and controls the electrical power supply to the pump. As stated earlier, is works in tandem with the pressure tank to maintain consistent water pressure and optimize the frequency of pump operation. A small, box-like unit, the pressure switch has a built-in flexible diaphragm that moves back and forth reacting to the water system pressure (Figure 26). The movement of the diaphragm opens and closes a set of contact points that control the power to the pump motor. This is a snap-acting switch, so the electrical contact points are quickly opened.

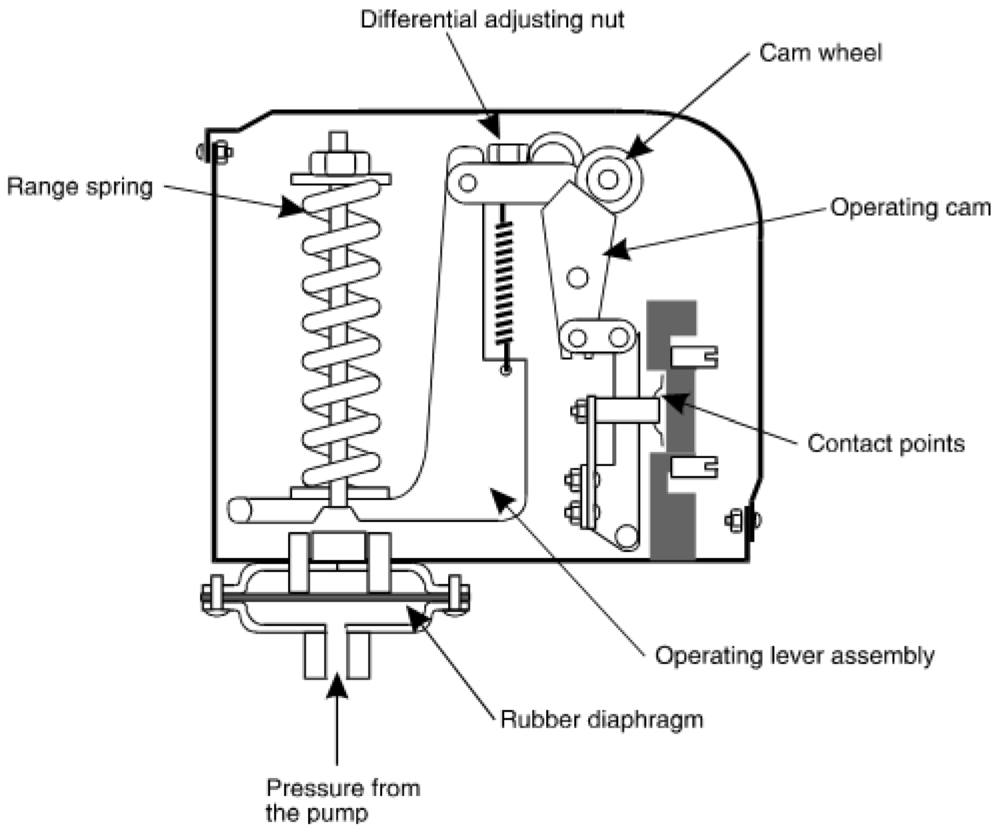

Figure 26. Pressure switch

All Pressure switches have two operating thresholds known as the cut-in (Reset Point) and cut-out (Trip Point) settings. The cut-in point is for the falling pressure where the pump will be started, and the cut-out point is for the rising pressure when the pump will be stopped. The standard pressure differential between these two points is 140 kPa (20 psi). Pressure switches are available from the manufacture at pre-set ranges of:

- 140 kPa (20 psi) pump cut-in and 280 kPa (40 psi) pump cut-out
- 210 kPa (30 psi) pump cut-in and 345 kPa (50 psi) pump cut-out
- 280 kPa (40 psi) pump cut-in and 410 kPa (60 psi) pump cut-out

Both the entire range and the differential can be adjusted.

Some Pressure switches come with a low pressure cut-off to protect the pump (Figure 27). It is set at 10 psi. and shuts off the pump in the event of an abnormally low system pressure. These switches will have a manual reset lever which allows the pump to be run, and build up pressure, once the problem is resolved.

Figure 27. Pressure switch with low pressure cut-off

VFD constant pressure systems do not use these types of conventional pressure switches instead they use electronic transducers as pressure sensors.

VFD Pressure Sensor/Transducer

A pressure transducer, also known as a pressure sensor (Figure 28), is a device that converts the mechanical force exerted by the fluid into an electrical signal. In a VFD system the pressure transducer continuously monitors the pressure and sends the corresponding electrical signal to the VFD controller. The VFD controller then adjusts the motor speed, based on the signal received from the pressure transducer, to maintain a constant pressure setting.

Figure 28. VFD pressure sensor

Mascontrol

The Mascontrol is a type of self-contained constant pressure device designed to replace both the pressure tank and the pressure switch (Figure 29). This control has a diaphragm switch that reacts to pressure change and energizes the pump. It will operate the pump whenever there is a demand on the system. The reasoning behind this device is that the pump will accumulate less starts if it operates on demand rather than recharging the pressure tank multiple times for long usage cycles. This reasoning is dependent on the type of water usage. For example, does the user have a lot of long run applications, such as irrigation, that would require multiple pump starts with a conventional tank system. The Mascontrol is not a VFD as the pump runs at full speed when activated, the constant pressure output is controlled by an integral flow valve. It also has low pressure switch to protect the pump against dry running.

Figure 29. Mascontrol pump controller

Pressure Relief Valve

The submersible pump you choose may have the ability to generate higher pressure than what the pressure system components can withstand. For this reason, manufacturers of submersible pumps recommend the installation of a pressure relief valve. This relief valve is typically set at 10 psi above the cut-out pressure of the pressure switch, offering protection against overpressure in the system in case the pressure switch malfunctions.

To facilitate the installation of the relief valve, as well as the pressure switch, pressure gauge, and drain valve, a manufactured tank tee (Figure 30) provides a convenient connection point. This tank tee serves as a practical and efficient solution for incorporating these components into the system.

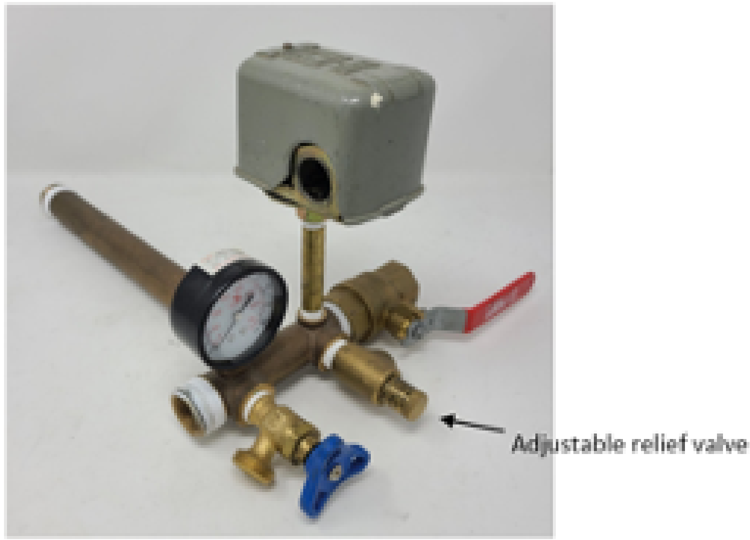

Figure 30. Tank tee

Now complete Self-Test 1 and check your answers.

Self-Test 1

Self-Test 1

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://opentextbc.ca/plumbing4c/?p=45#h5p-1 (https://opentextbc.ca/plumbing4c/?p=45#h5p-1)

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Learning Task 2

Select and Size Water Supply Pressure Systems

The purpose of well pumps is to transport water from its source to various supply points within a household or building. However, the selection and sizing of the pump are influenced by various factors, that will dictate the type and size of pump that can be utilized. Therefore, before proceeding with the selection and installation of the pump and accompanying system components, plumbers must carefully evaluate the unique variables specific to each installation.

The plumber will have to:

- Gather well data: Well size, depth, and yield are necessary to select the pump.
- Estimate water demand: Factors such as the number of household members, water usage patterns, and any specific water demands such as irrigation or livestock watering are considered. This will help determine the gallons per minute (GPM) or liters per second (L/s) flow rate needed.
- Calculate the Total Dynamic Head (TDH): The TDH represents the total resistance the pump must overcome to deliver water from the well to its intended destination. It includes factors such as vertical lift, horizontal pipe length, pipe diameter, friction losses, and any elevation changes. Calculate the TDH using hydraulic principles and equations.
- Select the Pump Type: Choose the appropriate type of pump based on the well depth, water quality, and specific application requirements. Common types include submersible deep well pumps, and convertible jet pumps. Consider factors like pump size, motor type (single-phase or three-phase), and the need for additional features like built-in controls or protection mechanisms.
- Size the Pump: Based on the selected pump type, refer to the manufacturer's pump sizing charts or utilize pump sizing software to determine the correct pump size. Consider factors such as the available power supply, discharge pipe size, and the pump's ability to handle the anticipated water demand.
- Select the other major components that suit the installation including: pressure tank, pressure switch, check valves, pressure relief valve, lightning arrestor, and overload protection

Well Data

The well data is used to ensure the proper pump is selected to match the well size, depth and yield. The property owner should have a copy of the well data with their property records. For wells constructed since 2016 the well ID plate number, attached to the casing, can be used to obtain the well records from the online government database. The database contains information on well construction such as date of construction, driller name, well depth, geology that the well is constructed in, estimated well yield/productivity at the time of construction, and static water level.

The diameter of the well will affect the type of pump you can select. The standard casing size is 6”, submersible pumps require a minimum well size of 102 mm (4”).

The depth to the pumping water level is an important consideration in any pumping system. This information is based on the drawdown in the well (Figure 31) when the pump is running, and must be known to ensure that the pump setting depth is sufficient to prevent the water level from dropping below the pump or foot valve level.

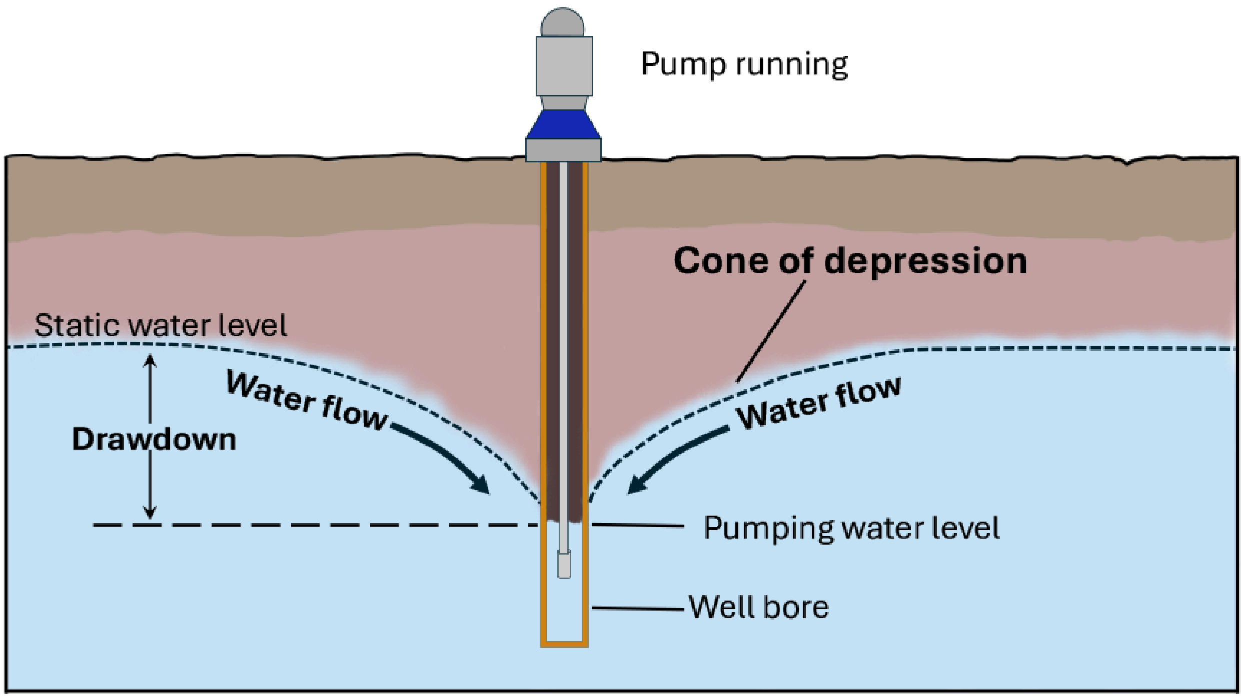

Figure 31. Well water levels

When a well is pumped, water is drawn from the surrounding aquifer or underground water source. As water is extracted, the pressure in the well decreases, causing the water level in the well to drop. The difference between the water level in the well when it is not being pumped (static water level) and the lowered water level during pumping is referred to as the drawdown.

Well Yield

The drilling records will also include data on the productivity of the well at the time of construction. A yield test is performed by the driller to determining the sustainable rate at which the well will produce water. A temporary; pump, flow rate, and water level measuring devices are installed. To perform the yield test, the static water level is first measured then water gets pumped from the well. at a steady rate continuously for at least one hour. The pumping water level is measured at specific intervals during the test to determine the maximum capacity of the well. The well yield will always determine the maximum size pump that the well can accommodate. For most single-family homes, a minimum flow of 6 GPM is suggested from a well or spring. This flow would provide 360 gallons of water each hour, which would be sufficient to meet most home water peak demands. If the maximum pump capacity allowed by the well will not meet the peak flow requirements of the user then other intermediate storage options may need to be employed.

Estimate Water Demand

In general, we use 190 to 380 litres (50 to 100 US gallons) water per person per day in our homes. For the purposes of planning a water system, the total daily water use is less important than the peak usage, as the water demand is rarely evenly spaced over a 24-hour period. There are a number of different methods and guidelines available to determine water demand.

Two common methods of determining residential capacity requirements are:

- Fixture count
- Peak demand tables

Both methods should yield similar results

Fixture Count Method

A simple method is to count the number of fixtures in a house and allow 1 USGPM per fixture. For example, if you had a household with two bathrooms with a toilet, sink and shower in each, a washing machine and laundry sink, 2 outside hose faucets, a kitchen sink and dishwasher you would estimate 12 fixtures so you would need a pump that had a capacity of 12 USGPM.

Peak Demand Tables

There are many versions of peak demand tables similar to the example shown in Figure 32. From the table you conclude the approximate potential number of occupants in the home by looking up the number of bedrooms then cross reference that to the number of available bathrooms. This will give you the necessary pump capacity in GPM to meat the estimated peak demand.

Figure 32. Peak Demand Period Usage (GPM) Based on Number of Bedrooms and Bathrooms

# of Bedrooms	**1 Bathrooms in Home**	**1 ½ Bathrooms in Home**	**2-2 ½ Bathrooms in Home**	**3-4 Bathrooms in Home**
2	6 GPM	8 GPM	10 GPM	
3	8 GPM	10 GPM	12 GPM	
4	10 GPM	12 GPM	14 GPM	16 GPM
5		13 GPM	15 GPM	17 GPM
6			16 GPM	18 GPM

Both methods should yield similar results. Farm applications will require more detailed calculations than residential applications.

Estimating Farm Systems

In addition to the requirement for the house or other structures, the drinking and cleaning requirements of the animals must be determined. A table such as the one shown on Figure 33 can be used to determine the animals daily water requirements. Generally, the pumping system should be capable of supplying the animal's daily requirements within a two-hour period.

$$\text{Pump Capacity (GPM)} = \frac{\text{Total daily requirement (gallons)}}{\text{120 minutes (2 hours)}}$$

Figure 33. Daily farm animal water consumption

Type of Animal	**Total Usage per Day (Gallons)**
Horse, mule or steer	12
Dry cow	15
Milking cow	35
Hog	4
Sheep	2
Chickens (per 100)	6
Turkeys (per 100)	20

Additional Supply Considerations

It is important to ensure that water supply systems have sufficient reserve capacity to meet future needs. This includes considering potential expansions of structures, the addition of water-consuming appliances, animals, irrigation, and fire protection requirements. When designing domestic irrigation systems, it is possible to work within the houses calculated demand flow by utilizing zoning and setting timers for off-peak periods.

As mentioned earlier, if the total system demand exceeds the yield of the well, it is necessary to explore intermediate water storage options. In cases where the maximum allowable pump size is nearly sufficient, oversizing the pressure tank may help meet peak demand requirements.

Alternatively, a two-pump system can be installed (Figure 34), where the well pump supplies water to an atmospheric holding tank at a rate that falls within the well's capacity. The size of the tank would be designed to meet the peak demand usage period. A float switch or liquid level sensing devices in the storage tank controls the well pump. This enables the well pump to run for several hours to fill the holding tank, thereby not exceeding the supply capability of the well. The second pump functions as a booster pump, supplying pressurized water from the holding tank to the system. The booster pump is sized to handle the peak demand flow rate.

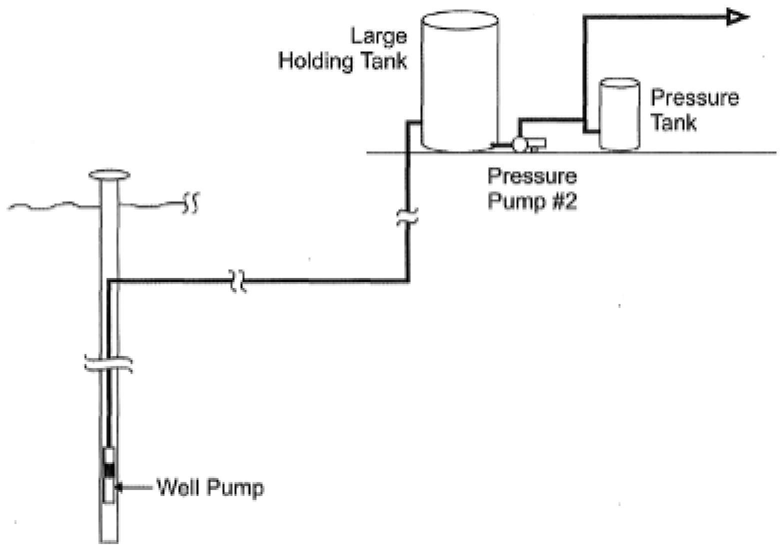

Figure 34. Low yield two-pump system

After the capacity requirements of the system have been determined and the well yield confirmed the pumping head requirements of the system must be determined.

Calculate the Total Pumping Head

Centrifugal pumps allow some fluid to remain within the pump casing due to the clearance between the impeller rim and the pump jacket, which permits some slippage of the fluid. This characteristic is important to understand and is why centrifugal pumps are known as variable displacement pumps. As discharge pressure or height (pumping head) increases, the pump's capacity to move water diminishes due to increased slippage.

To calculate the total pumping head, it is necessary to consider various factors that affect water flow, including:

- Vertical suction lift from the water source to the pump
- Suction pipe friction loss
- Vertical discharge lift from the pump to the intended point of use
- Discharge pipe friction loss
- Desired pressure at the point of use

It is important to note that the pump does not differentiate between head (vertical lift) and pressure or height of the pumped fluid. Therefore, all measurements need to be converted into feet of head for accurate calculation and understanding.

Suction head is all of the resistance created by the vertical lift from the water in the well to the pump.

Discharge head is all of the resistance created on the discharge side of the pump. For submersible installations there are no suction resistance factors to consider in the total pumping head calculations.

Pipe Friction Loss

Any two substances that touch while moving past one another will cause friction, and this is also true of water travelling through a pipe. The piping friction loss is the loss of pressure or head caused by this movement.

Friction loss on the suction side adds feet in lift. Friction loss on the discharge side results in a loss of pressure. Although in reality, friction loss and how it contributes to the overall pump resistance are the same on both the suction and discharge sides of the pump.

The amount of friction loss that increases the total head of a pumping system depends on many things, including type, length and size of pipe and fittings, as well as rate of flow. There are many sources of information available to assist you in determining the piping friction loss including formulas, spreadsheets, tables and phone apps. Two examples of friction loss tables are shown in Figure 35. It is important to use a table that matches the type of pipe. You will notice when comparing these two tables the friction loss shown for the same nominal sizes is much lower on the PE than the PVC. In this case it is primarily due to the smaller inside diameter of the IPS Sch80 PVC compared to the PE SDR size.

[Skip Table] (#skip_table_1)

Figure 35 A: Polyethylene (PE) SDR 7, 9, 11.5, 15
Sizes 1" through 2" Flow 1 gpm through 100 gpm
Friction loss per 100 Feet of Pipe (psi/100ft.)

Flow (gpm)	**1″, ID: 1.049**	**1 ¼”, ID: 1.380**	**1 ½”, ID: 1.610**	**2″, ID: 2.067**
1	Velocity (ft/s): 0.37, Loss (psi): 0.04	Velocity (ft/s): 0.21, Loss (psi): 0.01	Velocity (ft/s): 0.16, Loss (psi): 0.00	Velocity (ft/s): 0.10, Loss (psi): 0.00
2	Velocity (ft/s): 0.74, Loss (psi): 0.14	Velocity (ft/s): 0.43, Loss (psi): 0.04	Velocity (ft/s): 0.31, Loss (psi): 0.02	Velocity (ft/s): 0.19, Loss (psi): 0.01
3	Velocity (ft/s): 1.11, Loss (psi): 0.29	Velocity (ft/s): 0.64, Loss (psi): 0.08	Velocity (ft/s): 0.47, Loss (psi): 0.04	Velocity (ft/s): 0.29, Loss (psi): 0.01
4	Velocity (ft/s): 1.48, Loss (psi): 0.50	Velocity (ft/s): 0.86, Loss (psi): 0.13	Velocity (ft/s): 0.63, Loss (psi): 0.06	Velocity (ft/s): 0.38, Loss (psi): 0.02
5	Velocity (ft/s): 1.85, Loss (psi): 0.76	Velocity (ft/s): 1.07, Loss (psi): 0.20	Velocity (ft/s): 0.79, Loss (psi): 0.09	Velocity (ft/s): 0.48, Loss (psi): 0.03
6	Velocity (ft/s): 2.22, Loss (psi): 1.06	Velocity (ft/s): 1.29, Loss (psi): 0.28	Velocity (ft/s): 0.94, Loss (psi): 0.13	Velocity (ft/s): 0.57, Loss (psi): 0.04
7	Velocity (ft/s): 2.60, Loss (psi): 1.41	Velocity (ft/s): 1.50, Loss (psi): 0.37	Velocity (ft/s): 1.10, Loss (psi): 0.18	Velocity (ft/s): 0.67, Loss (psi): 0.05
8	Velocity (ft/s): 2.97, Loss (psi): 1.80	Velocity (ft/s): 1.71, Loss (psi): 0.47	Velocity (ft/s): 1.26, Loss (psi): 0.22	Velocity (ft/s): 0.76, Loss (psi): 0.07
9	Velocity (ft/s): 3.34, Loss (psi): 2.24	Velocity (ft/s): 1.93, Loss (psi): 0.59	Velocity (ft/s): 1.42, Loss (psi): 0.28	Velocity (ft/s): 0.86, Loss (psi): 0.08
10	Velocity (ft/s): 3.71, Loss (psi): 2.73	Velocity (ft/s): 2.14, Loss (psi): 0.72 1	Velocity (ft/s): 1.57, Loss (psi): 0.34	Velocity (ft/s): 0.95, Loss (psi): 0.10
11	Velocity (ft/s): 4.08, Loss (psi): 3.25	Velocity (ft/s): 2.36, Loss (psi): 0.86	Velocity (ft/s): 1.73, Loss (psi): 0.40	Velocity (ft/s): 1.05, Loss (psi): 0.12
12	Velocity (ft/s): 4.45, Loss (psi): 3.82	Velocity (ft/s): 2.57, Loss (psi): 1.01	Velocity (ft/s): 1.89, Loss (psi): 0.48	Velocity (ft/s): 1.15, Loss (psi): 0.14
14	Velocity (ft/s): 5.19, Loss (psi): 5.08	Velocity (ft/s): 3.00, Loss (psi): 1.34	Velocity (ft/s): 2.20, Loss (psi): 0.63	Velocity (ft/s): 1.34, Loss (psi): 0.19

16	Velocity (ft/s): 5.93, Loss (psi): 6.51	Velocity (ft/s): 3.43, Loss (psi): 1.71	Velocity (ft/s): 2.52, Loss (psi): 0.81	Velocity (ft/s): 1.53, Loss (psi): 0.24
18	Velocity (ft/s): 6.67, Loss (psi): 8.10	Velocity (ft/s): 3.86, Loss (psi): 2.13	Velocity (ft/s): 2.83, Loss (psi): 1.01	Velocity (ft/s): 1.72, Loss (psi): 0.30
20	Velocity (ft/s): 7.42, Loss (psi): 9.84	Velocity (ft/s): 4.28, Loss (psi): 2.59	Velocity (ft/s): 3.15, Loss (psi): 1.22	Velocity (ft/s): 1.91, Loss (psi): 0.36
22	Velocity (ft/s): 8.16, Loss (psi): 11.74	Velocity (ft/s): 4.71, Loss (psi): 3.09	Velocity (ft/s): 3.46, Loss (psi): 1.46	Velocity (ft/s): 2.10, Loss (psi): 0.43
24	Velocity (ft/s): 8.90, Loss (psi): 13.79	Velocity (ft/s): 5.14, Loss (psi): 3.63	Velocity (ft/s): 3.78, Loss (psi): 1.72	Velocity (ft/s): 2.29, Loss (psi): 0.51
26	Velocity (ft/s): 9.64, Loss (psi): 16.00	Velocity (ft/s): 5.57, Loss (psi): 4.21	Velocity (ft/s): 4.09, Loss (psi): 1.99	Velocity (ft/s): 2.48, Loss (psi): 0.59
28	Velocity (ft/s): 10.38, Loss (psi): 18.35	Velocity (ft/s): 6.00, Loss (psi): 4.83	Velocity (ft/s): 4.41, Loss (psi): 2.28	Velocity (ft/s): 2.67, Loss (psi): 0.68
30	Velocity (ft/s): 11.12, Loss (psi): 20.85	Velocity (ft/s): 6.43, Loss (psi): 5.49	Velocity (ft/s): 4.72, Loss (psi): 2.59	Velocity (ft/s): 2.86, Loss (psi): 0.77
35	Velocity (ft/s): 12.98, Loss (psi): 27.74	Velocity (ft/s): 7.50, Loss (psi): 7.30	Velocity (ft/s): 5.51, Loss (psi): 3.45	Velocity (ft/s): 3.34, Loss (psi): 1.02
40		Velocity (ft/s): 8.57, Loss (psi): 9.35	Velocity (ft/s): 6.30, Loss (psi): 4.42	Velocity (ft/s): 3.82, Loss (psi): 1.31
45		Velocity (ft/s): 9.64, Loss (psi): 11.63	Velocity (ft/s): 7.08, Loss (psi): 5.49	Velocity (ft/s): 4.30, Loss (psi): 1.63
50		Velocity (ft/s): 10.71, Loss (psi): 14.14	Velocity (ft/s): 7.87, Loss (psi): 6.68	Velocity (ft/s): 4.77, Loss (psi): 1.98
55		Velocity (ft/s): 11.78, Loss (psi): 16.87	Velocity (ft/s): 8.66, Loss (psi): 7.97	Velocity (ft/s): 5.25, Loss (psi): 2.36
60		Velocity (ft/s): 12.85, Loss (psi): 19.82	Velocity (ft/s): 9.44, Loss (psi): 9.36	Velocity (ft/s): 5.73, Loss (psi): 2.77
65			Velocity (ft/s): 10.23, Loss (psi): 10.86	Velocity (ft/s): 6.21, Loss (psi): 3.22
70			Velocity (ft/s): 11.02, Loss (psi): 12.45	Velocity (ft/s): 6.68, Loss (psi): 3.69

75			Velocity (ft/s): 11.81, Loss (psi): 14.15	Velocity (ft/s): 7.16, Loss (psi): 4.19
80			Velocity (ft/s): 12.59, Loss (psi): 15.95	Velocity (ft/s): 7.64, Loss (psi): 4.73
85			Velocity (ft/s): 13.38, Loss (psi): 17.84	Velocity (ft/s): 8.12, Loss (psi): 5.29
90				Velocity (ft/s): 8.59, Loss (psi): 5.88
95				Velocity (ft/s): 9.07, Loss (psi): 6.50
100				Velocity (ft/s): 9.55, Loss (psi): 7.15

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Figure 35 B: PVC Schedule 80 IPS
Sizes 1" through 2" Flow 1 gpm through 100 gpm
Friction loss per 100 Feet of Pipe (psi/100 ft.)

Flow (gpm)	**1″, ID: 0.935**	**1 ¼”, ID: 1.254**	**1 ½”, ID: 1.476**	**2″, ID: 1.913**
1	Velocity (ft/s): 0.47, Loss (psi): 0.06	Velocity (ft/s): 0.26, Loss (psi): 0.01	Velocity (ft/s): 0.19, Loss (psi): 0.01	Velocity (ft/s): 0.11, Loss (psi): 0.00
2	Velocity (ft/s): 0.93, Loss (psi): 0.21	Velocity (ft/s): 0.52, Loss (psi): 0.05	Velocity (ft/s): 0.37, Loss (psi): 0.02	Velocity (ft/s): 0.22, Loss (psi): 0.01
3	Velocity (ft/s): 1.40, Loss (psi): 0.45	Velocity (ft/s): 0.78, Loss (psi): 0.11	Velocity (ft/s): 0.56, Loss (psi): 0.05	Velocity (ft/s): 0.33, Loss (psi): 0.01
4	Velocity (ft/s): 1.87, Loss (psi): 0.77	Velocity (ft/s): 1.04, Loss (psi): 0.18	Velocity (ft/s): 0.75, Loss (psi): 0.08	Velocity (ft/s): 0.45, Loss (psi): 0.02
5	Velocity (ft/s): 2.33, Loss (psi): 1.16	Velocity (ft/s): 1.30, Loss (psi): 0.28	Velocity (ft/s): 0.94, Loss (psi): 0.13	Velocity (ft/s): 0.56, Loss (psi): 0.04
6	Velocity (ft/s): 2.80, Loss (psi): 1.63	Velocity (ft/s): 1.56, Loss (psi): 0.39	Velocity (ft/s): 1.12, Loss (psi): 0.18	Velocity (ft/s): 0.67, Loss (psi): 0.05
7	Velocity (ft/s): 3.27, Loss (psi): 2.17	Velocity (ft/s): 1.82, Loss (psi): 0.52	Velocity (ft/s): 1.31, Loss (psi): 0.24	Velocity (ft/s): 0.78, Loss (psi): 0.07
8	Velocity (ft/s): 3.73, Loss (psi): 2.78	Velocity (ft/s): 2.08, Loss (psi): 0.67	Velocity (ft/s): 1.50, Loss (psi): 0.30	Velocity (ft/s): 0.89, Loss (psi): 0.09
9	Velocity (ft/s): 4.20, Loss (psi): 3.45	Velocity (ft/s): 2.34, Loss (psi): 0.83	Velocity (ft/s): 1.69, Loss (psi): 0.37	Velocity (ft/s): 1.00, Loss (psi): 0.11
10	Velocity (ft/s): 4.67, Loss (psi): 4.20	Velocity (ft/s): 2.59, Loss (psi): 1.01	Velocity (ft/s): 1.87, Loss (psi): 0.46	Velocity (ft/s): 1.11, Loss (psi): 0.13
11	Velocity (ft/s): 5.13, Loss (psi): 5.01	Velocity (ft/s): 2.85, Loss (psi): 1.20	Velocity (ft/s): 2.06, Loss (psi): 0.54	Velocity (ft/s): 1.23, Loss (psi): 0.15
12	Velocity (ft/s): 5.60, Loss (psi): 5.88	Velocity (ft/s): 3.11, Loss (psi): 1.41	Velocity (ft/s): 2.25, Loss (psi): 0.64	Velocity (ft/s): 1.34, Loss (psi): 0.18
14	Velocity (ft/s): 6.53, Loss (psi): 7.83	Velocity (ft/s): 3.63, Loss (psi): 1.88	Velocity (ft/s): 2.62, Loss (psi): 0.85	Velocity (ft/s): 1.56, Loss (psi): 0.24
16	Velocity (ft/s): 7.47, Loss (psi): 10.03	Velocity (ft/s): 4.15, Loss (psi): 2.40	Velocity (ft/s): 3.00, Loss (psi): 1.09	Velocity (ft/s): 1.78, Loss (psi): 0.31
18	Velocity (ft/s): 8.40, Loss (psi): 12.47	Velocity (ft/s): 4.67, Loss (psi): 2.99	Velocity (ft/s): 3.37, Loss (psi): 1.35	Velocity (ft/s): 2.01, Loss (psi): 0.38
20	Velocity (ft/s): 9.33, Loss (psi): 15.16	Velocity (ft/s): 5.19, Loss (psi): 3.63	Velocity (ft/s): 3.75, Loss (psi): 1.64	Velocity (ft/s): 2.23, Loss (psi): 0.47

22	Velocity (ft/s): 10.27, Loss (psi): 18.08	Velocity (ft/s): 5.71, Loss (psi): 4.33	Velocity (ft/s): 4.12, Loss (psi): 1.96	Velocity (ft/s): 2.45, Loss (psi): 0.56
24	Velocity (ft/s): 11.20, Loss (psi): 21.24	Velocity (ft/s): 6.23, Loss (psi): 5.09	Velocity (ft/s): 4.49, Loss (psi): 2.30	Velocity (ft/s): 2.68, Loss (psi): 0.65
26	Velocity (ft/s): 12.13, Loss (psi): 24.64	Velocity (ft/s): 6.75, Loss (psi): 5.91	Velocity (ft/s): 4.87, Loss (psi): 2.67	Velocity (ft/s): 2.90, Loss (psi): 0.76
28	Velocity (ft/s): 13.07, Loss (psi): 28.26	Velocity (ft/s): 7.26, Loss (psi): 6.77	Velocity (ft/s): 5.24, Loss (psi): 3.06	Velocity (ft/s): 3.12, Loss (psi): 0.87
30	Velocity (ft/s): 14.00, Loss (psi): 32.12	Velocity (ft/s): 7.78, Loss (psi): 7.70	Velocity (ft/s): 5.62, Loss (psi): 3.48	Velocity (ft/s): 3.34, Loss (psi): 0.99
35	Velocity (ft/s): 16.33, Loss (psi): 42.73	Velocity (ft/s): 9.08, Loss (psi): 10.24	Velocity (ft/s): 6.55, Loss (psi): 4.63	Velocity (ft/s): 3.90, Loss (psi): 1.31
40		Velocity (ft/s): 10.38, Loss (psi): 13.11	Velocity (ft/s): 7.49, Loss (psi): 5.93	Velocity (ft/s): 4.46, Loss (psi): 1.68
45		Velocity (ft/s): 11.68, Loss (psi): 16.31	Velocity (ft/s): 8.43, Loss (psi): 7.38	Velocity (ft/s): 5.02, Loss (psi): 2.09
50		Velocity (ft/s): 12.97, Loss (psi): 19.83	Velocity (ft/s): 9.36, Loss (psi): 8.97	Velocity (ft/s): 5.57, Loss (psi): 2.54
55		Velocity (ft/s): 14.27, Loss (psi): 23.65	Velocity (ft/s): 10.30, Loss (psi): 10.70	Velocity (ft/s): 6.13, Loss (psi): 3.03
60		Velocity (ft/s): 15.57, Loss (psi): 27.79	Velocity (ft/s): 11.24, Loss (psi): 12.57	Velocity (ft/s): 6.69, Loss (psi): 3.56
65			Velocity (ft/s): 12.17, Loss (psi): 14.58	Velocity (ft/s): 7.25, Loss (psi): 4.13
70			Velocity (ft/s): 13.11, Loss (psi): 16.73	Velocity (ft/s): 7.80, Loss (psi): 4.74
75			Velocity (ft/s): 14.05, Loss (psi): 19.01	Velocity (ft/s): 8.36, Loss (psi): 5.38
80			Velocity (ft/s): 14.98, Loss (psi): 21.42	Velocity (ft/s): 8.92, Loss (psi): 6.06

85			Velocity (ft/s): 15.92, Loss (psi): 23.96	Velocity (ft/s): 9.48, Loss (psi): 6.78
90				Velocity (ft/s): 10.03, Loss (psi): 7.54
95				Velocity (ft/s): 10.59, Loss (psi): 8.34
100				Velocity (ft/s): 11.15, Loss (psi): 9.17

Ordinarily the pump piping will be sized to match the manufacture pump connection size. For example, a common residential 4” size submersible pump, with a capacity of 10 to 20 gpm, will have a 1 ¼” NPT pipe connection. Whereas jet pumps commonly use 1” pipe for the drive line and 1 ¼“pipe for the suction line. In some instances, the lines must be upsized if long runs are encountered or if the pump is working close to its design lifting capacity.

Figure 36 shows the pressure loss for 1” Sch 80 PVC at 10 GPM when using a phone app. Notice the result is 9.688 ft/100ft. This is comparable to the table results when converted to like terms.

$$9.688 \text{ ft./100ft} \times 0.433 \text{ psi/ft} = 4.19 \text{ psi/100ft}$$

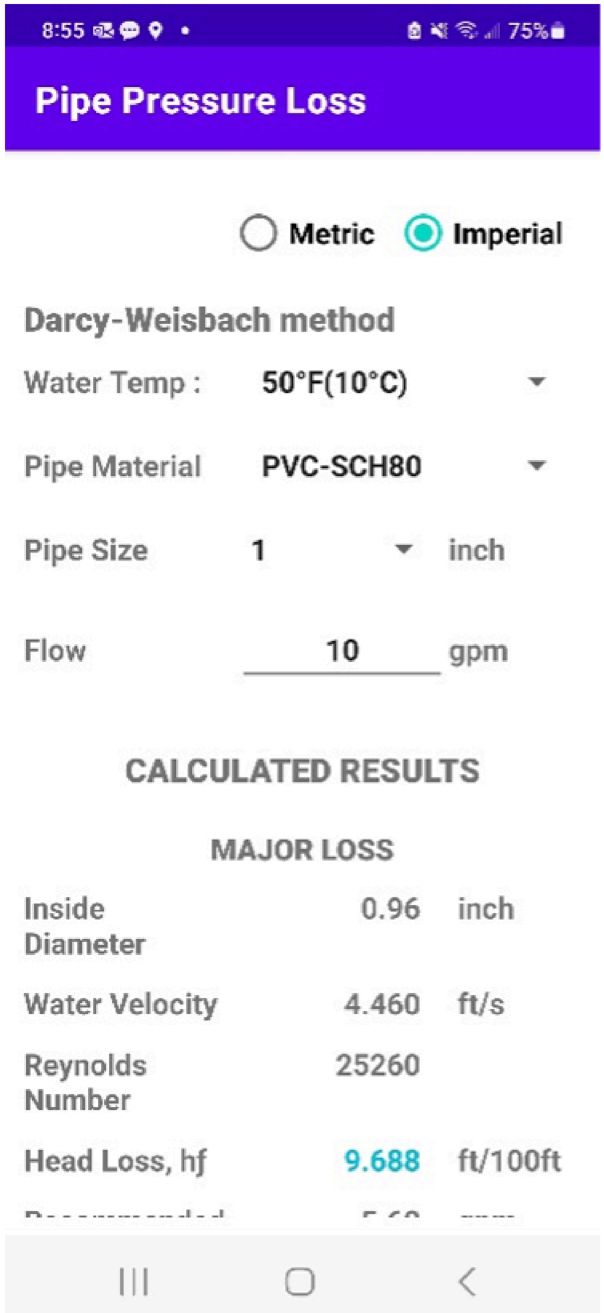


Figure 36. Pressure loss app

As water travels through the suction and discharge piping, it also encounters friction losses as it travels through various fittings. Friction losses may be caused by check valves, shut-off valves, connection fittings and elbows or other bends.

Figure 37 is an example of a fitting friction loss table. Notice the friction losses for fittings are usually expressed in equivalent lengths of straight pipe. In other words, the diameter of a fitting is matched to the diameter of a pipe section and the friction loss of water that flows through lengths of that size of pipe. For example, a 1¼” gate valve would create the same friction loss as 5′ of 1¼” steel pipe. The equivalent fitting length would be added to the actual length of pipe and that length would be used to determine the total friction loss of the pipe and fittings.

Figure 37. Friction losses of valves and fittings

Type of Fitting and Application	Pipe and Fitting	1/2″	3/4″	1″	1 1/4″	1 1/2″	2″	2 1/2″
Insert coupling	Plastic	3	3	3	3	3	3	3
Threaded adapter (plastic to thread)	Plastic	3	3	3	3	3	3	3
90 standard elbow	Steel	2	3	3	4	4	5	6
	Plastic	4	5	6	7	8	9	10
Standard tee (flow through run)	Steel	1	2	3	3	3	4	5
	Plastic	4	4	4	5	6	7	8
Standard tee (flow through side)	Steel	4	5	6	8	9	11	14
	Plastic	7	8	9	12	13	17	20
Gate valve	Steel	2	3	4	5	6	7	8
	Plastic	4	4	7	9	10	11	12
Swing check valve	Steel	4	5	7	9	11	13	16
	Plastic	7	8	11	13	17	19	22
In Line Check Valve (Spring) or Foot Valve	Steel	4	6	8	12	14	19	23
	Plastic	7	10	12	18	20	25	29

Friction loss example:

A 10 gpm submersible pump has 100 ft. of 1” PVC sch80 pipe with one 90º elbow and one above ground swing check valve. What is the friction loss of the pipe and fittings?

Note: The manufactures internal check valve built into the pump body discharge does not have to be accounted for in the friction loss calculation.

Step 1 – Figure equivalent length:

- 1” 90º elbow is equivalent to 6 ft. of straight plastic pipe
- 1” Swing check is equivalent to 11 ft. of straight plastic pipe
- 100 ft. of pipe – equivalent to 100 ft. of straight pipe
- Total equivalent length = 117 ft. = Total equivalent pipe

Step 2 Figure friction loss for the equivalent length of 1” plastic pipe at an assumed flow of 10 GPM:

- PVC Friction loss app shows 9.69 ft. loss per 100 ft. of pipe.

- In step 1 above we have determined total equivalent ft. of pipe to be 117 ft.
- Convert 117 ft. to percentage 117 ÷ 100 = 1.17
- Multiply 9.69 × 1.17 = 11.34 ft
- 11.34 ft. (4.91 psi) is the total friction loss for this system.

Suction Head

For shallow well jet pump installations, the pump may be mounted on the well head, in a pump house close by or in the house itself. With a suction pipe that is inserted into the well or lake that transports water to the inlet of the pump. The vertical distance from the pumping water level to the inlet of the pump is the suction lift. As has been previously discussed the maximum theoretical suction lift of a pump installed at sea level is approximately 34 feet at sea level, but the pump's actual lift capability is lower due to factors such as friction loss in the suction pipe and the pump's efficiency. The maximum practical suction lift for a centrifugal pump installed at sea level is typically around 25 feet.

Suction head = suction lift + friction loss in suction pipe and fittings

Discharge Head

The pressure at the outlet of the pump may be required to transport water both horizontally and vertically, either to a pressure tank or the supply connections within a building. Most pumping systems have a pressure tank that acts as a reservoir and helps to maintain consistent pressure differentials in the system. The determination of resistance on the pump's discharge side relies on whether the pump is supplying water to an open system, a pressure tank, or a VFD pressure sensor.

If the pump system includes a pressure tank or a variable frequency drive (VFD) with a pressure sensor, the total discharge head is determined by measuring the vertical distance from the pump discharge to the elevation of the pressure tank or sensor. This is then added to the maximum pressure setting, converted to feet, and the piping friction loss up to the tank or sensor. Any pressure losses occurring beyond the tank or sensor would be considered in the sizing of the building code distribution piping, with the tank or pressure sensor serving as the supply point.

In the less common scenario of an open system, the discharge head is calculated as the vertical distance to the highest delivery point. Additionally, the discharge piping friction loss and the desired delivery point's residual pressure (converted to meters or feet) are taken into account.

Total Head Calculations

The type of pump and the physical demands of each site will change the nature of the total head calculations. For example, a submersible pump system would have a suction lift of zero, and total head would be equal to discharge head. Figure 38 shows information that is needed to calculate the total head requirement for an installation.

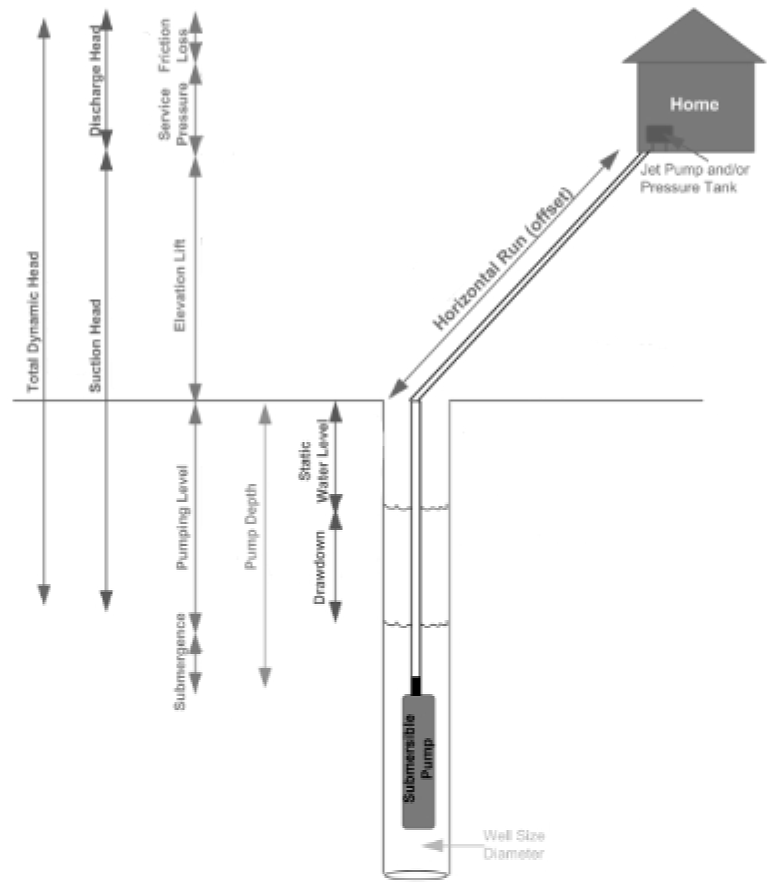


Figure 38. Total head data

A basic method of calculating the total head requirement is:

- Calculate suction head as sum of:
  - depth to static water level (metres or feet)
  - drawdown (metres or feet)
  - friction losses to pump (metres or feet)
- Calculate discharge head as sum of:
  - elevation from discharge of pump to pressure tank, VFD sensor, or highest delivery point
  - pressure tank, VFD sensor, or delivery point required static pressure (converted to metres or feet)
  - friction losses of piping and fittings (metres or feet)
- Total head = suction head + discharge head

Work through these examples to see the effects that different pump installations have on the total pumping head calculations.

