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Private Drinking Water Wells: The Distribution System

Jan R. Hygnstrom, Extension Project Manager
Wayne Woldt, Extension Water and Environment Specialist
Sharon O. Skipton, Extension Water Quality Educator

This publication is one of six in a series designed to help rural families understand and manage their private drinking water wells.

A water distribution system is needed to pump water out of the well to the surface and deliver it under pressure to the place where it will be used. A typical private water distribution system consists of a pump with a motor, and a pressure storage tank *(Figure 1)*. The system also needs a control device, such as a pressure switch, in order to operate. Since temperatures can get very cold in Nebraska, the system must be designed to prevent the water from freezing in the distribution system.

Pumps

Most private drinking water systems require a pumping system, usually a pump and motor, to move water from the well to the surface for use by a household or business. The type of pump selected depends on the depth of the groundwater, the distribution system, the pressure required, the number and required flow rate of fixtures on the system, as well as other factors. Most pumps are powered with electricity from a public utility. In remote areas, a pump motor may be powered by a wind turbine, solar collector, or fuel-powered generator.

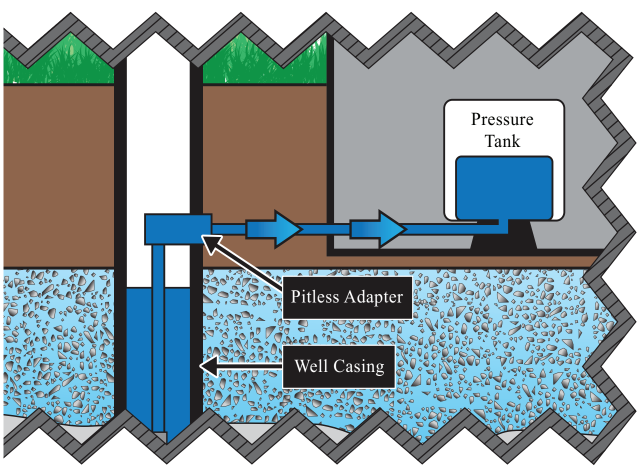

Figure 1. Water is pumped from the well through the pitless adapter to the pressure tank, then to various water fixtures in the building.

A **submersible pump** is commonly used in drilled wells. The pump and motor are in one unit, usually about 3½ inches in diameter and 2 to 3 feet long. The unit is placed in the well below the water level. The well casing must be at least 4 inches in diameter, although some submersible pumps are available for wells 3 inches in diameter.

The pump does not need frost protection since it is located below the frost line, and the groundwater in which it is located will not freeze. If repairs are needed, the pump must be pulled from the well. The submersible pump is sometimes used as a booster pump in pipelines if water must be pumped long distances and one pump isn't sufficient.

There are two types of **jet pumps** used with private drinking water wells. Shallow-well jet pumps are used when the water is less than 25 feet below the surface. Deep-well jet pumps are used when the water is 25 to 250 feet below the surface. They may be used in wells that are 3 inches or less in diameter. The pump may be placed on top of the well or offset from the well in a pump house, and connected to the well with piping. Jet pumps typically have a lower operating pressure and a lower water yield than submersible pumps. They operate by forcing water through a narrow, cone-shaped device called a venturi. This creates a partial vacuum and draws water from the well into the waterline. For shallow wells, the jet is at the pump intake. For deep well units, the jet is in the well, below the water level.

Like the submersible pump, a jet pump has few moving parts and produces a smooth even flow of water. Both shallow-well and deep-well jet pumps can be located a distance from the well. They can produce relatively high capacity at low heads. Because the pump is above ground, it is easy to access for repairs but requires frost protection. The jet pump must be primed (filled with water) when first started. An air leak in the suction pipe or a water leak in the drop pipes will cause the pump to lose its prime. The deep-well jet must be removed from the well for service. The suction pipe must have a check valve to hold water so the pump will not lose prime.

A **centrifugal** pump is a very simple and versatile pump that produces a smooth, even flow. It has a maximum suction lift of 25 feet and a maximum total lift of 300 feet. The rotating impeller develops a partial vacuum at the eye of the impeller that provides the suction lift. The impeller increases the velocity of the water. The diffuser converts the velocity to pressure. The pump must be primed to begin operation. Any leak on the intake can cause the pump to lose prime. It works well as a booster pump.