Example 1

You have a shallow jet pump unit complete with a mounted pressure tank, installed at a cottage pump house. The pumping level is 15 ft. and the foot valve depth is 20 ft. The pump house is located 60 ft from the well head at the same elevation. The pump has a capacity of 5 USGPM with 30-50 psi pressure switch at the tank. The suction pipe connection is 1 ¼” and the discharge is ¾” you will use Sch 80 PVC for the suction pipe.

Calculate the total head:

1. Calculate suction head (friction losses + vertical lift):

- Suction friction loss
    - Equivalent length:
    - 3 ea 1 ¼” 90º elbow is equivalent to 21 ft. of straight plastic pipe
    - 1 ea 1 ¼” Foot valve is equivalent to 18 ft. of straight plastic pipe
    - 20 ft depth + 60 ft horizontal <u>80 ft</u>. of straight pipe
    - Total equivalent length = 119 ft. = Total equivalent pipe
    - Figure friction loss for 119 ft. of 1 ¼” PVC pipe at an assumed flow of 5 GPM:
        - Sch. 80 PVC pressure loss table shows 0.28 psi loss per 100 ft. of pipe.
        - 0.26 psi = 0.6 ft
        - $119 \text{ feet} \times \dfrac{0.6}{100 \text{ ft}} = 0.71 \text{ ft}$
    - Total suction head = 15 ft + 0.71 ft = 15.71 ft

2. Calculate discharge head (vertical distance + friction losses + delivery pressure):

- For this installation the pressure tank is mounted directly onto the pump as a package unit therefore there is no vertical lift or friction loss to account for.
- The pressure switch has a range of 20-40 psi, so the maximum (shut-off) pressure of 40 psi will be used. You will need to convert this tank pressure to ft. head
- Total discharge head = 40 psi × 2.31 ft/psi = 92.4 ft

3. Calculate the total head (suction head + discharge head):

- 15.71 ft + 92.4 ft = 108.1 ft

Example 2

You have a 1 ½ HP submersible pump with an estimated capacity of 16 USGPM with 40-60 psi pressure switch at the pressure tank. The pumping level is 130 ft. and the pump submergence is 50 ft. The pressure tank is located within the house 100 ft away and 20 ft higher. The pipe connection is 1 ¼” and you will use Sch 80 PVC pipe with 4 elbows on the route to the pressure switch mounted at the tank tee.

Calculate the total head.

1. Calculate suction head (friction losses + vertical lift):

- As this is a submersible installation there will not be any suction head calculations.

2. Calculate discharge head (friction losses + vertical lift distance + delivery pressure):

- Discharge friction loss
    - Equivalent length:
    - 4 ea 1 ¼" 90º elbow is equivalent to 28 ft. of straight plastic pipe
    - Length of pipe(130 + 50 + 20) = <u>200 ft.</u>
    - Total equivalent length = 228 ft. = Equivalent pipe
    - Figure friction loss for 228 ft. of 1 ¼" PVC pipe at an assumed flow of 15 GPM:
        - Sch. 80 PVC pressure loss table shows 2.40 psi loss per 100 ft. of pipe.
        - 2.40 psi = 5.54 ft
        - $228 \text{ feet} \times \frac{5.54}{100 \text{ ft}} = 12.63 \text{ ft}$ of discharge friction loss
    - Total discharge lift (pumping level + elevation lift)
        - 130 ft + 20 ft = 150 ft
    - The pressure switch has a range of 40-60 psi, so the maximum (shut-off) pressure of 60 psi will be used. You will need to convert this tank pressure to head:
        - 60 psi × 2.31 ft/psi =138.6 ft. head
    - Total discharge head (friction losses + vertical lift distance + delivery pressure): 12.63 + 150 + 138.6 = 301.23 ft

3. Calculate the total head (suction head + discharge head):

    - 0 ft + 301.23 ft = 301.23 ft

Select the Pump Type

When selecting a residential rural water supply pump, several considerations come into play to ensure optimal performance and reliability. The two most common choices are submersible deep well pumps or convertible jet pumps.

Jet pumps can be used with suction lift from 20 to 25 feet and have discharge capacities ranging from 200 to 1500 US gallons per hour at pressures varying from 20 to 50 pounds. If the jet pump is used in a deep well configuration it is usually limited to depths of approximately 100 feet, and its discharge capacity is reduced.

The submersible pump is more hydraulically efficient than a jet pump and can be used for much deeper wells. The pump may require a larger, more powerful motor to drive it as it lifts water from greater depths. Submersible pumps perform well in both shallow well applications as well as at depth to 2000 feet. There are a large range of submersible pump models available, allowing for a precise match to the system capacity requirements.

The pump selection process involves assessing factors such as well depth, water quality, motor type, specific application requirements, pump size, and the need for additional features like built-in controls or protection mechanisms.

Well Depth

The depth of the well is an essential factor to consider when selecting a pump. Submersible deep well pumps are specifically designed for use in deep wells and can handle greater vertical lifts. If the well is deep, a submersible pump is often the preferred choice.

Water Quality

Assessing the water quality is crucial to determine the appropriate pump type. If the water contains debris, sediment, or other particles, a submersible pump with built-in filtration may be necessary to prevent clogging and ensure reliable operation. Water with high mineral content or hardness may require additional treatment or specific pump materials to resist corrosion.

Motor Type

Consider the available power supply and choose the motor type accordingly. Single-phase motors are commonly used for residential applications with standard household power supply, while three-phase motors are typically employed in larger-scale applications or when a three-phase power source is available. Verify the compatibility of the selected pump with the available power source.

Specific Application Requirements

Consider the specific needs of the application. If the water supply is intended for irrigation, livestock watering, or other agricultural purposes, a pump with sufficient flow rate and pressure capabilities should be selected. On the other hand, residential applications such as domestic use, firefighting, or small-scale irrigation may have different requirements in terms of flow rate and pressure.

Pump Size

Determining the appropriate pump size involves considering the anticipated water demand and the pump’s performance characteristics. It should be capable of meeting the required flow rate and head (total dynamic head) of the system. The manufacturer's specifications and performance curves are used to determine the suitable pump size for the desired application.

Additional Features

Depending on the specific requirements and desired convenience, consider the need for additional features such as built-in controls, pressure switches, or protection mechanisms like overload protection and thermal sensors. These features can enhance the pump's functionality, efficiency, and longevity while providing ease of use and safety.

To find a suitable pump, you will need to conduct research and consult the manufacturer's documentation, technical specifications, and guidelines specific to the chosen pump type and model. Consider factors such as pump efficiency, motor power requirements, and durability.

Size the Pump

Once you have gathered all the necessary information about your household and well, it is time to determine the appropriate size for your pump. Look for pumps that can handle the required total head and provide the desired flow rate. This ensures that the pump operates optimally and meets your specific needs.

As previously mentioned centrifugal pumps have a variable displacement in that, the amount of water discharged from the pump decreases as it is asked to do more work, such as raising the height of fluid lift or increasing output pressure. These performance characteristics are shown on a pump curve graph. Being able to read a pump curve is essential when selecting a pump. The pump curve will tell you whether it is able to efficiently perform the required flow rate at a certain pressure, and therefore whether it is suitable for your application.

Usually a pump curve will have flow rate on the horizontal axis and the pressure on the vertical axis (Figure 39) . The curve represents the flow rate the pump will produce at certain levels of pressure when the pump is operating properly, or oppositely, the pressure the pump will work at when it is providing a certain flow rate. A centrifugal pump curve has its highest point on the left and gradually slopes down to the right. Looking at the pump curve in Figure 39 the points of intersection show that the pump is capable of producing just over 14 US gpm when working against approximately 400 ft, of head. This point at which the flow rate and pressure intersect is called the operating point or duty point. The curve also indicates that it will produce zero flow at about 540 ft. and a maximum flow of 20.5 US gpm at 240 ft, this is known as the shut off head.

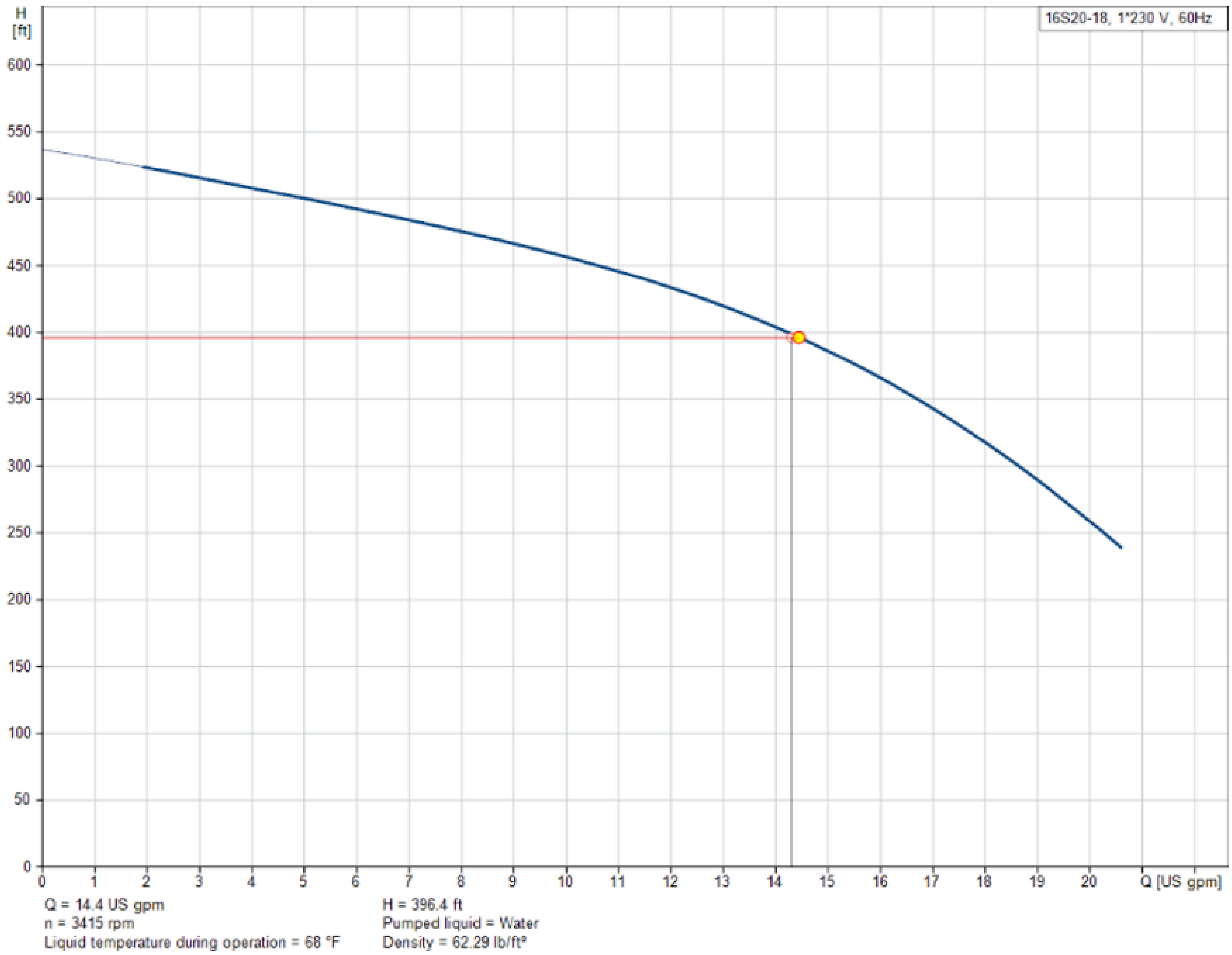


Figure 39. Grundfos 2HP 18 stage submersible pump curve

While a pump curve illustrates the range of flow rates and pressures a pump can handle, it is important to note, this does not mean the pump should be operated at all points on a pump curve. As a simple comparison a car has many gears, and although first gear may take you from zero to 40 mph, it would not be good for the engine to be driven at 40 mph in first gear. Neither is it good for the engine if the car is driven at 10mph in third gear even though it is possible for the engine to operate at these speeds.

All centrifugal pumps have a point in the curve whereby they operate at their highest efficiency. Figure 40 is an exaggerated drawing of a pump curve indicating the various problems that can occur if the pump is ran too far to the left or right of the best efficiency point (BEP). It is ideal for the pump to operate within two thirds of its curve, and at the duty point there should be at least a 10% rise to the left of the curve (pressure) above the duty point.

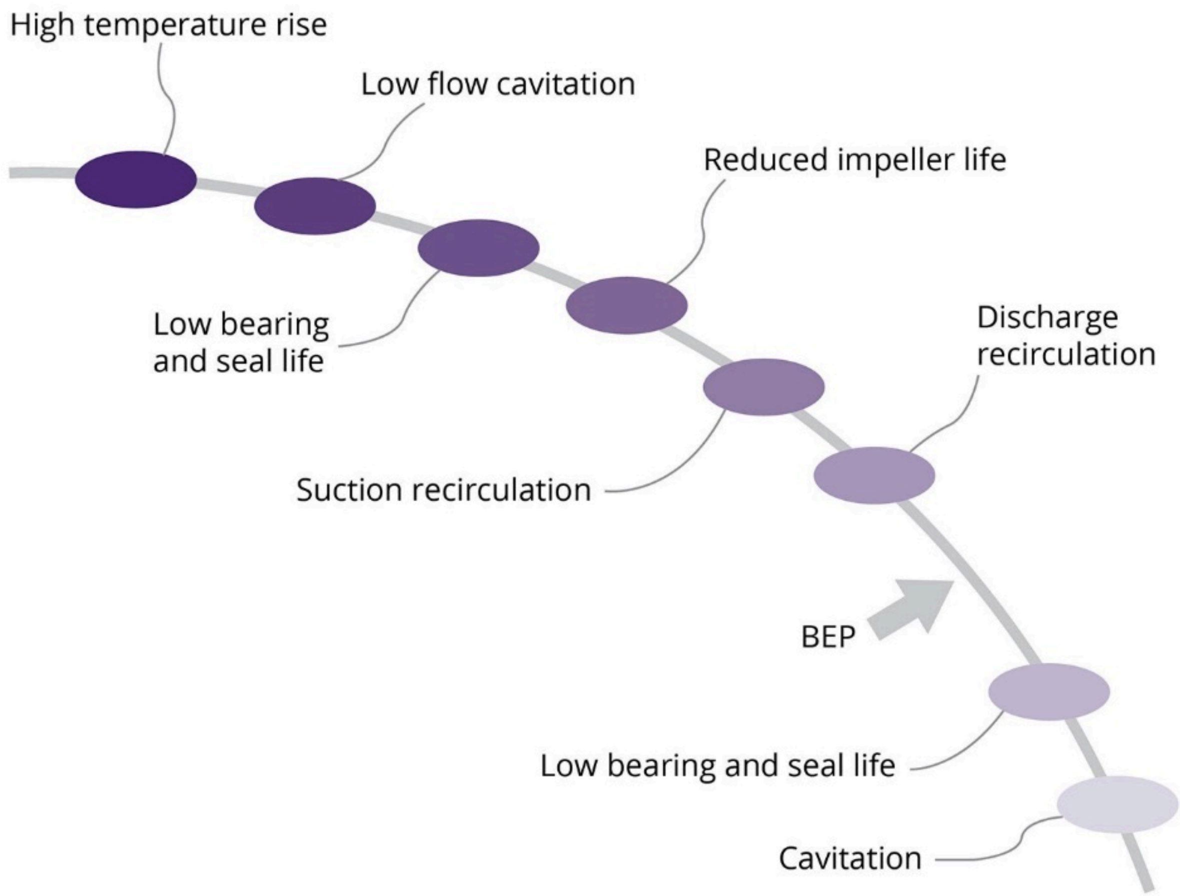


Figure 40. Pump performance problems

When sizing a pump, you will need to navigate multiple manufacturer's supplied performance curves and selection charts. Submersible pumps, are typically organized together on a single data sheet based on their common flow range family. Within this flow range family, you will find various pumps with different numbers of impellers and motor power requirements to meet diverse total head requirements. Some examples of manufactures performance curves and selection charts have been provided in A (#c1appendixA) and Appendix B (#c1appendixB) at the end of this learning task.

Example 1

Is a shallow well jet pump installation with:

- Desired flow rate of 15 USGPM
- A total pump head of 107 ft

Referring to the copy of the manufacture's performance data from Appendix A (#c1appendixA) shown in Figure 41. When you know the total head required and the capacity you need, refer to the manufacturer's pump curves. Find your capacity (15 gpm) required on the horizontal axis and draw a line upwards. Find the total head (107 ft.) on the vertical axis and draw a line across until it intersects with the capacity. At this point you select the first pump curve above that point, in this case it is the ¾ HP pump which will supply slightly more than 15 GPM at a total head of 107 ft.

For this same pump notice there is also a pump selection chart that uses the pump suction and discharge head separately to determine the capacity. For example if we split our pumps total pumping head up into; 15 ft of total suction head (including friction loss) and a 40 psi (92 ft.) cut-out pressure switch setting. The selection chart indicates a capacity of 16.5 GPM which is consistent with the value previously determined on the performance curve.

ORDERING INFORMATION – SHALLOW WELL

Catalog Number	HP	Discharge Pressure in Lbs.	Capacity in U.S. Gallons per Minute Suction Lift in Feet			Shut-Off PSI
			5	15	20	
HJ50S*	1/2	20	14.5	11.5	6	65
		30	14.5	11.5	6	
		40	10	8	5	
		50	5.5	3.5	2	
HJ75S*	3/4	20	23.5	17.5	10.5	69
		30	23.5	17.5	10.5	
		40	[illegible]	16.5	10.5	
		50	12.5	[illegible]	5	
HJ100S*	1	20	27.5	21	13	67
		30	27.5	21	13	
		40	25.5	21	13	
		50	19	15.5	12	

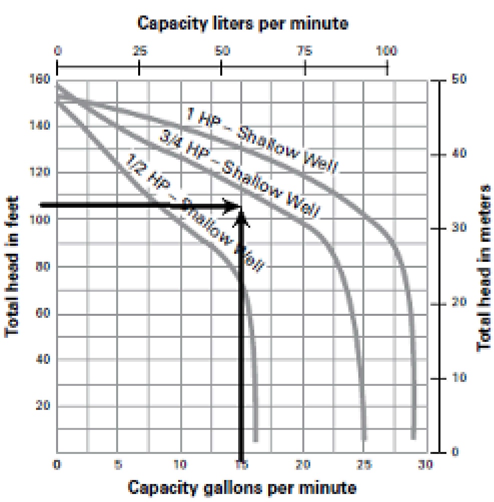
*For brass impeller add "-1" to Catalog Number, i.e.: HJ50D-1

ORDERING INFORMATION – DEEP WELL

Catalog Number	HP	Pressure Switch Setting	Average Regulator Setting	Jet Package Cat. Number			Capacity in U.S. Gallons per Minute Distance to Low Water Level in Feet									
				Cast Iron	Bronze	Packer for 2" Well	30	40	50	60	70	80	90	100	110	120
HJ50D*	1/2	20/40	22	DW50-I	DW50	P50	10.5	9.5	8	6	5	4	2.5			
		30/50	22	DW50-I	DW50	P50	9	8	7	5.5	4.5	3.5				
HJ75D*	3/4	20/40	26	DW75-I	DW75	P75	16.5	13.5	10	8	7	6	4	3	1	
		30/50	26	DW75-I	DW75	P75	15.5	12	10.5	7.5	6	5	3	2		
HJ100D*	1	20/40	34	DW100-I	DW100	P100	18	15.5	12.5	10	9	8	5.5	4.5	2.5	1
		30/50	34	DW100-I	DW100	P100	18	15	12	10	9	7.5	5	4	2	1

*For brass impeller add "-1" to Catalog Number, i.e.: HJ50D-1

PUMP PERFORMANCE



Repair Parts Kits

Model	Kit	Includes
HJ50D	PK50	Shaft seal, impeller, diffuser, gasket, O-ring, venturi, and nozzle
HJ75D	PK75	
HJ100D	PK100	

Figure 41. Convertible jet pump performance data (Courtesy of Pentair Myers) [Image Description] (#c1fig41_desc)

Example 2

Is a Submersible pump installation with:

- Desired flow rate of 9 USGPM
- Total discharge head (friction losses + vertical lift distance + delivery pressure):
    - Friction loss was calculated to be 30 ft.
    - Total vertical lift from pumping water level is 230 ft.
    - The pressure switch has a range of 40-60 psi, so the maximum (shut-off) pressure of 60 psi will be used, (60 psi × 2.31 ft/psi =138.6 ft. head).
- Therefore, Total Head = 30 + 230 + 138.6 = 399 ft

First step is to select a submersible pump model family based on the desired flow rate. Using the manufactures submersible pump data supplied in Appendix B (#c1appendixB) you notice that both the 7 GPM and 10 gpm models have a recommend flow range that will handle our flow requirements of 9 GPM. We will select the 10 GPM family as our 9 GPM requirement is in the middle of its 5-14 GPM flow range which will typically equate to a more efficient pump operation.

Looking at the performance curve for the 10 GPM models shown in Figure 42, find the capacity (9 gpm) required on the horizontal axis and draw a line upwards. Find the total head (399 ft.) on the vertical axis and draw a line across until it intersects with the capacity. The curve above that point, indicates the 1 ½ HP pump which will supply slightly more than 9 GPM at a total head of 399 ft.

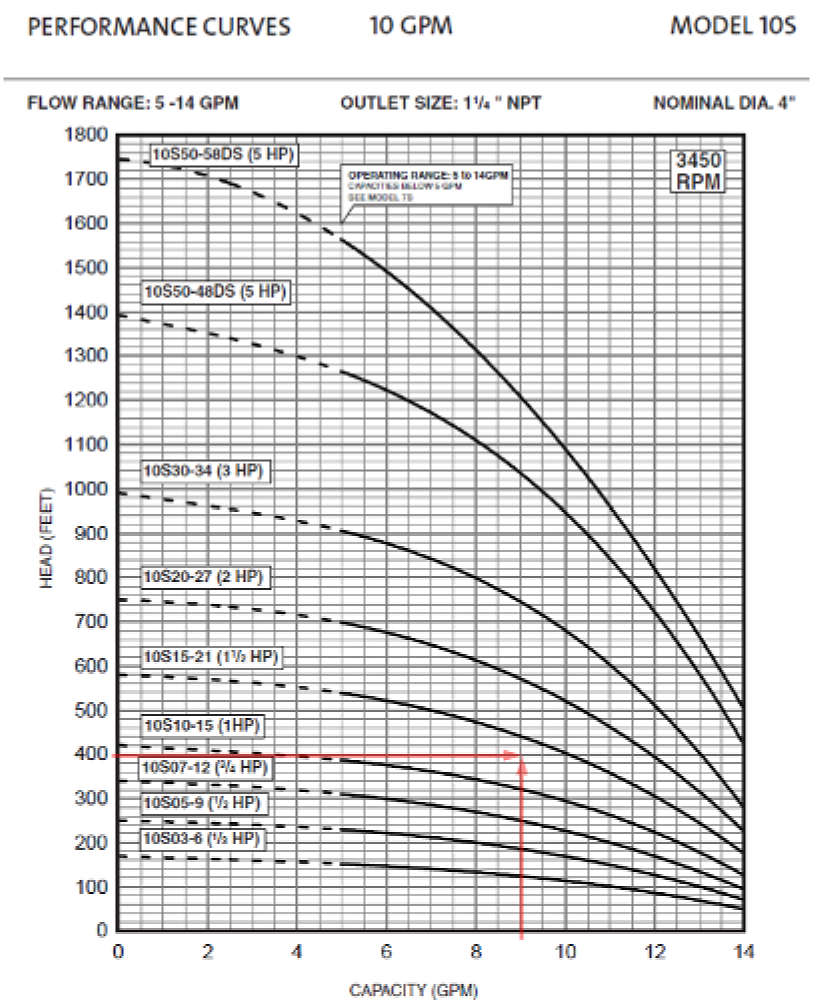


Figure 42. Submersible pump performance curve (Courtesy of Grundfos)

For the same pump model family notice there is also a pump selection chart (Figure 43). For our example, deducting the pressure switch setting of 60 psi (139 ft.) leaves a discharge lift of 261 ft. The selection chart for the same 21 stage 1 ½ HP indicates a capacity of 9.9 GPM at 60 psi and 260 ft. of lift which is consistent with the value previously determined on the performance curve. It is worth noting that if the pressure switch was to fail and the pump continued to run this pump would generate a pressure of 142 psi, which is shown in the shut-off psi row below each pump. For this reason, submersible pump manufactures always recommend that a pressure relief valve be installed.

10 GPM

SELECTION CHARTS (Ratings are in GALLONS PER MINUTE-GPM)

FLOW RANGE (5 TO 14 GPM)

PUMP OUTLET 1 1/4" NPT

			DEPTH TO PUMPING WATER LEVEL (LIFT) IN FEET																								
PUMP MODEL	HP	PSI	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	340	400	460	520	600	700	800	900	1000	1100
10S03-6	1/3	20	14.0	13.5	12.4	10.0	8.9	5.3																			
		30	13.2	11.8	10.4	8.4																					
		40	11.9	10.1	8.3																						
		50	9.8	7.5																							
		60	7.7	3.9																							
SHUT-OFF PSI:			64	55	47	38	29	21	12	3																	
10S05-9	1/2	0				14.1	13.3	12.4	11.4	10.4	9.5	8.5	6.6	3.5													
		20		13.9	13.1	12.1	11.1	10.1	9.2	7.9	5.8	2.0															
		30	13.8	13.0	12.0	11.0	10.0	9.0	7.8	5.3	1.2																
		40	12.9	11.8	10.8	9.8	8.8	7.3	4.8																		
		50	11.7	10.7	9.7	8.8	7.0	4.3																			
		60	10.5	9.5	8.4	6.7	3.7																				
SHUT-OFF PSI:			100	92	83	74	66	57	48	40	31	23	14	5													
10S07-12	3/4	0					14.3	13.8	13.2	12.6	11.7	11.0	10.2	9.5	8.7	7.6	6.0										
		20			14.2	13.6	12.9	12.2	11.5	10.7	10.0	9.3	8.4	7.2	5.4	2.6											
		30		14.1	13.5	12.9	12.1	11.4	10.6	9.9	9.2	8.2	7.0	5.0	2.0												
		40	14.0	13.4	12.8	12.0	11.3	10.5	9.8	9.0	8.1	6.7	4.7	1.4													
		50	13.3	12.6	11.9	11.1	10.4	9.7	8.9	7.9	6.5	4.2															
		60	12.5	11.8	11.0	10.3	9.6	8.8	7.7	6.2	3.8																
SHUT-OFF PSI:			137	129	120	111	103	94	85	77	68	59	51	42	33	25	16										
10S10-15	1	0							14.1	13.6	13.1	12.5	11.9	11.3	10.7	10.1	9.6	8.2	3.8								
		20					13.9	13.5	12.9	12.3	11.7	11.1	10.5	10.0	9.4	8.7	7.9	5.2									
		30				13.9	13.4	12.8	12.2	11.6	11.0	10.5	9.9	9.3	8.6	7.7	6.6	2.6									
		40		14.2	13.8	13.3	12.7	12.1	11.5	10.9	10.4	9.8	9.2	8.5	7.8	6.3	4.6										
		50	14.1	13.7	13.2	12.6	12.1	11.4	10.9	10.3	9.7	9.1	8.3	7.4	6.1	4.3	1.7										
		60	13.6	13.1	12.6	12.0	11.4	10.8	10.2	9.6	9.0	8.2	7.2	5.9	3.9												
SHUT-OFF PSI:			174	165	157	148	139	131	122	113	105	96	87	79	70	61	53	35	18								
10S15-21	1 1/2	0									14.3	13.9	13.6	13.3	12.9	12.5	12.0	11.2	9.9	8.5	6.3						
		20							14.1	13.9	13.5	13.1	12.7	12.3	11.9	11.5	11.0	10.2	8.9	6.9	2.6						
		30						14.1	13.8	13.5	13.1	12.7	12.3	11.9	11.4	11.0	10.5	9.7	8.3	5.7							
		40					14.1	13.8	13.4	13.0	12.6	12.2	11.8	11.3	10.9	10.5	10.1	9.2	7.5	4.1							
		50				14.0	13.7	13.3	13.0	12.5	12.1	11.7	11.3	10.8	10.4	10.0	9.6	8.7	6.5	3.8							
		60		14.2	14.0	13.6	13.3	12.9	12.6	12.1	11.8	11.2	10.8	10.4	9.9	9.5	9.1	8.0	5.1								
SHUT-OFF PSI:				237	229	220	211	203	194	185	177	168	159	151	142	133	125	107	81	55	29						
10S20-27	2	0												14.1	13.9	13.7	13.4	12.9	11.8	10.8	9.8	8.3	4.7				
		20										14.1	13.8	13.6	13.3	13.0	12.7	12.0	11.0	10.0	9.0	7.1	1.5				
		30									14.0	13.8	13.6	13.3	12.9	12.6	12.3	11.6	10.6	9.7	8.6	6.2					
		40							14.2	14.0	13.8	13.5	13.3	12.9	12.6	12.2	11.9	11.2	10.3	9.3	8.1	5.2					
		50						14.2	14.0	13.7	13.5	13.2	12.8	12.5	12.2	11.9	11.5	10.9	9.9	8.9	7.4	3.8					
		60					14.1	13.9	13.7	13.4	13.1	12.8	12.5	12.1	11.8	11.6	11.1	10.5	9.6	8.4	6.8	2.1					
SHUT-OFF PSI:							285	276	268	259	250	242	233	224	216	207	198	181	155	129	103	68	35				
10S30-34	3	0																13.5	13.2	12.5	11.9	10.8	9.6	7.9	4.8		
		20														13.9	13.7	13.3	12.7	12.0	11.3	10.3	9.3	6.7	2.7		
		30													13.9	13.7	13.5	13.1	12.4	11.7	11.0	10.0	8.5	6.0	1.3		
		40											14.0	13.9	13.7	13.6	13.3	12.9	12.2	11.5	10.8	9.7	8.3	5.1			
		50										14.0	13.8	13.6	13.4	13.2	13.0	12.6	11.9	11.2	10.5	9.4	7.5	4.2			
		60										13.8	13.6	13.4	13.2	13.0	12.8	12.3	11.6	10.9	10.2	9.0	6.9	3.1			
SHUT-OFF PSI:												332	324	316	306	298	290	272	246	220	194	169	116	73	29		

Figure 43. Submersible pump selection chart (Courtesy of Grundfos)

Manufactures Sizing Software

Most manufactures have pump sizing software that is readily available on their web sites. By simply inserting information into the required fields, pump options are given with all of the performance characteristics and specifications.

To demonstrate we will use the Grundfos online sizing software that is available on their web site. The installation criteria from our previous example will be used in order to compare our results. Figure 44 shows the initial selection parameters input screen.

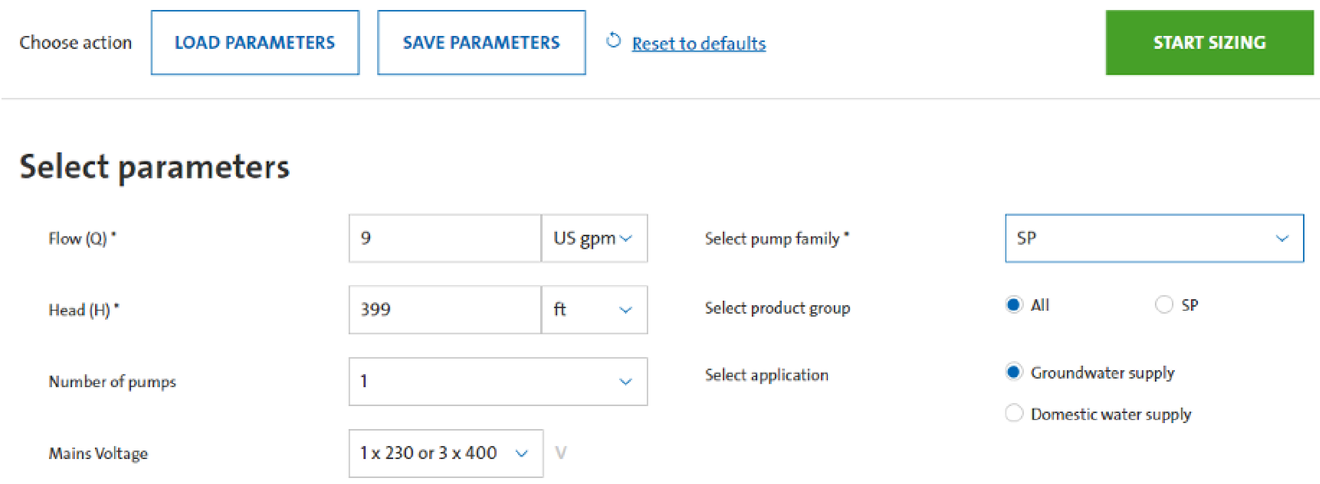
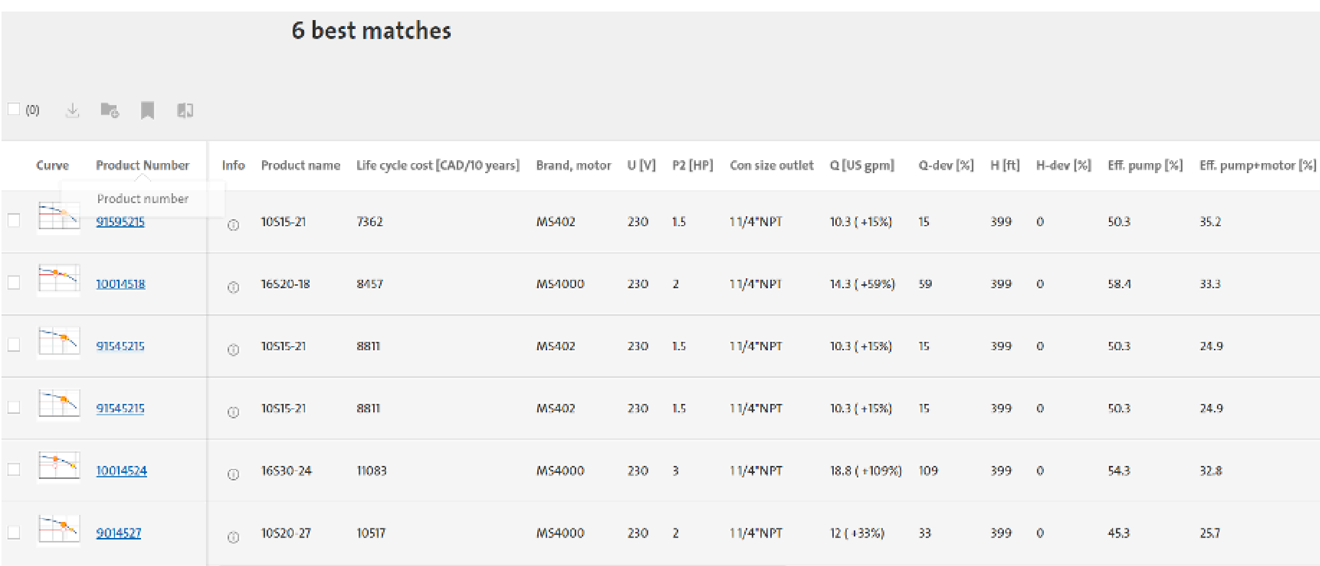


Figure 44. Sizing software parameter selection screen shot

Once these parameters are submitted the software returns the best available matches for this installation (Figure 45). There are many more columns of information to the right for each option that we were not able to be shown on a screen capture. If you look at the product name column notice that our previously chosen pump (10S15-21 is listed three times this is due to its different available options. For example, the option at the top of the list has a pump and motor efficiency of 35.2 %. In this case the higher combined efficiency is due to a different motor option being used.

There are also 3 other different pump options given by the selection software. These would not have been as easily identified if we were simply attempting to comparing all of the available printed pump curves and charts.



6 best matches

(0)

Curve	Product Number	Info	Product name	Life cycle cost [CAD/10 years]	Brand, motor	U [V]	P2 [HP]	Con size outlet	Q [US gpm]	Q-dev [%]	H [ft]	H-dev [%]	Eff. pump [%]	Eff. pump+motor [%]
	91595215		10S15-21	7362	MS402	230	1.5	1 1/4"NPT	10.3 (+15%)	15	399	0	50.3	35.2
	10014518		16S20-18	8457	MS4000	230	2	1 1/4"NPT	14.3 (+59%)	59	399	0	58.4	33.3
	91545215		10S15-21	8811	MS402	230	1.5	1 1/4"NPT	10.3 (+15%)	15	399	0	50.3	24.9
	91545215		10S15-21	8811	MS402	230	1.5	1 1/4"NPT	10.3 (+15%)	15	399	0	50.3	24.9
	10014524		16S30-24	11083	MS4000	230	3	1 1/4"NPT	18.8 (+109%)	109	399	0	54.3	32.8
	9014527		10S20-27	10517	MS4000	230	2	1 1/4"NPT	12 (+33%)	33	399	0	45.3	25.7

Figure 45. Pump matches screen shot

When we click any of the product number links on the left side column all of the data for that pump becomes available, including its performance curve (Figure 46). There are many options that can be turned on or off for example in this image we have the efficiency curve also being shown.

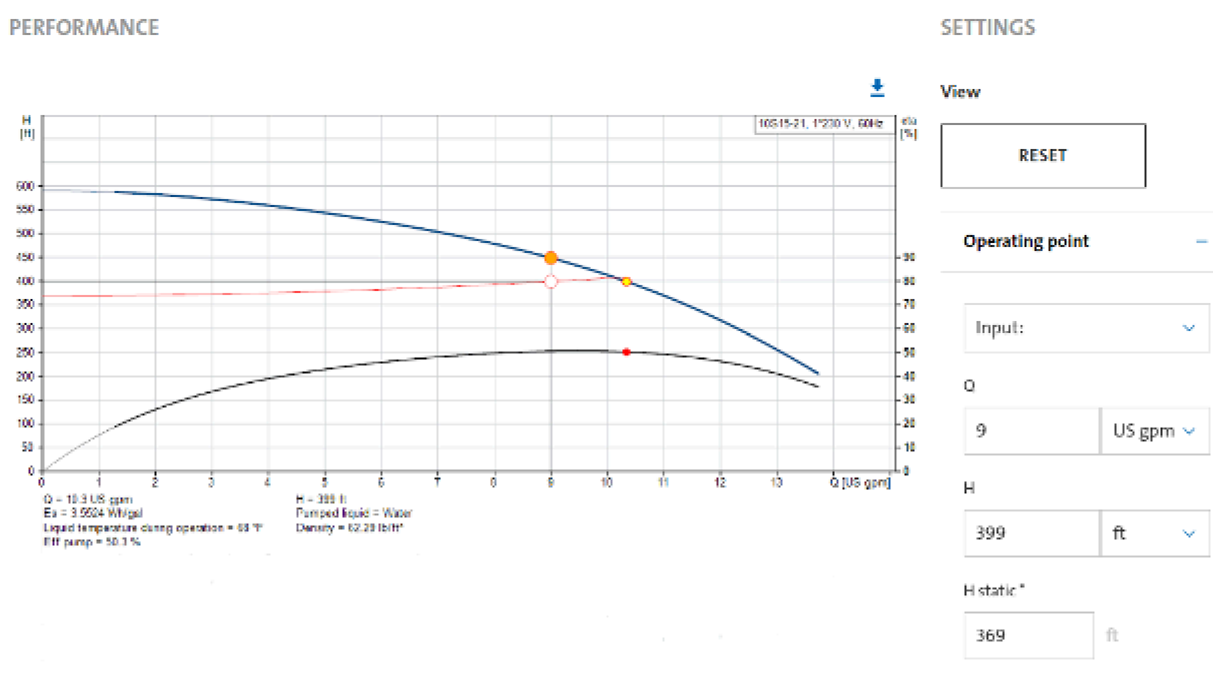


Figure 46. Software performance curve

Sizing for a variable speed constant pressure is another one of the selection options that we could have used at the initial selection parameters input screen (Figure 47). With the increase variables to consider when selecting a constant pressure system, the sizing software is an invaluable tool.

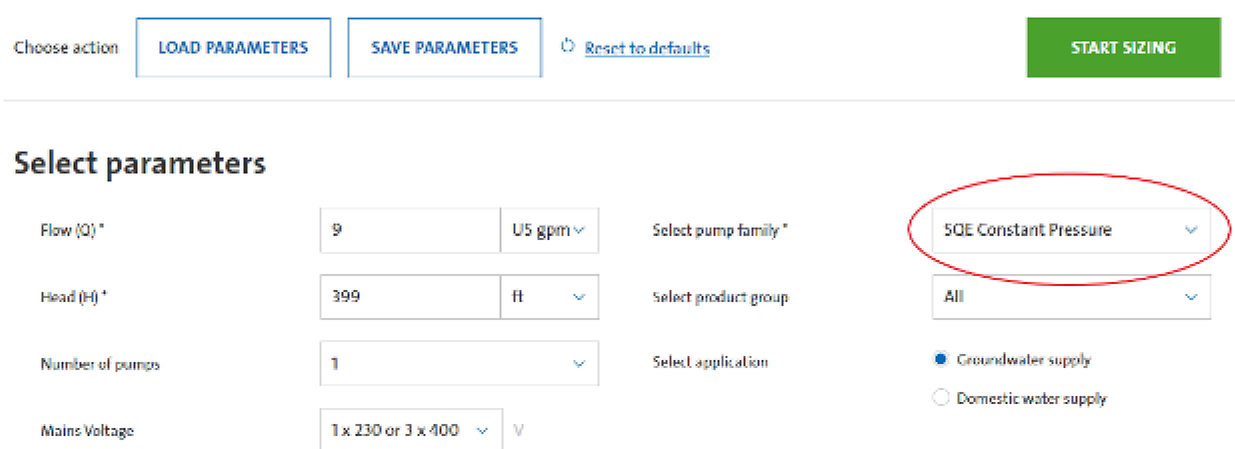


Figure 47. Constant Pressure parameter section screen shot

The software returned two different 1 ½ hp pump options, the pump curve for the 15 GPM model is shown in Figure 48. Notice there are now both maximum and minimum pump speed curves shown on the graph. For our flow requirements the pump will be operating at 90% of it maximum speed to deliver our estimated peak demand of 9 GPM. For all lower flow requirements, the electronic controller will reduce the pump speed to match the flow and maintain the programed setpoint pressure.

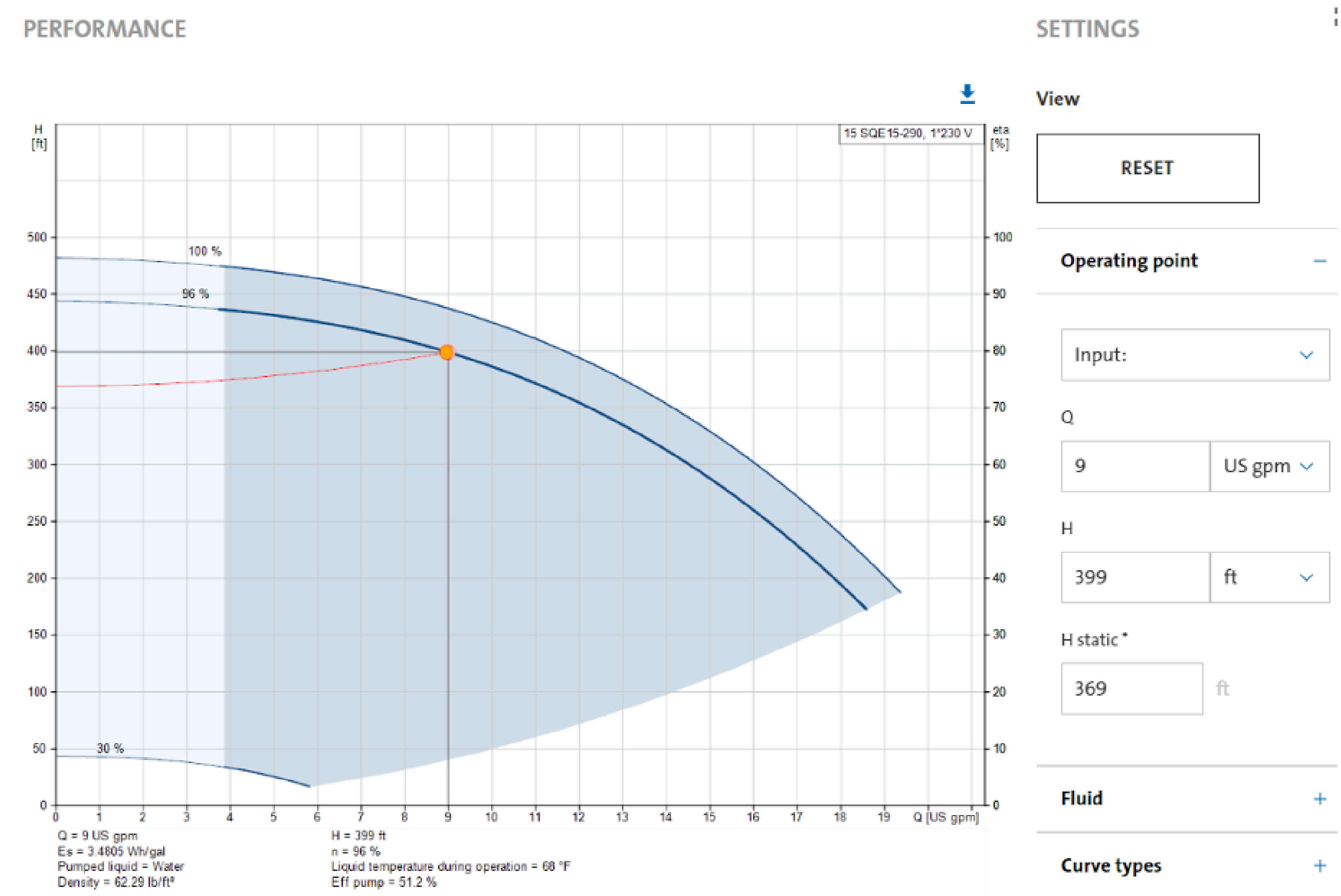


Figure 48. Constant pressure pump performance curve

By utilizing pump sizing software, you can access a wealth of additional information such as life cycle cost, annual energy cost, and a personal index, among others. To gain a comprehensive understanding of the extensive data provided by sizing software, we suggest visiting a manufacturer's website and conducting your own sizing scenarios. This hands-on approach will enable you to explore and evaluate the various data points available, allowing for a deeper comprehension of sizing software's capabilities.

Pressure Tank Sizing

A conventional fixed speed single phase pump motor will consume 6 times normal power at start-up. Frequent motor starts can create excessive heat in the motor and cause damage to its windings or insulation. As previously mentioned the primary purpose of a pressure tank is to provide a reservoir of stored pressurized water to be used when the pump is not running. Without an adequate amount of stored water, the system/pump will rapid cycle on and off shortening the life of the motor and consume excess amounts of electrical power.

The amount of water stored in the pressure tank to be used between pump run cycles is known as draw down or acceptance volume. The general rule is to size the tank to match the GPM of the pump so that once the pump turns on, it will run for a minimum of one minute to fill the tank. Notice in Figure 49 that the drawdown volume is not the same as the actual tank size. The drawdown volume would actually be the difference between the volume of air in the tank at pump cut-in pressure (P1) and cut-out Pressure (P2).

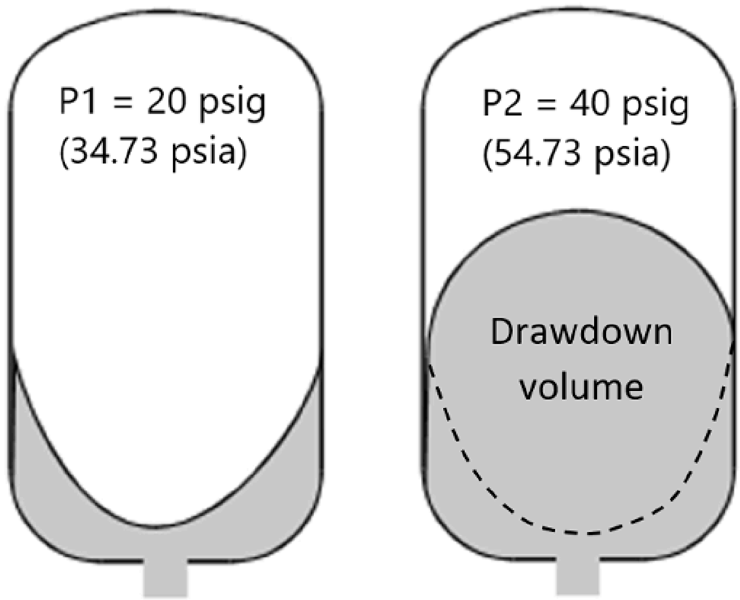


Figure 49. Drawdown volume

For example, if the precharged diaphragm tank in Figure 49 had 15 gallons of air volume at 20 psig (34.73 psia) cut-in we can use Boyles to demonstrate the actual amount of drawdown volume available at 40 psig (54.73 psia):

$$(P1\,V1) = (P2\,V2)$$
$$(34.73 \text{ psia} \times 15 \text{ gallons}) = (54.73 \text{ psia} \times V2)$$
$$V_2 = \frac{34.73 \times 15}{54.73} = 9.52 \text{ gallons of air at pump cut out}$$
$$\therefore \text{Drawdown is } 15 \text{ gallons} - 9,52 \text{ gallons} = 5.48 \text{ gallons}$$

Even though most pressure switches are set up with a 20 psi differential range (20/40, 30/50, 40/60) the actual pressure settings affect that amount of drawdown volume available for a given pressure tank. For example, if our previous tank drawdown calculations were done for a 30/50 pressure switch the results would change:

$$(44.73 \text{ psia} \times 15 \text{ gallons}) = (64.73 \text{ psia} \times V2)$$
$$V2 = \frac{44.73 \times 15}{64.73} = 10.36 \text{ gallons of air at pump cut out}$$
$$\therefore \text{Drawdown for the } 30/50 \text{ pressure switch is } 15 \text{ gallons} - 10.36 \text{ gallons} = 4.64 \text{ gallons}$$

The previous calculations were only given for the purpose of demonstrating the affect of different pressure settings on the drawdown volume of a tank. In practice you will not need to calculate the tank size as this information is readily available from manufactures tables or sizing software.

It is also worth noting that diaphragm in the pressure tank shown in Figure 49 was not bottomed out in the tank at the cut-in pressure point. This is due to the fact that the tank air precharge is set at 2-4 psi lower that the systems operating cut-in pressure. This will ensure there is not a slight pause in the water supply just before the pump is activated.

Figure 50 is an example of a pressure tank selection table designed to give a one-minute pump run time. Notice there are two size columns for each pressure switch setting. Column A is for a modern diaphragm tank. Whereas, column B is for old style standard pneumatic tanks that can not be precharge therefore require a larger tanks size to achieve the equivalent drawdown volume as a diaphragm tank.

[Skip Table] (#skip_table_3)

Figure 50. Pressure tank selection table

Pump Capacity (GPH)	**Pump Capacity (GPM)**	**Minimum Drawdown Gallons**	**Pressure Switch Setting: 20 to 40 PSI**	**Pressure Switch Setting: 30 to 50 PSI**	**Pressure Switch Setting: 40 to 60 PSI**
240	4	4	A: 10, B: 25	A: 15, B: 40	A: 15, B: 55
300	5	5	A: 15, B: 30	A: 15, B: 50	A: 20, B: 70
360	6	6	A: 15, B: 40	A: 20, B: 60	A: 20, B: 85
420	7	7	A: 20, B: 45	A: 25, B: 70	A: 25, B: 100
480	8	8	A: 20, B: 50	A: 25, B: 80	A: 30, B: 110
540	9	9	A: 25, B: 60	A: 30, B: 90	A: 35, B: 125
600	10	10	A: 30, B: 65	A: 30, B: 100	A: 40, B: 140
660	12	12	A: 35, B: 80	A: 40, B: 120	A: 45, B: 165
720	13	13	A: 35, B: 85	A: 40, B: 130	A: 50, B: 180
780	15	15	A: 40, B: 100	A: 50, B: 150	A: 55, B: 210
840	17	17	A: 45, B: 110	A: 55, B: 170	A: 65, B: 235
900	19	19	A: 50, B: 125	A: 60, B: 190	A: 70, B: 265
960	20	20	A: 55, B: 130	A: 65, B: 200	A: 75, B: 280
1020	23	23	A: 65, B: 150	A: 75, B: 230	A: 85, B: 320
1080	25	25	A: 70, B: 160	A: 80, B: 250	A: 95, B: 350
1140	27	27	A: 75, B: 175	A: 85, B: 270	A: 100, B: 375
1200	30	30	A: 80, B: 195	A: 95, B: 300	A: 110, B: 415
1260	33	33	A: 90, B: 215	A: 105, B: 330	A: 125, B: 460
1320	36	36	A: 100, B: 235	A: 115, B: 360	A: 135, B: 500
1380	38	38	A: 105, B: 245	A: 125, B: 380	A: 140, B: 530
1440	41	41	A: 110, B: 265	A: 135, B: 410	A: 155, B: 570
1500	44	44	A: 120, B: 285	A: 140, B: 440	A: 165, B: 610
1560	47	47	A: 130, B: 305	A: 150, B: 470	A: 175, B: 655
1620	50	50	A: 135, B: 325	A: 160, B: 500	A: 185, B: 700
1680	53	53	A: 145, B: 345	A: 170, B: 530	A: 200, B: 735
1740	57	57	A: 155, B: 370	A: 185, B: 570	A: 215, B: 790
1800	60	60	A: 165, B: 390	A: 190, B: 600	A: 225, B: 835

The tank can not be selected until the pump capacity has been determined. You will recall our previous submersible pump sizing exercise where we required a pump to deliver at least a 9 GPM duty point with a 40/60 pressure switch. Referring to our previous software performance curve shown in Figure 46 we see that the pump will actually deliver slightly over 10 gpm when installed into our system. This is worth noting, as any correctly selected pump will usually always end up performing at a greater duty point than the minimum required capacity. It is quite uncommon to have a pumps minimum required capacity land exactly onto the pump curve line. Therefore, the pressure tank for our example should have at least 10 gpm of drawdown not 9 GPM.

Manufacture online pressure tank sizing software is also a readily available option. Figure 51 shows a screen capture of the tank sizing results for our 10-gpm pump operating with a 40/60 pressure switch. You will notice the 37.4-gallon result is comparable to the 40 gallons result you would get using the selection table. Also, the software gives you the option to increase the desired pump runtime.

Figure 51. Tank sizing software screen shot

Tanks for Constant Pressure Systems

The motors that are used for constant pressure systems, are specifically designed to handle frequent starts and stops. The purpose of a pressure tank serving a constant pressure system is not to supply reserve capacity but rather to act as a buffer for pump starts and stops. Therefore, the required tank size is very small, as its only purpose is maintaining system stability and preventing pressure fluctuations. The tank must be installed as close as possible after the pump and the precharge pressure is typically 70% of the controller pressure setpoint. For residential applications an 8 liter (2 gallon) tank is appropriate. The table in Figure 52 shows one manufactures recommend tank sizes for constant pressure systems.

Figure 52. Diaphragm tanks for constant pressure systems

Rated Flow of Pump GPM (m^3/h)	**Minimum Diaphragm Tank Size** Gallons (Liters)
0-26 (0-6)	2 (8)
27-105 (7-24)	4.4 (18)
106-176 (25-40)	14 (50)
177-308 (41-70)	34 (120)
309-440 (71-100)	62 (180)

Now complete Self-Test 2 and check your answers.

Self-Test 2

Self-Test 2

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://opentextbc.ca/plumbing4c/?p=77#h5p-5 (https://opentextbc.ca/plumbing4c/?p=77#h5p-5)

Appendices

- Appendix A: Myers Jet pump Specifications [PDF] (https://opentextbc.ca/plumbing4c/wp-content/uploads/sites/464/2024/07/appendix-A.pdf)

- Appendix B: Grundfos Submersible Pump Performance Data [PDF] (https://opentextbc.ca/plumbing4c/wp-content/uploads/sites/464/2024/07/appendix-B.pdf)

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- Figure 41. "Convertible jet pump performance data (Courtesy of Pentair Myers) (https://www.pentair.com/en-us/flow/myers/myers-products/myers-residential-water-supply-pumps/myers-jet-pumps/myers-hj-series-convertible-jet-pumps.html)" from Pentair Myers is used for educational purposes under the basis of fair dealing.
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- Figure 44. "Sizing software parameter selection screen shot" from the Grundfos' online sizing software (https://product-selection.grundfos.com/ca). It is being used under the basis of fair dealing.
- Figure 45. "Pump matches screen shot" from the Grundfos' online sizing software (https://product-selection.grundfos.com/ca). It is being used under the basis of fair dealing.
- Figure 46. "Software performance curve" from the Grundfos' online sizing software (https://product-selection.grundfos.com/ca). It is being used under the basis of fair dealing.
- Figure 47. "Constant Pressure parameter section screen shot" from the Grundfos' online sizing software (https://product-selection.grundfos.com/ca). It is being used under the basis of fair dealing.

- Figure 48. “Constant pressure pump performance curve”from the Grundfos’ online sizing software (https://product-selection.grundfos.com/ca). It is being used under the basis of fair dealing.
- Figure 49. “Drawdown volume” by Rod Lidstone is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en).
- Figure 51. “Tank sizing software screen shot” from Amtrol’s online well tank sizing software (https://www.amtrol.com/resources-rewards/selection-tools/). It is being used under the basis of fair dealing.

Image descriptions

Figure 41. “Convertible jet pump performance data (Courtesy of Pentair Myers)” image description: A table of ordering information for shallow wells. The table has been split into three separate tables for this description.

Catalog number: HJ50S, HP: ½, Shut-off PSI: 65

Discharge pressure in pounds	Capacity of 5 U.S. Gallons per Minute	Capacity of 15 U.S. Gallons per Minute	Capacity of 20 U.S. Gallons per Minute
20	14.5	11.5	6
30	14.5	11.5	6
40	10	8	5
50	5.5	3.5	2

Catalog number: HJ75S, HP: ¾, Shut-off PSI: 69

Discharge pressure in pounds	Capacity of 5 U.S. Gallons per Minute	Capacity of 15 U.S. Gallons per Minute	Capacity of 20 U.S. Gallons per Minute
20	23.5	17.5	10.5
30	23.5	17.5	10.5
40	19.5	16.5	10.5
50	12.5	9	5

Catalog number: HJ100S, HP: 1, Shut-off PSI: 67

Discharge pressure in pounds	Capacity of 5 U.S. Gallons per Minute	Capacity of 15 U.S. Gallons per Minute	Capacity of 20 U.S. Gallons per Minute
20	27.5	21	13
30	27.5	21	13
40	27.5	21	13
50	19	15.5	12

[Return to Figure 41] (#c1fig41)

Learning Task 3

Describe the Installation of Piping and Equipment for Pressure Systems

In the Province of BC the Water Sustainability Act requires that all well drillers and well pump installers be certified and registered. An individual becomes certified as a Well Pump Installer by completing the ITA challenge process. You may also work as an unregistered well pump installer under the direct supervision of a registered well pump installer, or a professional with a competency in hydrogeology or geotechnical engineering. In many rural areas relying on private water systems, it is common for a plumbing contractor, with a certified installer, to handle the entire process of pump selection, and installation in addition to the buildings water supply piping.

The installation procedures described below pertain to a typical shallow well jet pump or a submersible pump in a well. However, the fundamental steps and considerations are applicable to various pump types, and will aid in the planning and execution of any installation.

Evaluate the Well

To ensure that the well will produce clean, clear water, the well must be developed or proven. Newly drilled wells will contain sand, mud, or debris and should have already undergone thorough development and testing by the well driller. It is advisable to verify the status of the well with the driller to ensure its suitability.

In cases were the well's condition is unknown, it is recommended to install a temporary pump to assess the water supply. The pump is activated, and the well is pumped to evaluate water quality. If the water appears turbid (cloudy), the pump continues to be run until the water clears, after which the temporary pump is removed. Subsequently, the homeowner's pump and pipe can be installed for supplying water to the residence. In situations where an existing pump is in place but the well has been unused, that pump can be utilized to evaluate the well's condition. It is essential to analyze the well water to determine its composition, as this information can influence pump selection. For instance, if the well water is highly acidic, a corrosion-resistant pump must be chosen.

Assess Well Dimensions and Capacity

Before purchasing a pump, it is crucial to calculate the estimated capacity of the well and the household's water supply requirements. It is important to note that the well log provides only an estimate of the well's capacity. Consider the time of year when the well was established, as water levels in some areas fluctuate significantly with the seasons. This will help gauge whether the estimate is relatively high or low. Wells with low yield will require a different type of pump or a distinct pumping system configuration compared to those with high yield.

Determining the well's depth and the pumping level of water is crucial for planning the arrangement of piping and fittings and deciding where to suspend the intake piping or the pump itself. To determine the correct setting depth use the driller's records. The well depth can be checked by lowering a weighted fishing line into the well until it touches the bottom. A fishing real with a depth counter makes it easier to measure the line length. The same setup, with a weighted float can be used to measure the water level. There are also specialized well measuring devices for company's who are measuring wells on a regular basis. These water level meters feature a metal probe attached to a measuring tape (Figure 53). They put out a small electrical current, to a weighted probe attached to the end of a long flexible measuring tape. When the probe is submerged, the unit emits a loud beep and the static water level can be read on the measuring tape. The probe can then also be dropped until it hits the bottom to measure total well depth.

Figure 53. Water level meter

The pump inlet screen or foot valve can be placed at different levels in the water. A general rule is that they should be at least 1 m (3′) below the pumping level of the water in the well. For jet pumps the foot valve or ejector should be at least 0.6 m (2') from the bottom to prevent mud or silt from being drawn in. For submersible installations check manufacturers recommendations for the minimum setting distance from the bottom or a well. These vary from 1.5m (5') to 3 m (10').

The greater distance from the bottom is important for submersible pumps as their motors rely on carrying heat away from the motor by forced convection. The pumped water must flow past the motor on its way into the pump intake. It is important to set the pump above the casing perforations or well screen to ensure that fresh water from the aquifer must flow up past the pump motor rather than cascade down and into the inlet screen.

The inside diameter of the well plays a crucial role in submersible pump selection, as the pump must fit snugly within the well casing. The well cannot be too large for the submersible pump, as their electric motors require a minimum cooling flow water velocity to circulate over and around the entire motor length, to preventing overheating. (Figure 54).

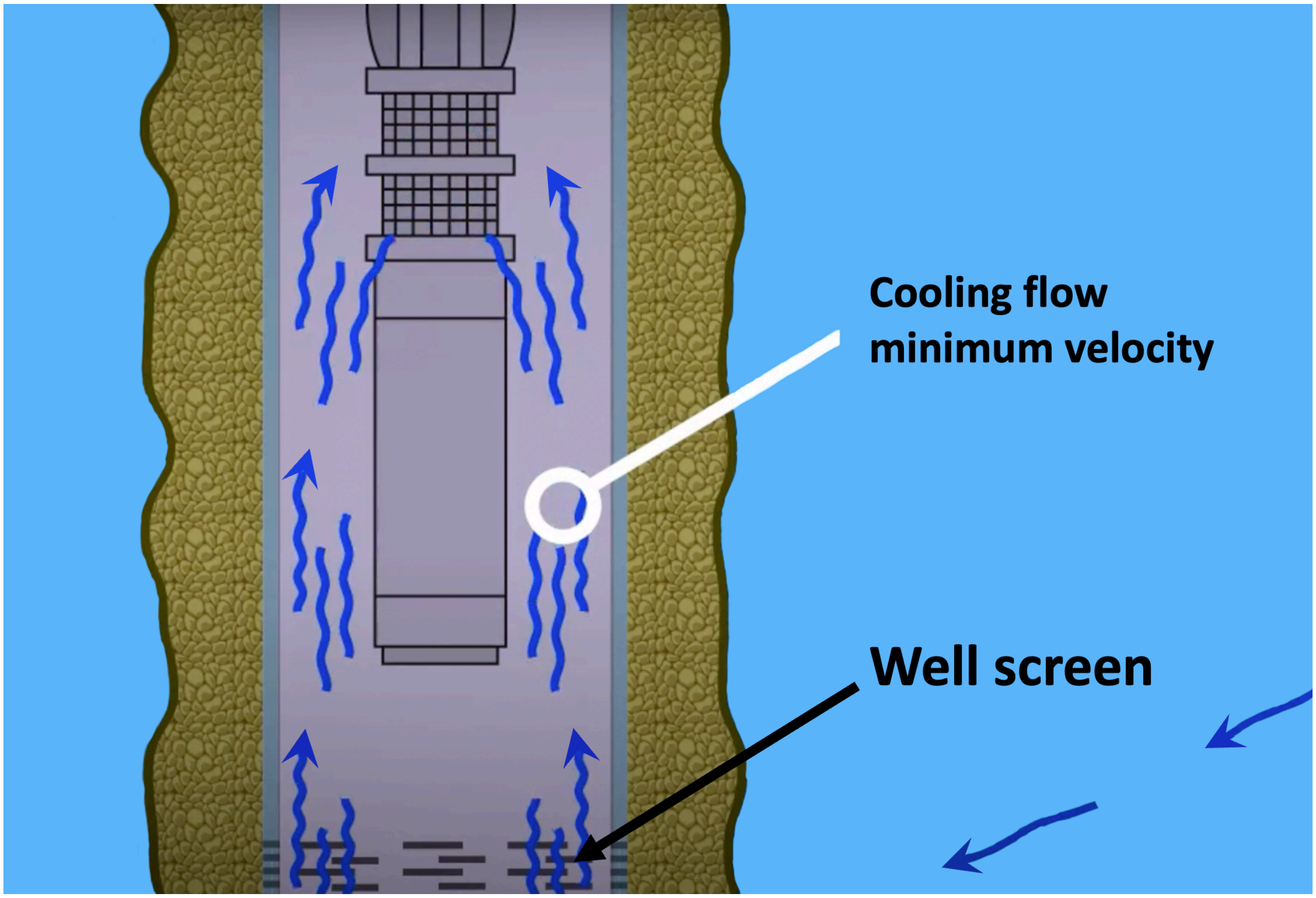

Figure 54. Submersible motor cooling

The actual flow velocity will vary based on the; well diameter, motor size and pumping capacity (gpm). Check with the manufacture to determine required cooling flow for different pump sizes. Manufacture may supply a cooling flow table by motor type and casing size. Alternately the following formula can be used to calculate the flow velocity past the motor:

$$fps = \frac{\text{gpm} \times 0.409}{\text{ID}^2 - \text{OD}^2}$$

fps= feet per second
gpm= gallons per minute
ID= internal diameter of casing (inches)
OD = outside diameter of the motor (inches)
.409 is a constant used because of the various units of measurement used (inches, feet, etc.)

Installation Preparation

Upon receiving the pump and its components from the supplier or manufacturer, carefully inspect them to ensure there is no damage resulting from shipment. Handle the pump and fittings with caution, avoiding any dropping or impact that could cause harm. Verify that all the necessary parts are included in the package. Keep the pump in its packaging until you are ready to install it at the well.

Locate a small metal nameplate attached to the motor or wired to the pump. Verify motor nameplate data meets the application – hp, voltage, phase, and Hertz. For dual voltage jet pumps check the factory setting matches your requirement. The change plug or dial is located under the motor end cover (Figure 55).

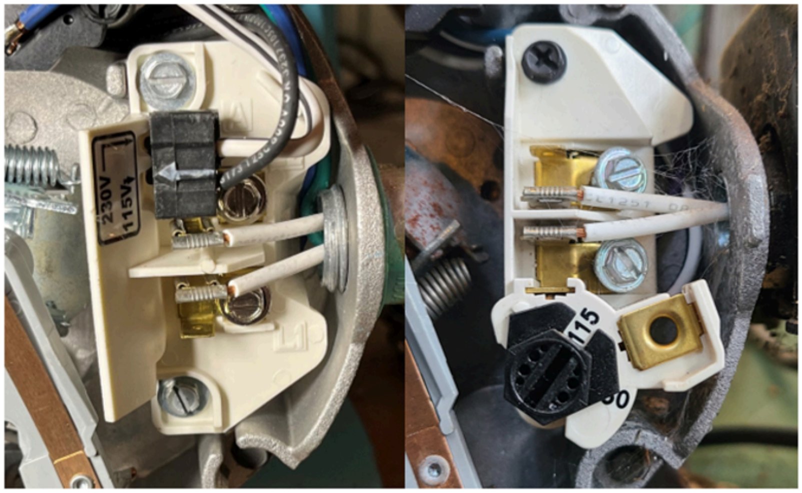

Figure 55. Dual voltage change plug (left) or switch (right)

Check that the motor shaft rotates freely by hand on the second of two complete rotations. Submersible pump manufactures will supply a data plate sticker this should be attached to the well head or control box for future reference.

To minimize friction loss, it is generally recommended to position the pump in close proximity to the well. Depending on the situation, the pump may be located in a basement or a separate pump house. Ensure that the pump is placed on a level and sturdy foundation, protected from harsh weather conditions. If the pump is installed inside a building, ensure adequate ventilation is provided. Confirm that all necessary parts are available and gather any additional tools required for the installation of each component. If the well is not equipped with a well house it is advisable to use a pitless adapter and a sanitary well cap.

If the distance between the pump and the nearest electrical panel exceeds 90 meters (300 feet), a 230V circuit is recommended due to electrical losses that occur over long wire distances. Additionally, a 230V motor operates more efficiently than a 115V motor due to reduced current flow. Ensure that your power to the pump is on a circuit that is protected by a circuit breaker. A disconnect switch should also be wired in, near the pump or control box.

Ensure that the screen on the end of the suction pipe or submersible pump is suitable for the well water conditions. If the well contains sand or fine gravel at the bottom, ensure that the screen is fine enough to prevent these particles from entering the pumping system. Refer to the manufacturer’s catalogues for recommendations on appropriate screen types for different soil conditions.

Flow Sleeve

For submersible installations if it was determined that the minimum cooling flow could not be met then a flow inducer sleeve (cooling shroud) must be installed onto the pump prior to installation (Figure 56). A flow inducer sleeve is also always required in an open body of water.

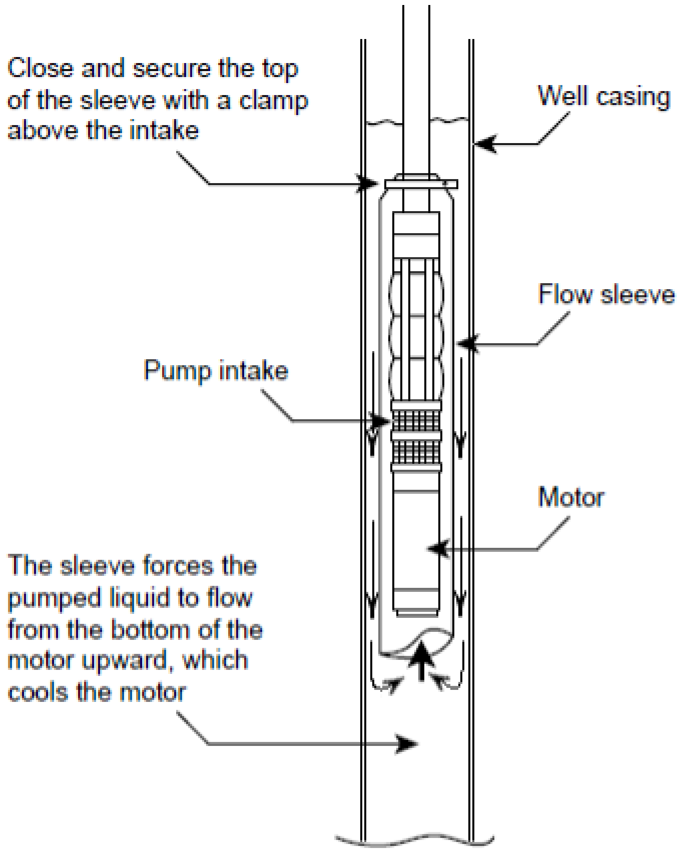

Figure 56. Flow inducer sleeve

The conditions requiring a flow sleeve are:

- Well diameter is too large to achieve minimum cooling flow velocity
- Pump is in an open body of water.
- Pump is in a rock well or below the well casing.
- Pump is set in or below casing screens or perforations creating a top feeding (a,k,a, cascading) supply.

In addition to factory-made, ready-to-use flow sleeves, it is also possible to make flow sleeves from PVC pipe and stainless steel hose clamps. Both options are effective in cooling a submersible motor when sized properly. The motor sleeve is generally of the next nominal diameter of standard pipe larger than the motor or the pump, depending on the sleeve configuration used. The tubular/pipe material can be plastic or thin walled stainless steel (corrosion resistant materials preferred). The cap/top must accommodate the power cable without damage and provide a snug fit, so that only a very small amount of water can be pulled through the top of the sleeve. The fit should not be completely water tight as ventilation is often required to allow escape of any air or gas that might accumulate. The sleeve body should be stabilized by self tapping stainless steel screws installed through the side wall of the flow sleeve to prevent rotation and keep the motor centered within the sleeve. The sleeve should extend to a length of 1-2 times the sleeve diameter beyond the bottom of the motor when possible. Sleeves are typically attached immediately above the pump intake or at the pump/column connection. Avoid setting bottom of flow sleeve near bottom of well.

Pitless Adapter Installation

The general purpose of a pitless adapter is to provide a water tight, 90° connection through the well casing, below the frost line. They also provide a quick connect assembly, between the drop pipe (riser pipe) from the submersible pump or foot vales to the underground service pipe.

The slide type pitless adapters are the most common for residential and commercial applications up to 2″ drop pipe sizes (Figure 57). The slide pitless adapter allows for easy installation or removal of the drop pipe by lifting the pitless elbow using a threaded pull pipe also known as a snare pipe. A single O-ring makes a compression seal between the two mating parts ensuring a leak free connection.

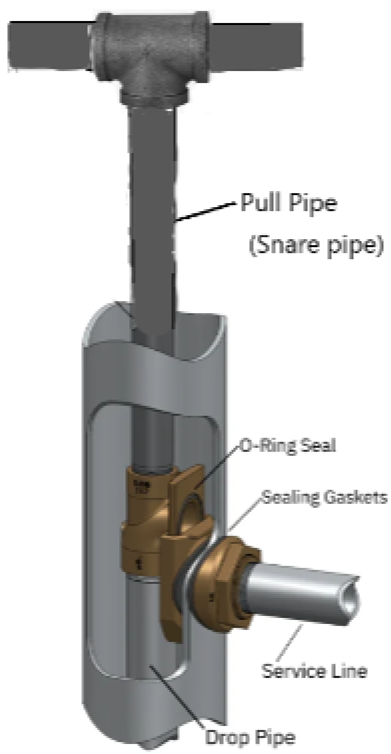

Figure 57. Slide pitless adapter

The pitless adapter will need to be installed through a hole drilled in the well casing prior to the installation of the drop pipe. A water tight sanitary seal is made using compression gaskets on both the inside and the outside of the well casing. The curved rubber compression sealing gaskets are designed to fit a range of casing sizes.

A holesaw is used to cut through the casing below ground deeper than maximum local expected frost depth. The size of the hole is determined by measuring the adapter or using the supplied template. Position the hole so the service line will be pointing the correct direction. Placing a small hacksaw cut into the upper lip of the casing and directly over the pitless adapter's outlet will help you line up the inner portion of the pitless unit once the service line is backfilled and you can no longer see the outside mating portion of the adapter. Ensure that the sealing surface on the casing is clean and smooth to allow the sealing gaskets to compress evenly as the clamping device is tightened on the outside. To install the adapter, remove the large outer nut, collar and outer gasket from the inner components. Cut and thread a pull (snare) pipe of adequate length and attach one end to the dead end threaded tapping on the top of the adapter. It is good practice to use a pull pipe that is long enough to rise above the well a comfortable height for holding and connect the top end of the pull pipe to the branch of a threaded tee with two long nipples on the run outlets of the tee to serve handles and also as a safety precaution to stop the pitless adapter and pull pipe from falling into the well. Lower the pitless adapter into the well casing to the depth of the hole and slide it through the casing. A rigid pull pipe is better for maneuvering and aligning the adapter. Make sure both the inner and outer gaskets are in place and tighten the collar and nut onto the threaded portion of the adapter that is extending through the well casing. Finally lift the pull pipe with the attached inner portion of the pitless adapter fitting out of the well to allow the inner fitting of the adapter to be attached to the pump drop pipe.

After the adapter is installed and the water service line can be connected to the adapter, be sure to keep the top of the well covered while the immediate area around the well is backfilled. Ensure that backfill does not damage your water line by carefully backfilling the area around the adapter by hand and compressing the dirt along the service line with your feet before filling the trench.

Install Submersible Pumps

The following steps outline the procedure used to install a common type of submersible pump. They are intended to introduce you to the process of installing a pump and are not applicable to all pumps. Always refer to specific manufacturer's directions when installing pumps.

Materials

The typical materials you will need include:

- torque arrestors,
- pipe for pump drop and supply line to the pressure tank. Series #160 Polyethylene is commonly used for residential installations,
- a pitless adapter for the size of the casing and drop pipe used,
- suitable stainless steel or brass insert adapters and threaded fittings,
- clamps for connecting the poly tube to insert adapter (the clamps are to be all stainless steel, including the tightening drive nut),
- safety rope or cable used to raise the pump when servicing or replacement is necessary,
- a well cap or sanitary seal for the well,

- a pressure tank,
- a tank tee,
- a pressure switch and gauge,
- a drain valve for the tank tee,
- an adjustable pressure relief valve for system pressure protection,
- a suitable shut-off valve for the pressure tank, to be placed at the outlet of the tank tee to allow shut-off of the distribution system,
- Submersible, single phase, 3-wire motors require the use of a control box. The control box and 3-wire motor must match in HP and voltage to operate properly,
- If there is a potential for the well to run dry another electrical no-load control box is recommended to protect the pump,
- Constant pressure systems will require a special electronic control or VFD and a pressure transducer,
- screws to fasten the pump's control box to a wall,
- some electrical box wire connectors,
- a suitable water proof splice kit to attach the cable wires to the motor leads of the submersible motor,
- tie wraps to fasten the electrical cable to the drop pipe,
- appropriate size and length of electrical drop cable.
    - Power cables must be selected to match the type of motor (i.e., single-phase, three-phase), voltage, horsepower and length. Always check manufacturer's recommendations. The Table below shows a sample of the range of wire sizes that are specified for each type of submersible motor depending upon the total cable length required from the motor to the service power panel.
    - If the control box will be located close to the well head, as in a dedicated pumphouse, then the pump portion of the cable length should be cut long enough to reach the control box. In cases were the control box will be located away from the well head, within the building, then the pump portion of the total cable should be long enough to reach to the top of the well head with enough slack to make a connection to the wires coming from the control box in the building. The motor leads may be smaller than the specified cable, this is acceptable as the motor leads are short and there is virtually no voltage drop across the leads.

60 Hz 75°C (167°F) Maximum Submersible Power Cable Length Max. Cable Length In Feet (Meters) - Service Entrance to Motor														
Motor Rating		**AWG Copper Wire Size**												
Volts	**H.P.**	**14**	**12**	**10**	**8**	**6**	**4**	**3**	**2**	**1**	**0**	**0**	**0**	**0**
115	1/2	100 (300	160 (49)	250 (76)	390 (119)	620 (189)	960 (293)	1190 (363)	1460 (445)	1780 (543)	2160 (658)	2630 (802)	3140 (957)	3770 (1149)
	1/2	400 (122)	650 (198)	1020 (311)	1610 (491)	2510 (765)	3880 (1183)	4810 (1466)	5880 (1792)	7170 (2185)	8720 (2658)	10620 (3237)	12660 (3859)	15210 (4636)
	3/4	300 (91)	480 (146)	760 (232)	1200 (366)	1870 (570)	2890 (881)	3580 (1091)	4370 (1332)	5330 (1625)	6470 (1972)	7870 (2399)	9380 (2859)	11250 (3429)
	1	250 (76)	400 (122)	630 (192)	990 (302)	1540 (469)	2380 (725)	2960 (902)	3610 (1100)	4410 (1344)	5360 (1634)	6520 (1987)	7780 (2371)	9350 (2850)
	1-1/2	190 (58)	310 (94)	480 (146)	770 (235)	1200 (366)	1870 (570)	2320 (707)	2850 (869)	3500 (1067)	4280 (1305)	5240 (1597)	6300 (1920)	7620 (2323)
230	2	150 (46)	250 (76)	390 (119)	620 (189)	970 (296)	1530 (466)	1910 (582)	2360 (719)	2930 (893)	3620 (1103)	4480 (1366)	5470 (1667)	6700 (2042)
	3	**120* (37)**	190 (58)	300 (91)	470 (143)	750 (229)	1190 (363)	1490 (454)	1850 (564)	2320 (707)	2890 (881)	3610 (1100)	4470 (1362)	5550 (1692)
	5	-	**110* (34*)**	180 (55)	280 (85)	450 (137)	710 (216)	890 (271)	1110 (338)	1390 (424)	1740 (530)	2170 (661)	2680 (817)	3330 (1015)
	7-1/2	-	-	**120* (37*)**	200 (61)	310 (94)	490 (149)	610 (186)	750 (229)	930 (283)	1140 (347)	1410 (430)	1720 (524)	2100 (640)
	10	-	-	-	**160* (49*)**	250 (76)	390 (119)	490 (149)	600 (183)	750 (229)	930 (283)	1160 (354)	1430 (436)	1760 (536)
	15	-	-	-	-	**170* (52*)**	270 (82)	340 (104)	430 (131)	530 (162)	660 (201)	820 (250)	1020 (311)	1260 (384)

(https://opentextbc.ca/plumbing4c/wp-content/uploads/sites/464/2024/08/Screenshot-2024-12-10-at-8.54.17 AM.png)
Table: 60 Hz 75°C (167°F) Maximum Submersible Power Cable Length Max. Cable Length In Feet (Meters) – Service Entrance to Motor ("Size" is AWG Copper Wire Size) [Image Description] (#table_maximum_submersible_desc)

Table notes:

1. Both jacketed cable and single conductor cables may be used other then values marked **Bold** and * indicating conductor only (not jacketed).
2. Table based on copper wire. If aluminum wire is used, multiply lengths by 0.5. Maximum allowable length of aluminum is considerably shorter than copper wire of same size.

Submersible Pump Installation Steps

1. After carrying out the general pre-installation checks, assemble the pump and motor if necessary.
    - Never use a wrench on any part of the pump except the machined flats on the top of the pump.
2. Splice the motor cable. The splice requires covering with a shrink tube containing a sealing compound that releases when the shrink tube is heated, forming a seal for the electrical splice. The wires should be trimmed back to place each individual splice in the wires a short distance apart from the next splice to avoid a large ball of excess material at the splice location. A general procedure for splicing cables with a heat shrink splice kit is:
    - check that motor cable and drop cable are in good condition
    - stagger the motor leads by cutting each one successively shorter
    - cut the drop cable leads to match
    - if installing a single-phase motor, match colours

    - strip about 13 mm (½”) of insulation from each lead
    - slide pre-cut heat shrink tubing onto leads
    - connect leads with connectors and crimp the connecting lugs
    - slide tubing over connections and heat until tube contracts and sealant flows
    - spliced should be tested with an ohmmeter for leaks to ground prior to pump installation. *Procedure for testing motor cables and splices are explained in Learning Task 5.*

3. Lay out the riser pipe sections, fittings and pump. Make sure you have the appropriate thread compound, fittings or cements to join steel or plastic piping. Compare your measured well depths with the length of piping to ensure that the submersible will be suspended at the correct depth. The pump should always be at least 0.9 m (3’) below the maximum drawdown level of the well. If you use plastic piping, remember to allow for the stretching that will occur.
   Some people will cut a length of 4^{2} PVC pipe and attach it to the bottom of pump motor to act as a support to keep the pump a pre-set distance from the bottom of the well. **This practice is not recommended as it will affect the cooling of the motor and potentially void the manufactures warranty.**
4. Connect the first section of riser pipe to the discharge outlet of the pump. Make sure that you do not overtighten the threaded connections as this could damage the check valve in the discharge chamber and destroy the pump. Extra long barbed insert adapters are available for hanging pump on poly riser pipe. When tightening the threaded adapter into the pump only grip the pump by the two flats at the top of the pump. Do not hold the pump housing during installation of the riser pipe adapter or a check valve.
   If the pump uses an external check valve it will need to be installed first into the top pf the pump.
5. All polyethylene pipe connections should be double-clamped. The clamps should be installed in an alternate arrangement to place one head of a clamp on either side of the tube and the clamps should be placed to clamp over the barbs of the adapter. Do not overtighten the clamps, as they can be stripped. When applying the clamps, keep them as close together as possible, and tighten them in steps, snugging them up many times rather than tightening them in one step. Remember that the polyethylene you are using will be quite stiff and will slip more easily onto the mating portion of the barbed fitting if the poly is warm. In colder conditions, it may be necessary to warm the pipe ends with warm water or carefully with a heat gun. Do not heat the tube with a torch, as overheating may change the plastic to a brittle compound that can break under the stress of service.
6. Install a torque arrestor (Figure 58 left) to keep pump centered and control flexing movement of the pipe caused by the pump starting and stopping. The first torque arrestor is typically installed 18″-24″ above the submersible pump. Installation practices can vary depending on the depth, type of pipe and the pump horsepower. Some installers will install additional arrestors at 75-100 ft intervals to prevent the piping from rubbing the side of the casing and wearing the pipe and or cable. Cable guards (Figure 58 right) are another option to keep the upper section of the drop pipe centered and keep the power cable from rubbing against the well casing.

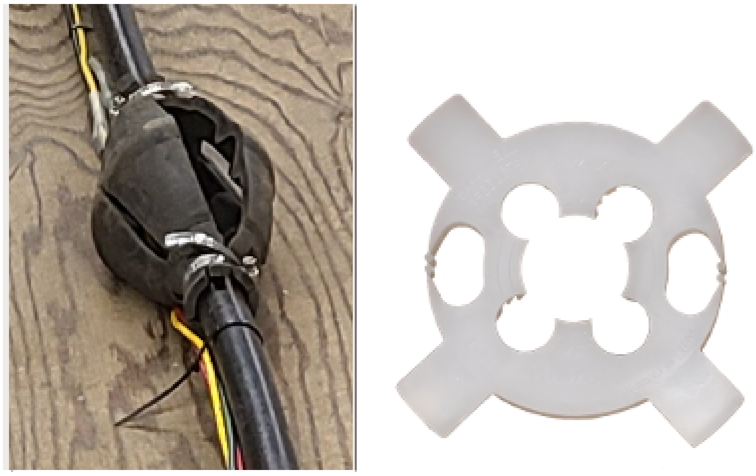

Figure 58. Torque arrestor and cable guard

7. Use cable ties to secure the drop cable to the riser pipe at minimum of 3m (10 ft) intervals to prevent cables tangling or being damaged. When securing the cable to the riser pipe, allow 2 inches of slack between the intervals as plastic pipe tends to stretch under load. Avoid using electrical tape to fasten the wires, as it is known to loosen and detach in the moist conditions of the well, commonly ending up at the intake of the pump and blocking it.
8. Attach a safety rope to the pump to assist in removal of the pump from the well. Under no circumstances should the pump be removed by using the electrical wires to lift the pump and discharge piping. Most pumps will have an integral hook or loop in the top of the pump to attach the rope securely.
9. Lower the pump and first section of riser pipe into the well. Depending on the type of drop pipe there are a number of different methods that are used to lower the pump smoothly and prevent damage.

    - If using polyethylene make sure to remove any sharp edges on the casing. Some installers will make a protective donut or rollers to help guide the pipe over the casing edge. Getting the full length of pipe, pump and wires into the well is heavy work that requires two people in charge of feeding the pipe down into the well head, and a third guiding the top end of the pipe.
    - If steel or ridged plastic pipe is used then some type of overhead hoist will be needed that is tall enough to elevate a full length of pipe. You will also need riser clamp or pipe holder to span the top of the well head for temporarily supporting the lowered sections each time you join the next section of pipe.

10. Slowly lower the pump, piping, power cable and safety rope to the required depth, clipping the drop cable and adding any necessary additional torque arrestors or cable guards. For pump settings 60 m (200 ft) or deeper, manufacturers recommend the installation of additional spring-loaded in-line check valves at regular 60 m (200 ft) intervals.
An ohmmeter, or megger should be used to measure the insulation resistance on the power cable every 20 feet as the pump is lowered. This will locate any fault in the cable.
Procedures for testing the insulation resistance are explained in Learning Task 5
11. Depending on whether the drop pipe will exist the well below or above ground, terminate the

drop pipe with either a well seal or a well cap with pitless adapter (Figure 59).

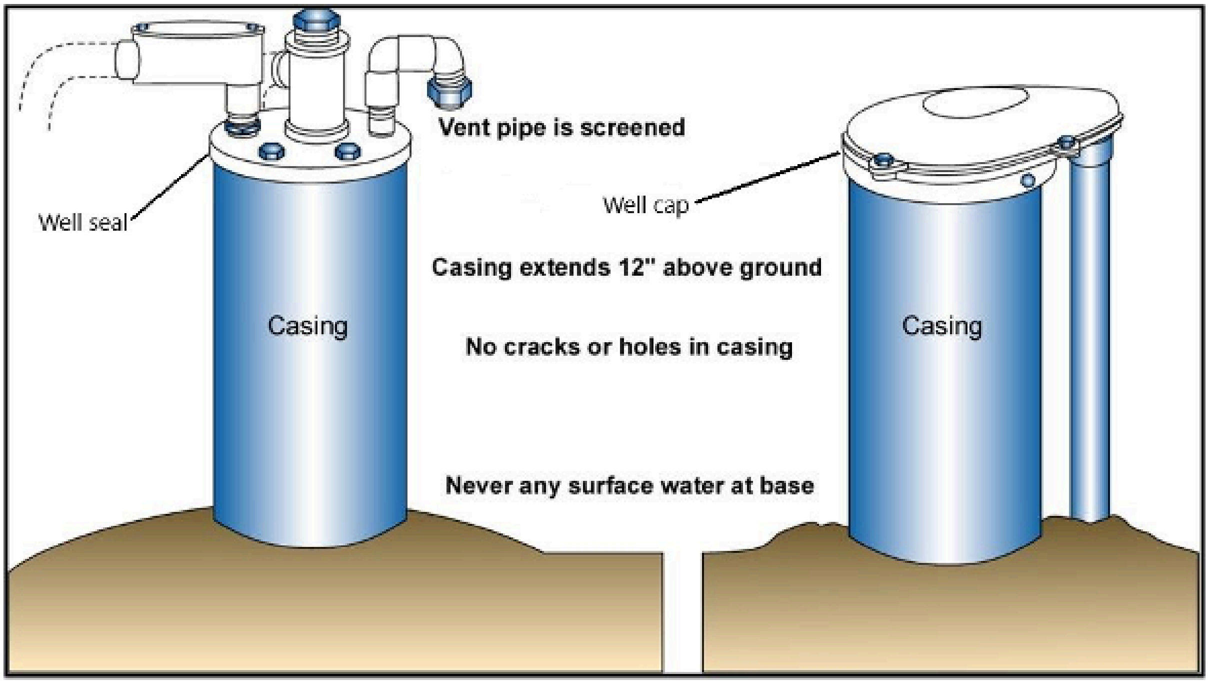

Figure 59. Well seal and well cap terminations

- For an above ground well seal termination, connect the necessary pipe adapter and threaded nipple onto the end of the drop pipe, while supporting the installed string of drop pipe. Slip the seal down over the threaded nipple and connect an elbow or tee for the above ground fitting. Run the pump cable and safety rope through threaded electrical conduit hole. Lower the pipe string until the tee or elbow is down on the seal, and the seal is seated on the well casing. Tighten the bolts to squeeze the packer against the inside of the well casing and the pipe. The other ½" threaded connection can be used to connect a well vent if needed.
- For a pitless adapter with well cap termination, slowly lower the drop pipe straight down the well with the snare pipe in your hands (Figure 60). As it lowers, with a small movement of the snare pipe feel the opening you are looking for. You may have to lift and turn the snare pipe slightly before it aligns and drops into the other half of the pitless unit. The adapter will seat with a solid feel when the two sections are properly meshed. Tie the end of the safety rope onto the rope hanger plate.