Water pumps and motors designed for use with **variable frequency drive** (VFD) motor controllers are popular, especially with submersible pumps. These are called constant pressure water systems, since the controller determines the speed of the pump motor needed to maintain the pressure. When water is used, the pressure drops and the pump speeds up. When the water pressure increases because water use has decreased or stopped, the pump slows down or stops to maintain a near constant pressure. These systems use less energy than other systems, as the pump will run for a longer duration, with fewer startups. More energy is used to start a pump than to keep it running.

For most household use, a VFD-controlled water pump needs only a small pressure tank (*Figure 2*); usually 1 to 2 gallons. However, these pumps also can be used with conventional pressure tanks if additional water storage is needed.

Pressure Switch

The pressure switch, usually located at or near the pressure tank, is the brain of the system. Because it is near the pressure tank, it can even out any pressure fluctuations caused by the pump turning on and off. After being set by the manufacturer or the installer, it determines the pressures at which the pump will start and stop. Usually, a pressure switch can be adjusted after installation.

Pressure Storage Tanks

The pressure tank in a private water system has three purposes. It stores water and provides water under pressure when the pump is not running. It builds up a reserve supply of water so the pump starts and stops less often, prolonging the life of the pump. In addition, it provides a reserve supply of water for use during times of high demand.

Operation of a pressure tank is based on physical properties. Water cannot be compressed into a smaller area, while air can. When water is pumped into a tank containing air, the air is compressed, putting the water under pressure. The more the air is compressed, the greater the water pressure. When the water reaches a preset level, typically 40 to 60 pounds per square inch (psi), the pump automatically shuts off. As water is used, the pressure in the tank is lowered. When the water reaches a preset level, typically 20 to 40 psi, the pump starts again.

Figure 2. Small pressure tank associated with a VFD-controlled water pump.

The minimum tank pressure must be at least as high as the pressure needed by any fixture or outlet. Almost all require at least 10 psi to operate properly. Water treatment units, water softeners, clothes washers, and dishwashers require at least 30 psi.

The type of pressure tank is determined by the type of water pump, the amount of water used, and the water yield from a well. Older types of pressure tanks include galvanized steel pressure tanks and galvanized steel tanks with a floating wafer. Now, pressure tanks with a diaphragm, and pressure tanks with a rubber bladder are common. A bladder tank is often used with systems utilizing a submersible pump.

Up until 1970, the most common type of pressure tank used with a private water system was a **galvanized steel tank** (*Figure 3*). This was used with jet, centrifugal, and piston pumps. This type of tank has a separate inlet and outlet, and requires an air volume control to maintain the appropriate air-to-water volume in the tank. The galvanized steel tank usually is located within 4 feet of the water pump because the intake side of the pump supplies the force to replenish the air in the tank. They do not need to be placed near submersible pumps or reciprocating pumps that have a separate air pump attached.

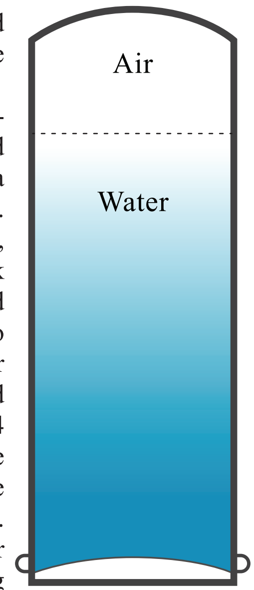

Figure 3. Galvanized steel pressure tank.

A disadvantage of the galvanized steel tank is that air and water are in direct contact with each other. Water can absorb some of the air, so the air must be replaced to prevent the tank from becoming waterlogged. If this happens, there is little air left in the tank to become compressed, so the pump runs nearly every time water is used. In addition, too much air in the tank is a problem because it reduces the space for water storage. Extra air must be released or the tank will become air-bound. An air-volume device attached to a steel pressure tank will control the volume of air automatically. These are designed to work with specific types of pump, well, and piping systems.