Figure 60. Well cap and pitless being installed

Warning

Contact with hazardous voltage could result in death or serious injury. Before starting any electrical work make sure that the power supply has been disabled and locked out so that it cannot be accidentally switched on. A qualified electrician should wire the electrical supply for any pump motor.

12. All pump wiring must be protected from physical damage. Submersible pumps usually have their power supply placed in the ditch with the water supply line to the residence. Armoured cable (Teck) or electrical conduit are laid from the house to the well at a depth of 3′ (1 m). A 3′ (1 m) depth of bury allows for some protection from shallow digging operations such as for gardens. The conduit/Teck cable comes up beside the well casing and is connected to the well cap for secure fastening. The conduit/Teck is commonly tie-wrapped to the casing below ground

level to keep it vertical while backfill is placed. The wires going to the pump and the wires coming from the house are commonly fastened together with watertight connections at the top of the well. The metal well head and metal casing must be connected to the ground circuit. Excess wire is left neatly coiled in the top portion of the well casing under the well cap to allow electrical measurements to be made at the well head.

13. Connected the pump power cable to the pump panel, control box, VFD or constant pressure controller as per manufactures instructions (Figure 61). Always connect the control box or panel-grounding terminal to supply ground per the Canadian Electrical Code (CEC) requirements.

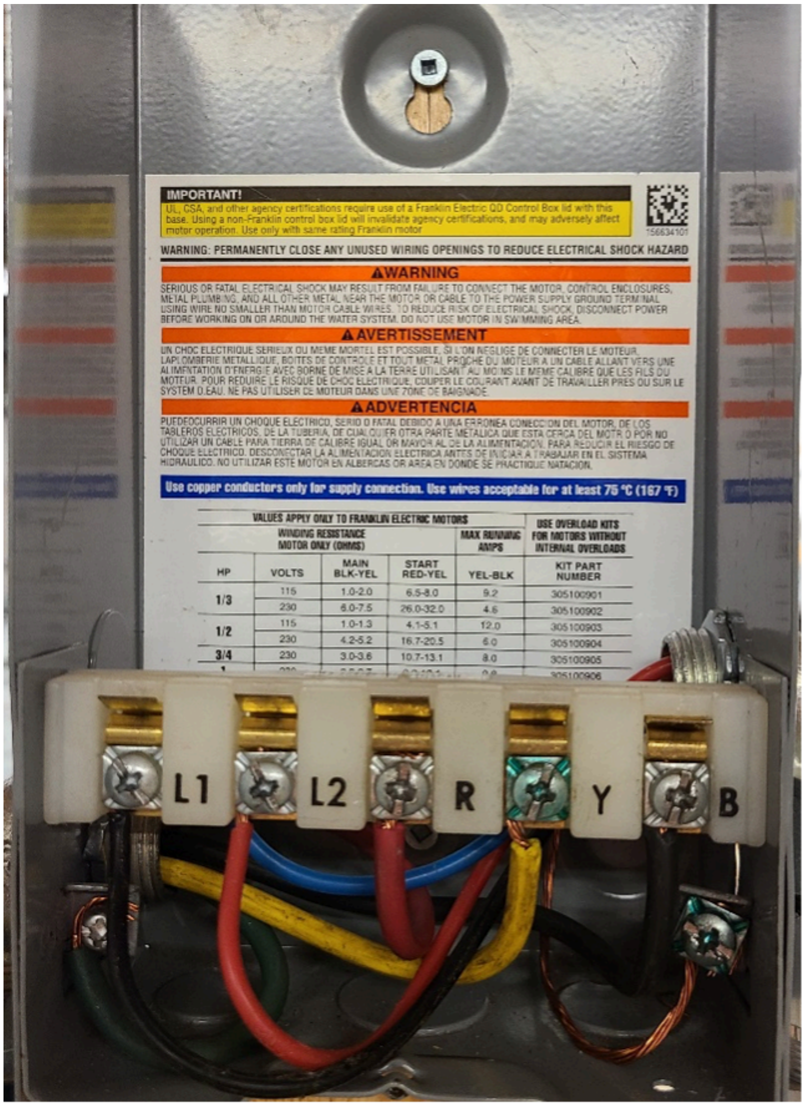

Figure 61. Control box connections

14. Connect the power supply and connections between the pressure switch and the control box as per the manufactures instructions and Canadian Electrical code (CEC). Include a disconnect switch near the control box.

After electrical work is completed and before pump is connected to pressure tank, the pump should run to test the water for clarity.

Pump start up will be covered in Learning Task 4- Describe the testing and commissioning of water supply pressure systems.

Install Jet Pumps

The following steps outline the procedure used to install a common type of convertible jet pump. They are intended to introduce you to the process of installing a shallow well or deep well jet pump and do not apply to all pumps. Always refer to specific manufacturer's directions when installing pumps in the field. The diagrams and instructions refer to PVC piping material but other approved material could be used.

In a deep well installation, the jet assembly is submerged in the well because the vertical distance to the water level exceeds the maximum practical suction lift of 25 ft. Adjustment of the regulator causes the correct amount of water to be diverted back down to the jet for the most efficient operation. The regulator may also be used to restrict the flow of water in a shallow well system if the convertible pump has the capacity to draw more water than the well can produce. In a shallow well installation, the jet assembly is attached directly to the pump because a vacuum will adequately lift water to the pump.

Shallow Well Installation

Before beginning the installation be sure to complete the installation preparation checks. Some pump assembly may be required. For example, you might need to connect the ejector onto the pump body for a convertible style of jet pump. Make sure that the pump foundation is firm and level. Secure the pump to the foundation. If the pump is near or in the house, place a rubber mat or under cushion between the pump and foundation to help deaden pump noise. Locate the pump as close to the well as possible to minimize friction losses. Refer to Figure 62 for these typical shallow well installation instructions.

1. Connect foot valve to 1-1/4" plastic pipe adapter and cement adapter to 1-1/4" rigid PVC pipe.
2. Add rigid PVC pipe sections and couplings (as required) while lowering foot valve into well to the proper depth. The foot valve should be at least 0.9 m (3') below the pumping level and at least 0.6 m (2') from the bottom. Verify these minimum dimensions with the manufacture.
3. Install well seal over rigid PVC pipe and into well casing. Cement 1-1/4" PVC elbow to top of pipe at correct length to position foot valve at proper depth. Lower foot valve/piping assembly carefully into well, using pipe riser clamp to hold onto. Draw up bolts on well seal until rubber gaskets are tight against both the well casing and the pipe.
4. Continue connecting horizontal piping from the well head to the pump, you may want to install unions when connecting to the pump. This pipe should slope upwards to the pump to avoid air locks. If the horizontal piping run from the well to the pump is more than 12 m (40'), some manufactures recommend the installation of a check valve near the pump.
5. Connect pressure tube between pump case and pressure switch on pump.

6. Install discharge tee in pump discharge until tight.
7. Make the electrical connections to the pressure switch as per the manufactures instructions and Canadian Electrical code (CEC). Include a disconnect switch near the pump.
8. After electrical work is completed and before pump is connected to pressure tank, the pump should be primed and test run.

Priming and start up will be covered in Learning Task 4 – Describe the testing and commissioning of water supply pressure systems

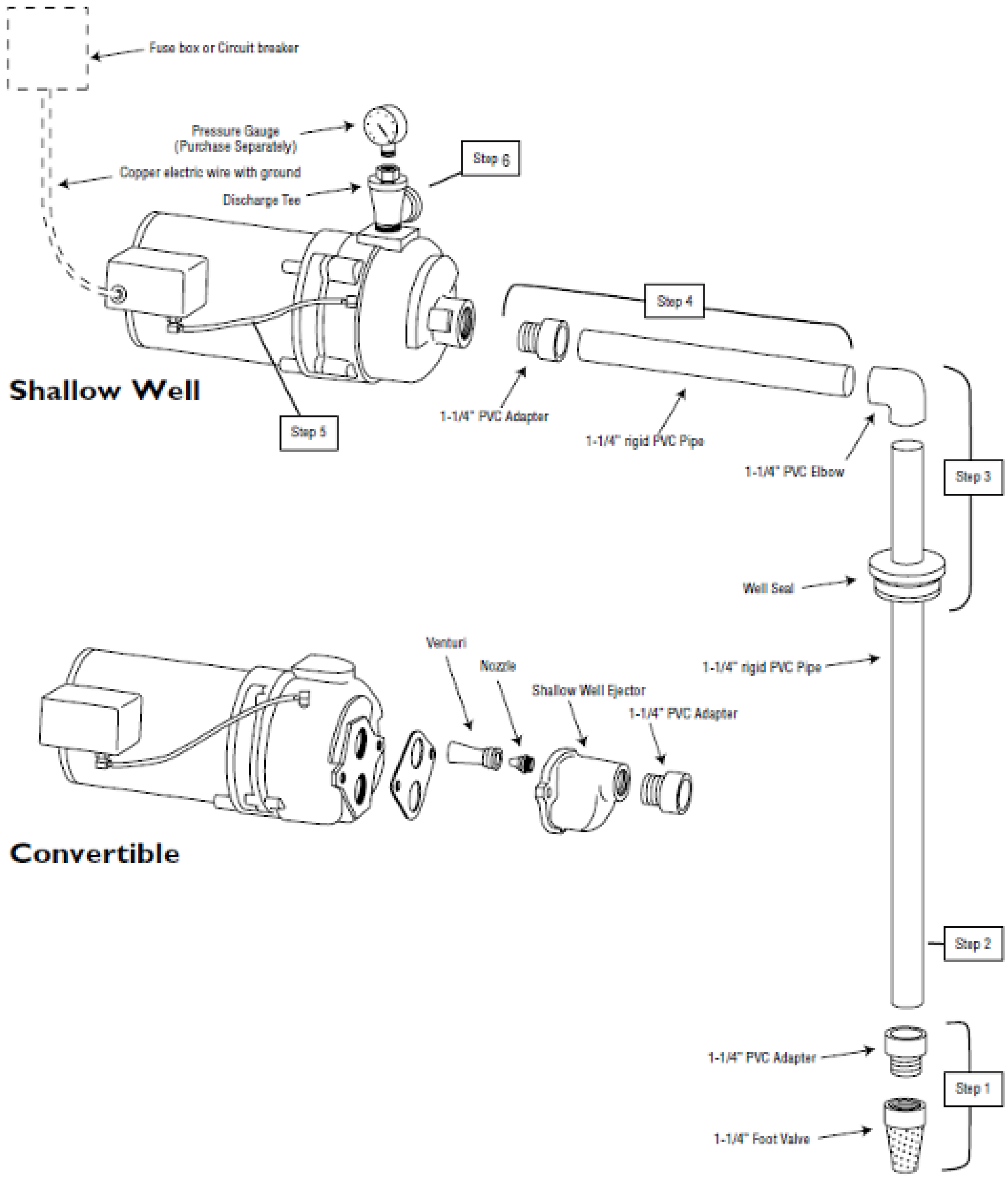

Figure 62. Shallow well pump installation

Deep Well Installation

Before beginning the installation be sure to complete the installation preparation checks. Refer to Figure 63 for these typical shallow well installation instructions.

1. Begin installation by attaching foot valve to close nipple of corresponding size. Connect nipple/foot valve assembly to bottom of ejector body. Next install plastic nozzle and venturi into top of ejector body.
2. Use adapters to connect a section of pressure and suction piping to the ejector body. Pressure piping is usually 1” diameter and suction pipe is 1¼” in diameter.
3. Add rigid PVC pipe sections and couplings (as required) while lowering the ejector assembly into well to the proper depth. The ejector should be at least 0.9 m (3’) below the pumping level and at least 0.6 m (2’) from the bottom. Verify these minimum dimensions with the manufacture.
4. After lowering pipes and ejector assembly into well, install well seal. Draw up bolts on well seal until the rubber gaskets are tight against the well casing and the two plastic pipes. For deep well jet pump, fill the vertical pipes with clean water before connecting to horizontal piping. This will help in priming the pump.
5. Cut top of 1” pipe 2” shorter than the 1-1/4” pipe, as shown in the installation diagram. Cement 1-1/4” PVC elbow and 1” PVC elbow to the top of each pipe.
6. Connect horizontal piping from the well head to the pump. These pipes should slope upwards to the pump to avoid air locks.
7. Make the electrical connections to the pressure switch as per the manufactures instructions and Canadian Electrical code (CEC). Include a disconnect switch near the pump.
8. After electrical work is completed and before pump is connected to pressure tank, the pump should be primed and test run.

Priming and start up will be covered in Learning Task 4- Describe the testing and commissioning of water supply pressure systems.

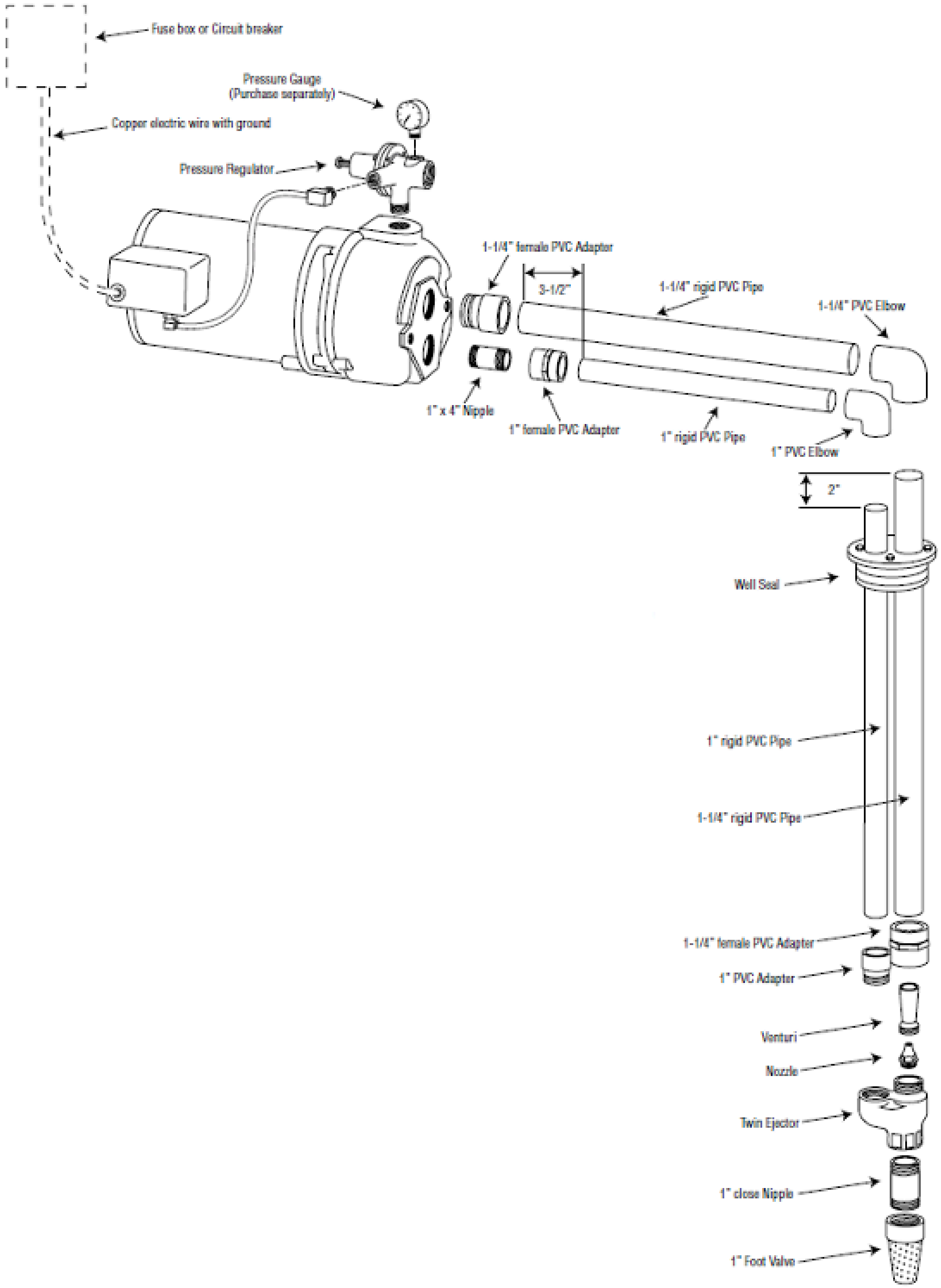

Figure 63. Deep well pump installation

If you are installing a deep well pump in a weak well, you may connect the foot valve and screen onto an 11 m (35’) tailpipe which is coupled to the ejector assembly. As the water lowers past the ejector fitting the suction head will increase, reducing the capacity of the pump. The farther the water lowers below the fitting, the lower the amount of water the pump can produce, until the delivery capacity of the pump matches itself with the amount of water coming into the well from the aquifer.

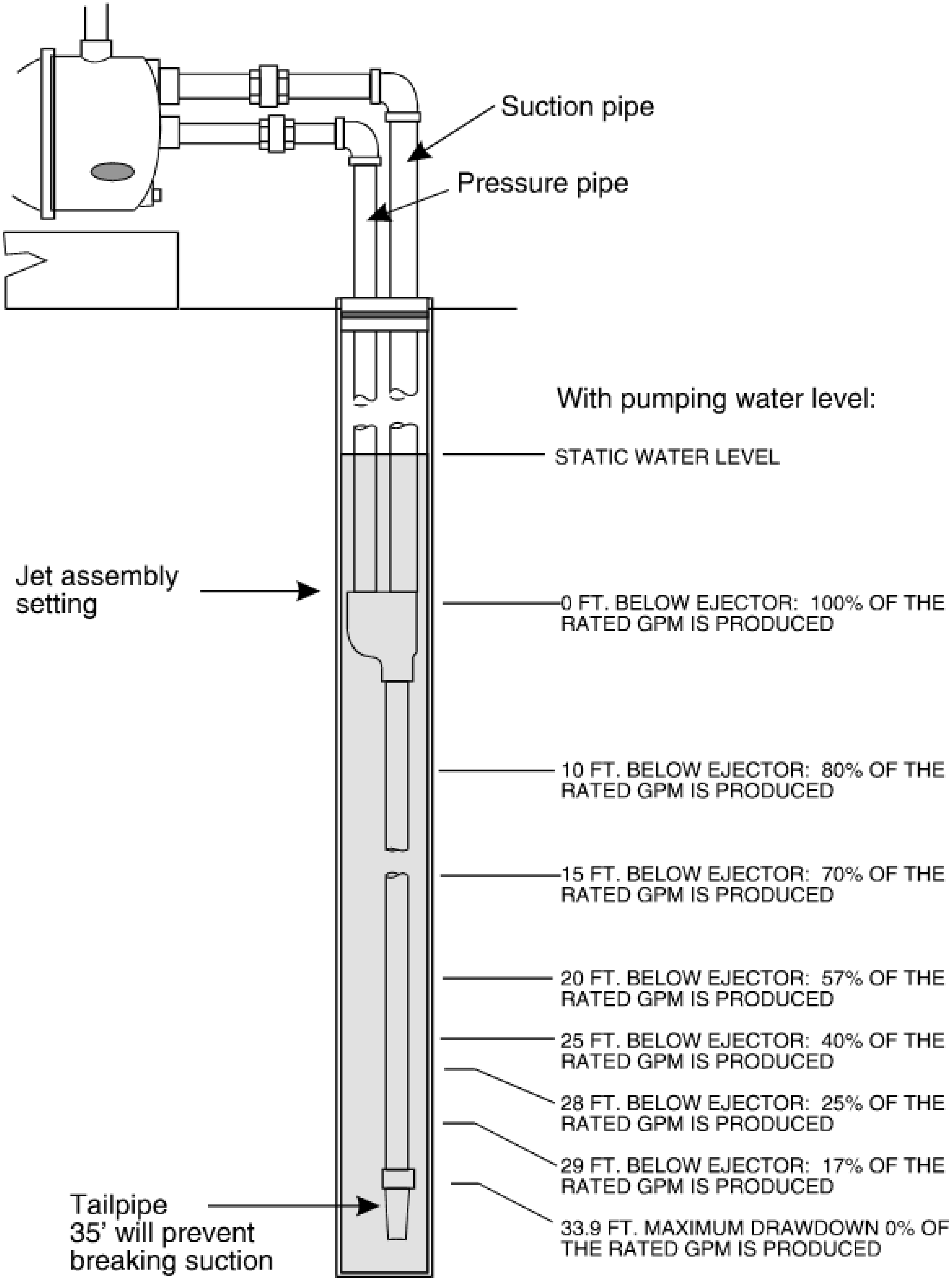

Figure 64. Low yield well tail pipe solution

Install Pressure Tanks

Although the well would have been developed and proved by the driller prior to the pump installation, it is good practice to test the well water for clarity before connecting to the pressure tank and house piping.

Priming and start up are covered in Learning Task 4- Describe the testing and commissioning of water supply pressure systems

For these instructions it is assumed you are installing a diaphragm or bladder type pressure tank, were pressure tank has previously been selected and sized to match the requirements of the pumping system..

Upon receiving the tank from the supplier or manufacturer, carefully inspect it to ensure there is no damage resulting from shipment. Keep the tank in its packaging box until you are ready to install it. Check the factory pre-charge of air in the tank with an ordinary tire gauge onto the valve stem at the top of the tank. If there is no factory precharge this may be an indication of a faulty tank. You may need to add of remove compressed air so that the pre-charge is correct for your system. The pre-charge pressure is only to be measured or adjusted when there is no water in the pressure tank. For conventional fixed speed pump systems, the precharge pressure should be approximately 2 psi lower that the cut-in setting of the pressure switch. For example, if the pump has a 30/50 PSI switch, the tank pre-charge pressure should be 28 PSI.

For pressure tanks serving a constant pressure pumping system the precharge pressure is usually about 70% of the actual controller setpoint, but check with the manufacture instructions.

Determine the best location for the pressure tank, for jet pumps the tank should be located as close as possible to the pump. Never install the tank where it could freeze. A floor drain located in close proximately will help with service and maintenance of the system. Place tank in a vertical position on a level surface. The base should be fully supported to ensure maximum stability and the floor should be stable and level. Some small inline tanks do not have a base, these will need to be suspended and supported independently of the piping, with the tank connection on the bottom. Locating the connection on the bottom for water supply pressure tanks ensures that any sediment that might accumulate in the tank is flushed out with each pumping cycle.

After the pump has been test run and the water is clear connect the pipe and fittings to the tank. The system should include at least one union for service, tank tee, gauge, check valve, pressure relief valve, drain valve, pressure switch or (VFD pressure sensor), and a valve to isolate the service line from the pressure tank. By using an appropriate length tank tee you can easily incorporating all of these components into the system at one convenient location (Figure 65).

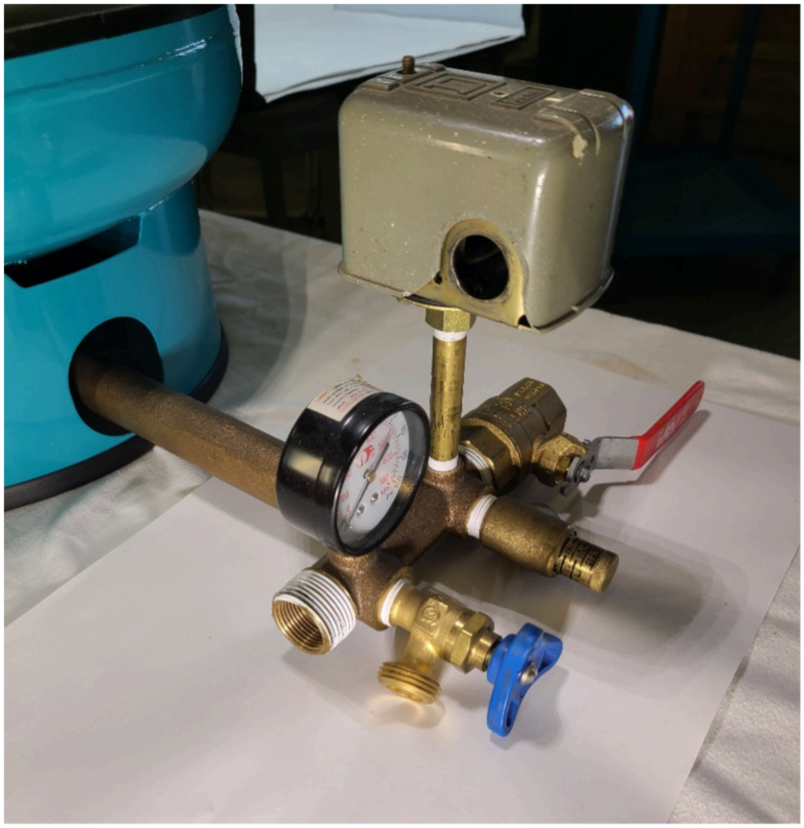

Figure 65. Connected tank tee

Pressure Switch Wiring

As has been previously mentioned you should not attempt any electrical wiring procedures unless you are qualified and know exactly what you are doing and how to proceed with it. Even the most casual treatment of electricity can kill you and cause severe damage to property, equipment and other personnel.

Surface wiring connections for pumps can vary depending on the type of pump used and the demands of each installation. Jet pumps are supplied with the pressure switch attached to the pump body and the wiring from switch to the motor already completed. For submersible pumps a common configuration of control box, disconnect box, motor and pressure switch connections is shown in Figure 66.

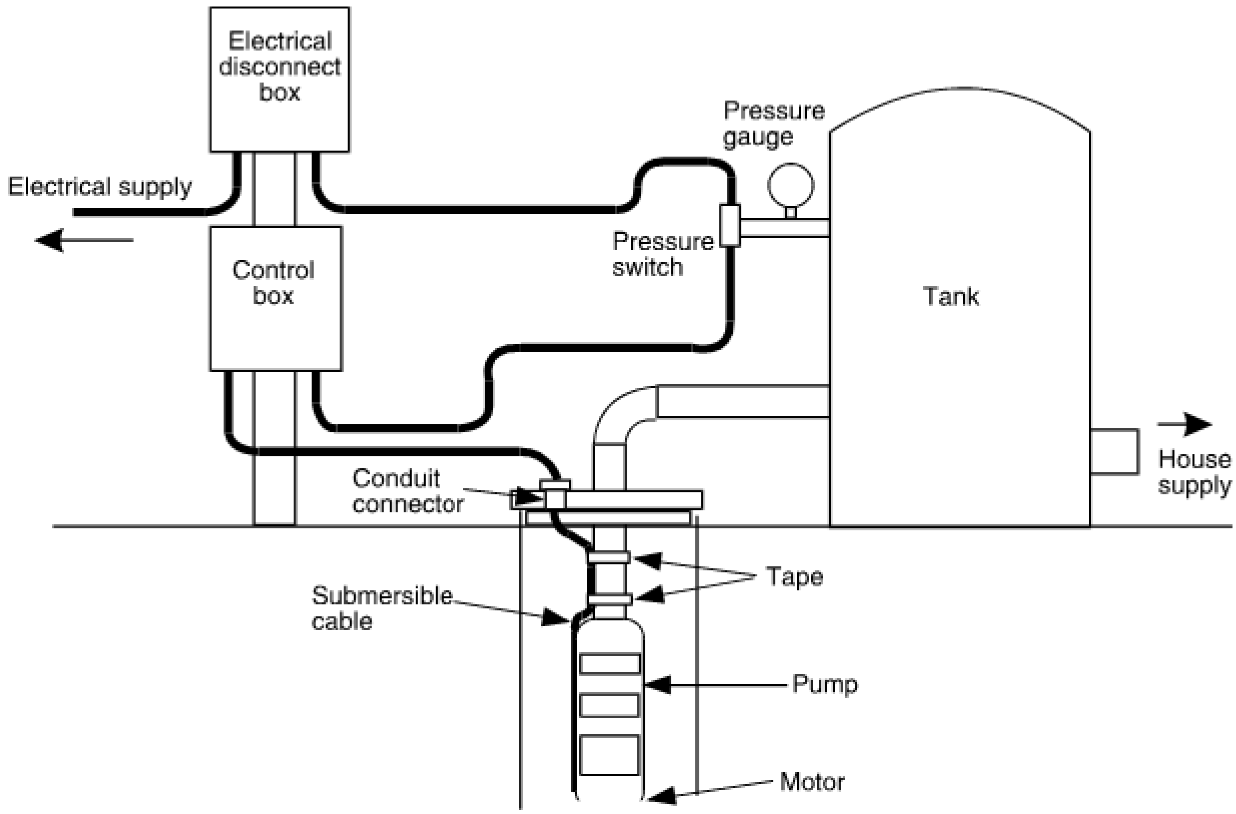

Figure 66. Submersible pump wiring

The pressure switch is a double pole single throw switch (Figure 67). First connect the ground wire to one of the grounding connections. The incoming power leads are connected to the two outer screws (1 & 4). The inner screws (2 & 3) are responsible for linking to the motor supply in the case of a two-wire submersible pump, or connecting to the L1 and L2 terminals in the control box for a three-wire pump.

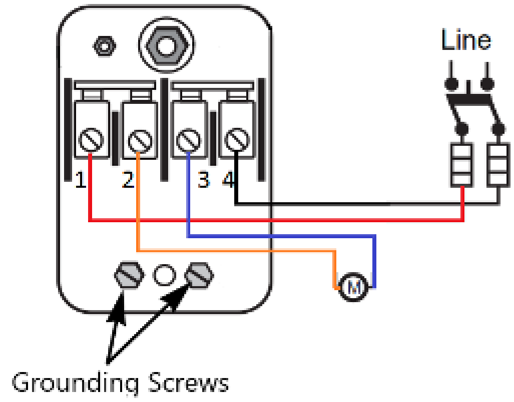

Figure 67. Pressure switch wiring

☑ Now complete Self-Test 3 and check your answers.

Self-Test 3

Self-Test 3

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://opentextbc.ca/plumbing4c/?p=127#h5p-7 (https://opentextbc.ca/plumbing4c/?p=127#h5p-7)

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Image Descriptions

Table: 60 Hz 75°C (167°F) Maximum Submersible Power Cable Length Max. Cable Length In Feet (Meters) – Service Entrance to Motor *[Skip Table]* (#table_maximum_submersible)

60 Hz 75°C (167°F) Maximum Submersible Power Cable Length Max. Cable Length In Feet (Meters) – Service Entranc Motor
("Size" is AWG Copper Wire Size)

Motor Rating (Volts)	**Motor Rating (H.P.)**	**Size: 14**	**Size: 12**	**Size: 10**	**Size: 8**	**Size: 6**	**Size: 4**	**Size: 3**	**Size: 2**	**Size: 1**	**Size: 0**	**Size: 00**	**Size: 000**	**Siz 000**
115	½	100 (300)	160 (49)	250 (76)	390 (119)	620 (189)	960 (293)	1190 (363)	1460 (445)	1780 (543)	2160 (658)	2630 (802)	3140 (957)	377 (11
230	½	400 (122)	650 (198)	1020 (311)	1610 (491)	2510 (765)	3880 (1183)	4810 (1466)	5880 (1792)	7170 (2185)	8720 (2658)	10620 (3237)	12660 (3859)	152 (46
230	¾	300 (91)	480 (146)	760 (232)	1200 (366)	1870 (570)	2890 (881)	3580 (1091)	4370 (1332)	5330 (1625)	6470 (1972)	7870 (2399)	9380 (2859)	112 (34
230	1	250 (76)	400 (122)	630 (192)	990 (302)	1540 (469)	2380 (725)	2960 (902)	3610 (1100)	4410 (1344)	5360 (1634)	6520 (1987)	7780 (2371)	935 (28
230	1 ½	190 (58)	310 (94)	480 (146)	770 (235)	1200 (366)	1870 (570)	2320 (707)	2850 (869)	3500 (1067)	4280 (1305)	5240 (1597)	6300 (1920)	762 (23
230	2	150 (46)	250 (76)	390 (119)	620 (189)	970 (296)	1530 (466)	1910 (582)	2360 (719)	2930 (893)	3620 (1103)	4480 (1366)	5470 (1667)	670 (20
230	3	**120* (37)**	190 (58)	300 (91)	470 (143)	750 (229)	1190 (363)	1490 (454)	1850 (564)	2320 (707)	2890 (881)	3610 (1100)	4470 (1362)	555 (16
230	5		**110* (34*)**	180 (55)	280 (85)	450 (137)	710 (216)	890 (271)	1110 (338)	1390 (424)	1740 (530)	2170 (661)	2680 (817)	333 (10
230	7 ½			**120* (37*)**	200 (61)	310 (94)	490 (149)	610 (186)	750 (229)	930 (283)	1140 (347)	1410 (430)	1720 (524)	210 (64
230	10				**160* (49*)**	250 (76)	390 (119)	490 (149)	600 (183)	750 (229)	930 (283)	1160 (354)	1430 (436)	176 (53
230	15					**170* (52*)**	270 (82)	340 (104)	430 (131)	530 (162)	660 (201)	820 (250)	1020 (311)	126 (38

[Return to Table] (#table_maximum_submersible)

Learning Task 4

Describe the Testing and Commissioning of Water Supply Pressure Systems

The proper testing and commissioning of pumped rural water supply systems serving single-family dwellings is of utmost importance in ensuring the well-being, and quality of life for individual households. Detecting and rectifying potential issues during the testing phase, such as leakages, pressure irregularities, or water contamination, ensures that the system operates efficiently, saving the homeowners from unexpected repair expenses and water wastage.

Moreover, commissioning a pumped water supply system for a single-family dwelling optimizes its performance and reliability. Proper integration with the household's plumbing ensures a steady flow of water, providing convenience and meeting daily needs.

If the well water was not analysed when the well was developed this should be done immediately, before connecting to the house plumbing, to determine if any special water treatment equipment is required.

After electrical work is completed and before pump is connected to pressure tank, the pump should be primed and test run.

Jet Pump Initial Start and Performance Check

For a centrifugal pump to function effectively, it must undergo a priming process. Priming involves filling the suction line with water and maintaining it at capacity while the pump operates. This step is particularly crucial for suction pumps, as it requires patience, time, and a substantial amount of water to ensure the suction line is completely full and the pump case has enough water to generate suction. Submersible pumps generally do not require priming when placed in a well since they are positioned below the well's static water level, ensuring a positive suction head to start efficiently.

A discharge tee and priming plug may need to be installed onto the pump if it was not supplied with one (Figure 68). Install temporary piping or hose with a shutoff valve onto the branch outlet of the discharge tee. Route the temporary piping or hose to a drain to enable the pump to be run for a period of time to ensure all of the air has been removed.

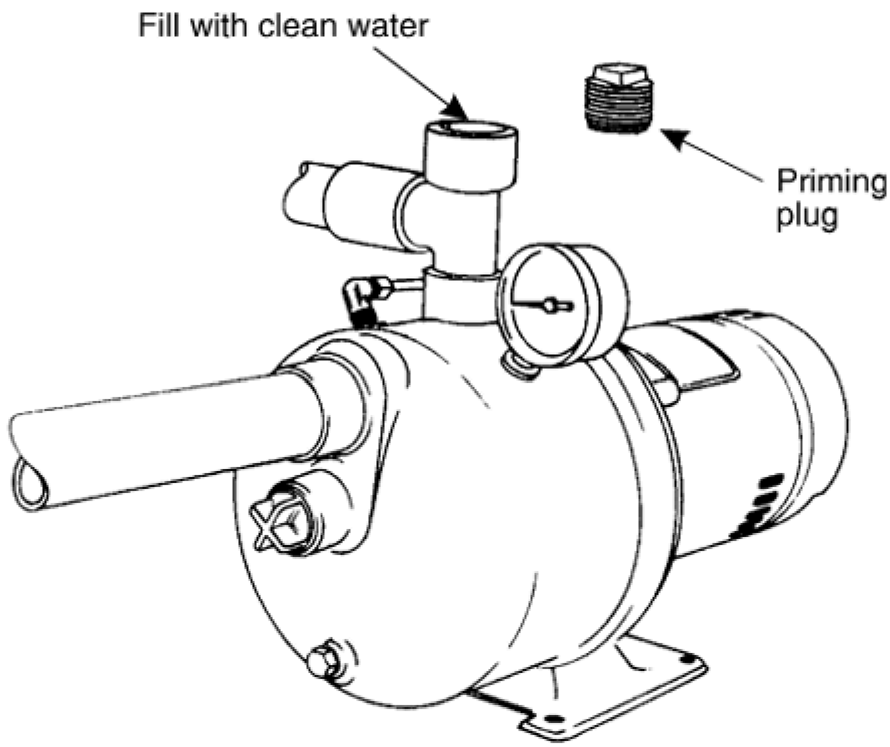

Figure 68. Shallow well pump with discharge tee

To successful prime and test run the pump several important steps must be taken:

- The entire line from the pump location to the foot valve in the well must be fully filled with water to eliminate any air from the suction line.
- Filling the entire suction line and pump case through the top of the priming tee requires multiple cycles of closing the priming opening and starting the pump to ensure a sufficient water level.
- A quicker way to prime the pump's suction line is to fill it entirely before connecting it to the pump. By observing the water level in the suction pipe before the connection, you can ensure the foot valve holds water, speeding up the priming process as only the pump case needs to be filled with water, possibly venting some air from the suction line.
- Priming is greatly assisted by having the suction line rise slightly (graded) from the pitless adapter or wellhead to the pump's inlet.
- When priming a two-pipe jet pump installation, make sure to fill both lines before connection to the pump.
- Confirm that the pressure gauge and pressure switch sensing line are connected.
- Close the temporary discharge shutoff valve and start the pump. If pump is installed with a horizontal offset line of 4 feet or more, it may take several minutes to prime. Opening the discharge valve slightly the may help removed air from the pump casing. If pump pressure does not build up in 5 minutes stop the motor, remove the priming plug, add more water and

repeat.

- For a deep well jet turn regulator adjusting screw down tight. If pump is properly primed, a high pressure will immediately show on pressure gauge. With pump operating at high pressure, slowly unscrew regulator adjusting screw until maximum water flow is obtained without pressure dropping to zero. If pressure does drop completely, again tighten down regulator adjusting screw and readjust until steady operation is obtained
- Allow pump to run to drain long enough to clear the well of any sand or dirt and to be sure the well is not going to run out of water.

Stop pump and complete connections to pressure tank. Allow the pump to cycle automatically several times to check pressure switch setting and operation.

Submersible Pump Initial Start and Performance Check

To ensure system performance the following steps must be taken at initial start up of a submersible pump before making the final connection to the discharge system.

Startup Procedures

- Install a pressure gauge and valve on the end of the discharge pipe.
- Route the temporary piping or hose to a drain to enable the pump to be run for a period of time.
- Discharge valve must be closed to approximately 1/3 open when the pump is started to slow the air released from the drop pipe, in tum causing backpressure on the pump as the air becomes slightly compressed before escaping from the valve.
  Notice:
  Never start a new pump installation with the discharge valve completely open. When a submersible pump operates at high flow – low head, it can cause the pump to up thrust the impellers-shaft assembly, which can cause premature wear and failure.
- Once the air has escaped, open the valve gradually until the pump operates at its full capacity. Avoid turning off the pump even if it experiences water deprivation during well cleaning or development. Shutting down the pump under such circumstances could lead to clogging due to the accumulation of tiny solid particles, making it difficult to restart when needed. However, if the pump continues running while water re-enters, there is a higher likelihood of successfully pumping these particles through the pump stages.
- As the valve is being opened, the drawdown should be checked to ensure that the pump always remains submerged. Continue to run the pump until the drawdown of the water in the well becomes stable. Should the water level drop to the pump intake the installation of a protection device against dry operation is recommended.
- Continue to run until the water that is flowing out of the temporary discharge pipe is clear.

Caution the piping has not been connected to the tank and pressure switch yet, therefore the pump *pressure could continue to rise above the system setpoint and beyond possibly damaging the supply piping and or fittings. Watch the pressure gauge carefully during this stage and be prepared to shutoff the pump if the pressure gets over 550 kpa (80 psig).*

Pump Performance Checks

Check the pump and well performance before making the final connection to the discharge system.

Close the valve and start the pump, check the pressure developed against the closed valve. If the pump has a three-phase motor and the pressure is substantially less than expected, the pump may be running backward. To change the rotation of a three-phase motor, interchange any two leads, then. run the motor again at shut-off, measuring discharge pressure. The cable arrangement that produced the highest discharge pressure is the correct one to ensure proper rotation.

The pump must not operate above the motor nameplate maximum amps. With the pump running open the gate valve gradually until full flow is achieved. Use a clamp-on amp meter to read the current, which should approximate the full-load current given on the motor nameplate, but must not exceed the service factor rating of the motor. Record the running current for future reference.

For three-phase motors, after the correct rotation has been established, check the current imbalance.
The procedure for checking three-phase motor current imbalance is explained in Learning Task 5

Use a voltmeter to verify the voltage at the starter while the pump is running. The voltage must be within 10% of the motor rating, and the maximum variation of any phase of a three-phase system from the average should not exceed 1%.

The most reliable indications of the condition of a submersible pump are the current drawn by the motor and the insulation resistance of the installation below ground. Check and record the insulation resistance for future reference.
The procedure for checking insulation resistance is explained in Learning Task 5.

Completed System Checks

Once the initial pump start-up and performance check have been completed then the piping connection can be completed to the pressure tank and household. The final system checks can now be performed.

Energize the pump and monitor the pressure gauge to confirm the pressure switch cut-off setting. If the pressure continues to build up past the cut-off setting, shut off the pump and trouble shoot the pressure switch.

Once the pump has shut-off open a large demand faucet or hose bib and allow the pump to cycle automatically several times to check pressure switch setting and operation. If the pressure cut-in or cut-out setting are not correct then the pressure switch will need be to be checked out and possibly adjusted. Observe and record the amount of pump run time for each cycle. If the run time is longer or shorter than the expected then you will need to trouble shoot the pump or pressure tank.

Once the installation system has checked out, all of the system information must be recorded and given to the owner. An example of an owner's information form is shown below:

Owners Information

Name of Dealer:____ Phone: ______
____

Address: ____
____

Pump Model No: ______GPM:___________ Total Dynamic Head: _______ (FT) Date Installed:
____

HP: ________Volts: _______Phase: ______HZ: _________ Service Factor Amps:________
____

AWG Cable Size: __________Ft.:____________________

Well Diameter: _____________(IN). Well Depth:_____________(FT). Amount of Casing:
(FT).

Static Water Level:______(FT). Well Drawdown: _______ (FT). Pump Setting:_________
_______(FT).

Pipe Size in Well: _________ (IN). Length of Pipe in Well:_______ (FT).

Pipe Material: PE: ________ PVC: ________ Galv:________________

Pipe Size from Well to Discharge Point: ______ (IN). Length of Pipe from Well to Discharge Point:
(FT).

Now complete Self-Test 4 and check your answers.

Self-Test 4

Self-Test 4

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://opentextbc.ca/plumbing4c/?p=158#h5p-8 (https://opentextbc.ca/plumbing4c/?p=158#h5p-8)

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Learning Task 5

Describe Service and Maintenance of Water Supply Pressure Systems

The service and maintenance of well pump systems are essential for ensuring a reliable water supply, as even high-quality pumps designed to last 15 to 20 years can encounter issues over time. The stresses endured during water transportation and delivery can gradually wear down even the most efficient pumps and motors. Operating problems will occur in most installations, necessitating careful investigation and repair or replacement of worn or damaged parts. Troubleshooting these well pump issues demands a combination of knowledge about the system's operating principles, keen instincts, and technical expertise to effectively address and rectify any challenges that may arise. Regular upkeep and attentive problem-solving are key to prolonging the lifespan and optimizing the performance of well pump systems.

Maintenance

Fortunately, proper placement and the movement of relatively clean fluids translate to minimal and infrequent maintenance issues for contemporary pumps. Instances that lead to pump complications encompass:

- Operating the pump close to its designated parameters for water quantity or maximum head,
- Employing the pump for tasks outside its intended applications.

Such scenarios impose a typical strain on the pump, rendering its expected operational life nonstandard. For instance, a pump tasked with handling sand will inevitably exhibit a shorter lifespan compared to a pump dealing with clear water. Similarly, a pump that operates at maximum head may not be able to move water at all if the tolerances between its impeller and diffuser change because of wear.

As the pump wears, the motor current increases, until eventually the overloads trip to protect the motor. Proper care of a submersible installation should include periodic check-ups to avoid interruptions in the water supply. Manufactures recommended checking the motor's insulation resistance every six months. When the insulation resistance falls below 10 megohms, check it frequently for further deterioration and pull the pump when the resistance falls to 0.5 megohm or below.

Several types of gauges and instruments are used to check the efficient operation of pumps:

- a pressure gauge can be used to check proper rotation of a three-phase motor
- vacuum gauges can be used to check that the pump is developing sufficient pressure differentials
- a multimeter is an invaluable tool for example:
  - the ohmmeter allows you to quickly pinpoint the problem when you encounter difficulties in starting motors

- the clamp-on ammeter can be used to detect current imbalance
- and the voltmeter can be used to match the motor voltage to your supply voltage

Since modern pump motors are electrical, many problems you encounter will require you to be familiar with electrical test instruments. Always refer to manufacturer's detailed instructions when testing the efficient operation of your pump and motor.

In British Columbia a plumber must hold a valid electrical licence to modify any wiring on pumps.

Preliminary Troubleshooting Tests

Complete these tests before removing the motor from the well or other location. These tests are for all sizes, including single- and three-phase.

- Line-to-Line voltage (Nameplate +/-10%)
- Amperage in all motor wires
- Line-to-Ground insulation resistance
- Line-to-Line winding resistance

Voltage Measurements

1. Ensure the motor is off.
2. Measure voltage supply at pressure switch or line contactor. For single phase motors, measure between line and neutral. For three-phase motors, measure between the legs.
    - Ensure the voltage reading is ± 10% of motor rating.
3. Turn the motor on until it is running normally.
4. Measure voltage at load side of pressure switch or line contactor with pump running.
    - Ensure the voltage reading remains the same except for slight dip on starting. Loose connections, bad contacts, ground faults, or inadequate power supply can cause excessive voltage drop.
    - Either low voltage or ground faults cause relay chatter.

Current (Amp) Measurements

When the pump is running, is the motor drawing enough amperage to indicate it is doing some work, or is it drawing maximum amperage, indicating maximum working conditions? A bound pump causes locked rotor amps and overloading tripping. Pump running at shut-off pressure, worn pump, or stripped drive shaft splines may cause low amps. Use a clamp-on style ammeter to measure current on all motor leads (Figure 69).

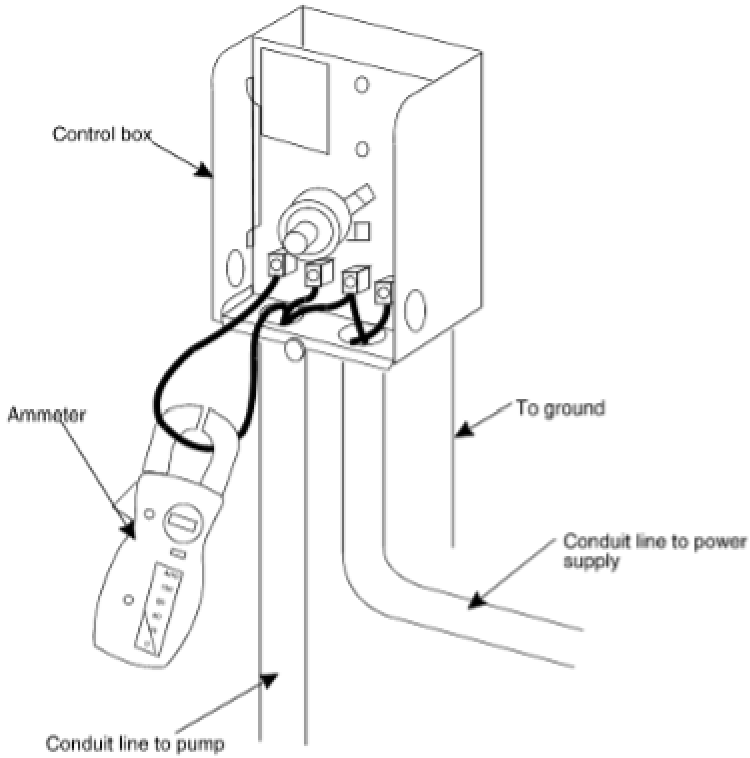

Figure 69. Ammeter test

Single phase submersible measurements at the control box include:

- Ensure current in red lead is momentarily high, then drops within one second to manufactures specifications. This verifies relay or solid state relay operation. Relay or switch failures cause red lead current to remain high and overload tripping.
- Check current in black and yellow leads does not exceed manufactures specifications. Open run capacitor(s) cause amps to be higher than normal in the black and yellow motor leads and lower than normal in the red motor lead.

Check three-phase motor current imbalance

For three phase motors currents in the individual phases must be approximately equal:

- Individually clip your ammeter to each leg at the control box or starter to measure and record the amps on each leg.
- If there is considerable difference between the legs disconnect the power and change all three connections at the starter. Be careful to shift the leads (not changing the order) so the rotation remains the same. Restart the pump, then measure and record the current on each leg.
- Disconnect the power and shift the cable leads for a third set of readings.
- Select the most consistent set of readings and find the average of the three amp values.
- Compare each single leg reading from that set to the average to identify the leg that had the

greatest amp difference from the average.

- Divide the greatest difference by the average to obtain the percentage of unbalance, as shown in the example below.

EXAMPLE:

Phase 1	54.0 amp
Phase 2	55.0 amp
Phase 3	60.0 amp
Average:	56.3 amp

$$\% \text{ Unbalance} = \frac{(60 - 56.3) \times 100}{56.3} = 6.6\%$$

Should the unbalance exceed 5%, first check voltage balance between the incoming lines. If the incoming power is balanced then you may have one of the following:

- burnt contacts on the motor starter
- loose terminals in starter or control box
- cable defects
- motor windings have shorted
- pump is damaged

Line-to-Ground Insulation Resistance Measurements

Use an ohmmeter or megohmmeter (megger) to the motors insulation resistance:

- Open master breaker (lockout) and disconnect all leads from control box or pressure switch to avoid electric shock hazard and damage to the meter
- Use a megohmmeter set to 500 Volt (1000 Volt maximum).
    - If using an ohmmeter, set to R X 100k. Zero the meter.
- Connect one meter lead to any one of the motor leads and the other lead to the ground wire, metal drop pipe, or metal well casing (Figure 69). Repeat and records readings for each motor lead.
    - If the drop pipe is plastic, connect the meter lead to ground

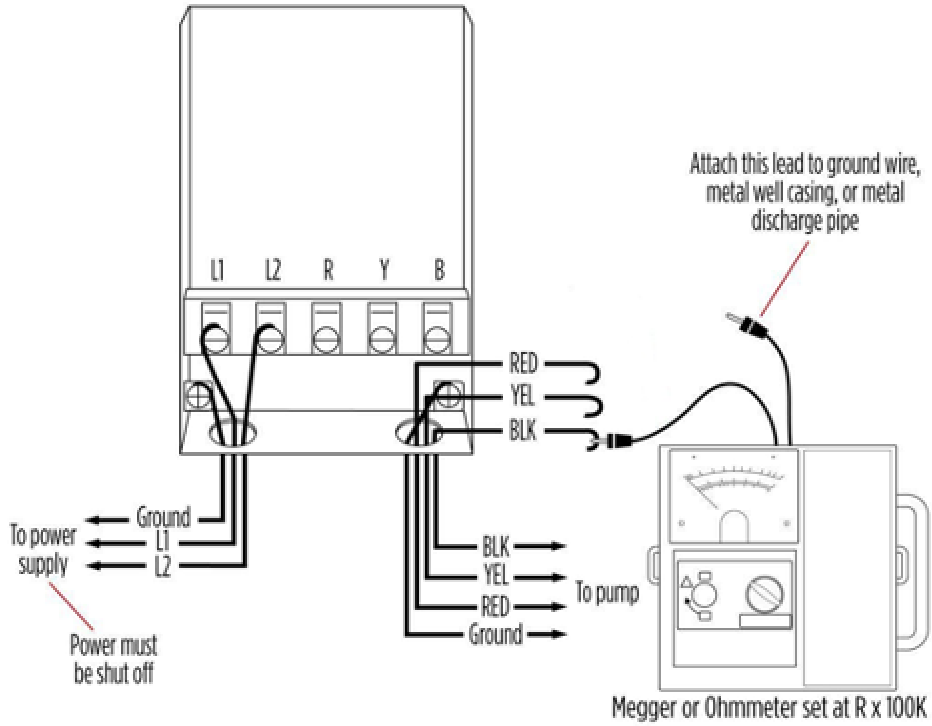

Figure 70. Submersible pump insulation resistance test

- Insulation resistance varies little with rating. Motors of all hp, voltage, and phase rating have similar values of insulation resistance. The table in Figure 71 shows typical manufacture recommend readings
    - If the ohms value is normal, the motor is not grounded and the cable insulation is not damaged.
    - If the ohms value is below normal, either the windings are grounded or the cable insulation is damaged. Check that the cable insulation at the well seal is not being pinched

Figure 71. Insulation resistance readings

Condition of motor & leads	**In well?**	**Megohm Value**	**Ohms Value**
A new motor (without drop cable)	No	200.0 (or more)	200 000 000 (or more)
A used motor which can be reinstalled in well	No	10.0 (or more)	10 000 000 (or more)
*New motor	Yes	2.0 (or more)	2 000 000 (or more)
*Motor in good condition	Yes	0.50 – 2.0	500 000 – 2 000 000
*Insulation damage (locate and repair)	Yes	Less than .50	Less than 500 000

NOTE: *Readings are for drop cable plus motor

Line-to-Line Winding Resistance

Use an ohmmeter to test condition of the motor windings and circuits:

- Open master breaker (Lockout) and disconnect all leads from control box or pressure switch to avoid electric shock hazard and damage to the meter.
- Use a multi-meter set to 20 ohms or an ohmmeter set to R X 1 for values under 10 ohms. Use next scale up for values over10 ohms. Zero the meter.
    - On 3-wire motors measure the resistance of yellow to black (main winding) and yellow to red (start winding) (Figure 72).
    - On 2-wire motors measure the resistance from line-to-line.
    - For three-phase motors measure the resistance line-to-line for all three combinations.

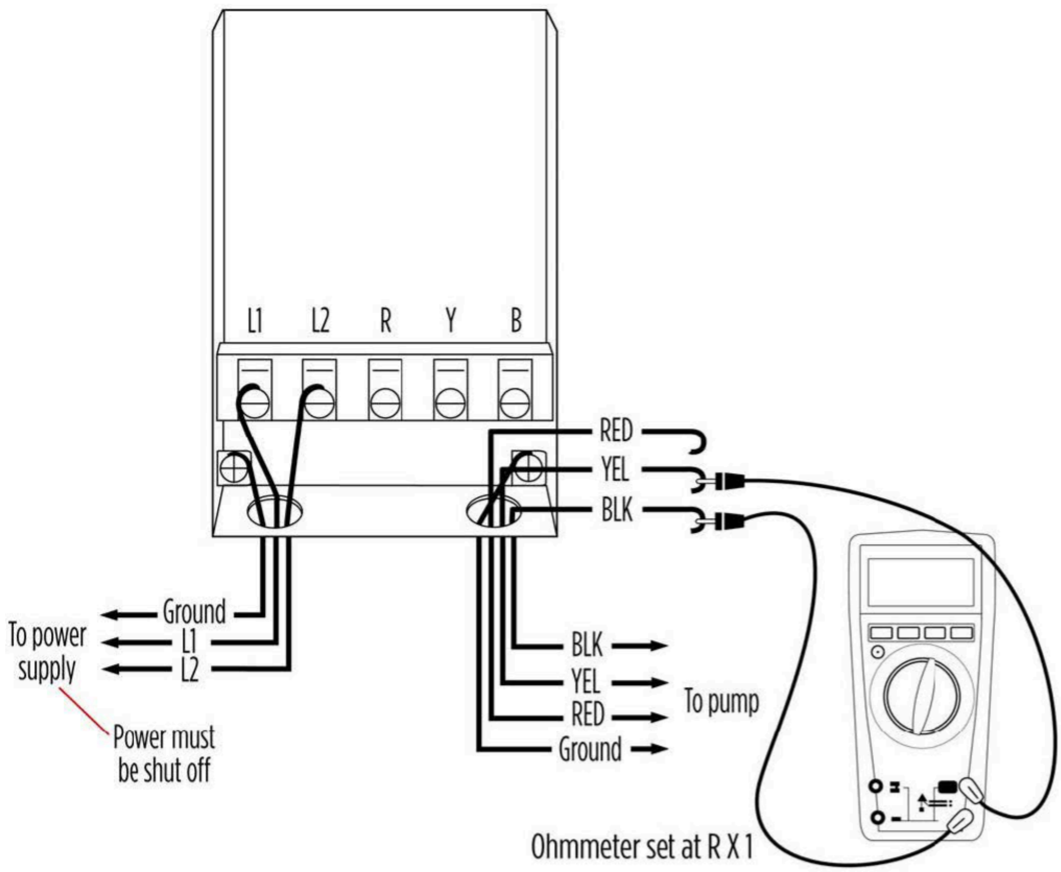

Figure 72. Motor winding test

- Compare the reading to the manufacture's specifications. These values are often supplied on the label located under the control box cover (Figure 73). Notice these reading are for the resistance of the motor only. The resistance values for different drop cable are readily available and will need to be added to the motor winding values to compare to the actual readings.

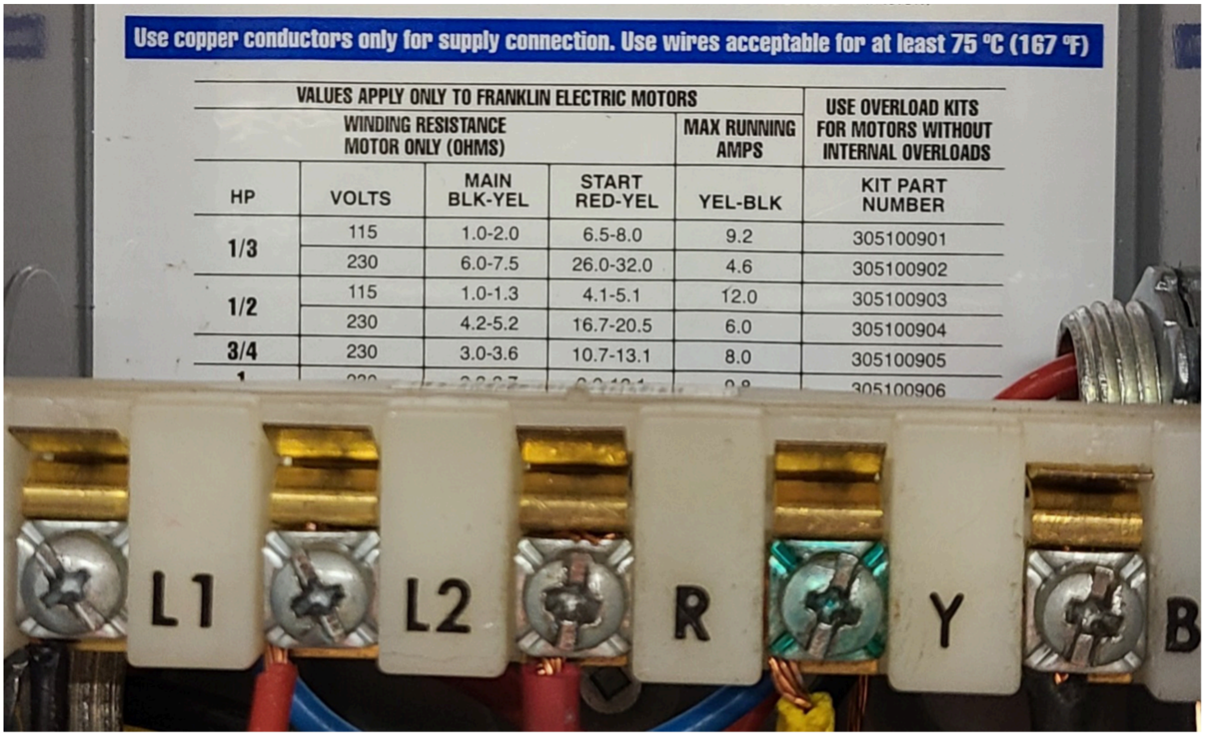

Figure 73. Control box connections and label

- If all ohms values are normal the motor windings are neither shorted nor open, and the cable colors are correct (not mixed).
    - If any one value is less than normal, the motor is shorted.
    - If any one value is greater than normal, the winding or the cable is open, or there is a poor cable joint or connection.
    - If some ohms values are greater than normal and some less on single-phase motors, the leads are mixed. This could have occurred when the leads were spiced, refer to the manufacture instruction on how to use an ohm meter to identify cables with an ohmmeter.

Additional Tests

Here are some additional tests that may need to be performed as part of a pump performance check or system troubleshooting.

Flow (Bucket) Test

The actual flow rate of the water supply system should be checked at initial installation as well as part of a troubleshooting process. Two distinct flow test procedures are employed, depending on whether the pump has been integrated into the building's plumbing system or not. The bucket test is a very useful and "low tech" test method. It consists of simply timing the filling of a vessel of known volume, and doing the math to determine a flow rate. The unit of US gallons per minute is used as that is the unit most often quoted in the pump specifications. You will need a stop watch a 5 US gallon bucket with marked increments.

If you are performing a flow test before the pump supply has been connected to the building plumbing then follow these steps:

1. Measure the amount of time (seconds) it takes to fill the bucket
2. Divide the gallon size of the bucket by the number of seconds it took for the bucket to be filled, then multiply by 60. This will give you the flow rate measured in gallons per minute (gpm).

When conducting the flow test with the pump linked to the building plumbing, an alternative approach is required. Merely timing the bucket's filling duration is insufficient due to water replenishment of the pressure tank while the pump is active.

If you are performing a flow test of a water supply system with a pressure tank and on/off pressure switch then follow these steps:

1. Locate the pressure switch and tank. For this test you will need to know when the pump starts and stops. For a jet pump system this will be obvious as you will be able to hear the pump, whereas for a submersible you will need to listen to the pressure switch contactors. It may be easier to observe the pressure switch with the cover removed.
2. Make sure the pump is not running and no water is flowing anywhere in the building.
3. Open a faucet to drain water from the system the drain hose bib at the tank tee works best. As soon as the pump turns on, close the faucet so that the pump can fill up the pressure tank. Once the pump has turned back off, begin the next step.
4. Open the faucet into a five-gallon bucket and have the stop watch ready for the next step. If the system has a large pressure tank you may need more than one bucket. Measure the entirety of the water discharge before the pump turns back on.
5. As soon as the pump turns on, shut the faucet and use a stopwatch to time the pump cycle. Make a note of the pump cycle time (round to the nearest second) once the pump has turned back off.
6. You now know the time it takes for the pump to recharge the pressure tank, and you know the acceptance volume of the pressure tank, so you can calculate the average pumping rate as follows:

$$\text{Averaged Pumping Rate (GPM)} = \left(\frac{\text{Volume}}{\text{Recharge Time}}\right) \times 60$$

For example:

- Recharge Time = 30 seconds
- Volume = 4 gallons

- $\text{Averaged Pumping Rate} = \left(\frac{4}{30}\right) \times 60$

= 8 gallons per minute

** The expression Averaged Pumping Rate refers to the fact that the pump will be running at different head pressures during the pump cycle. Therefore, the calculated bucket test flow rate will represent the average of the pumps performance over the full range of the pressure switch settings.*

Isolating Leakage in Cable and Splices

As was previously mentioned if the insulation resistance of a submersible pump is below 0.5 megohms, you will need to removed the pump from the well and locate and repair the problem.

When pulling the pump, either coil the cable on a reel or raise it from the ground to dry. Check the insulation again when the cable and splices are dry. if the insulation reading remains low, disconnect the motor from the cable and check the motor separately. Should the motor be defective, check the pump end for wear and obtain a replacement for either the motor alone, or the pump unit, as necessary. However, if the insulation value between the line and motor casing increases to 50 megohms or more the problem is in the cable. You will need to isolate the fault in the cable or the splice and make the necessary repairs.

The procedure for using an ohmmeter to locate a cable leak is as follows:

1. Submerge the cable and splice in a steel barrel of water with both ends out of water (Figure 74).
2. Set the ohmmeter selector knob on R X 100 K and adjust the needle to zero (0) by clipping the ohmmeter leads together. Then ground one lead by attaching it to the metal tank. Clip the other to the various cable leads in turn at one end of cable. Be sure the other end of the cable remains out of the water and dos not contact the tank.
3. If the needle deflects to zero (0) on any of the cable leads, starting pull the cable out of the water slowly until the needle falls back to infinity, or no reading. When the needle falls back the leaking portion of the cable is just above water level.

Figure 74. Cable leakage test

Checking and Adjusting Pressure Switch

Mechanical pressure is a relatively simple electrometrical device which contains a diaphragm that presses against a piston and springs to open or close the electrical contacts. When a pressure switch malfunctions, it may be damaged or simply require cleaning.

A tell-tale warning that the pressure switch is not working is the failure of the pump to turn on and off at the cut-on and cut-off points. Although these symptoms may be signs that your pressure switch is failing, they may also signal a problem elsewhere in your system. Therefore, it is important to be able to test the pressure switch operation before assuming it is the problem.

Pump Not Shutting off

If the pump is not shutting off and the pressure is building up above the cut out setpoint, and it is a new system, the pressure switch setting may need to be adjusted. If it is an existing system which just started malfunctioning this is not likely the problem and you should check the following:

- Before turning off the power to the pump observe the pressure in the system is above the cut-out setpoint.
- Shut off the power to the pump and the pressure switch.
- With the power OFF, take the switch cover off to do a visual inspection of the four contact points. Check again for the presence of no electricity with a non contact voltage tester.
- The contacts should be in the open position. Examine the four contacts for burning or pitting on the surface that may be bridging the contacts. If you see signs of damage, you may need to replace the pressure switch. To clean the contacts fold a small piece of fine-grit emery paper in half and push it between the contacts to clean burned or pitted contacts.

- If the contacts are closed and the pressure is above the cut-out setting the problem may be a block sensing port or tube to the bottom of the pressure switch. Debris can get lodged inside the bottom of the pressure switch and "blind" it from reading the pressure. For jet pumps you'll want to check the copper/plastic tubing. Before you unscrew this pipe or tube connection be sure to drain all the pressure from the system. If there is a lot of sediment visible in the diaphragm of the pressure switch you can try cleaning it out, but it is best to replace the pressure switch.

Pump Not Coming on

If the pump is not coming the pressure switch is not the most likely cause but it can easily be checked:

- Before turning off the power to the pump observe the pressure in the system is below the cut-in setpoint.
- Shut off the power to the pump and the pressure switch.
- With the power OFF, take the switch cover off to do a visual inspection of the four contact points. Check again for the presence of no electricity with a non contact voltage tester.
- Confirm that all four wiring connections are firmly connected to their terminal screws.
- If the contacts are open and the pressure is below the cut-in setting the problem may be a block sensing port or tube to the bottom of the pressure switch.
- If the contacts are closed as they should be you will need to verify that the switch is getting the proper power supply. Turn the power back on and use a volt meter to test the power to the two input terminals. If the switch is getting the correct voltage then next check the voltage drop across the two load terminals. If the correct voltage is observed at the two load terminals then the problem is not with the pressure switch and the pump wiring or motor will need to be checked. If there is no, or reduced, voltage the contacts may be faulty. Turn the power back OFF
- Confirm again for the presence of no electricity with a non-contact voltage tester before checking the contacts. Examine the four contacts for burning or pitting on the surface that may be resisting flow through the contacts. If you see signs of damage, you may need to replace the pressure switch. To clean the contacts, you will need to force them open with your hand or a screwdriver to insert a small folded piece of fine-grit emery paper.

Adjusting Pressure Switch Settings

After close observation of the operating system pressures it may be determined that the pressure switch requires adjustment. Another factor that you should consider is the switches are not individually factory tested which means if you get a 30-50 PSI switch that is operating at 28-48 PSI. Pressure switches can also stick sometimes, so it could possibly come on 1 or 3 PSI different from one cycle to the next. Remember the bladder style pressure tank should be pre-charged at 2 psi less than the cut-on pressure, therefore any adjustment of the pressure switch will require a change in the pressure tank pre-charge. Do not adjust the cut-off pressure too high. If the pump cannot produce enough pressure it will not shut off (and cause motor failure).

To adjust the pressure switch:

- The first thing to do is disconnect the power to the switch from the power supply before you attempt to do any adjustments.
- Loosen the nut on top to remove the cover on your pressure switch. Notice there is wealth of information given under the cover of the pressure switch including the factory pre-sets (Figure 75). You will notice two springs. The range adjustment nut on the larger center spring controls both the cut-in and cut-out settings together. The smaller spring controls only the highest pressure in the range (cut-out). This is a less commonly used part of the pressure switch, and you'll only want to adjust this one if you have a very specific reason to do so. *Remember that the 20 psi differential range is part of the overall system design that limits the amount of pump cycles in a day. If the range gets reduced to lass than 20 psi it will shorten the pump run time and reduce the pump life.*
- To adjust the switch use a $\frac{3}{8}$" deep socket nut driver. Rotate the center spring range nut in a clockwise direction for higher cut-in pressure and counter clockwise for lower cut-in pressure. As you start to change the cut-in value, the cut-out value will change by the same amount and in the same direction. The rule of thumb is that one full rotation will adjust the pressure 2-3 psi.
- After making the adjustment you will need to monitor the system to ensure the pressure setting is what you desired. Note that the adjustment you make to the pressure switch can only be read after the pump has reached its first adjusted shut off. The next cut-in and cut-off pressure is your new setting.
- Replace the cover onto the switch, turn the power back on
- Open the drain to get the pressure below the cut-in point. Once the pump turns on close the drain. Keep a close eye on the pressure gauge so that you can identify the exact point that the pump turns off.
- Repeat adjustments if necessary and continue monitoring for a couple more cycles

As mentioned there are very few applications where you should use the small spring to adjust the differential. Adjusting the differential will only adjust the cut-off pressure. Turn the differential nut counter clockwise to lower cut-off pressure or turn the nut clockwise to raise cut-off pressure.

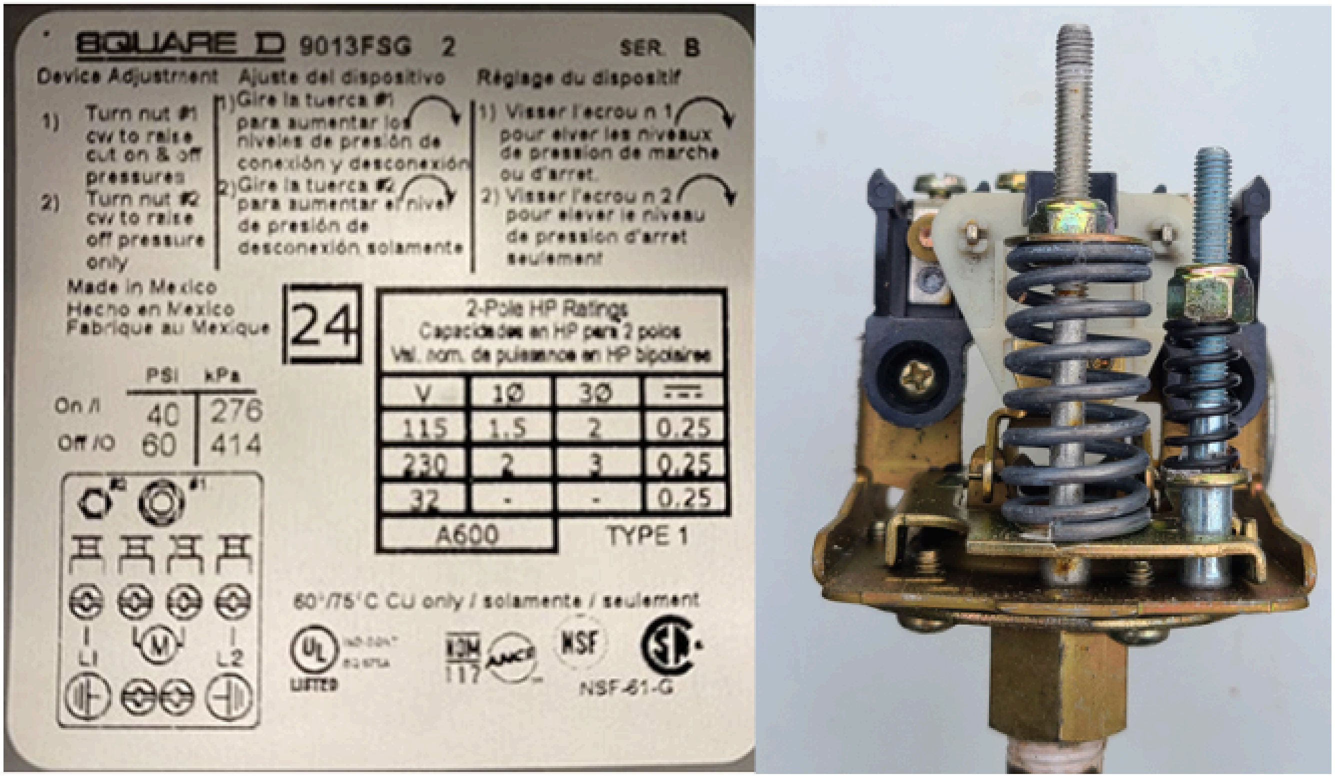

Figure 75. Pressure switch cover removed

Protective Devices

For pump protection, additional devices can be installed that monitor motor load and incoming power conditions to provide protection against dry well conditions, waterlogged tanks, and abnormal line voltage conditions. These devices interrupt power to the motor whenever the load drops quickly or below a pre-set level. Some devices can also be connected to the a mobile App to provide real-time system monitoring.

In Figure 76 the devices shown on the left are designed for single-phase motors. Whereas the device shown on the right is for protection of three-phase motors.

Figure 76. Pump no load protection devices

Troubleshooting Pump Problems

When trying to solve a problem with a pumping system the causes can seem endless, but fact-finding and observation go hand in hand with resolution of the problem. When you encounter a problem with the operation of a pump or some part of the pumping system, always look for the most obvious causes and try the straightforward solution. Work progressively from easy solutions to the more difficult ones. Always weigh the relative costs in time and materials when deciding whether to repair or replace defective components.

These troubleshooting charts [PDF] (https://opentextbc.ca/plumbing4c/wp-content/uploads/sites/464/2024/08/Shallow-Well-Jet-Pump-Troubleshooting-Chart.pdf) look at common problems encountered with different types of pumps and systems. The problem is listed first, followed by a series of checking procedures.

Now complete Self-Test 5 and check your answers.

Self-Test 5

Self-Test 5

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://opentextbc.ca/plumbing4c/?p=164#h5p-9 (https://opentextbc.ca/plumbing4c/?p=164#h5p-9)

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Competency C2: Install Residential Water Treatment Systems

Learning objectives

After completing the learning tasks in this chapter, you will be able to:

- Identify issues associated with surface and ground water sources
- describe residential water treatment equipment
- identify the components found in a residential water treatment system

Learning Task 1

Describe Water Treatment Equipment

The Water Cycle

All life on the planet depends on water for its existence, and the availability of potable (safe for human consumption) water for mankind to survive is dependent on the earth's "water cycle", also known as the "hydrologic" or "hydrological" cycle (see Figure 1).

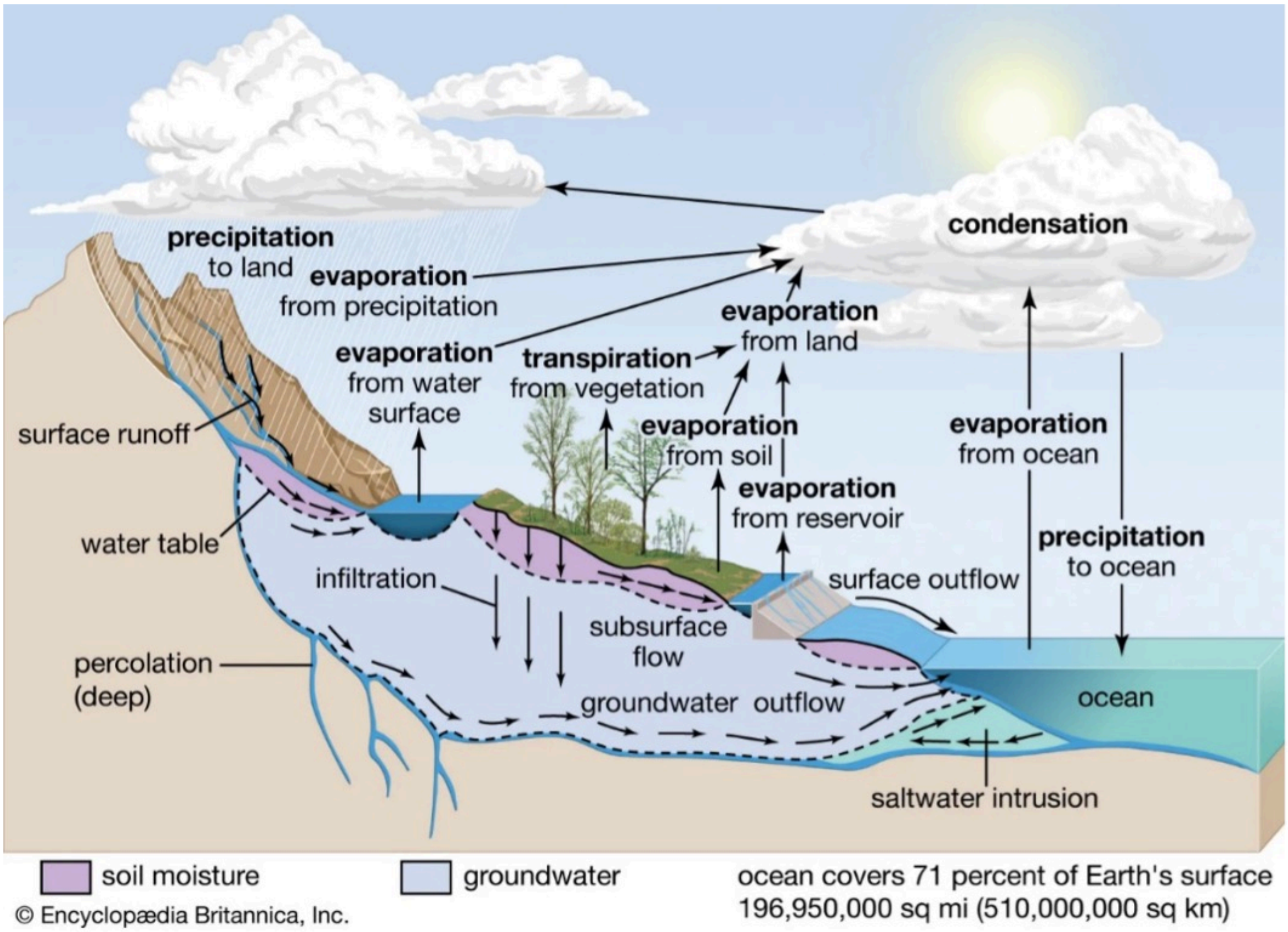

Figure 1. The water cycle

One way to describe the hydrological cycle of the earth is "the sum of all processes in which water moves from the land and ocean surface to the atmosphere and back again. The short form explanations of these processes are:

- precipitation – water is released from clouds as rain, snow or sleet
- condensation – water in the air condenses into small airborne particles to form fog, dew or

clouds

- infiltration – water enters the ground by contact with rain or snow
- percolation – water from infiltration moves vertically through the ground by gravity and capillary action until it reaches an aquifer
- runoff – water that can't be absorbed into the ground moves horizontally across it where it collects in bodies such as rivers, lakes or oceans
- evapotranspiration – also known as transpiration, this is water that is released into the atmosphere through plants as they "breathe"
- sublimation – the process whereby glacial ice and snow release water vapour without first melting into a liquid
- evaporation – liquid water when heated turns into a vapour, leaving behind any impurities such as minerals and chemicals

Water is continuously moving between the atmosphere and the earth through the processes listed above, and the only source of pure water within the water cycle is the earth's atmosphere, where it is either invisible in low concentrations or can be seen in high concentrations as clouds. Once released from clouds as rain, snow, or a mixture of the two (sleet), pure water falls to the earth's surface. On the way, it picks up any impurities that may be present in the air, such as dust, chemicals, gases, etc. This now impure water finds its way to various sources of water supplies such as lakes, rivers, and oceans, known as "surface water". As well, it soaks into the ground to become part of an underground stream or lake called an "aquifer". This water supply is known as "ground water".

Surface Water Supplies

Although fresh water from lakes and rivers is relatively "soft" (free of dissolved minerals), it is prone to contamination from other sources. Bacteria and parasites from human and animal wastes, as well as chemicals from manufacturing and silt and debris ("turbidity") from surface runoff are all possible components of surface water supplies.

Ground Water Supplies

As surface water percolates through the ground, many of the impurities it has collected are filtered out by the soil. However, when it meets carbon dioxide within the soil, carbonic acid is formed. This dissolves some of the mineral content of the soil or rock it contacts, in particular calcium and magnesium, thus adding these minerals to the water, which makes it "hard".

The Need for Water Treatment (Water Conditioning)

Regardless of the source of supply, water will need some form of treatment before it can be considered potable. This learning guide will describe the different impurities that can be present in residential water supplies and the methods and equipment used to treat or remove them.

Common Impurities in Water

A molecule of pure water is made up of two atoms of hydrogen and one atom of oxygen (H2O), making it a compound. Water is called a universal solvent because it can dissolve much more substances, called solutes, than any other liquid found in nature; however, it cannot dissolve every substance. For example, water cannot dissolve fats, waxes, and hydroxides due to the low solubility of oppositely charged particles. Water molecules consist of a polar arrangement of two hydrogen atoms and one oxygen atom. The hydrogen atoms have a positive charge while the oxygen atom carries a negative charge. These polar charges help the water molecule to bind to different types of molecules. This is called "hydrogen bonding", where the positive hydrogen of one water molecule will link with the negative oxygen of the next molecule, whose hydrogen atoms will then be attracted to the next oxygen, and so on. The attraction between the electrical charges in the water (solvent) and the substance (solute) cause the solute's particles to be pulled apart and eventually dissolve. The rule of thumb is that "like dissolves like" and so a polar solvent like water can only dissolve solutes that also possess polar atoms, which are also known as ionic compounds. Ionic compounds are substances formed through chemical bonds between ions with opposite charges.

A good example of a polar solute is table salt (NaCl or sodium chloride). The sodium ions in sodium chloride have a partial positive charge, while the chloride ions have a partial negative charge. The sodium are attracted to the partial negative oxygen atoms of the water molecule, while the chloride ions are attracted to the partial positive hydrogen atoms of the water molecule. Eventually, this causes the atoms within the NaCl molecule to "pull apart" and dissolve into the water.

Dissolved Solids

Dissolved solids, known as "total dissolved solids", or "TDS", is an expression that represents the total concentration of dissolved substances in water. Common inorganic salts that can be found in water include calcium, magnesium, potassium and sodium, which are all "cations" (positively charged ions) and carbonates, nitrates, bicarbonates, chlorides and sulfates, which are all "anions" (negatively charged ions). Although the effects of TDS in water can be seen, such as staining of fixtures, the water may appear clear, and the presence and concentration of TDS can only be determined by analysis. Alone, a high concentration of dissolved solids is usually not a health hazard. However, high concentrations of solids such as calcium will influence piping and pressure vessels such as boilers and water heaters. A buildup of hardness minerals, called scale, on the inside walls of pipe can reduce water , and scale can cause a loss of efficient heat transfer in water heating appliances.

Suspended Solids

Suspended solids are substances like silt and clay, which aren't ionic compounds and therefore don't dissolve in water, so they stay in suspension and make the water murky and unappealing. This is called "turbidity" and is a characteristic of water that is visually identifiable. Over time, turbid water will cause a buildup of silt in storage containers in the water system, such as hot water tanks, boilers, and toilet tanks.

Gases

Gases such as hydrogen sulphide (H_2S) and methane (CH_4) can be dissolved and be present in ground water supplies. Although methane is tasteless, colourless and odourless, the same cannot be said of hydrogen sulphide. Even in very small concentrations, H_2S has a rotten egg odour that makes tap water quite unappealing, and also quite corrosive. CH_4 in water is much less noticeable but, in high enough concentrations, it can be an issue if allowed to come out of solution and collect.

Bacteria and Pathogens

Due to the filtering effect of the soil as water moves through it, deep wells are less prone to contamination from pathogens (disease-causing bacteria, viruses and protozoa) than are shallow wells. Animal or human waste (feces), runoff from industrial or residential developments, and runoff from landfills, septic fields and sewer pipes can carry pathogens into shallow ground water supplies. When these are found to be present in a water supply, it is of great concern and the situation must be rectified. Examples of waterborne infectious pathogens include Escherichia coli (E. coli), Campylobacter, Salmonella, Giardia and Cryptosporidium.

Acidity/Alkalinity

Both surface and ground water supplies can be found with levels of acidity or alkalinity. The term “pH” stands for “potential of hydrogen” which is a measure of the number or concentration of hydrogen ions in a substance. The pH scale is numbered from 0 to 14, with a pH of 7 being neutral. Pure water has a pH of 7; an acid will have a pH lower than 7 and an alkali or base will have a pH higher than 7. The further a pH number is from 7, the stronger an acid or alkali it is. Acidic water, which is the more common pH condition found in water supplies, can be treated by the introduction of an alkali, such as limestone, to the water. This brings the water’s pH level back to as near 7 as possible. A pH reading in excess of 8.5 could indicate contaminated water and generally requires bacteriological and chemical analysis.

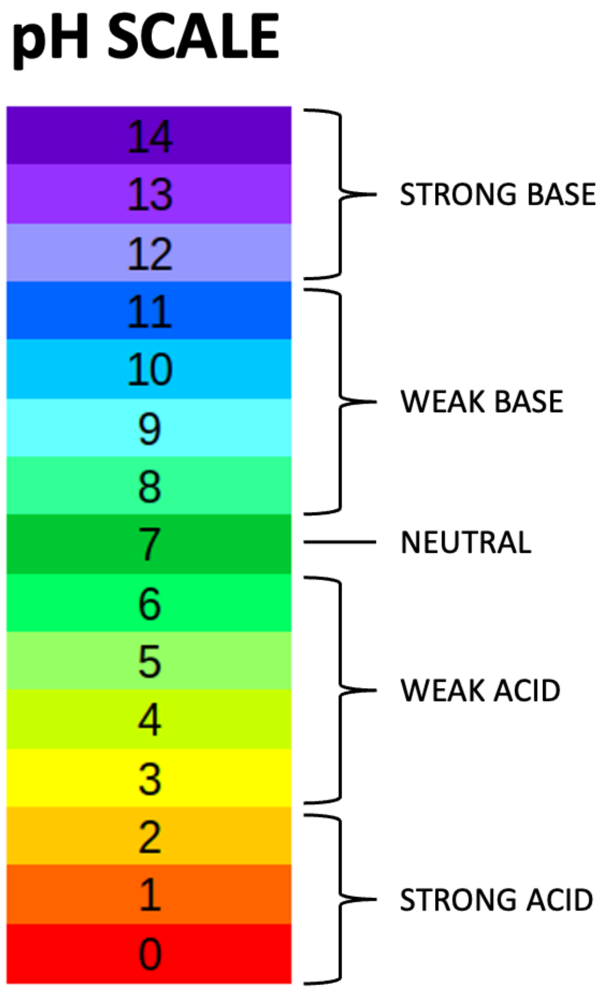

Figure 2. pH Scale

Iron

Iron content in a water supply is generally found in deep wells, where it occurs as either ferrous or ferric iron. Ferric iron will oxidize in water, turning it a light shade of red, and is called "red water iron". Water containing ferrous iron is clear and colorless because the iron is completely dissolved and is known as "clear water iron". Although an essential element for good health, iron in water causes taste issues as well as staining of fixtures. When iron exists along with certain kinds of bacteria, a smelly biofilm can form. To survive, the bacteria use the iron, leaving behind a reddish brown or black slime that can clog plumbing and cause an offensive odor. This slime or sludge is noticeable in the toilet tank when the lid is removed.

Manganese

Considered a "cousin" to iron, manganese is found naturally in groundwater, but levels can be increased by human activities like steel production and mining. Manganese can turn the water a brown or rust color, cause black or brownish-black staining of faucets, sinks, or laundry, and make the water have an off-taste or odor. A manganese greensand filter is commonly used to counteract manganese in water.

Tannins

Tannins, also known as humic or fulvic acid, are created as water passes through rotting organic matter or peaty soil in the water table. They're also caused by low hanging branches, dead leaves, and trees that are exposed to a shallow well or surface water source. Because they naturally occur in low concentrations in drinking water, they are normally an aesthetic rather than a health concern, although their presence can alter the taste and appearance of potable water. While low levels of tannins can be removed through carbon filtration or cation exchange water softeners, high levels are handled through the use of anion exchange or whole-house reverse osmosis units.

Other Contaminants in Water Supplies

- **Nitrate –** Nitrate is the most common chemical contaminant in the world's groundwater and aquifers. Present in chemical fertilizers, human sewage, and animal waste and fertilizers, nitrate can contaminate a private well through groundwater movement and surface water seepage and run-off. Once taken into the body, nitrates are converted into nitrites which interfere with bodily functions.
- **Heavy metals –** Heavy metals can leach into drinking water from household plumbing and service lines, mining operations, petroleum refineries, electronics manufacturers, municipal waste disposal, cement plants, and natural mineral deposits. Heavy metals include: arsenic, antimony, cadmium, chromium, copper, lead, selenium and many more. Heavy metals can contaminate private wells through groundwater movement and surface water seepage and run-off.
- **Organic chemicals –** Organic (carbon-based) chemicals are found in many household products and are used widely in agriculture and industry. They can be found in inks, dyes, pesticides, paints, pharmaceuticals, solvents, petroleum products, sealants, and disinfectants. Examples include gasoline, plastics, detergents, dyes, food additives, natural gas, and medicines. Organic chemicals can enter ground water and contaminate private wells through waste disposal, spills, and surface water seepage and run-off.
- **Fluoride –** Fluoride can be present in many aquifers and can be found in private wells. The occurrence of fluoride in groundwater is due to weathering and leaching of fluoride-bearing minerals from rocks and sediments. Fluoride when ingested in small quantities is beneficial in promoting dental health by reducing dental caries (tooth decay or cavities), whereas higher concentrations may cause fluorosis, a condition characterized by pain and tenderness of bones and joints.
- **Arsenic –** Arsenic (As) is a naturally occurring contaminant found in many ground waters. Arsenic in water has no color, taste, or odor, and can only be measured by an arsenic test kit or lab test. Public water utilities must have their water tested for arsenic and if desired, the results can be obtained through the utility's consumer confidence report. Private wells will need to have the water evaluated, and the local health authority can provide a list of test kits or certified labs.