The **steel galvanized tank with a wafer** has a floating wafer that separates the air from water (*Figure 4*). This almost doubles the usable stor-

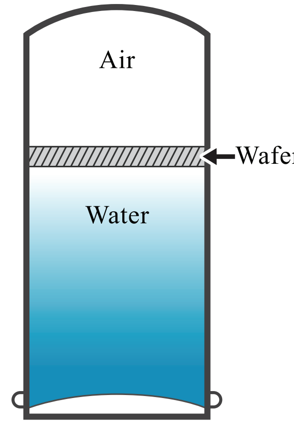

Figure 4. Steel galvanized tank with a wafer.

age space and eliminates the need for an air-volume device. A galvanized steel pressure tank can be converted to a wafer tank by rolling up the wafer and inserting it into the 1¼-inch opening in the side of the tank. The wafer tank still must be manually recharged with air every 6 to 12 months.

Since 1970, most private water systems have used **diaphragm or bladder-type pressure tanks** (*Figure 5*). The bladder is usually made of butyl rubber or flexible polyvinyl chloride. The water is contained in the bladder and does not touch the sides of the tank. The bladder holding the water expands into the pressurized air space in the tank as it is filled. This prevents air-water contact so an air injection or air release device is not needed. As water is used from the system, the bladder collapses until the water is almost emptied before the minimum pressure is reached, activating the pump.

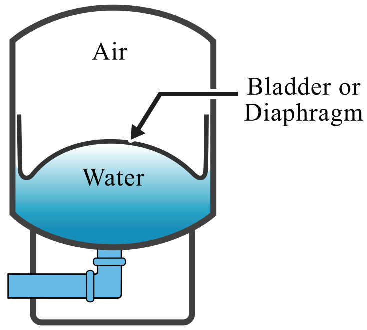

Figure 5. Diaphragm or bladder-type pressure tank.

Bladder pressure tanks have a single pipe that serves as both an inlet and an outlet. They are pressurized at the factory to around 20 psi, but the pressure can be increased using an air valve located near the top of the tank. Most manufacturers recommend charging this type of tank to about 2 psi lower than the pump-on pressure. Because there is almost no water left in the bladder at the pump-on pressure, these tanks may not be suitable for low-yield wells unless an additional tank is used.

A bladder-type pressure tank can be placed anywhere in the water distribution system. On systems with long pipe runs of greater than 500 feet, a second tank is sometimes used at or near the end of the pipeline, especially if flow rate and water pressure are critical.

Small bladder tanks are sometimes used at various points in large private water systems to minimize pressure fluctuations. In this case, the pressure tank becomes an air chamber to control water hammer. Water hammer can occur when water that is moving rapidly through a pipe is suddenly stopped due to a faucet being turned off quickly. A small bladder tank may provide a sort of cushion, compressing when the shock wave of the water hits, preventing the hammering effect.

One way to select the proper size for a pressure tank is to base it on the pump's flow rate (*Table I*). A typical home or farmstead pump supplies water at a rate of 5 to 10 gallons per minute (gpm). Multiply the flow rate by four to determine the size of a diaphragm or bladder tank. For example, a 9-gpm pump would require a 36-gallon storage tank. This would be the same sizing formula to use for a galvanized steel tank with a wafer installed. A galvanized steel tank is sized 10 times the flow rate; a 9-gpm pump would require a 90-gallon storage tank. Your pump supplier will recommend the pressure tank sized for a water system with a pump that provides more than 25 gpm. It may be more economical to use two smaller pressure tanks side-by-side, instead of one large pressure tank.

As previously mentioned, a VFD-controlled submersible water system uses a very small pre-charged pressure tank to even out small pressure fluctuations due to the pump turning on and off.

Water Distribution System

When water is used in a dwelling or structure, a demand is placed on the water supply system. All of the components work together to deliver water to the location of the water use. For example, when a dishwasher is started, the water system (including the well, pump, controls, and pressure tank) delivers water to the building distribution system. Then, the water distribution system, sometimes called the plumbing, transports the water throughout the building, and in this case, to the dishwasher. The water distribution system is often hidden behind walls and if you could see it, would look like a series of pipes that are installed throughout the building. Pipes are made of many different types of materials, with some of the common types being plastic, copper, and galvanized steel. The water distribution system also includes multiple fittings that control the flow of water within the piping network. Some of these fittings include valves, elbows, tees, pressure gauges, and check valves, among others. A poorly designed or installed piping system, or an aging plumbing system, can result in an inadequate water system, even when the water source (or aquifer), well, and pump are adequate. A licensed plumber will be an important contact if you need help with your water distribution system, since water well contractors may prefer not to work on the water distribution system.