There are two forms of arsenic: pentavalent arsenic (also called As (V), As (+5)) and trivalent arsenic (also called As (III), As (+3)). In well water, arsenic may be pentavalent, trivalent, or a combination of both. Although both forms of arsenic are potentially hazardous to health, trivalent arsenic is considered more harmful than pentavalent arsenic.

In summary, there is an expectation that surface and ground water sources will need some form of treatment due to water's characteristics as a solvent. Obviously, preventive measures are paramount to maintaining a healthy water supply. Fortunately, when undesirable substances are detected in water supplies, there are means and methods available to treat water and make it potable.

Now complete Self-Test 1 and check your answers.

Self-Test 1

Self-Test 1

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://opentextbc.ca/plumbing4c/?p=178#h5p-10 (https://opentextbc.ca/plumbing4c/?p=178#h5p-10)

Terminology of Water Treatment

The following is a glossary of terms used in water treatment, some of which may be encountered within this learning guide.

- **Activated carbon –** Granulated active carbon, or "GAC", used to remove tastes, odor, chlorine, chloramines, and some organics from water.
- **Adsorption –** The process by which molecules or colloids physically adhere (cling) to the surfaces of solids. Organic chemicals are adsorbed by carbon filters.
- **Aeration –** The process of adding air to a water supply for the purpose of oxidation. Aeration is frequently used to remove iron and hydrogen sulfide.
- **Algae –** Plant-like organisms which grow in water.
- **Alkalinity –** See Total Alkalinity.
- **Anion –** A negatively charged ion. Bicarbonate, chloride, and sulphate are the most abundant

anions in water.

- **Aquifer –** Any geological formation containing water; one that supplies water for wells, springs, etc.
- **Backwash –** Reverse of a solution's flow through a system. Often used as a cleansing step in softeners and sand and dual media filters. Backwashing cleans and resettles the filter bed.
- **Bacteria –** Disease-potential organisms living in soil, water, or organic matter and being autotrophic (self-generative) or parasitic.
- **Bromine –** A chemical sanitizer that kills bacteria and algae.
- **Buffer –** A chemical that resists pH change, e.g., sodium bicarbonate.
- **Calcium hardness –** A measure of the calcium salts dissolved in water.
- **Cation –** A positively charged ion. Sodium, magnesium, potassium, and calcium are the most abundant cations in water.
- **Chemical solution feeder –** A pump used to meter chemicals such as chlorine or polyphosphate into a water supply.
- **Chloramine –** A combination of free chlorine and ammonia gas that retains its bactericidal qualities for a longer time than does free chlorine. It is less effective than chlorine as a disinfectant but is often used because it reduces the harmful by-product chemicals produced by free chlorine. It is becoming more common as the standard disinfectant used by municipal water supplies. In general, it is more difficult to remove from water than free chlorine.
- **Chlorine –** A chemical sanitizer that kills bacteria and algae. A very toxic biocide. A halogen element isolated as a heavy irritating greenish-yellow gas of pungent odor used especially as a bleach, oxidizing agent and a disinfectant in water purification.
- **Chlorine demand –** The amount of chlorine required to react on various water impurities before a residual is obtained.
- **Chlorine, Free (Residual) –** Chlorine available to kill bacteria or algae. Chlorine that has not combined with other substances in water.
- **Contaminant –** any physical, chemical, biological, or radiological substance or matter in water.
- **Dl (deionization) –** The use of ion exchange resin to remove salts from water.
- **Demineralization –** The process of removing minerals from water, e.g. deionization, reverse osmosis and distillation.
- **Disinfection –** Destruction of bacteria, viruses and cysts in a water supply or distribution system.
- **Dissolved solids –** Any minerals, salts, metals, cations or anions dissolved in water.
- **Distillation –** Steam from boiling water is condensed on a cool surface, collected, and stored. Most contaminants do not vaporize and therefore do not pass to the condensate. Removes nearly 100 percent of salts and organics.
- **Ferric iron –** Iron that is oxidized in water and is visible. Also called red water iron.

- **Ferrous iron –** Iron that is dissolved in water. Also called clear water iron.
- **Flocculation –** A water treatment process where solids form larger clusters, or flocs, to be removed from water. This process can happen spontaneously, or with the help of chemical agents.
- **Flocculent chemical –** A chemical which, when added to water, causes particles to coagulate into larger groupings (flocs), which can then settle from the water.
- **GPD –** Gallons per day.
- **GPG –** Grains per gallon. A grain is $\frac{1}{7000}$ of a pound. The grain per gallon (gpg) count is a unit of water hardness defined as 1 grain (64.8 milligrams) of calcium carbonate dissolved in 1 US gallon of water (3.78 L) which translates into 1 part in about 58 000 parts of water, or 17.1 parts per million (ppm). Because an Imperial gallon is larger than a US gallon, one grain of hardness in 1 Imp. Gal. will have a lower concentration, which would be 14.3 ppm. This is the most common measurement for hardness.
- **Ground water or groundwater –** Water confined in semipermeable rock layers; in other words, well water.
- **Hardness –** The concentration of calcium and magnesium salts in water. Water hardness is responsible for most scale formation in pipes and water heaters and forms an insoluble "curd" when it reacts with soaps. Hardness is usually expressed in grains per US gallon (gpg), parts per million (ppm) or milligrams per liter (mg/l), all as calcium carbonate equivalent.
- **Heavy metals –** Metals having a high density or specific gravity. A generic term used to classify contaminants such as arsenic, cadmium, lead, and mercury.
- **Hydrogen sulfide –** A toxic gas (H2S) that is detectable by a strong "rotten egg" odor.
- **Hydrologic cycle (hydrological cycle, water cycle) –** The term used to describe how water travels through the environment by processes such as evaporation, condensation, and precipitation.
- **Ion exchange –** A chemical reaction in which ions are exchanged in solution. Water softening and deionization are common applications of ion exchange.
- **Magnesium hardness –** A measure of the magnesium salts dissolved in water.
- **Membrane –** A polymer film utilized as the semipermeable separation mechanism in reverse osmosis.
- **Mg/l –** Milligrams per liter. For our purpose, same as ppm. Normally used for a more accurate measurement or where small quantities of certain elements cause big problems in relation to iron, manganese, sulfur, nitrates and silica. There are 1000 mg in 1 gram, and 1000 grams in 1 litre, so 1000 mg × 1000 g = 1 000 000 mg in 1 litre.
- **Micron –** A unit of length, which is $\frac{1}{1\,000\,000}$ of a meter. It is the most common measurement of the size of particulate that a filter can trap. Filter sizes are designated in microns.
- **Muriatic Acid –** An acid used to reduce pH and alkalinity. Also used to remove stain and

scale.

- **Osmosis –** The spontaneous flow of water from a less concentrated solution to a more concentrated solution through a semipermeable membrane occurring until energy equilibrium is achieved.
- **Ozone –** A powerful oxidizing agent with three atoms (O_3) which, when dissolved in water, produces a broad-spectrum biocide that destroys all bacteria, viruses, and cysts. Normally used commercially for large-scale disinfection of water.
- **Particulate –** Minute, separate particles.
- **Permeable –** Allowing some material to pass through.
- **Permeate –** The portion of the feed stream that passes through the membrane. Also called “product water” of a reverse osmosis unit, meaning the finished water that you drink.
- **pH –** A measure of the acidity or alkalinity of water. The pH scale runs from 0 to 14 with 7 being the mid-point or neutral. A pH of < 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of >7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity. The pH value is an exponential function, so pH 12 is 10 times more alkaline than pH 11 and 100 times more alkaline than pH 10. Similarly, a pH 4 is 100 times more acidic than pH 6.
- **PPM –** Parts per million. One part dissolved material in one million parts of water. Used as a measurement for iron, manganese, TDS, hydrogen sulfide, chlorides, sulfates, and tannins.
- **Regeneration –** Refers to the process by which an ion exchanger (i.e., a water softener) or media filter renews its ability to do its job.
- **Rejection –** Material not being allowed to pass through a membrane. A reverse osmosis unit “rejects” contaminants and does not allow them to enter the permeate, or product water.
- **Residual –** Usually applying to chlorine in water, it is the amount of chlorine left after initial contact time that will provide disinfection. It is measured as mg/litre.
- **Resin –** Specially manufactured polymer beads used in the ion exchange process to remove dissolved salts from water.
- **Reverse osmosis –** The separation of one component of a solution from another component by means of pressure exerted on a semipermeable membrane. Reverse osmosis is a popular and effective drinking water treatment that reduces “dissolved solids” that are often not filterable by other means.
- **Scale –** Crust of calcium carbonate, which generally refers to calcium buildup in pipes or the interior of appliances like hot water heaters.
- **Semipermeable –** Able to allow certain size material to pass through while rejecting other size material. A reverse osmosis unit uses a semipermeable membrane.
- **Soda ash –** A chemical (sodium carbonate) used to raise pH and total alkalinity.
- **Sodium bisulfate –** Also called dry acid, it is a chemical used to lower pH and total alkalinity.
- **Soft water –** Water containing less than 17 PPM calcium or magnesium.

- **Solute –** Dissolved particles in a solvent.
- **Superchlorination –** Application of large dosages of chlorine to destroy build-up of undesirable compounds in water.
- **Suspended solids –** Small solid particles which remain in suspension in water, making it turbid (see Turbidity).
- **Titration –** A method of testing by adding a reagent of known strength to a water sample until a specific color change indicates the completion of the reaction.
- **Total alkalinity –** A measure of the acid neutralizing capacity of water which indicates its buffering ability (a measure of its resistance to a change in pH). Generally, the higher the total alkalinity, the greater the resistance to pH change.
- **Total dissolved solids –** The weight of solids, per unit volume of water, which are in true solution. It can be determined by evaporating a measured volume of filtered water and determining the residue's weight. A common alternative method to determine TDS is to measure the water's ability to conduct an electrical current through it.
- **Turbidity –** Muddy, clouded, stirred-up sediment, silt, clay, etc.
- **Ultraviolet disinfection –** The use of ultraviolet light to interrupt the DNA of, and sterilize bacteria, protozoa, and cysts.

Types of Water Treatment

Water quality standards in Canada are prescribed by Health Canada's *"Guidelines for Drinking Water Quality"*. These guidelines are prioritized and developed in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water. The most significant risks to peoples' health from drinking water come from microscopic organisms such as disease-causing bacteria, protozoa, and viruses. The guidelines that relate to these microorganisms are stringent because the associated short- and long-term health effects can be quite severe. Chemical and radiological substances may also be found in some drinking water supplies, but these are generally only a concern if they are present above guideline levels, with exposure to them over a period of years. However, new science is showing that exposure to some chemical contaminants above guideline levels may be a concern in the short-term as well. Aesthetic quality guidelines address parameters which may affect consumer acceptance of drinking water, such as taste, odour, and colour, and the choice to rectify aesthetic concerns is mainly left to the consumer.

The need for water treatment is established through the testing of water samples. The various tests and their procedures will be covered later in this learning guide.

Once a sample has been analyzed and a report of the test findings is generated, appropriate treatment methods and equipment can be prescribed. The following is a list of water treatment categories which will be covered in this text, although not necessarily in this order:

- Basic filtration
- Neutralization
- Ion exchange
- Oxidation

- Chlorination
- Distillation
- Ultraviolet sterilization
- Reverse osmosis

Filtration

Water filters come in a variety of forms. They range from small point-of-use (single fixture) cartridge-type to larger point-of-entry (whole-house) fibreglass tanks containing various types of filter media. Basic filtration involves the removal of sediment, silt or particulate that is large enough to be trapped by fine filtering media such as sand or fabric filters.

Cartridge-type filters

These are an inline variety and can be single units or two or more filters in series. Plastic housings containing a filter cartridge are intended to be installed on cold water lines only, whereas a hot water line would require a stainless steel housing. The maximum pressure that most manufacturers state they should be exposed to is usually 100 psi (700 kPa). Depending on the manufacturer, the filter housing (sump) is sometimes made of clear plastic so that the cartridge can be inspected visually for buildup. They can be supported by the pipe they are fitted to or mounted to a wall with a mounting bracket and hardware. A sump wrench is normally supplied with it for easy sump removal. Optional built-in valves on the inlet and outlet allow for isolation to enable quick cartridge changes, and a pressure-release button on the body relieves pressure from the housing prior to changing the cartridge. Filter assemblies come in various sizes with a range of maximum flow rates. The filter cartridges are designated by the size of particulate, in microns, that they can trap. Some types of cartridges, such as pleated polyester varieties, can be cleaned and re-used, however most cartridges are single-use and are discarded once full of sediment (loaded). Cartridge-type filters are normally considered point-of-use equipment and their intent is limited to treating screening dirt and sediment from the water, although activated carbon filter cartridges are also available for these units, to help in the reduction of bad tastes and odours and chlorine tastes and odours.

Figure 3. NOVO® Plastic and stainless-steel filter housings

Figure 4.NOVO® Pleated, string wound, and activated carbon cartridges

Whole-house filters

When whole-house treatment is desired, large fibreglass tanks containing filter media can be used. These allow higher flows rates through them than the cartridge-type, and the impurities they trap can be flushed to drain many times before the media needs to be replaced. Water conditions that can be treated by whole-house filter media include turbidity, iron, pH, manganese, hydrogen sulphide, chloramines, and taste/odour.

Figure 5. NOVO® Fibreglass whole-house media filter

The media inside the fibreglass tank is particular to the condition being treated, for example, a base substance such as limestone is used to neutralize acidic water. There are normally three layers of material within the tank, which are;

- the media, forming the top layer
- coarse gravel as the bottom layer, and
- finer granular material sandwiched between the coarse gravel and media layers

There is some unused space, called “freeboard” above the top layer. This allows room for the filter media to expand or “fluff up” during the backwash cycle.

A distributor pipe connected to the valve assembly extends through the layers of media and fine gravel into the bottom of the coarse gravel layer at the bottom of the filter. In the service position (normal operation) water is directed from the valve head down through the distributor tube and through a screened fitting into the coarse gravel bed. The two gravel beds screen and trap particles of dirt and unwanted matter. As well, they help prevent the loss of filter media during the backwash cycle and also prevent channeling of water through the filter media. The screened water is treated as it flows upward through the media and exits the filter through the connected house piping. When it is time to regenerate the filter, the valve operates to reverse the direction of flow through the media and gravel which flushes the trapped particulate to the drainage system and rinses the gravel and media. Once this cycle is completed, the filter is once again in its “service position” and ready to go to work.

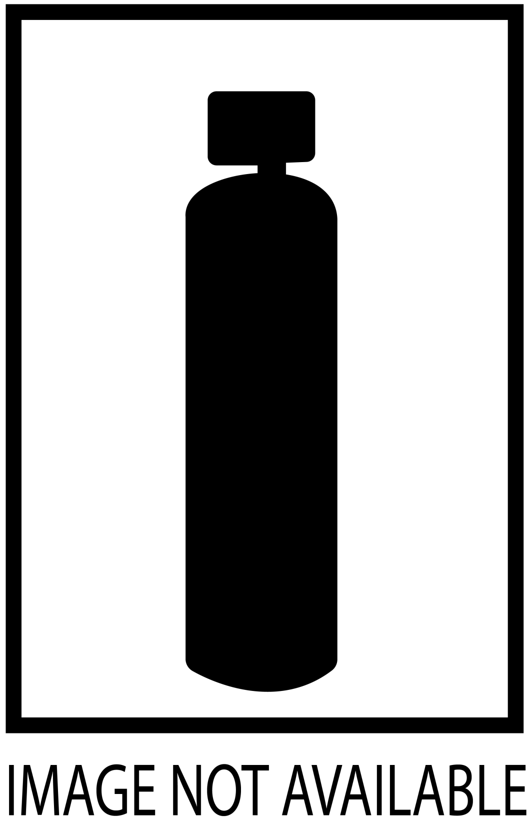

Figure 6. Cutaway of whole-house filter tank (unavailable)
[Image Description] (#c2fig6_desc)

The timer and valve assembly, mounted to the top of the filter tank, can be either analog (oldest technology) or digital (more up to date). In most cases, the assembly is powered by the house electrical system, and a battery backup in the timer retains the programs in the event of a power outage. The valve head contains servo motors and valves that direct water through the filter and into the house piping when in its service position or through other positions such as “backwash” and “rinse” to periodically regenerate the filter.

Figure 7. NOVO® 485 digital valve

Media for whole-house filters

Activated carbon

Activated carbon, or activated charcoal, is a porous substance produced from any base material that is carbonaceous (has a high percentage of carbon content), such as wood, nut pits or shells, animal bone, hydrocarbon sludge, peat, lignite, bituminous coal and anthracite coal. Carbonaceous material is first placed in an inert (without oxygen) tank and subjected to extremely high temperatures of between 800 – 900°C. This carbonized material, or char, must now be activated to fully develop the pore structure. This is done through oxidizing the char at temperatures again between 800-900 ºC but now in the presence of air, carbon dioxide, or steam. Once this process is complete, the activated carbon has a high surface area–to–volume mass ratio that allows it to adsorb organic compounds that produce taste, odour, colour, and toxicity issues, and can also reduce free chlorine present in the water supply.

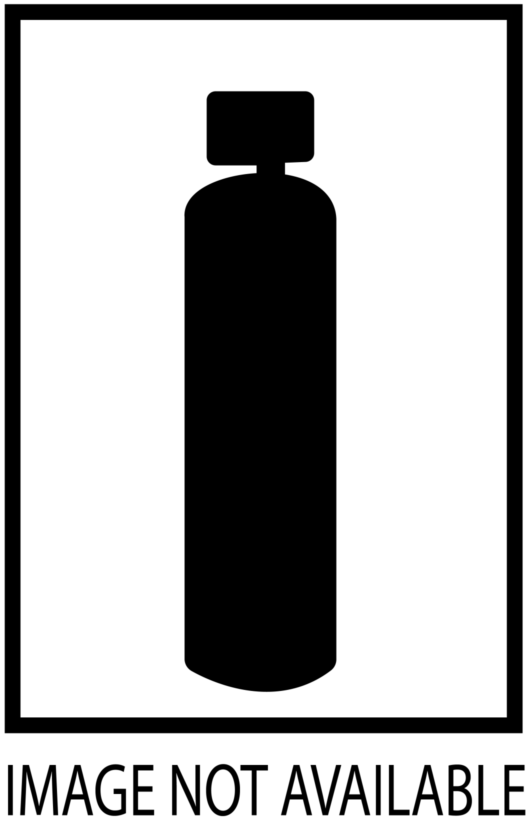

Figure 8. Activated carbon filter (unavailable) [Image Description] (#c2fig8_desc)

Calcium carbonate

Calcium carbonate (CaCO3), also known as limestone, is a crushed and screened white marble material that is used in filters called *neutralizers* to adjust the pH of water that is in the range of pH 5.0 to 6.0. Acidic waters will slowly dissolve the limestone media, thereby raising its pH level to close to pH 7. The addition of calcium to the treated water may increase the hardness levels in the product water, and so may require the addition of a water softener for this reason. The calcium carbonate media will require periodic replacement depending on the incoming water’s pH and usage.

Magnesium oxide

Magnesium oxide (MgO) can also be used in neutralizers where more correction to acid water in the range of pH 4.0 to 6.0 is needed. However, in low flow conditions, magnesium oxide may cause overcorrection issues and turn the product water alkaline. For this reason, acid filters sometime use both calcium carbonate and magnesium oxide as the filter media. Magnesium oxide, like calcium carbonate, will need to be periodically replaced due to being dissolved through the neutralizing process.

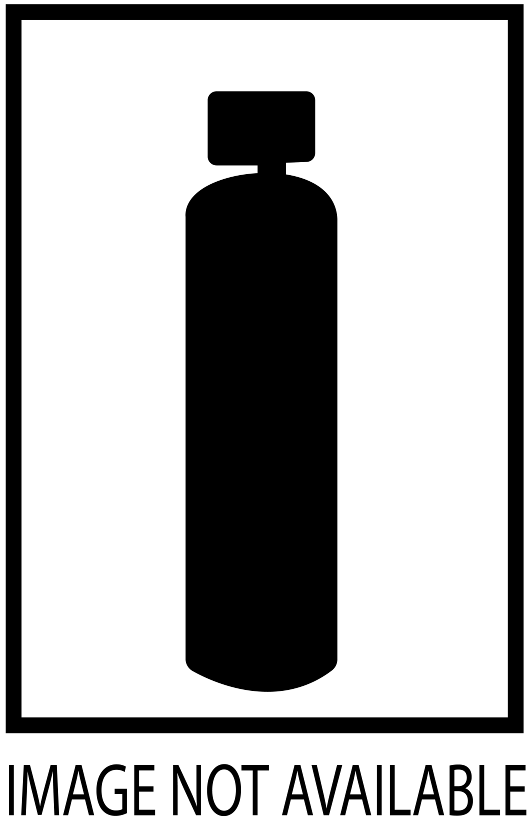

Figure 9. Acid neutralizer (acid filter) (unavailable) [Image Description] (#c2fig9_desc)

Manganese greensand

Manganese greensand is used to remove soluble iron and manganese, as well as hydrogen sulphide, from water supplies. It is a purple-black filter media processed from glauconitic greensand. A solution of potassium permanganate ($KMnO_4$) and water is periodically passed over the manganese greensand to regenerate it, in a process like that which is used in a water softener.

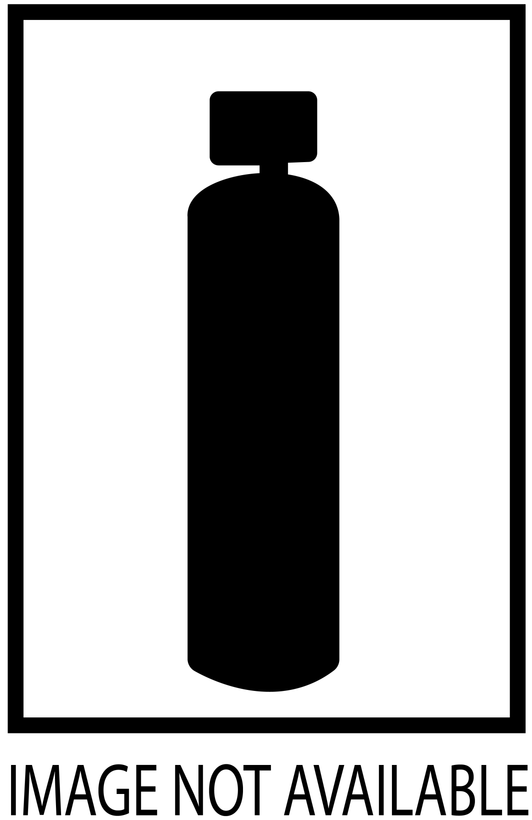

Figure 10. Manganese greensand filter (unavailable) [Image Description] (#c2fig10_desc)

Sand

Sand is by far the most widely used filter media for water treatment, primarily to screen solid particles (sediment) from water. The sand must be of a type that is hard and sharp, normally produced through a crushing process, in comparison to river sand which normally has a rounded profile due to erosion. A sand filter can be found as a stand-alone component of a well water system that has much sediment and particulate to be removed, or as a component of a multi-media filter along with other substances such as anthracite and garnet to provide a broad-spectrum filter media.

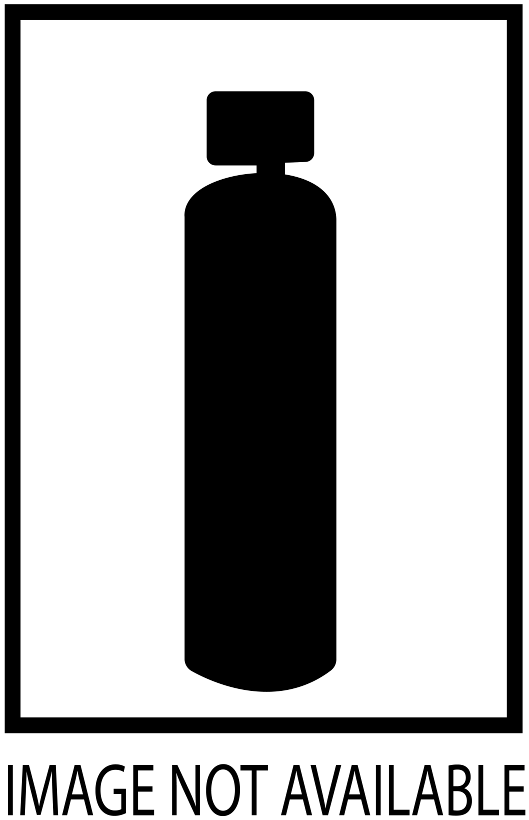

Figure 11. Multi-media filter (unavailable) [Image Description] (#c2fig11_desc)

Now complete Self-Test 2 and check your answers.

Self-Test 2

Self-Test 2

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://opentextbc.ca/plumbing4c/?p=178#h5p-11 (https://opentextbc.ca/plumbing4c/?p=178#h5p-11)

Filtration Continued

Iron filters

When iron is present in water in concentrations above that which can be treated with a softener, a separate iron filter can be used. There are two varieties, which are:

Manganese greensand filter – this has all the same components as a water softener, with the differences being:

- the substitution of magnesium greensand in place of the resin
- a potassium permanganate solution as the regeneration medium in place of sodium chloride brine, and
- a solution tank built specifically for the dry potassium permanganate agent

The filter goes through the same regeneration processes as does a softener.

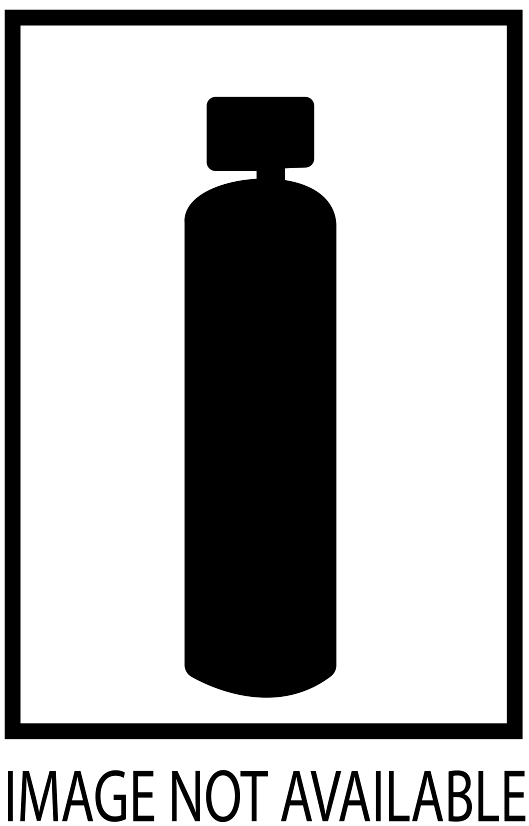

Figure 12. Manganese greensand filter (unavailable) [Image Description] (#c2fig12_desc)

Chemical-free iron filter – the tank in this variety is also similar to a softener tank, but unlike the manganese greensand filter there is no secondary tank holding a regeneration solution. Air is introduced into the water supply through an air induction valve, also known as a *hydrocharger* or *air injector*, as it travels through the valve head assembly on the filter. This starts the *oxidation* process, with the balance of oxidation occurring within the special filter material within the tank. Once oxidized, the iron precipitates out of solution and can be trapped in the filter bed, where it can be removed through the regeneration process.

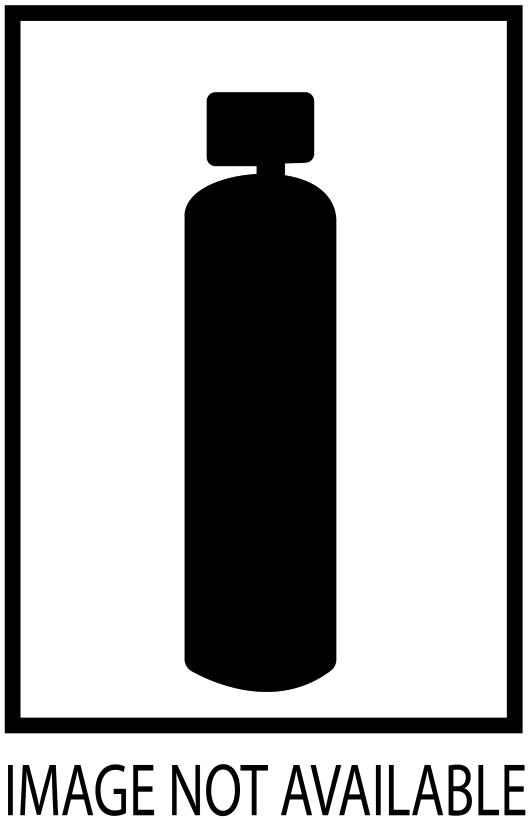

Figure 13. Chemical-free iron filter [Image Description] (#c2fig13_desc)

Reverse osmosis filtration

The process of reverse osmosis (RO) is one of the finest levels of water filtration available for residential use. Depending on the manufacturer and size of unit, an RO unit will have either 3 or 4 vessel housings containing cartridge-type filters. The extra housing contains a pre-filter intended to remove suspended particulate that may be present. The first carbon filter, usually found on the upstream side of the membrane, is intended to remove chlorine from the water. The second carbon filter, called a post-filter, is mounted downstream of the membrane and is there to remove any taste or odour from the product water prior to delivery to the storage tank. The RO housing consists of a semi-permeable membrane with a very large surface area due to it being rolled into a cylindrical shape. According to many manufacturers, incoming water pressure must be at least 40 psi (280 kPa), with the optimum pressure being 50 – 75 psi (350 – 525 kPa). If water supply pressure is too low, units with a self-contained booster pump are available. The pressure of the incoming water pushes only pure water molecules through the membrane and into the post-filter housing. Depending on their molecular or atomic weight, various mineral salts, heavy metals, and particulate matter, as well as some organic molecules are repelled by the membrane's surface and are rejected to the drainage system. The filtered water, called *product water*, is directed to the storage tank. RO units should only be applied to bacteriologically safe water supplies, as the membrane will not be effective to remove most bacteria and viruses.

Residential RO units are typically small capacity, delivering on average either 25, 50 or 75 US gallons of product water per day, and their membrane cartridges are colour-coded to indicate their daily capacity. RO units are used as point-of-use items and are most often located at kitchen sinks. The vessel housings and product water tank are installed within the sink's cabinet, with a faucet (spigot) installed through the countertop and adjacent to a sink bowl. Because the unit is considered a cross connection (interconnected between the water supply and drainage system), the faucet must contain an air gap. This controls the cross connection and, provided the installer follows the manufacturer's installation instructions, prevents backflow of drainage into the water supply.

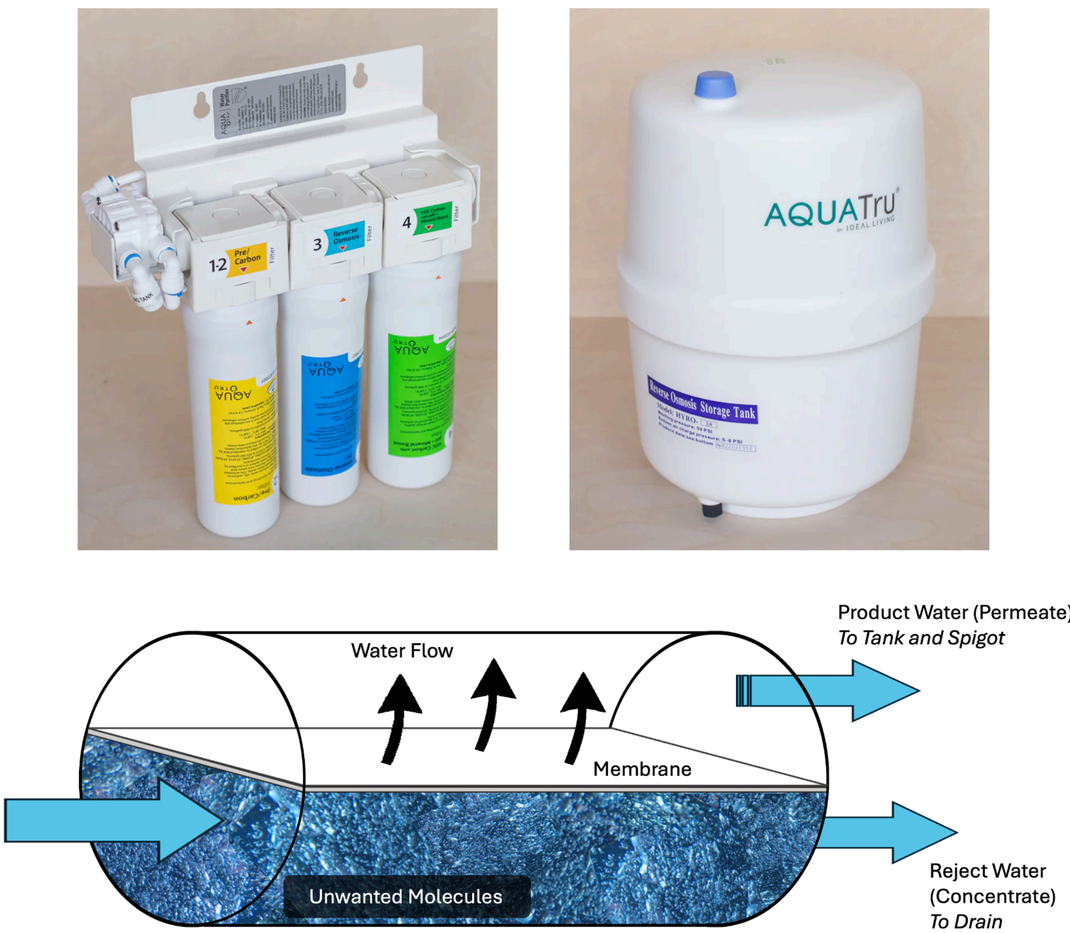

Figure 14. RO unit filters, tank, and membrane

Chlorination

When unwanted bacteria are present, a disinfecting agent such as chlorine can be added to kill the bacteria, provided it is in sufficient concentration and there is adequate contact time. As well, chlorine is an effective oxidizing agent, and so it can also be used to remove hydrogen sulphide. Chlorine is usually added to the water supply using a chemical feed pump, also known as a metering pump. This is a very precise operation, requiring accurate monitoring of the amount of chlorine injected to maintain a level that will be effective in disinfecting the water, which is termed “residual chlorine” and is measured in mg/l. Too much chlorine residual will create taste and odour issues as well as being corrosive to piping; too little will be a waste of chlorine and will not provide adequate disinfection. As well, chlorinated water can produce trihalomethanes (THMs). THMs are produced when chlorine reacts with organic matter, and there is concern among experts in Canada that THMs may pose a risk in the development of cancer. The simplest way to reduce or eliminate THMs in chlorinated drinking water is to use a water pitcher with a carbon filter, install a tap-mounted carbon filter or RO unit, or to use bottled water.

Figure 15. Chlorine feed pumps

Distillation

The process of distillation involves the evaporation and condensation of water. When water is heated and turns to vapour, any dissolved impurities it contained are left behind. Capturing and condensing the water vapour results in pure water, which may still possess some objectionable taste and odour. These issues can be removed by passing the product water through a carbon filter. Distillation effectively removes bacteria, cysts, some chemicals, colour, and dissolved solids.

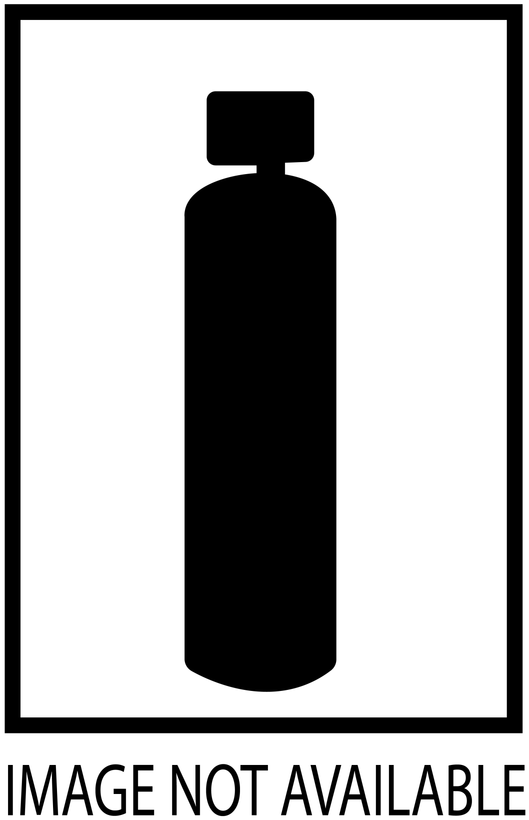

Figure 16. Cutaway of residential water distiller (unavailable) [Image Description] (#c2fig16_desc)

Ultraviolet “sterilization”

The most common means of disinfecting residential water is through the use of ultraviolet (UV) treatment. A specific spectrum of ultraviolet light emitted from one or more mercury vapour lamps inside a quartz-glass sleeve damages the DNA part of microorganisms so that they cannot reproduce. The five major groups of harmful microorganisms are viruses, bacteria, fungi, algae, and protozoa. Cells that can’t reproduce are considered dead, since they are unable to multiply to numbers considered infectious within a host. Both chlorine and UV treatment produces numbers of micro-organisms that are very low (approximately 99.9999% efficient) but not necessarily zero, and so although both processes are historically called *sterilization*, only high heat can truly sterilize a water supply. UV units are only effective if the water entering them has been filtered to a very high degree, as bacteria and other micro-organisms are so small that UV light can be blocked by particles of dirt or silt between the bacteria and the lamp.

Figure 17. Combination UV/filter treatment unit

Now complete Self-Test 3 and check your answers.

Self-Test 3

Self-Test 3

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://opentextbc.ca/plumbing4c/?p=178#h5p-12 (https://opentextbc.ca/plumbing4c/?p=178#h5p-12)

Ion Exchange Softeners

When the analysis of a water quality sample has determined that there is too much hardness (readings and their meanings will be covered in a later section of this learning guide), a water softener is usually prescribed. Water softeners work on the principle of *ion exchange*. Calcium and magnesium particles, the culprits behind hardness, possess a positive electrical charge. Left alone, they collect and form a layer called scale on the inside walls of pipes and vessels such as hot water tanks and boilers. Water softeners contain a bed of a substance known as resin. Today's resin bed is made of small beads of plastic, whereas in decades past the resin was a natural volcanic material called zeolite that mainly consists of aluminum, silicon, and oxygen. In either case, the resin possesses a negative electrical charge. The softening process involves exposing the resin bed to a strong sodium chloride (NaCl) solution called brine. The positively charged sodium ions are attracted and cling to the resin and the softener is ready to do its job. As hard water ions pass through the resin bed, their attraction to the resin is stronger than that of the soft sodium ions, so the sodium is displaced into the water stream and out to the faucets, while the calcium and magnesium ions are held by the resin. When there are no more soft sodium ions left on the resin, the softener is exhausted and needs to be regenerated.

Water softeners have six basic control and valve settings, which are:

- service position
- backwash position
- brine position
- slow rinse position
- rapid rinse position, and
- brine tank refill

The service position

The "service" position refers to the state that the softener is in where hard water entering the softener is treated and soft water exits to the piping system supplying fixtures. In the service position, incoming hard water is directed through the valve head into the top of the tank, where it is pushed downward through the resin bed (downflow). This is where the exchange between hard calcium and magnesium ions in the water and soft sodium ions on the resin takes place. Softened water enters the distributor pipe at the bottom of the tank and travels upward through the valve head and out to the fixtures.

The other softener positions are part of the regeneration process.

The regeneration process

This refers to the steps necessary to be taken when the softener is no longer able to exchange soft ions for hard ions; in other words, the resin bed is depleted. In the regeneration process, the softener goes through several processes, which are backwashing, brining, and rinsing. As well, the salt tank is refilled with water to create a brine solution for the next regeneration cycle.

The backwashing position

Backwashing is simply pushing water in the reverse direction of flow through the resin bed. Water is directed from the head to the bottom of the tank through a vertical tube called the distributor pipe. Water exits the pipe through a nozzle which creates a swirling action. The swirling upward flow through the resin bed loosens suspended solids and impurities while expanding ("fluffing") the resin bed up to 50% of its initial volume, preparing it for the next stage. The water then exits the top of the tank, taking the contaminants to the drain. This cycle takes about 10 minutes, at a flow rate of 4 – 8 GPM. If the softener is fed from a relatively clean municipal water system, it can be programmed to backwash less frequently.

The brining position

In a separate tank, sodium chloride ($NaCl$ or salt) is dissolved into water to make a brine solution. Although potassium chloride (KCl) may also be used, this text will focus on sodium chloride solutions. In the "brining" position, brine is drawn from the brine tank through a venturi in the valve head and passed through the resin bed. If the brine concentration is strong enough, the hardness ions that have collected on the resin will be replaced with sodium ions, and the hardness ions removed from the resin, along with some excess sodium and chloride ions as well as any trapped particulate, are sent to the drain.

The brine flow through the resin can be either upward or downward depending on the model of the water softener. In downflow brining, the brine flows through the softener resin from top to bottom, in the same direction that the service flow occurs, and is termed "co-current". In upflow brining, the brine flows through the softener from the bottom to the top, in the opposite direction of service flow, called "counter-current". In general, upflow brining softener systems are more brine-efficient than downflow systems. This is because, at the beginning of a regeneration cycle, the resin highest in hardness is at the top of the bed, and the resin with the least amount of hardness is at the bottom of the bed. In downflow (co-current) regeneration, hardness that is exchanged off the resin during brining is pushed down the bed, where it continues to exchange on and off the resin until it's pushed from the bed. The freshest brine is being used on the most depleted portion of the bed. In upflow (counter-current) regeneration, the hardness that is exchanged off the resin during brining is pushed back up the bed, exiting the system at the top of the bed. The freshest brine is being used to regenerate the least depleted portion of the bed. This highly regenerated portion of resin acts as a polisher which decreases hardness "leakage" (hardness ions left on the resin after regeneration). This allows an upflow regenerated softener to use, by some estimates, up to 75% less salt and up to 65% less water. The brining cycle takes about 30 minutes, at a flow rate of .05 to 1 GPM.

The slow rinse position

Once the brine draw is complete, fresh water is directed into the resin bed to give the resin a rinse. This flow moves slowly, allowing the ion exchange process to be complete. It removes the brine and sends it towards the drain. This cycle takes about 20 minutes, at a flow rate of .5 to 1.0 GPM. Besides brining, this is the only other process where the direction of flow is reversed in an upflow regeneration system. Direction of flow for backwashing and fast rinse are the same in both regeneration processes.

The fast rinse position

Once the slow rinse cycle is complete, a fast rinse cycle commences, flowing quickly through the resin bed from top to bottom. This rinse removes any remaining brine and hardness compounds and compacts the resin bed, preparing it for its service cycle. The cycle takes about 20 to 50 minutes, at a flow rate of 1.5 to 2.0 GPM.

The refill position

In this last stage before being returned to the service position, water is directed into the brine tank, where it dissolves some of the salt to create brine in preparation for the next brine draw cycle.

Other factors of softener operation

Regeneration efficiency

There are two measures of regeneration efficiency – brine efficiency and water efficiency. Brine efficiency is a measure of how much salt a softener system uses to remove hardness from the water. The brine efficiency of a system is calculated as the grains of hardness removal capacity per pound of salt used to regenerate the system (grain/lb). Water efficiency is a measure of how much water the system uses to regenerate, and is usually calculated as gallons per regeneration, or gallons of regeneration water per 1000 grains hardness removed.

Softeners that are tested to the "NSF/ANSI Standard 44 for Residential Cation Exchange Water Softeners" can be efficiency rated if they use demand-initiated regeneration. These will be digital softeners that "learn" the building's water use and self-adjust regeneration frequency and duration accordingly. Analog or time clock softeners don't have this ability and therefore cannot be efficiency rated. Per the standard, efficiency rated softeners must have a rated salt efficiency of at least 3350 grains per pound of salt used for regeneration. Efficiency rated softeners must also meet a water efficiency of 5 US gallons of regeneration water (or less) per 1000 grains of hardness removed.

To make the sodium exchange back onto the resin, a strong brine solution is required. To optimize brine efficiency, the system is designed so that as little excess sodium chloride as possible is discharged to the drain while still providing a solution strong enough to enable the ion exchange. Optimizing brine efficiency lowers system operating costs and reduces the level of brine discharged into the environment.

Variable Brining

Most digitally metered, single tank softeners delay regeneration until the night after the meter reaches its set capacity. To ensure that soft water is available throughout the last day, a portion of the softener's capacity, equal to a day's usage, is included in the softener's sizing calculation. This is known as the *reserve*.

Variable brining is a control feature available on some upflow softeners whereby the controller determines how much reserve capacity has been used when the regeneration time is reached. Based on that remaining capacity, the system adjusts the salt dose used for that regeneration. This salt dose adjustment avoids using salt for resin that is still regenerated (not yet depleted). Fill time is varied to allow the salt dose to be matched to the actual amount of resin that is exhausted.

Variable brining will *not* work with downflow brining. With downflow brining, the first resin that is exposed to the brine is the most depleted. As that resin is regenerated, the hardness that is exchanged off the resin is pushed down the bed ahead of the more sodium-rich brine and will exchange onto less depleted resin. This resin will now be more fully depleted thus need to be fully regenerated. This continues all the way down the resin bed, so that resin with capacity remaining at the bottom of the bed will actually be depleted by the hardness ions being removed from the bed. This means that even if there is still some capacity remaining when regeneration starts in a downflow system, that capacity will be used by the time the full-strength brine reaches that portion of the resin bed.

Variable Reserve

Variable reserve is another means to minimize capacity wasted by the reserve setting. With a variable reserve system, the controller determines what the appropriate reserve for a system should be based on recent water usage patterns. This system increases and decreases the reserve capacity as required, helping to avoid both wasting salt and running out of soft water by optimizing reserve capacity.

Twin Tank Systems

Most softeners take approximately 2 hours to complete the regeneration process and the preferred time to start is 2am as there is normally little water use around that time. However, to maintain a water supply to fixtures during the regeneration process, the softeners engage an internal bypass feature that allows hard water to supply fixtures until the softener is ready to perform its duties once again. If there is a likelihood that there will be water used during this time of day and hard water to the faucets may be an issue, two softeners installed in parallel can alternate regeneration cycles so that there is always a supply of soft water to fixtures, regardless of time of day.

A twin tank system provides continuous soft water and only regenerates when the softener capacity is fully used. In a twin tank system, one tank is online and producing soft water while the other one is fully regenerated and waiting offline for its turn. When online tank capacity is reached, the offline tank is automatically brought online, and the depleted tank is taken offline and regenerated. Because regeneration can occur as soon as the capacity of the system is met, no reserve is required. The downside to this arrangement is the cost of the extra equipment.

Now complete Self-Test 4 and check your answers.

Self-Test 4

Self-Test 4

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Image descriptions

- **Figure 6. "Cutaway of whole house filter tank" image description:** A mineral tank with a timer and control valve on top. Within the mineral tank, a distribution tube runs inside from the top to the bottom with a distributor at the bottom. Within the mineral tank (from the bottom to the top), there is a layer of coarse gravel, a layer of fine gravel, a thick layer of media or filter bed, and a layer of free board. *[Return to Figure 6] (#c2fig6)*
- **Figure 8. "Calcium carbonate" image description:** A mineral tank with a timer and control valve on top. Within the mineral tank, a distribution tube runs inside from the top to the bottom with a distributor at the bottom. Within the mineral tank (from the bottom to the top), there is a layer of coarse gravel, a layer of fine gravel, a thick layer of activated carbon, and a layer of free board. *[Return to Figure 8] (#c2fig8)*
- **Figure 9. "Acidic neutralizer (acid filter)" image description:** A mineral tank with a timer and control valve on top. Within the mineral tank, a distribution tube runs inside from the top to the bottom with a distributor at the bottom. Within the mineral tank (from the bottom to the top), there is a layer of coarse gravel, a layer of fine gravel, a thick layer of calcium carbonate and magnesium oxide, and a layer of freeboard. *[Return to Figure 9] (#c2fig9)*
- **Figure 10. "Manganese greensand filter" image description:** A mineral tank with a timer and control valve on top. Within the mineral tank, a distribution tube runs inside from the top to the bottom with a distributor at the bottom. Within the mineral tank (from the bottom to the top), there is a layer of coarse gravel, a layer of fine gravel, and a thick layer of magnesium green sand. Flowing into the control valve is a Potassium Permanganate Solution.*[Return to Figure 10] (#c2fig10)*
- **Figure 11. "Multi-media filter" image description:** A mineral tank with a timer and control valve on top. Within the mineral tank, a distribution tube runs inside from the top to the bottom with a distributor at the bottom. Within the mineral tank (from the bottom to the top), there is a layer of course gravel, a layer of fine gravel, a layer of coarse garnet, a layer of fine garnet, a layer of fine sand, and a layer of Anthrafilt (Anthracite). *[Return to Figure 11] (#c2fig11)*
- **Figure 12. "Manganese greensand filter" image description:** A mineral tank with a timer and control valve on top. Within the mineral tank, a distribution tube runs inside from the top to the bottom with a distributor at the bottom. Within the mineral tank (from the bottom to

the top), there is a layer of coarse gravel, a layer of fine gravel, and a thick layer of magnesium green sand. Flowing into the control valve is a Potassium Permanganate Solution. *[Return to Figure 12] (#c2fig12)*

- **Figure 13. “Chemical-free iron filter” image description:** A mineral tank with a control valve on top. Flowing into the control valve are copper pipes that have an air vent and an air injector. Within the mineral tank, a distribution tube runs inside from the top to the bottom with a distributor at the bottom. Within the mineral tank (from the bottom to the top), there is a layer of coarse gravel, a layer of fine gravel, a thick layer of chemical-free iron filter media, and a layer of freeboard. *[Return to Figure 13] (#c2fig13)*
- **Figure 16. “Cutaway of residential water distiller” image description:** A labeled diagram of a residential water distiller, showcasing its main components. From top to bottom, the diagram highlights the activated carbon pre-filter, which removes impurities before distillation, the condensing coil, where steam cools and transforms back into liquid, and the boiling chamber, where water is heated to produce steam. It also includes the condensing fan, which aids in cooling, the heating element, responsible for boiling the water, the activated carbon post-filter, which further purifies the distilled water, and finally, the reservoir, where the clean, distilled water is collected. *[Return to Figure 16] (#c2fig16)*

Learning Task 2

Describe the Sizing of Water Treatment Equipment

Learning objectives

After completing the learning tasks in this chapter, you will be able to:

- describe the processes involved in testing the water supply
- identify water contaminants and their acceptable levels, and
- select methods for the treatment of contaminants in a water supply.

A surface or shallow well supply is more prone to turbidity and bacterial contamination than is water from a deep well source, while a deep well supply is more prone to contamination from iron, hardness, and gases than is a ground source. Regardless, a residential water supply that is *not* from a community system must be checked for both chemical and bacterial contamination, followed by the prescription of appropriate remedies if found. This is done by drawing and testing a water sample.

Testing the Water

Water samples should be taken as near the source as possible. This can be either from the well itself, or from a faucet as close to the well as possible. A glass or plastic container should be used and first cleaned and rinsed with the test water, which ideally should be between 20 – 25°C (68 – 77°F). The collected sample can either be tested on-site or be sent to a facility operated by a water treatment equipment manufacturer such as Novo® (formerly Watergroup®). Although taking longer to obtain, test results from a facility are usually more comprehensive and accurate, and don't require the sampler to purchase expensive test kits. As well, facility testing is usually manufacturer-specific, so the facility often suggests appropriate treatment equipment for the samples' results, in the hope that their equipment will also be chosen. A more thorough laboratory analysis can be performed on request if contamination by industrial wastes is suspected.

On-site testing can be very accurate but is limited to the scope of test equipment available and the knowledgeable practices of the tester. Note that both onsite and facility testing are limited to testing for chemical contamination only. Bacterial testing must be done by sending a water sample in a sterilized container to a government-approved laboratory, which can also test for iron bacteria. Iron bacteria cannot be detected by a standard iron test. Local health units, as well as plumbing wholesalers, normally carry water sample bottles and laboratory request forms for both types of tests. Tests for bacteriological content should be done on a regular basis (at least annually), as this aspect of a water source can change without creating a noticeable change in water quality.

Figure 18. Equipment suppliers' water sample container and form

A basic chemical analysis will reveal hardness and iron concentrations as well as the presence of manganese, total dissolved solids (TDS) and pH levels. Tests for hydrogen sulphide (H2S) are most accurate if performed onsite but can be done in a facility provided the test is performed within a short time of the sample being drawn, usually 24 hours, as H2S concentrations rapidly diminish after being exposed to air. While the presence of any of the above contaminants causes concern in various ways, they are usually considered an aesthetic issue and the choice to correct any water problems they cause lies with the homeowner.

A bacterial test will reveal the possible presence of two types of bacteria, which are:

- Total coliforms – these occur naturally in soil and in the guts of humans and animals, and their presence *may* indicate fecal contamination.
- Escherichia coli (E. coli) – these originate only in the guts of humans and animals, and their presence indicates *definite* fecal (sewage) pollution.

Although the 1996 edition of Health Canada's *Guidelines for Canadian Drinking Water Quality (6th edition)* indicates that no more than 10 total coliform bacteria per 100 ml in water is marginally safe to drink, the most recent September 2022 edition indicates that 0 total coliform per 100 ml of water is now the standard. Both editions indicate that water containing *any* measured amount of E. coli is unsafe to drink and that corrective action should be taken immediately.

Test Equipment and Procedures

Basic onsite water testing may be performed using test kits provided by water treatment equipment suppliers. Test kits can contain reagents, buffering compounds and colour comparison components, and can be single-task (checking for one water condition only) or multiple-task (checking for two or more conditions) as desired. Hardness, iron, manganese, pH, and chlorine content can all be detected onsite using chemical reagents. The only basic test that cannot be completed using chemicals is a measurement of total dissolved solids (TDS). This involves using a small electronic scale that measures the electrical conductivity of water, indicating the concentration of conductive metals in the water.

Figure 19. TDS meter

The chemicals in the test kits are age-sensitive and should be used within the expiry dates published. Any tests performed with out-of-date reagents should be considered inaccurate. Freezing or high temperatures may also affect these chemicals, and exposure to such conditions should be avoided.

Testing for Hardness

The simplest test for the presence of hardness minerals (calcium and magnesium) involves no test kit. This is called a soap test and involves taking a 5 to 20 ml sample of the water to be tested, in a 50 to 100 ml clean, clear container and adding 2 or 3 drops of dishwashing liquid to it. Cover the container and shake it vigorously for a few seconds. If this action produces suds, the water is relatively soft. If there are few suds but the water appears to be cloudy and has curds or lumps, the water is hard.

Hach® is a well-known manufacturer of water contaminant test kits, and the procedures that follow are particular to their products. We will limit the explanation of a chemical test procedure to this one for hardness. Other procedures, such as those for iron, manganese, etc. will be similar in execution but will involve different reagents and amounts. Always follow the instructions contained within any test kit carefully.

To test for hardness using a Hach® test kit, fill the plastic measuring tube to its fullest level with the water to be tested, and then pour it into the glass mixing bottle. Next, add the contents of the hardness reagent “UniVer 3” contained within a plastic pillow-type container. Swirl the mixing bottle to mix the reagent with the water sample. A blue colouration indicates soft water, and nothing further is required.

If the colour is red, hard water is indicated. Drop by drop, a titrant agent “Hardness 3” is added, with the mixing container swirled after each drop and the number of drops being counted. Continue adding titrant drops until the colour changes from red to blue. Each drop of titrant represents 1 grain per gallon hardness. This procedure is used for hardness up to 30 grains per gallon (gpg). If the number of drops reaches 30, with no change in colour, a similar procedure involving a different reagent must be used.

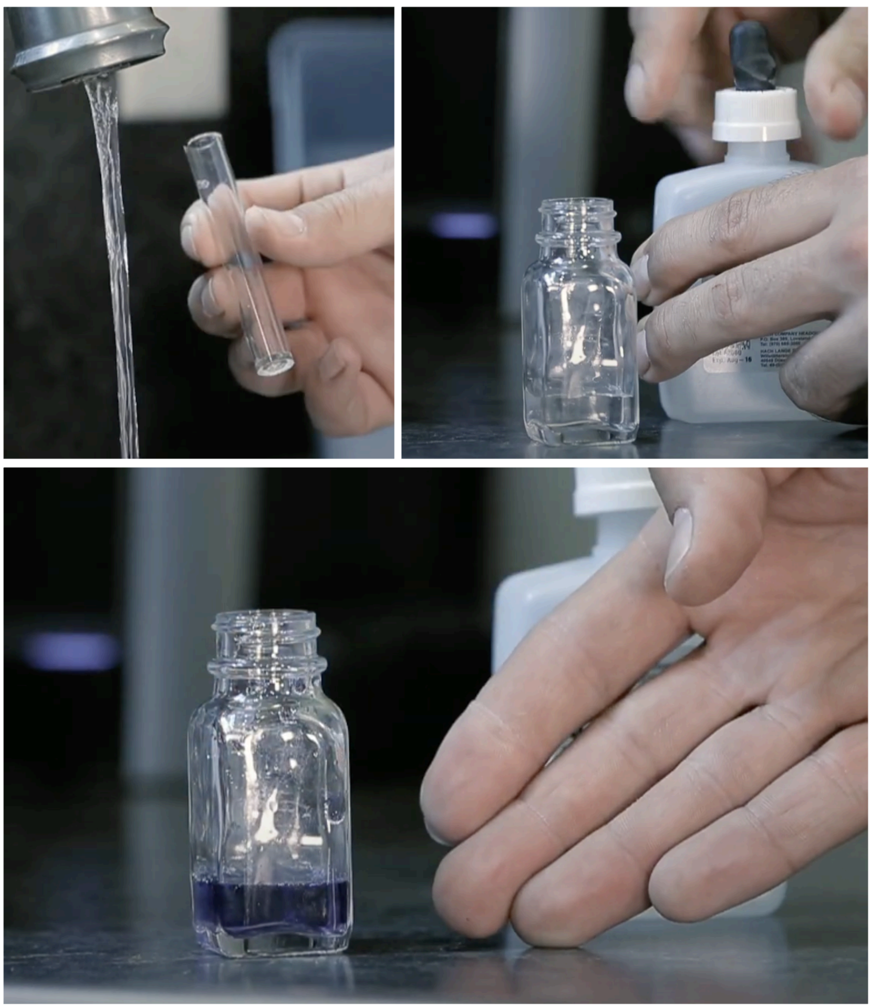

Figure 20. Mixing container, water measuring tube and reagent causing colour change

Testing for Iron

A different test kit, specific to iron in water, is used whereby, like the hardness test, a specified amount of reagent added to a measured amount of water causes a colour change in the sample. The sample's colour is compared side-by-side to a fixed colour comparison strip or wheel that has different shades of orange, indicating different levels of iron. Iron tests must be completed within a very short time of the sample being drawn, as exposure to air (oxygen) will alter test results quite quickly.

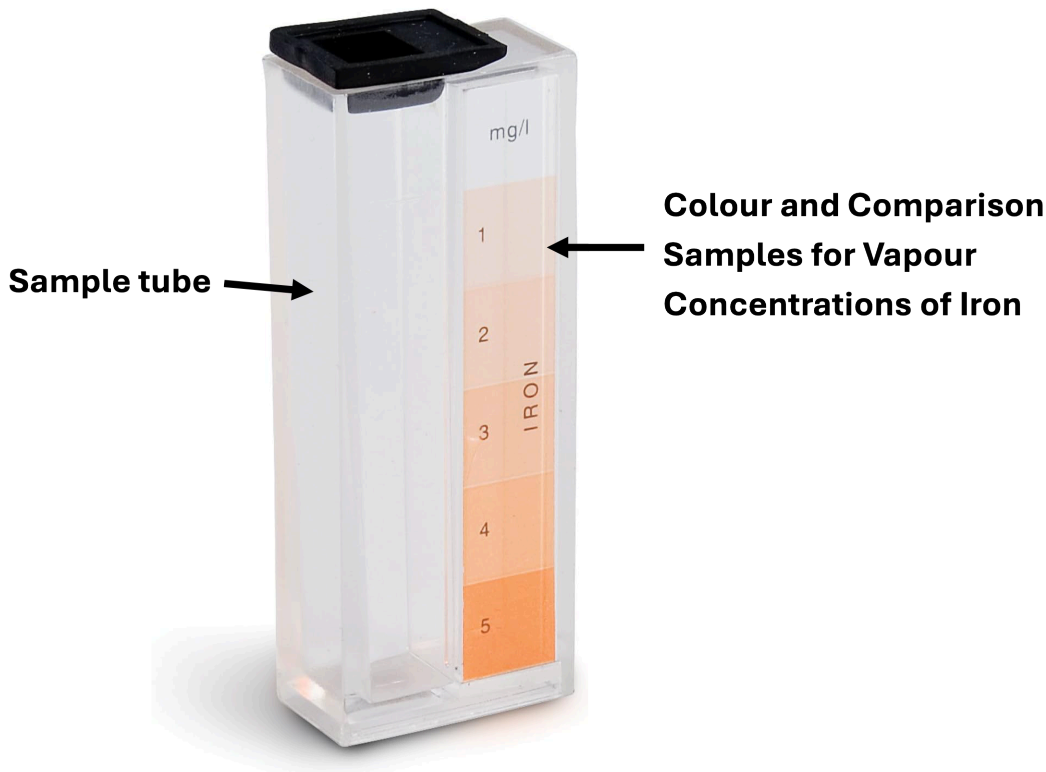

Figure 21. Iron test colour comparison equipment

Testing for Manganese and pH

The preparation of a water sample is similar to that for iron in water, using a specific test kit for manganese and a different one for pH. Procedures for manganese and pH tests will be similar as well, involving a colour comparison against a fixed chart while using differing amounts of reagents and volumes of sample water.

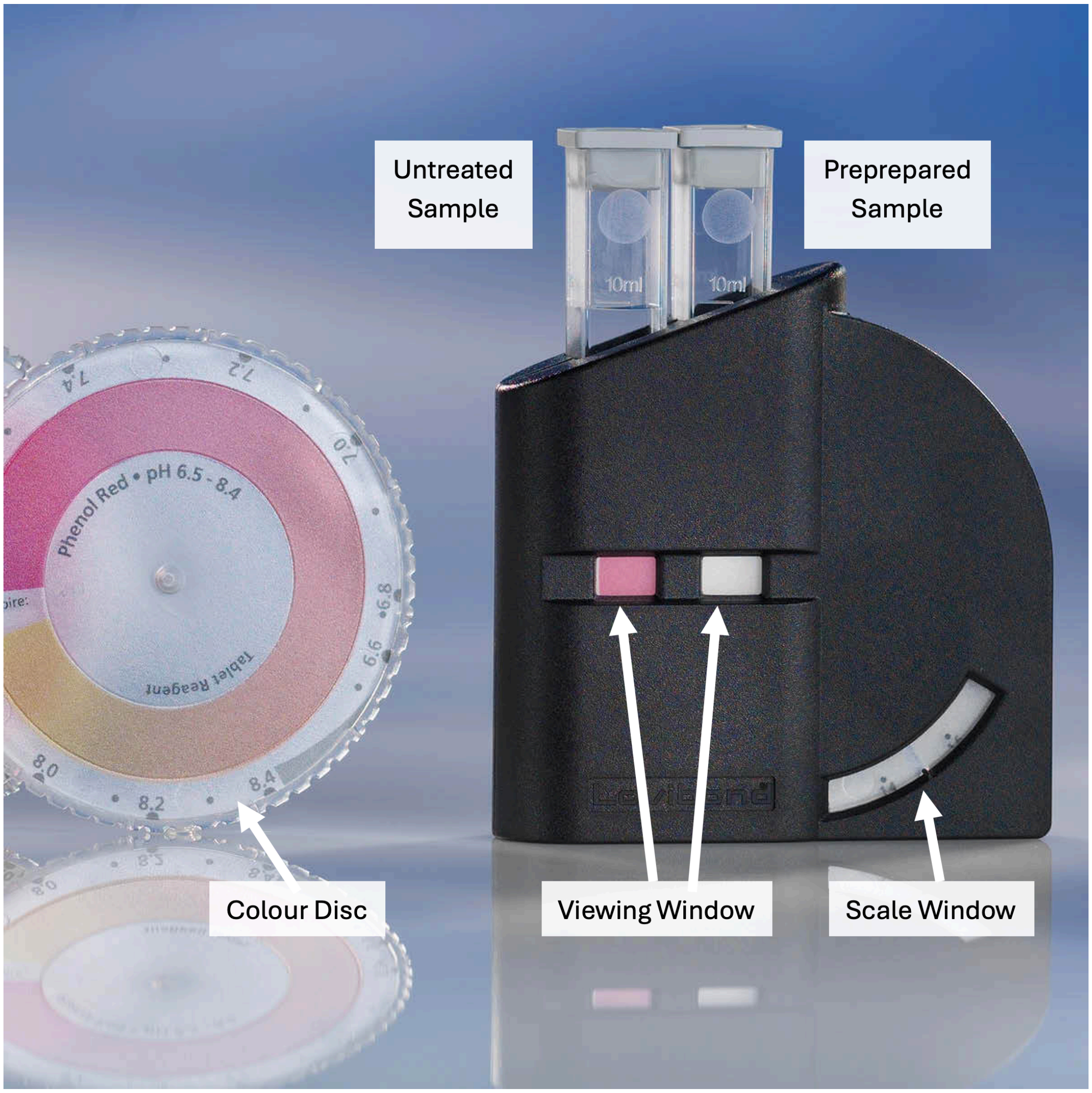

Figure 22. Colour comparator

Testing for TDS

As mentioned and shown earlier, testing for total dissolved solids doesn't use any reagents to cause a colour change. Rather, a specially designed meter is used where a small current, produced by batteries, is pushed through the water sample. The presence of dissolved metals causes water to be more electrically conductive, and consequently the higher the concentration of TDS, the more conductive the water will be. This is measured on a scale in parts per million (ppm).

Interpreting the Results

Hardness

A test result for hardness is normally expressed in grains per gallon of calcium carbonate (CaCO3) equivalent but can also be expressed as parts per million. Because there are both US and Imperial gallons in a water professional's vocabulary, there are two conversions at play. As mentioned earlier, there are 7000 grains per pound. Therefore, if one US gallon of water weighs 8.33 pounds, the conversion of gpg to ppm is:

1 gpg (US) = $\dfrac{\frac{1}{7000}\,\text{lb.}}{8.33\text{lb.}} \times 1\,000\,000$ = **17.1 ppm per 1 US gallon**

The conversion between gpg and Imperial gallons will be:

1 gpg (Imp) = $\dfrac{\frac{1}{7000}\,\text{lb.}}{10\,\text{lb.}} \times 1\,000\,000$ = **14.3 ppm per 1 Imp gallon**

Remembering also that *ppm* and *mg/l* are equivalent measures, the following classifications of hardness in water can be assumed. These are taken from the November 2022 edition of *"Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Hardness":*

- 0 to < 60 mg/L……..… soft
- 60 to < 120 mg/L…..… medium hard
- 120 to < 180 mg/L..…. hard
- 180 mg/L and above…. very hard

Equipment manufacturers may publish limits that differ from those above and should be considered as applicable to their equipment only. As well, the above terms such as "soft" and "hard" are for reference only – when choosing equipment to treat for hardness, the actual measurements in mg/l, ppm, or gpg are used. These measurements are known as "total hardness", meaning a summary of all the chemical constituents in the water. Total hardness of water is made up of "temporary hardness" and "permanent hardness" in varying proportions. Temporary and permanent hardness are terms used to denote bicarbonates (temporary) and carbonates (permanent) of calcium and magnesium dissolved in water. Water heated to over 140°F (60°C) in a vessel, such as a hot water tank, will cause bicarbonates to settle out and attach to surfaces as scale deposits. These deposits will clog piping and pipe outlets, causing reduced flow and efficiency issues. Water heated to temperatures exceeding 299°F (148°C), such as occurs in steam heating boilers, will cause carbonates, sulphates, nitrates, and chlorides to settle out. These constituents will quickly form a sludge layer in the bottoms of the pressure vessels and are usually removed daily by quickly opening a low-point outlet and using the steam's pressure to flush the sediment ("blow down") to a safe location.

Hard water causes incrustation in distribution systems and excessive soap consumption, whereas soft water may result in corrosion of metal water pipes. Also, public acceptability of the degree of hardness may vary considerably from community to community depending on local conditions. Therefore, a maximum acceptable level for hardness cannot be specified, and the following conditions are assumed (from *"Guidelines for Canadian Drinking Water Quality":*

- hardness levels between 80 and 100 mg/L (as $CaCO_3$) are generally considered to provide an acceptable balance between corrosion and incrustation.

- waters with hardness levels in excess of 200 mg/L are considered poor but have been tolerated by consumers, and
- waters with hardness in excess of 500 mg/L are unacceptable for most domestic purposes.

It is generally recommended that hardness in household applications not exceed 60 mg/l (3.5 US gpg or 4 Imp gpg). The use of a water softener is recommended when total hardness exceeds these limits but will only be effective if not over 100 gpg.

Iron

Iron is an essential element in human nutrition and intake of iron from a typical Canadian diet is more than sufficient to meet the minimum daily requirement. Toxic effects have resulted from the ingestion of large quantities of iron, but there is no evidence to indicate that concentrations of iron commonly present in food or drinking water constitute any hazard to human health. Therefore, a maximum acceptable concentration has not been set. At concentrations above 0.3 mg/L, iron can stain laundry and plumbing fixtures and produce undesirable tastes in beverages. The precipitation of excessive iron imparts an objectionable reddish-brown colour to water. Iron may also promote the growth of certain micro-organisms, leading to the deposition of a slimy coating in water distribution pipes (iron bacteria).

Generally, only a small percentage of the population will be able to taste iron in drinking water at concentrations below 0.3 mg/L, so the aesthetic objective for iron in drinking water is therefore ≤0.3 mg/L. Water softeners are capable of removing iron within these limits, up to 3 mg/l. However, ferric iron tends to foul the softener bed, so the backwashing and rinsing processes must be very thorough. The addition of a resin conditioner to the brine tank is recommended to assist in keeping the resin bed operational. At levels over 3 mg/l, a stand-alone iron filter is recommended. These are similar to a softener but have a filter bed of natural or synthetic manganese greensand and use a potassium permanganate solution as the regenerating agent rather than salt. Depending on the manufacturer, these will remove up to 10 mg/l of ferrous and ferric iron but will not remove iron bacteria. Chemical-free iron filters facilitate the removal of ferric and ferrous iron as well as iron bacteria by introducing a small amount of air into the system using a hydrocharger. The air causes oxidation of the iron in a special filter media within the tank, which needs no chemical reaction to be regenerated. This method works well on higher concentrations of iron, whereas the manganese greensand filter is more effective for lower concentrations.

Polyphosphate feeders and chlorinators are also effective for iron removal but require certain specific conditions for their use to be considered.

Manganese

Health Canada has set the Maximum Acceptable Concentration (MAC) of 0.12 mg/L for manganese in drinking water. The MAC is intended to protect all Canadians and is based on the most vulnerable/ sensitive population (e.g. infants and young children). Health Canada has also established a new Aesthetic Objective for manganese of 0.02 mg/L. Manganese in water at this concentration is not a health concern, but it may affect the colour or appearance of the water and can cause staining of fixtures and laundry. Water softeners and manganese greensand filters will reduce manganese content to acceptable levels, with manganese greensand filters requiring more care and attention due to resin bed fouling issues.

pH

Regardless of the form of test apparatus used (electronic potentiometers, test sensors, colour discs or test strips), water will need pH correction if it is outside the normally accepted range of pH 7.0 – 10.5 (Health Canada's *"Guidelines for Canadian Drinking Water Quality")*. Neutralizing filters are the most common residential correction device used for water that is acidic (pH <7.0), with soda ash feeders normally used for municipal water supplies as they require more careful monitoring. Extremely alkaline waters result from carbonates and bicarbonates in the earth and are not as common an occurrence as acidic water. Some cities in Canada, such as Vancouver, are increasing the target alkalinity levels in their water systems to between pH 8.3 to 8.5 to help control corrosion of copper pipes and inhibit the leaching of lead from soldered connections into drinking water.

TDS

The readings obtained by a conductivity test are expressed in microsiemens per centimetre (uS/cm). This can be multiplied by 0.65 to give an approximate reading for total dissolved solids in mg/l. Through taste testing, Health Canada has determined that an aesthetic objective of ≤500 mg/L has been established for TDS in drinking water. Although not usually a health concern, excessive levels of TDS can decrease the effectiveness of a water softener. In applications where the water is high in TDS, only reverse osmosis, demineralization, or distillation will work to improve water quality.

Calculating Water Softening Demand

The water conditioning industry widely recommends a three-day service period for water softeners, meaning they should be sized to allow soft water to be supplied to a household for three days before requiring regeneration. This allows a reserve capacity and has proven to achieve the most economical operational costs.

The water quality analysis will determine the grains per gallon content of calcium and magnesium, expressed as gpg of calcium carbonate, and will also report a reading of iron and manganese, if present, in ppm or mg/l. In order to size a softener, these three possible contaminants must be expressed as one term, which is gpg of hardness, so conversions must be made. The following are values commonly used by many softener manufacturers:

- every 1 ppm of iron is expressed as 4 gpg of hardness
- every 1 ppm of manganese is expressed as 8 gpg of hardness

It is important to use the values prescribed by the softener manufacturer chosen. These amounts would be added to the gpg hardness figure for calcium carbonate to arrive at a total hardness count for the sizing of the softener.

The sizing of a water softener is a mathematical issue, using the following factors:

- the hardness, iron, and manganese content of the water, expressed in grains per gallon (gpg)
- the number of people in the household using the water
- the average use of each person in gallons per day, and
- a 3-day regeneration period

The total hardness, number of people using the water system, and regeneration period are all easy to establish, whereas the average daily use of water per person can vary. The 2019 document *"Statistics Canada, Table 38-10-0271-01 "Potable water use by sector and average daily use"* has established that the average daily residential use per capita of the population served in Canada is *215 litres per day*. This equates to *47 Imperial gallons (56 USG) per person per day.* Many softener manufacturers use *60 US gallons/person/day* as the target amount for the purposes of calculating demand, so we will base our example on that figure.

Demand Example 1

We'll assume a household with 5 people uses a water supply with 28 gpg of calcium carbonate equivalent. The calculation for softener demand would be:

$$28\text{ gpg} \times 5\text{ people} \times 60\frac{\text{USG}}{\text{person}} \times 3\text{ days} = 25\,200\text{ grains of hardness}$$

Demand Example 2

Supposing that the above water analysis showed that it also contained 0.5 mg/l iron and 0.25 mg/l manganese, the revised calculation for total hardness would be:

$$28\text{ gpg} + \left(0.5\frac{\text{mg}}{l} \times 4\frac{\frac{\text{gpg}}{\text{mg}}}{l}\text{ iron}\right) + \left(0.25\frac{\text{mg}}{l} \times 8\frac{\frac{\text{gpg}}{\text{mg}}}{l}\text{ manganese}\right) =$$

$$28 + 2 + 2 = 32\text{ gpg total hardness}$$

The revised demand calculation for the softener would be:

$$32\text{ gpg} \times 5\text{ people} \times 60\frac{\text{UDG}}{\text{person}} \times 3\text{ days} = 28\,800\text{ grains of hardness}$$

Manufacturers' literature is then consulted for the selection of appropriately sized equipment.

Softener Sizing

Softener sizes will be expressed as grains of capacity they can hold at various salt settings, which can be manipulated with meter-initiated (digital) controls. For example, one manufacturer states that one of its models containing 1 cubic foot of resin, at the factory setting of 6 lbs salt per ft^3 of resin, will hold 20 000 grains of hardness. The same softener, when set at 10 lbs salt/ft^3, will hold 27 500 grains. Larger softener tanks will contain more resin, with the ability to exchange more hardness grains between regenerations. Varying tank sizes, variable salt settings and meter-initiated control valves allow fine tuning of efficiencies for salt and water usage and regeneration intervals.

Iron Filter Sizing

Calculation procedures for sizing iron filters will be like those in the examples above for softeners, with differing conversions particular to iron, manganese and hydrogen sulphide. Also, unlike the softeners, the regeneration frequency is *not* standard and will depend on the water conditions and equipment chosen. Both manganese greensand and chemical-free iron filters should be sized according to specific manufacturers' literature.

Now complete Self-Test 5 and check your answers.

Self-Test 5

Self-Test 5

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Learning Task 3

Describe the Installation of Water Treatment Equipment

Learning Objectives

After completing the learning tasks in this chapter, you will be able to:

- Identify considerations involved in water treatment equipment installations, and
- describe the appropriate installation procedures for various types of water treatment equipment

The installation of water treatment equipment must always follow manufacturers' specifications and recommendations. To not do so may jeopardize warranties and may also be ineffective in providing the intended corrections to water quality. Also, the following points must be considered when water treatment and equipment is required.

Safety

Safety is always paramount in any workplace. Workers must follow provincial and federal directives, such as those of WorkSafe BC, on any jobsite. If access to a confined space is necessary, the appropriate confined space entry procedures must be followed to the letter. Certified eye protection and safety footwear are standard Personal Protective Equipment (PPE) in any workplace scenario, with the possibility of hard hats, high visibility outerwear, and any other PPE to suit the specific installation site. Appropriate gloves should be used if there is a possibility of contact with rough surfaces or harmful chemicals, and the guidelines found in WHMIS legislation are always expected to be followed whenever working with hazardous products. A site assessment for safety should always be completed prior to any installation of equipment.

Transport and Handling

Equipment such as tanks can be heavy and awkward to handle and may require two people to ensure personal safety and to protect the equipment from damage. Two-wheeled hand trucks and dollies are usually beneficial tools when moving tanks and heavier components into place.

Items such as softeners and tank-type filters may be supplied pre-loaded with various layers of media, such as coarse gravel, fine gravel, and zeolite. It is extremely important that these tanks be transported as vertically as possible, to prevent the media layers from mixing, which can reduce the effectiveness of the device. The interior vertical space of many service vans is not high enough to allow the tanks to be loaded upright, so alternate arrangements for transport may be necessary.

Tools and Equipment

Most water treatment equipment is installed using standard tools found in a plumber's toolbox. Square-jawed wrenches such as spanners and adjustable wrenches are best for flat nuts as they won't mar the surfaces. Pipe wrenches should only be used on pipes where the jaw marks left won't be an issue, otherwise a strap wrench should be considered for any exposed piping. Teflon tape or pipe dope is appropriate for use on threads, provided any dope used is compatible with potable water and Teflon tape is applied leaving the first two threads bare, to avoid it balling up and being carried downstream. If installation involves soldered connections, avoid unnecessary heating of any fittings close to O-rings, washers, or plastic pieces. If they can't be isolated or dismantled, make sure to apply a wet rag as a heat sink between the heat and the vulnerable piece. Steel or galvanized pipe and fittings should not be used, due to corrosion issues. Also, the installation should conform to the requirements of the governing plumbing code.

Site Considerations

The need for water treatment is more a rural than an urban probability. Most treatment items will require a power supply and a protected area that is heated and has an adequately sized drain. Consequently, structures such as a pumphouse situated at the wellhead may be a good choice for locating whole house equipment provided an electrical supply and adequate room for equipment was considered at the planning stage. A backup electrical power supply should also be a consideration, at minimum to power the well pump but, more importantly, for protection from freezing during power outages. Otherwise, the equipment is best located adjacent to the water service entry point within the building. Placing equipment in a room without a solid floor should be avoided. Manufacturers usually specify installation on a firm, dry, stable base. Contact with moist soil or gravel may have an adverse effect on the bottoms of any tank or vessel. As well, the height and small footprint of filters and softeners make them prone to toppling, so they should be strapped to the structure using seismic-resistant components. The room should be adequately lit, heated, and ventilated.

Space Considerations

Most whole house water treatment equipment is floor mounted and will often require a fair bit of space for service and maintenance. This is rarely considered at the construction stage, so the norm is for equipment to be crammed into tight spaces. Items such as softeners and manganese greensand filters require a filter media tank and a second tank for the regeneration solution, which can be problematic for space needs. However, while manganese greensand filters are not normally supplied as single units, water softeners can be. Combination softener/brine tanks are available where the filter is located within the brine tank, or the brine tank wraps around the filter, as seen in the image below. These cabinet-type units need less floor space for their installation and in many cases may be the best option.

Figure 23. Novo® 485HE cabinet softener

Cross Connection Control

Any connections to a drainage system, from any water treatment device, must be made through an air break. This means there must be an unobstructed vertical space between the bottom end of the outlet pipe and the flood level rim of the drain, never to be less than 1 inch (25 mm) in height. This is a requirement of water purveyors and plumbing codes, and any contravention could have dire consequences. Filters or equipment that have the capability to automatically regenerate, such as softeners, will have an outlet that must be piped in a way that provides an air break while preventing splashing and overflow during operation. Cutting the end of the drain line at a 45-degree angle and securing it so it can’t be knocked out of position usually achieves this result.

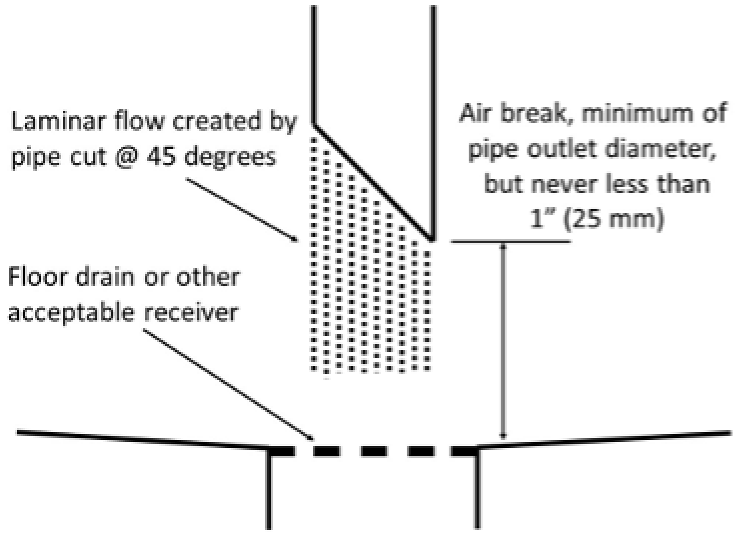

Figure 24. Air break

Sequence of Equipment

Depending on the source of supply and intended uses of the water, treatment units have a recommended sequence for installation. In the following figures, there are allowances for both raw water to outdoors and for hard filtered water usage. Some system outlets, such as for livestock feeders and exterior hosebibbs on a well system, have little need for treated water, and their inclusion in the treatment system will essentially be a wasteful practice. However, certain hosebibbs would benefit from dispensing softened water, such as those routinely used to supply water for car washing. Hard water deposits on the vehicle finish, called "spotting", are unsightly and extremely difficult to remove. The "specialty" hosebibb should be adequately marked as such to prevent unnecessary use of softened water.

The drains and valves in the figures that follow have been omitted for clarity. It is important, when installing multiple water treatment devices in series, that a sampling valve be installed in the piping downstream of each device. This allows the results of testing procedures, explained in the next chapter, to be obtained more accurately.

Figure 25 below shows the installation of an activated carbon filter and water softener on a municipal supply. Most municipal supplies deliver water that is free of large debris. If required by code, the integral screen of the pressure reducing valve (not shown) will capture debris that occasionally makes it through the system to that point. The activated carbon filter will take care of smaller particles that may pass through the PRV's screen and flush them to drain through its backwash cycle. If a pressure reducing valve isn't needed, a good choice would be to install a whole house cartridge type filter either upstream or downstream of the meter, as local bylaws allow. The softener should be installed downstream of the carbon filter and under no circumstances should water softeners be installed downstream of a water heater. Hot water will destroy the zeolite resin in the mineral tank of a softener. As well, the softener should always be protected from backflow of hot water from the water heater. The vacuum relief valve, installed on water heaters to prevent the collapse of the tank in the event of backflow created by backsiphonage, may in some circumstances be adequate for this purpose. A better choice would be an atmospheric vacuum breaker to both prevent tank collapse and prevent backflow. Because some water treatment devices change the quality of water due to the filter material used in the treatment process, the water softener should be the last piece of water treatment equipment in a series of treatment devices.

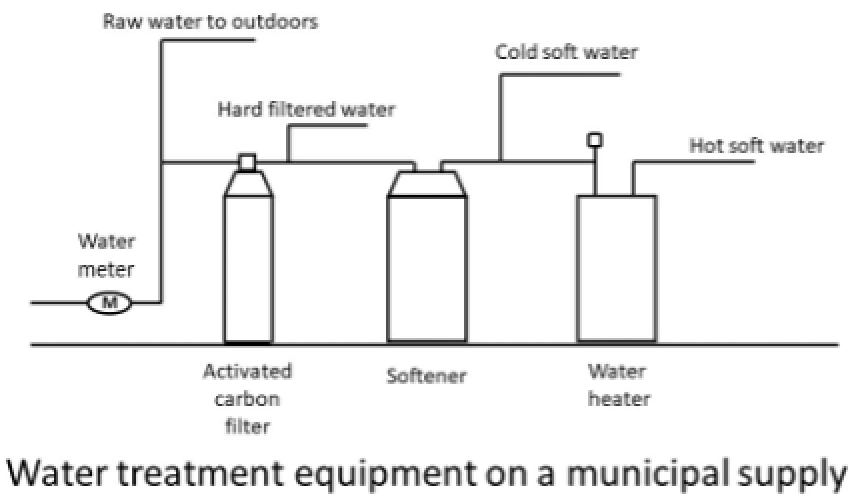

Figure 25. Water treatment equipment on a municipal supply

Figure 26 below shows a rural water supply system using an iron filter. When iron or sulphur in any other than minute amounts are present in the water supply, the softener's resin bed will become clogged. A dedicated iron filter protects the integrity of the softener.

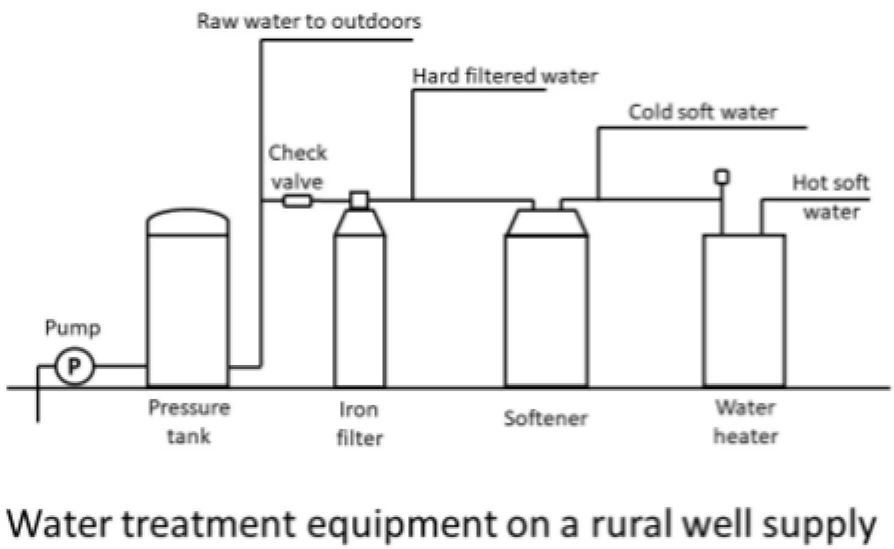

Figure 26. Water treatment equipment on a rural well supply

Multiple water treatment devices may be necessary when the quality of the water supply is poor. In Figure 27 below, a surface water supply source uses a chlorinator to remove bacteria and iron content. A sand filter is installed downstream of the chlorinator to reduce sediment and filter out the precipitated iron from the chlorination process. An activated carbon filter installed downstream of the sand filter will remove any taste and odour resulting from the chlorine and any hydrogen sulphide associated with the iron. The water softener, always located upstream of the water heater, takes care of hardness issues and any trace amounts of remaining iron.

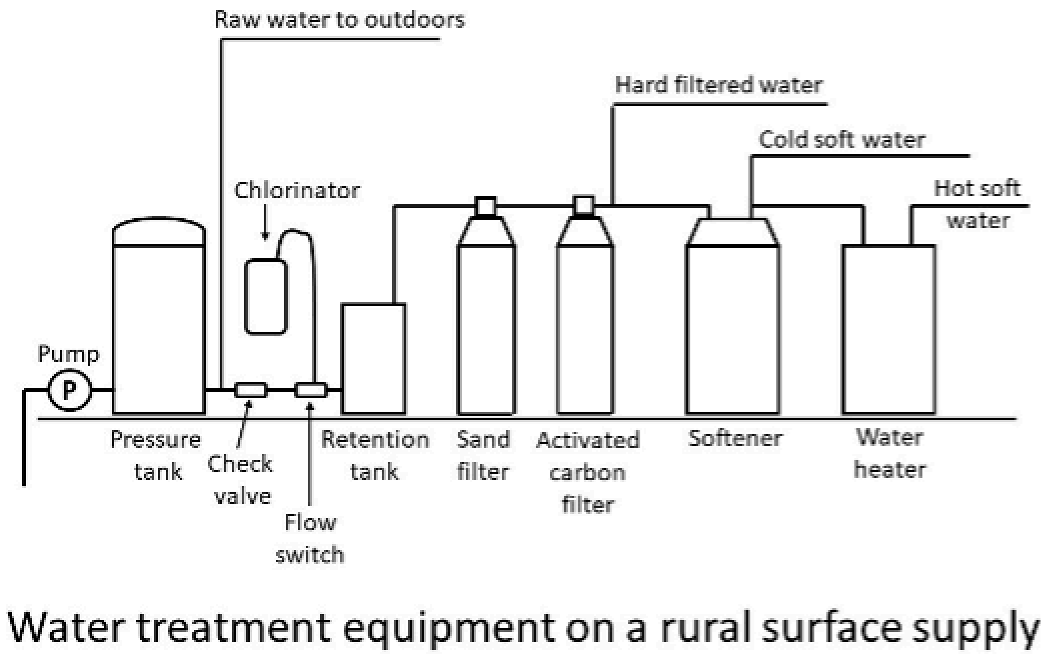

Figure 27. Water treatment equipment on a rural surface supply

When a chemical-free iron filter is used, the standard procedure is to install an air injector, known as a hydrocharger, on the pipe feeding into the pressure tank. Some manufacturers state that the hydrocharger should be located on the upstream side of the pressure switch to prevent the pump from rapidly cycling when the hydrocharger operates. Flow rates surrounding the installation of a chemical-free filter are critical. Piping should be sized according to manufacturers' instructions and an air release valve is necessary at any high point upstream of the filter when using a bladder-type pressure tank in conjunction with a chemical-free iron filter. Any accumulation of air on the piping feeding the filter must be avoided. As water flows through the hydrocharger, air is drawn in through a venturi and iron is oxidized, forming rust particles that can be filtered. Some of these will precipitate out of the relatively still water in the pressure tank. To remove them, the tank is periodically "blown down" such as is done with a steam boiler. The chemical-free iron filter will take care of the remainder of the iron precipitate. Again, locating the iron filter upstream of the softener protects the softener's resin bed from becoming clogged.