Freeze-Protection

In older wells, the pump was often housed in a hole, or pit located directly above the well. The pit was deep enough to provide frost protection, preventing the pump and water lines from freezing. Locating a well pit directly above a well is no longer legal — contaminated runoff from rain, melting snow, or flood water can carry contaminants into the pit and pollute the well. While a pit can be used, it must be located at least 10 feet away from the well. Instead, a pitless unit or

Table I. Useable pressurized storage amount in gallons for various types of pressure tanks with common pressure switch settings.

Total tank volume (gallons)			*Usable water storage or drawdown for pressure switch range (gallons)*		
Galvanized steel tank	*Pre-charged steel tank with wafer*	*Diaphragm or bladder tank*	*20 to 40 psi*	*30 to 50 psi*	*40 to 60 psi*
15	4.5	4.5	1.7	1.4	1.2
30	14	14	5.1	4.3	3.7
42	20	20	6.5	5.5	5
82	32	32	12	10	8.5
120	45	45	18	15	12

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pitless adapter is now used for most new wells. Pitless adapters are special fittings that attach to the well casing below ground and discharge water to the house or other buildings through a buried water pipe. Because the unit and pipe are deeper than the frost line, the water will not freeze. Pitless units reduce the risk of contamination from runoff and provide exceptional frost protection *(Figure 6)*.

Most rural properties have one or more outdoor hydrants to irrigate lawns and gardens, provide water for livestock and pets, offer fire protection, and more. While irrigation needs may be seasonal, other outdoor water needs must be met year-round, even in sub-zero temperatures. Outdoor hydrants are designed to be frost-proof to allow for outdoor water use during all seasons. An outdoor hydrant has a shut-off valve that is located below the frost line in the water distribution pipe. When the hydrant is closed, or shut off, any water remaining in the water distribution pipe drains down through a hole in the valve. No water is left in the upper portion of the distribution pipe where it could freeze.

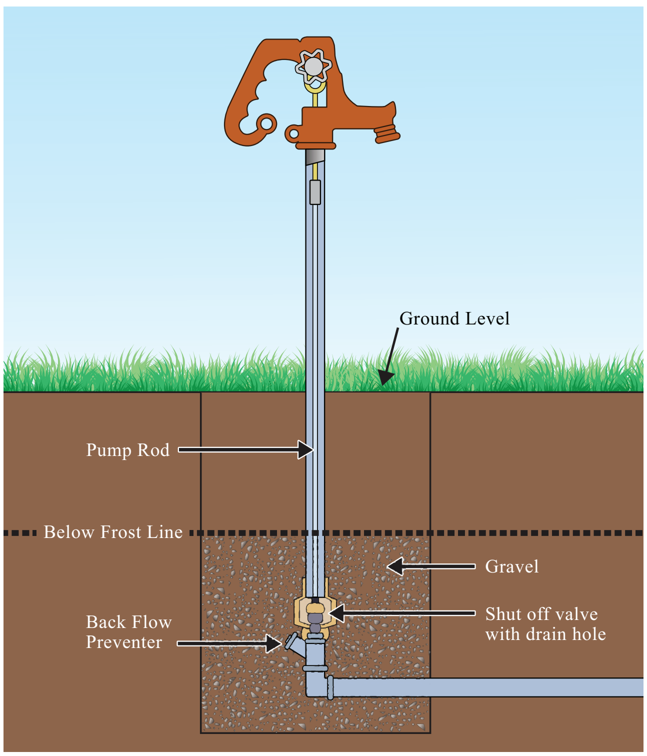

Figure 6. Pitless units reduce the risk of contamination from runoff

Summary

While your well driller and plumber will recommend the type of pump, pressure switch, and pressure tank suitable to meet your needs, it is worthwhile that you understand how each of these works, as well as the advantages and disadvantages of different types. It also is important to understand how the distribution system design prevents water from freezing as it moves from the well to the location of intended use.

Acknowledgments

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This publication contains information from the Midwest Plan Service publication *Private Water Systems Handbook*, which provides additional information on private drinking water systems. The publication can be purchased from: Midwest Plan Service, 122 Davidson Hall, Iowa State University, Ames, Iowa, 50011-3080; phone 800-562-3618; website *www.mwps.org*.

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