Figure 28 below shows a typical well system for water that may be high in iron content.

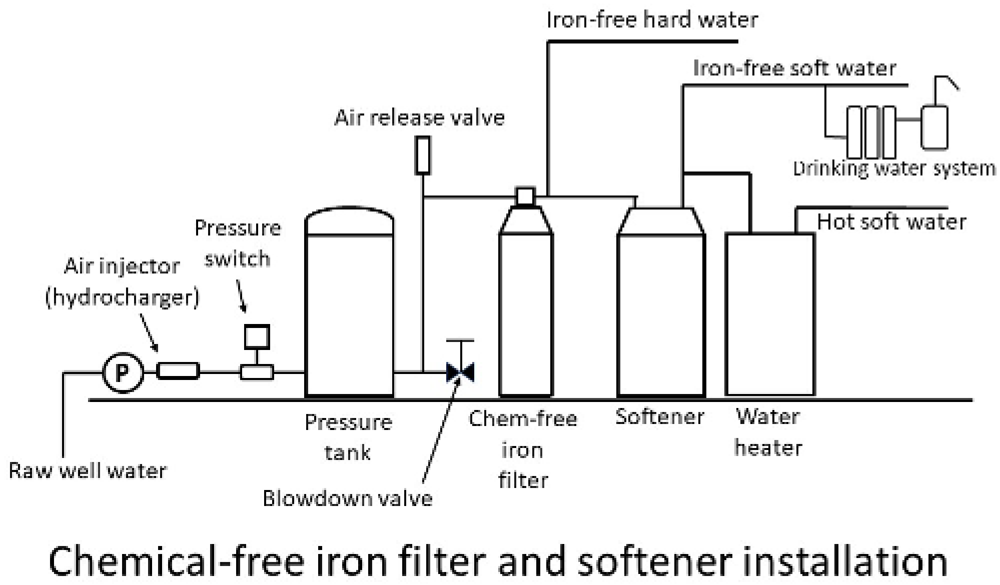

Figure 28. Chemical-free iron filter and softener installation

When a chemical-free iron filter is to be installed and there is a desire to also supply raw water for outdoor use (called “split-stream”), some manufacturers recommend the installation of two pressure tanks, as shown in the following figure. The hydrocharger is installed between the primary and secondary pressure tanks, and a normally closed solenoid valve is installed upstream of the hydrocharger. A secondary pressure switch is installed, downstream of the hydrocharger, that is wired to operate the solenoid valve.

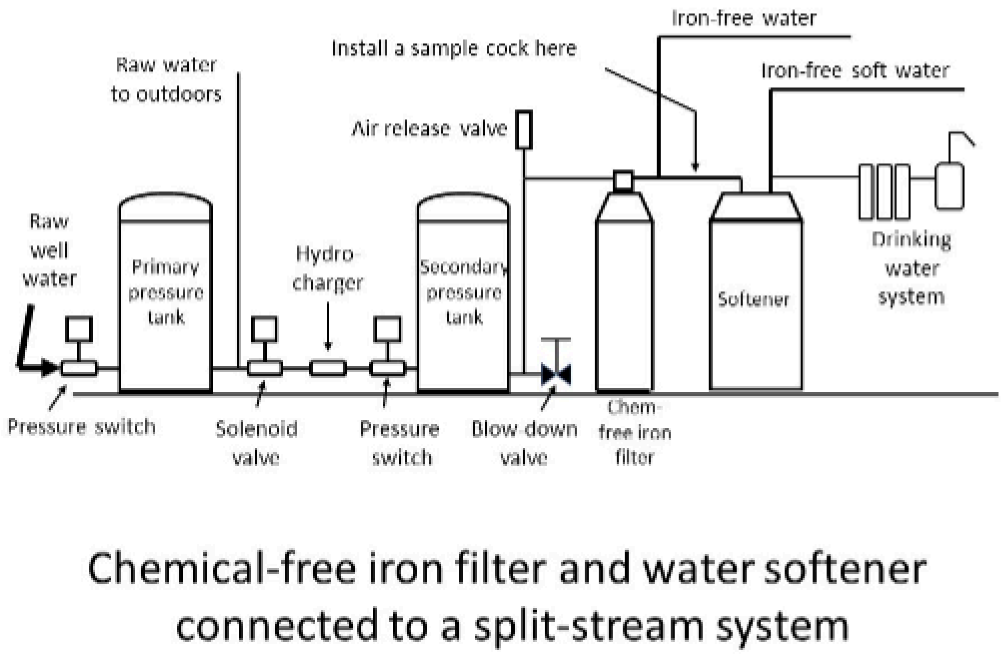

Figure 29. Chemical-free iron filter and water softener connected to a split-stream system

Systems using a chemical-free iron filter require precise planning and component placement, and strict adherence to manufacturers' installation recommendations is strongly suggested.

Installation Accessories

Bypass valving allows the shutdown of equipment for routine maintenance without shutting off flow to the rest of the house. Manufactured bypass valves are either a supplied component of a softener or are available as an accessory. They are constructed of brass or plastic and connect to the rear of the control head with clips and O-rings. An optional 90-degree bypass adapter is available that allows the softener to be installed closer to the wall than if using a standard bypass valve that is oriented horizontally.

Figure 30. Horizontally-oriented manufactured bypass

Alternatively, a piped bypass can be constructed onsite using standard pipe, valves, and fittings. Figure 31 is a diagram of a common bypass arrangement in the service and bypass positions.

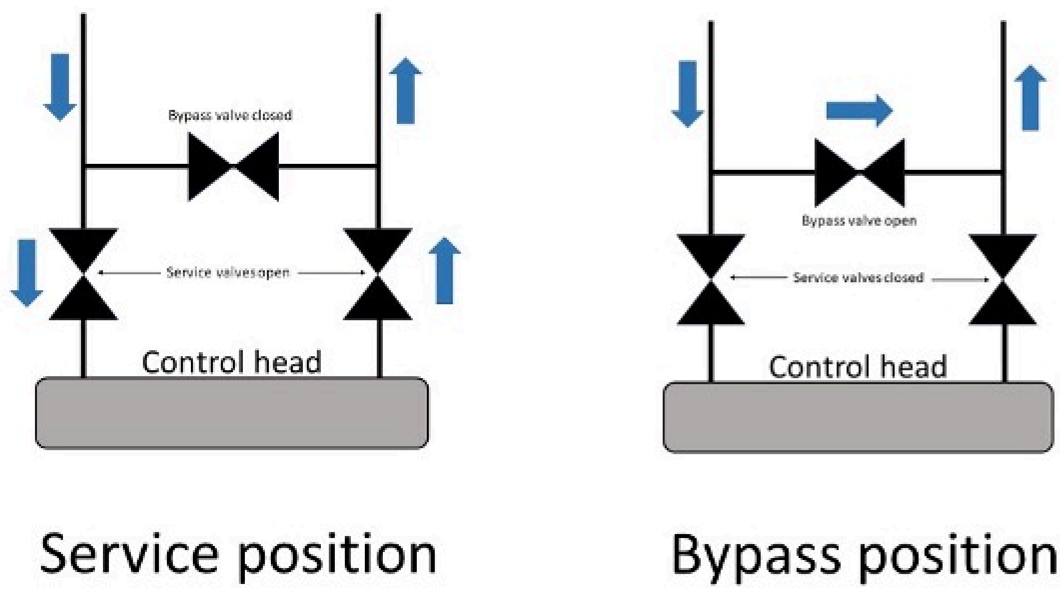

Figure 31. Onsite-fabricated piped bypass arrangement

Reverse Osmosis (RO) Units

Residential RO units are considered point-of-use water treatment devices, normally mounted on the inside wall of the kitchen sink cabinet. Manufacturers use a combination of 3/8” and ¼” plastic tubing of different colours to ensure no piping crossovers occur. Water supply is taken from the cold line feeding the sink via a saddle tee/valve. This is common practice although the plumbing code states that saddle-type fittings are prohibited, and so some jurisdictions may insist that the supply be made through a fitting arrangement that conforms to code. The drain line connects to the sink’s continuous waste on the upstream side of the trap via a supplied saddle-type fitting (also normally prohibited by code). This connection is critical in that it constitutes a direct cross connection that may contaminate the water supply. However, the installation is deemed acceptable because the connection between the RO unit and drain is through an air gap built into the dispensing spigot mounted on the countertop adjacent to the sink. Older RO models may not have this feature and should not be reinstalled.

Figure 32. NOVO® reverse osmosis system

Ultraviolet (UV) Sterilizers

For UV sterilizers to be effective, they must have an uninterrupted power supply and a high-quality upstream filtration system. Firstly, without an operational electric supply to power the UV lamp, there will be no microorganisms rendered harmless. They will pass through the system and multiply. Secondly, viruses and other living organisms are so small that even the tiniest particle of dirt or grit between them and the UV bulb can block the UV rays, again allowing them to pass through the system untreated. The water entering the unit should be pre-treated to the following levels:

- Less than 7 grains per gallon of hardness, or less than 120 PPM

- Free of color and crystal clear.
- Iron should be less than 0.3 mg/L.
- Manganese should be less than 0.05 mg/L
- pH range should be 6.5 to 9.5
- 5-micron filtration

There should be two 5-micron filters, piped in series, on the incoming water supply, with bypasses around each filter to enable filter replacement without system shutdown. Also, there should be a piped bypass around the UV unit. If the bulb is being replaced, there should be no flow allowed through the system until the UV unit can be re-started. If the UV unit is out of commission while water is needed to be supplied, the system should not be used for drinking water purposes and the system should be sanitized prior to re-establishment of the UV's operation.

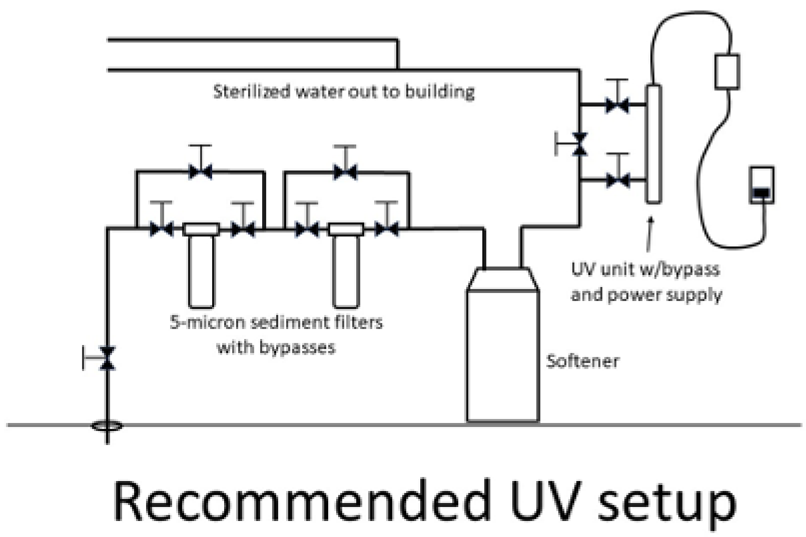

Figure 33. Recommended UV setup

The UV unit can be mounted in any orientation although horizontal is preferred and should be located where it can be routinely inspected and serviced. There should also be adequate space at its service end to allow replacement of the mercury bulb. They are normally provided with an alarm to alert the homeowner of any power interruption, so the alarm transmitter should be located where it can be heard easily. Manufacturers' installation instructions are very specific and must be followed exactly if bacterial contamination issues are to be avoided.

Figure 34. NOVO® Ultraviolet sterilizer

Now complete Self-Test 6 and check your answers.

Self-Test 6

Self-Test 6

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://opentextbc.ca/plumbing4c/?p=224#h5p-15 (https://opentextbc.ca/plumbing4c/?p=224#h5p-15)

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Learning Task 4

Describe the Testing and Commissioning of Water Treatment Systems

Learning Objectives

After completing the learning tasks in this chapter, you will be able to:

- Describe commissioning procedures for water treatment devices
- Identify tests performed after equipment installation, and
- Interpret test results

Once installed, softeners and other water treatment equipment should be operated and checked to ensure that they are performing as intended. Pre-treatment testing and equipment specifications alone do not ensure that the device's operation will rectify the problem. Adjustments may be required to ensure the equipment is performing correctly. Each piece of equipment will have manufacturers' installation, startup, and troubleshooting information, and it is important to consult this literature as it may be particular to the device. Many of the points that follow in this chapter have been taken from NOVO® literature and, as much as possible, are meant to be generalized examples only. Always consult the specific manufacturer's literature for startup and commissioning procedures.

Softeners

Once plumbed and tested for leaks, the softener can be put into service. The startup points covered will be specific to softeners with digitally metered valves, as the clock-type are considered outdated.

1. Manually add water to the brine tank until there is approximately 1 inch (25 mm) of water above the grid plate or, in absence of a grid plate, until the water depth is 3 inches (75 mm). Do not add salt to the brine tank yet.
2. Purge air from the unit by initiating a manual regeneration process. This will start the unit in the "backwash" cycle. Open the bypass inlet valve very slowly until there is a steady stream of water to the drain. Opening the bypass inlet too quickly could result in resin being expelled from the unit and into the plumbing lines. With the valve in the backwash position the unit will purge air from the system, sending it to the drain. Once any "spurting" of air ceases, open the bypass inlet valve fully.
3. Advance the controls to the "refill" position and operate the controls until there is the required level as specified in step 1 (consult manufacturer's instructions).

4. Return the controls to the “service” position and slowly open the bypass outlet valve.
5. Assuming the unit has been sized by the process as explained in learning task 2, enter the date, time of day, number of persons in the house, and compensated hardness value. Do not adjust the factory salt setting.
6. Depending on manufacturer, there may be choices of water source such as “municipal” (clean) or “well” (dirty), as well as variable start times, with 2am being the default start time for most manufacturers. As well, NOVO® has a “Smart Clean” setting that ensures the softener is operated once a week so that, in periods of inactivity, the resin bed is “fluffed” and kept from settling and compacting (“cementing”) which would render it inoperative.
7. Add 80 to 100 pounds (36 to 45 kg) of salt to the brine tank. The unit will automatically fill the water to the correct level when it regenerates.

The unit is now ready to regenerate at the appropriate time.

If the water source is not municipal water and contains up to 2.0 mg/l/ppm of ferrous (clear water) iron and/or up to .75 mg/l/ (ppm) of manganese, extra equipment and setup will be required to prevent the resin bed from becoming plugged. Consult the specific manufacturers for their recommendations.

Once the softener and any extra components to it are installed, a water sample should be taken from the sample cock immediately downstream of the softener on the day following a regeneration cycle. Using the same test equipment and procedures as explained in learning task 2, the resulting hardness should be checked to ensure the softener is operating properly. A reading of between 0 and 0.5 gpg indicates that there is virtually no hardness left in the finished water. A sampling and testing should also be done the evening before the next regeneration cycle to ensure there is no hardness slippage (exhaustion of soft sodium ions). A hardness level above the results taken the day after regeneration would mean that the settings need to be checked and adjustments to them made.

Manganese Greensand Iron Filter

Setup procedures for a manganese greensand filter are very similar to those for a softener. The media tank and control head may, for some manufacturers, be used for either application, with the control settings and solution tank being the only differences. Once the filter and potassium permanganate solution tank are installed as per manufacturer’s specifications, the control valve must be programmed to operate as a greensand filter which has settings that differ from those for a softener, such as a 4-day regeneration interval rather than 3-days for a softener. Like the softeners, the filter tank is set to the backwash cycle and the inlet valve is opened slowly to prevent losing any media, and the flow to the drain is observed. Once there is a steady stream to the drain, which may appear milky white for a short time, the inlet valve is opened fully and flow rate to the drain is checked using a bucket and stopwatch. An adequate backwash is critical to properly clean the Greensand media and prevent it from cementing together. For this reason, greensand filters usually require a minimum inlet pressure of 20 psi (140 kPa). Once the stream to the drain is clear and free of air, the controls are cycled to the “rinse” position for roughly five minutes or until the water to the drain is once again clear. The control can now be set to the “service” position and the outlet valve opened fully. A faucet near the filter, preferably one with no aerator, such as a bathtub or laundry tub, is opened and flow is observed until the water runs clear.

Potassium permanganate tanks are smaller and built differently than the brine tanks for softeners. Approximately one 5-pound (2.25 kg) jug of solution is all that is needed every 3-4 months. Add the required amount to the tank and ensure the control valve has a fresh battery installed so that the programming won't be lost due to a power failure.

Just as in the checking of softeners, a water sample should be taken immediately downstream of the greensand filter the morning after and the evening before the filter regenerates. Iron readings should be within acceptable parameters and any differences between them should be investigated and remedied as per manufacturers' instructions.

Chemical-Free Iron Filter

With inlet and outlet valves closed, the unit is powered and set to the "backwash" position and the inlet valve is opened slowly. The flow to the drain is observed until all air has been purged and the flow is clear, usually taking 3 to 4 minutes. Power to the unit is then unplugged, and with the inlet valve now fully opened, flow is allowed to the drain for 30 minutes. The power cord is then plugged back in and the control is set to a manual regeneration, which will start the backwash cycle. The control is then advanced to the "brine" (air draw) position and allowed to complete that cycle. The valve will then automatically advance to the "service" position and the outlet valve can now be opened fully. The unit is then programmed according to the specific manufacturer. Some units need only the current date and time settings and will regenerate every 4 days or 600 gallons (2730 litres) on average.

Downstream sampling at the same intervals as softeners and greensand filters will determine that the unit is working as expected.

Reverse Osmosis Units

RO units have no controllers and need no programming. After installing the unit as per manufacturer's instructions, turn on the incoming cold water at the supply stop. Check the system for leaks and tighten/push in any fittings as necessary. If the RO system supplies a refrigerator/icemaker, make sure the ice maker is off, i.e., allow no water to flow to it until flushing is complete and the tank has been allowed to fill completely. The piping connecting the RO to an icemaker system should have an in-line valve installed so it can easily be isolated. The RO tank must be allowed to fill up fully for the icemaker system to work properly.

At this point, if equipped with a booster pump where house system pressure is inadequate, the power supply to the unit is plugged in. Next, open the RO faucet and leave it open until water begins to trickle out (it will come out slowly). After water trickles out of the faucet, close the RO faucet allowing the storage tank to fill with water. It may take 4 to 6 hours to fill the tank completely depending on the production capability of the membrane, local water temperature and water pressure. Ensure the ball valve on the RO storage tank is open. During the fill period, water may be heard trickling to the drain due to the reverse osmosis process.

After the tank has filled, open the RO faucet and empty the tank completely to remove carbon particles from the final filter. The tank can be observed to be empty when the flow rate from the RO faucet is again down to a trickle. Repeat this step two more times. The fourth tank can now be used for drinking. Flushing of the tank 3 times is only necessary during the initial startup and after replacing the membrane. Product water rarely requires testing after installation if filters and membranes are installed as per manufacturers' instructions.

Ultraviolet Sterilizers

With piping into and out of the unit installed as per manufacturer's instructions, the quartz sleeve and mercury vapour lamp can be installed. Ultraviolet lamp and quartz sleeve are easily damaged, therefore avoid touching the sides of either the quartz sleeve or lamp. Handle them by the ends only. The sleeve and lamp are inserted into the housing and held in place and sealed by O-rings and aluminum nuts. Install these to hand-tight first and when satisfied that proper alignment has been achieved, tighten further being careful to not over-tighten. Next, turn on the water supplying the UV unit and check for leaks, repairing any if necessary. Then, plug the ballast cord into an electrical outlet which should be protected by a GFCI (ground fault circuit interrupter) and run water through the unit for 5-10 minutes.

Before using the system, it should be sanitized by adding ½ to 1 cup of bleach to the pre-filter, or by shocking the well and sanitizing the entire piping system as laid out later in this chapter. For badly contaminated piping or piping with sediment or scale, this procedure may need to be repeated to kill all bacteria downstream of the UV unit upon start-up.

Finally, turn on the UV lamp. Most units will have a green light on the ballast which means the UV lamp is operating normally and water flowing through the UV unit is sterilized. If the ballast light is red, this means the lamp is not operating as it should and water flow should be stopped until the problem is corrected. If the lamp has burned out, there should be an alarm in addition to the red light. There may also be a solenoid valve installed to automatically stop flow if there is a problem with the bulb. Most units will have an audible alarm to indicate that there is a problem.

If a UV unit is required, the well water should be tested at least annually, and water samples from interior faucets should also be tested at intervals recommended by the manufacturer and local health authority to ensure the unit is working properly.

Plumbing System Cleanup

A household's plumbing system and water-using appliances that have been exposed to contaminated water must be cleaned or contamination will continue to be a problem, even after a new water treatment system is installed. The following are descriptions of procedures used when equipment has been installed to correct iron and bacteria issues.

For Iron Issues:

Toilet Tanks

Pour a small amount of a stain remover, such as “Iron-Rid®” or “Super Iron-Out®” into the flush tank of the toilet. It chemically changes the rust into a clear, soluble state. Let it dissolve, then slightly depress the flush lever to let some of the solution out, so that the water outlet – ports around the flush rim of the bowl get cleaned. Let the mixture stand overnight and flush to drain in the morning. If iron deposits or stains remain, repeat the procedure until the toilet tank is clean.

Water Heater

Gas water heater: make note of the temperature setting on gas valve, then turn to “pilot”.

Electric water heater: Shut off breaker switch on main fuse panel.

Turn the valve off on the cold water supply to the heater. Connect a garden hose to the water heater drain valve, then open the valve so water will drain to a safe location.

Next, open one or two hot water faucets in the house to provide air so the tank can drain properly. Once the tank is completely empty, turn on the cold water inlet valve for 30 seconds to stir up any sediment which has collected at the bottom of the tank. Then let the sediment run to drain. Repeat this 3 or 4 times or until water runs clear. Check this periodically by catching some water in a small white container. When water runs clear, close the drain valve, then let the heater fill with water until it starts to run out of the open hot water faucets. Now, close the hot water faucets.

Gas water heater: reset gas control valve to original temperature setting.

Electric water heater: turn breaker switch back on at the fuse panel.

Repeat the above procedure at least twice during the first 6 months after installing new water treatment equipment, and more often if you have an older water heater. If the water heater does not clean out after several attempts, it should probably be replaced.

Note: If a “rotten egg” smell occurs in hot water, there is likely a reaction between sulphates that may be present in the water, and the metal of the anode. Close the cold water inlet valve to the hot water tank, drain about a gallon of water from the drain valve and remove the anode rod from the tank’s top. Pour half a gallon of household bleach into the tank and let stand for one hour before draining the tank. Reinstall a zinc or aluminum-zinc alloy anode rod, rather than a magnesium one, open the cold water inlet valve and refill the tank. If the problem persists, the water system should have a chlorinator installed.

Washing Machine and Dishwasher

With the machine empty, add 6 ounces of stain remover instead of soap. Run the machine through a normal cycle. Repeat the process is necessary. Also, if installed, clean out the sediment screen at the water inlet fitting on the machine's water pump.

Faucet Screens and Aerators

Remove and clean any crud or rust particles from all faucet screens and aerators. They should then stay clean indefinitely.

Old Bypass Valves

If rusty water shows up anywhere after the above clean up has been done, check for the possibility of a defective bypass valve that may still be plumbed in the lines where an old water softener or iron filter may have been. Remove the bypass if it is not required.

For Bacteria Issues:

How to Disinfect (Sanitize) a Well and Water System: Overview

When bacterial contamination has been detected, the entire system must be "shocked" by super chlorination and then flushed. Use ordinary liquid laundry bleach to shock chlorinate the water system. From available information such as the table shown below, determine how much bleach to use, then pour the bleach down the well and circulate it through the entire water distribution system. Wait 6 – 12 hours for the chlorine to work, then flush the chlorinated water from the well and pipes. Retest the water after 2-3 days.

Step-by-Step Instruction for Shocking (Super Chlorination)

1. Create an opening at the top of the well to pour in the chlorine solution. Well caps vary and this step may be easier for some wells than others.

- If a flat or domed cap on top of a well with no pipes sticking up out of it, unbolt the cap and remove it.
- If pipes protrude from the well cap, do not remove any bolts! The bolts pull the bottom plate toward the top plate, compressing the rubber piece between them to create the seal. If the bolts are removed, the bottom plate will drop down into the well. In addition, the weight of the pump may be resting on the cap, and if the cap is removed, the pump may drop down into the well. The best option is to use the vent pipe opening. If this short gooseneck piping can be removed, the chlorine solution can be poured through the opening into the well.

2. Determine the amount of bleach needed. An initial chlorine concentration of 50 to 100 parts per million (ppm) is recommended. To estimate how much bleach to use for this concentration, use the table below based on the well diameter and depth of water in the well. Note: Do not use the total depth of the well. The depth of water is the distance from the water level to the bottom of the well. This information should be found in the well log.

Table 1 below is a rough guideline for chlorine to be added to a well, given the well's diameter and the depth of water within it.

Well diameter	**<50'**	**50 – 100'**	**100 – 150'**	**>150'**
2 inches	1 cup	1 cup	1 cup	1 cup
4 inches	1 cup	2 cups	3 cups	4 cups (1 qt)
6 inches	2 cups	4 cups (1 qt)	6 cups (1.5 qts)	½ gal (2 qts)
8 inches	4 cups (1 qt)	½ gal (2 qts)	½ gal (2 qts)	¾ gal (3 qts)
10 inches	½ gal (2 qts)	¾ gal (3 qts)	¾ gal (3 qts)	1 gal (4 qts)
12 inches	½ gal (2 qts)	¾ gal (3 qts)	1 gal (4 qts)	1 gal (4 qts)

Table 1 – Amount of ordinary chlorine laundry bleach required to shock a well (to approximately 100 ppm) based on well diameter and water depth (in U.S. units)

3. Make sure to use the right type of chlorine bleach. Use plain liquid laundry bleach ("Clorox"®, "Purex"®, or a generic brand). Do not use bleach with additives or special scents. The label should indicate "sodium hypochlorite" and the concentration should be about 5% – 6%.
4. Dilute the bleach. Use 2 cups or less per 2-gallon bucket of water and be sure to add the chlorine to the water. 100% chlorine can corrode metal well parts.
5. Pour the diluted chlorine bleach solution down the well. Wear rubber gloves, use protective eyewear and be careful not to splash on clothes or skin.
6. Mix the chlorine and well water by first attaching a hose to a faucet near the well and running the water until chlorine can be detected by smell. If chlorine isn't smelled within a few minutes, add some more before circulating the water. Then, direct the water from the hose back down into the top of the well, again possibly through the vent opening. Allow the water to circulate in this manner for 5 minutes.
7. Make sure the system is chlorinated by opening each fixture's faucets one at a time and let water run until chlorine can be smelled. Be sure to run hot water faucets to draw chlorine into the water heater. This will take some time depending on the size of the heater. If after a reasonable period of time you don't smell chlorine, add more diluted bleach solution as in step 6 and circulate with the hose again.
8. Once chlorine has been detected at each outlet, hold the chlorine in the pipes for 6 – 12 hours. Don't use the water! (A few toilet flushes are O.K.)
9. Remove chlorinated water from well and pipes. Connect a hose to the furthest faucet in the house and run it outdoors until you no longer smell chlorine. Be careful with this water –

don't use it on plants or allow it to discharge into fish habitat. Next, try to attach a hose to each faucet if possible and run it outside, or catch faucet water into a bucket and dispose outside into gravel if possible. Admit as little chlorine water as possible into a drainage system that runs to a septic tank, as chlorine can have a negative effect on the anaerobic bacteria that allow the tank to work properly. Less chlorine into the tank is better.

10. About 3 days later, test for coliform bacteria. Do not consume the water until you receive "clean" test results.

In summary, all newly installed water treatment devices should:

- Be installed as per manufacturers' specific installation instructions and local code requirements
- Be tested for leaks, correcting any if found
- Be commissioned as per manufacturers' startup instructions
- Be checked for correct operation by monitoring finished product water at points and intervals recommended by the manufacturer
- Have operational adjustments made if necessary, and
- Be registered with the manufacturer, either by the homeowner or installer, to ensure conformance to warranty requirements

Now complete Self-Test 7 and check your answers.

Self-Test 7

Self-Test 7

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://opentextbc.ca/plumbing4c/?p=227#h5p-16 (https://opentextbc.ca/plumbing4c/?p=227#h5p-16)

Learning Task 5

Describe the Servicing and Maintenance of Water Treatment Systems

Learning Objectives

After completing the learning tasks in this chapter, you will be able to:

- Describe maintenance procedures for water treatment devices, and
- Recognize troubleshooting and repair procedures for water treatment equipment

No piece of water treatment equipment will operate indefinitely. All will require periodic maintenance and inspection to ensure proper treatment is taking place. The maintenance intervals will vary with the type of treatment involved, the inlet water quality and water usage. As in Learning Task 4, this chapter will target softeners, iron filters, reverse osmosis units and UV sterilizers, as these are the most common pieces in use for residential water treatment. For safety's sake, remember to isolate the piece of treatment equipment, both power-and-water-wise, before disassembling any unit. Lock out or tag out equipment as necessary.

Media Filters

Whole-house filters fall into several categories, which treat problems in water such as:

- Taste and odor
- Chloramine removal
- Suspended solids (silt and sediment)
- Acidity

The media in the tanks that treat taste and odor, chloramines, and suspended solids will generally not be consumed so will not need replacement for many years. On the other hand, acid filters contain base (alkaline) elements that dissolve as they neutralize the acid in the water. Therefore, acid neutralizers will require periodic replacement of the media. Limestone chips, also known as calcium carbonate or calcite, have typically been the common material for acid neutralizers. Always use the product that is recommended by the manufacturer. To check the level of calcite in the tank, shine a flashlight up against the back of the tank. The level of calcite should be visible through the opaque fiberglass. Consult manufacturers' literature for recommended media levels. To add calcite, available in bags of approximately 50 pounds (22.7 kgs) first put the neutralizer onto bypass. Next loosen and undo the union fittings between the control head and bypass valves. Expect some water to escape the piping and have rags on hand to contain the drips. Then remove the control head by unscrewing it counterclockwise from the tank. Carefully wiggle the control head upward and clear of the tank, ensuring the distributor tube stays in place in the tank. Block the top of the tube using tape or a pipe cap so that no calcite drops into it during the calcite refilling process. Next, siphon some of the water out of the tank, to create space for the fresh calcite. Inspect, clean, and reinstall the removeable strainer that is attached to the underside of the control head, as well as the end of the distributor pipe before plugging or capping it. Always be sure to lubricate any O-rings using manufacturer-recommended lubricants or silicone-based lubricant. Using either a makeshift funnel or one specific for the purpose, with the distributor pipe end capped off, pour the required amount of calcite from the bag into the tank until it reaches the level recommended by the manufacturer. The level should be able to be seen and measured through the tank opening as well as via the flashlight method. Remove the cap from the distributor pipe and lubricate the tank seal O-ring and any O-ring sealing the distributor pipe to the control head. Carefully align and introduce the distributor pipe into the control head and tighten the control head back onto the tank. Refasten the bypass to the control head and slowly open the incoming water valve to pressurize the neutralizer. Check for leaks, then slowly open the outlet valve. Trapped air should escape the tank into the piping and be bled off at the faucets. Remove faucet aerators when bleeding off in case any calcite is carried out of the tank in the initial filling process.

Softeners

To retain the appearance of a new water softener, occasionally clean it with a mild soap solution. Do NOT use abrasive cleaners, ammonia, or solvents, and take care to not allow any cleaning solution to get inside the control head.

The maintenance of the interior components of a water softener is largely dependent upon the specific manufacturer's recommendations. The seals and spacers along with the piston assembly should be inspected/cleaned or replaced annually or as required depending on the inlet water quality and water usage.

If the inlet water to the softener contains iron, even in small amounts, the resin could become clogged in a short period of time, necessitating resin replacement. To avoid this problem, an approved resin cleaner must be used. Bottled solutions such as RESCARE® are available and attach easily to the inside of the brine tank. The solution is automatically dispensed through a wick into the brine solution where it helps to clean the resin during the regeneration cycle. The most important consideration when using a resin cleaner is to make sure the solution bottle is never empty. The media inside the tank should give many years of trouble-free operation, but if salt is being consumed at its regular rate without the water being softened, it is an indication that the media bed is needing to be replaced. When media replacement is required, manufacturers will specify the type and amounts of media needed for each model of softener and will also provide instruction on proper replacement. The process is similar to that of adding calcite to an acid neutralizer, with the exception that all the contents must be removed and replaced. Once the head is removed, softener tank is inverted and, using a garden hose, the contents are rinsed away. New layers of coarse gravel, fine gravel and media will be poured in around the distributor tube. The head is reinstalled, and the softener is put through the same procedures as when it was initially started.

The control head contains piston assemblies, seals and spacers that may require maintenance. The manufacturer's literature will contain instructions and exploded-view diagrams specific to each model, to allow service or replacement of malfunctioning components. Make sure to follow manufacturers' instructions to the letter, which include the use of silicone lubricant, rather than petroleum-based grease, on seals and O-rings.

Probably the most common repair to the control head involves the cleaning of the brine injector. Sediment, salt, and silt are the common culprits for clogging injectors, which can result in an excessive water level in the brine tank. Fortunately, most manufacturers recognize that this component may require frequent service, so they locate it on the side of the control head where access is relatively easy. To clean the injector, the injector cover is removed, and the injector can be carefully pulled from the injector body. Encrustations of salt can first be removed by mechanically breaking them off using a small implement such as a small screwdriver, wire, or paper clip, and then immersing the injector in a mild acid such as vinegar to clean out the small holes in the orifice and throat. Reassembly is the reverse of disassembly, using silicone lubricant on any seals or O-rings.

Brine tank maintenance involves two main considerations, which are maintaining a salt level in the tank and ensuring the salt doesn't "bridge". Bridging is the term used when water has dissolved the salt below the observed top of the salt heap, leaving a void below. 80 to 100 pounds (36 to 45 kgs) of clean salt labeled for water softener use, in the form of crystals, nuggets, pellets or buttons, is initially added to the brine tank on startup. Thereafter, make sure the salt level is always above the level of the brine solution. The use of natural rock salt is discouraged because it contains insoluble silt and sand which build up in the brine tank and causes problems with the system's operation. To prevent bridging, whenever checking the salt level, use a clean stick to poke through the top of the salt heap which will knock down any compacted bridges. Alternately, pour warm water down the inside walls of the tank or gently tap against the outside of the tank with a rubber mallet, being careful to not break the plastic.

Brine tanks will build up a layer of sludge (undissolved salt) that will increase over time, so every 2 – 3 years the tank should be cleaned out and restarted using the initial startup procedures.

Too much or not enough salt being used can be an indication that the initial settings of the control head should be re-examined. Before assuming that a component is malfunctioning, check the settings and make sure the hardness value is compensated for any iron or manganese detected in the water supply. As well, the number of people in the house could have changed over time, which will affect regeneration intervals.

Manganese Greensand Iron Filters

Iron filters that use greensand as the media bed operate in much the same manner as a softener. The greensand filter media oxidizes dissolved iron and manganese on contact as the water flows through the filter media. These elements precipitate (form solids) in the bed of the filter, and the regeneration process backwashes these small particles to drain every few days, thereby cleaning and restoring the filter media. Most problems occur when the permanganate solution is not being drawn into the filter during each backwash cycle. To check this operation, disconnect the brine tank tubing at the control valve and consult the operation manual to initiate a brine cycle. A fairly strong vacuum should be felt at the brine tube inlet port of the control head. If not sensed, the injector inside the head is likely plugged and must be cleaned. If there is vacuum there, check the brine tank float for obstructions or the possibility of a rubber band, installed for shipping purposes, still in place around the float. If there is vacuum there, but no permanganate solution is being drawn in, the float assembly must be cleaned or replaced.

It is also important to check and maintain the incoming water's pH level to between 6.7 and 8.8. An acid neutralizing filter, installed on the upstream side of the greensand filter, may be needed to achieve these levels.

Dripping at the drain pipe opening when the unit is in the "service" cycle is an indication that there is an issue with the control valve. The control head valve contains pistons and O-rings that may need periodic cleaning, lubrication, or replacement. Manufacturers' literature contains exploded parts diagrams and will detail the steps required to enable routine maintenance of the control head. These steps are usually simple enough that homeowners, using basic tools, will be able to perform them. Be sure to have the specific literature on hand before attempting to disassemble any control head.

Pink water out of the home's faucets indicate that potassium permanganate residue is being carried through the system. The control head's settings should be adjusted to provide adequate backwash and rinse cycles, provided that the flow rate through the unit is sufficient. To achieve proper flow rates, most manufacturers recommend a minimum of 30 psi (210 kPa) at the filter's inlet and suggest that a minimum of 40–50 psi (280-350 kPa) works best.

Sometimes if the brine tank is not filling adequately, it is possible that the float assembly in

the tank is set too low. The float should be several inches above the air check valve inside the tank. This will allow for enough water to be added to the tank before shutting the brine fill cycle. If necessary, pull the float assembly rod up to the appropriate height, and cut the rod at that height while keeping the rubber washers positioned with adequate space to hold the float in place.

The level of potassium permanganate in the "brine" tank should be checked periodically and maintained to manufacturers' recommendations. Manufacturers suggest 5 pounds (2.3 kg) of dry potassium permanganate powder be added to the tank every two or three months to maintain an acceptable level. Greensand replacement interval is generally every 4 – 6 years. Follow specific manufacturers' instructions to do so.

Chemical-Free Iron Filters

Chemical-free iron filters do not use a regenerating agent such as salt or potassium permanganate. Instead, they rely on the oxidation of clear water iron (ferrous) and red water iron (ferric) into particles of rust that can be trapped by the special media inside the tank and backwashed to a drain. For the special media to work efficiently, the incoming water must be within certain parameters, which are:

- pH of 7.0 to 8.5 or 6.0 to 6.9 (depending on model chosen)
- Iron concentration maximum of 30.0 ppm
- H2S maximum of 5.0 ppm
- Manganese of 0.0 to 1.0 ppm (depending on model chosen)

- Minimum 20 psi (140 kPa) inlet water pressure

If low pH incoming water is encountered, a neutralizing filter should be installed upstream of the chem-free iron filter, or alternately a variety of chem-free iron filter that contains a neutralizing media bed can be used. If so, the media bed will be dissolved over time and will need periodic replacement. A routine water analysis on both upstream and downstream water samples will provide information indicating any change in water quality that may necessitate service or repair.

Although the chem-free iron filters use no regenerating agent, the control head valves still require periodic service, and their disassembly follows the same general procedures as the softeners and greensand filters. Always make sure to use proper PPE and remove both power and water pressure to the unit before working on it and to follow manufacturers' specific instructions.

Air injector assemblies of chem-free iron filters require periodic inspection and service, and like the brine injectors on softeners and greensand filters, are easy to access, usually located on the side of the control head. They can be disassembled, cleaned, and reinstalled relatively easily without the use of special tools.

Any red colour either in the water when drawn or left as stains on fixtures indicates that the chem-free filter is not doing its job and needs to be serviced. Insufficient air draw and/or improper backwashing cycles are the most common culprits for these issues. The air injector should be serviced, and the programming should be checked to ensure proper cycling of the filter, particularly the length of the backwash cycle.

If excessive pressure loss through the filter is experienced, the media bed may have become compacted due to excessive buildup of precipitated iron and will need to be broken up by removing the control head and manually stirring with a stick or pipe. The control should then be reprogrammed to backwash at more frequent intervals to avoid recurrence.

Reverse Osmosis Units

Routine maintenance RO system is fairly straightforward, in that there are only three main components to the system, which are the faucet, cartridge bank, and pressure tank.

RO faucet (spigot) – This component normally needs no regular maintenance. The swivel gooseneck should move freely and, if not, may need the O-ring seal to be lubricated or replaced. If the trigger or handle controlling the flow leaks, dismantle it and lubricate or replace the seals (if possible), otherwise replace the spout.

Cartridge bank – RO units have either 3 or 4 cartridges. Those with 3 cartridges have, in order of flow, a sediment filter, membrane, and carbon filter; the 4-cartridge variety have two carbon filters, one upstream of the membrane (called a carbon block filter) and the other downstream of it (called a polishing or post GAC filter). The following are the replacement intervals suggested by most manufacturers, with a note that incoming water quality and amount of usage can necessitate more frequent replacement.

- Sediment filter – every 12 months

- Carbon block filter – every 6 to 12 months
- RO membrane – every 2 to 5 years
- Granular activated carbon (GAC) filter – every 6 to 12 months

Because 12 months is an interval common to the carbon and sediment filters, that is the usual replacement interval for them. Most public water supplies are chlorinated, and chlorine will harm the RO membrane, so the presence and regular replacement of the carbon block filter is critical to the life of the RO membrane used on a public water supply.

Cartridges are of a push-and-turn type, with O-rings mounted on the cartridge stem to provide the seal. Replacement usually involves shutting off the water supplies to both the unit and from the pressure tank and opening the faucet to relieve any pressure in the cartridge bank. With a shallow pan under the assembly to catch any drips, the cartridges can then be removed and replaced. Follow the specific manufacturer's instructions for flushing the system after replacement, as each cartridge will have different requirements for flushing.

Pressure tank – The pressure tank operates similarly to one in a well pump system. It has a bladder that separates the air in it from the product water. Check the air pressure in the tank when there is a noticeable decrease in the available water from the RO system. To do this, the tank must first be emptied of water by shutting off the water supply to the unit and opening the RO faucet. When the flow of water from the faucet has slowed to a trickle or stopped, check the air pressure at the Schrader valve and adjust it to the manufacturer's specifications, usually from 6 to 10 psi (42 to 70 kPa) using a tire pump or oil-free compressor and a low-pressure tire gauge. If the tank is visually leaking or requires frequent topping up, it is an indication that the tank should be replaced. Follow the specific manufacturer's instructions for flushing the tank and system after tank replacement.

Sanitizing an RO System

Eventually, an RO system will accumulate slime and other deposits and will require cleaning and sanitization. Most manufacturers suggest sanitizing RO systems annually, coincidental with cartridge replacement. The manufacturer's instructions should be followed but in their absence, the following are recognized as appropriate steps.

- If sanitizing the system when new filters will be installed, all new filters should remain in the original packaging until it is time for replacement.
- The service area should be free of any excess dirt or dust
- Wash hands with soap and water, and/or wear sanitary gloves
- Shut off the main valve completely, and dispense all of the water from the RO faucet
- Remove the existing membrane and filters from their housings and screw the empty housings back into place
- Pour about 1 cup of hydrogen peroxide into the housing furthest upstream
- Turn the main valve back on and allow the system to run (without the filters, the storage tank will refill rapidly) until no water flow can be heard

- Turn off the main valve and turn on the RO faucet, let run until the water flow stops
- Turn off the RO faucet and turn on the main valve, again wait until no more water flow is heard.
- Repeat the last two steps one more time, then shut off the main valve again and install the new filters
- Turn the main valve on, let the tank fill back up and then perform one more fill and drain sequence

Some manufacturers suggest exhausting at least three tanks of water before drinking from it. If the RO unit supplies an ice maker, always shut off the supply to the ice maker before any cartridge replacements or sanitization is done and discard the first two trays of ice after being put back into operation.

Arsenic,Chlorine and RO Systems

As mentioned in Learning Task 1, RO systems are very effective at removing pentavalent arsenic, bringing the content down to within government standards for drinking water, but they will not convert trivalent arsenic to pentavalent arsenic. A free chlorine residual in the water supply will rapidly convert trivalent arsenic to pentavalent arsenic, as will other water treatment chemicals such as ozone and potassium permanganate. A combined chlorine residual, called chloramine, in a water supply may not convert all the trivalent arsenic into pentavalent arsenic. If a water supply is from a public water utility, contact the utility to find out if free chlorine or combined chlorine is used in the water system. This is important for two reasons, the first being the effect that chlorine will have on the RO membrane, likely requiring a carbon block filter upstream of the membrane and/or more frequent membrane replacement. The second is the possibility of small amounts of trivalent arsenic being present in the water supply. Based upon field testing, one manufacturer has determined that their RO units are capable of removing up to 2/3 of trivalent arsenic from drinking water, provided the RO membrane is maintained according to its recommended maintenance cycle. Frequent testing of the incoming and product water may be necessary to ensure the health and well being of the household occupants.

UV Sterilizers

The inside of the quartz-glass sleeve should be cleaned every 6 months with a mild solution of soap and water, and dried before reinstalling. Poor water quality or the presence of iron will necessitate more frequent cleaning. Use only an approved silicone-based lubricant on O-rings and seals. The 5-micron filtering system upstream of the UV unit must be maintained to ensure the effectiveness of the UV system.

Although UV lamps will last longer than a year (usually 9000 hours), their effectiveness diminishes with time. Therefore, they are expected to be replaced annually. Some manufacturers provide a countdown timer, set for 365 days, to ensure the owner is reminded of the replacement interval. Once the lamp has been replaced, the timer must be reset. The timer is not an integral component to the UV assembly and can be mounted anywhere that it’s notification “beep” can be heard. Although the battery inside the timer generally lasts for years, it's a good idea and of relatively little cost to replace it coincidently with the lamp.

Remember that the UV sterilizer is there due to possibly harmful microorganisms in the water supply, therefore, when any service is done to the UV unit, it is imperative that the water not be used for drinking until the system has been sanitized and the UV unit is back online.

Now complete Self-Test 8 and check your answers.

Self-Test 8

Self-Test 8

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Versioning History

This page provides a record of edits and changes made to this book since its initial publication. Whenever edits or updates are made in the text, we provide a record and description of those changes here. If the change is minor, the version number increases by 0.01. If the edits involve substantial updates, the version number increases to the next full number.

The files posted by this book always reflect the most recent version. If you find an error in this book, please fill out the Report an Error (https://collection.bccampus.ca/report-error) form.

Version	Date	Change	Details
1.00	May 6, 2025	Book published.	