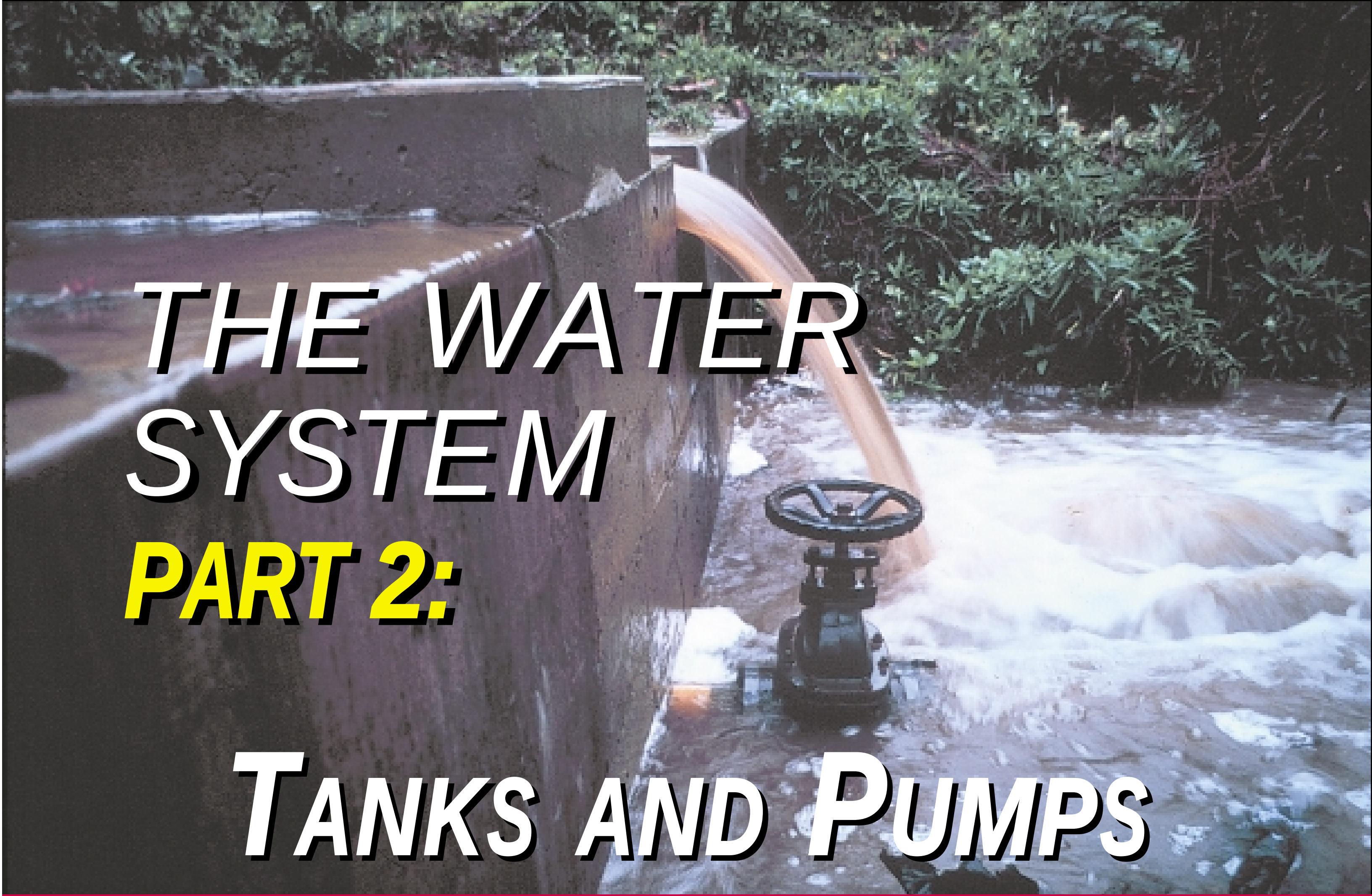


# THE WATER SYSTEM PART 2: TANKS AND PUMPS

BY MICHAEL HACKLEMAN

It is versatility that ensures a robust and reliable water system. In the last issue (July/August 1999, Issue 58) I detailed potential sources of water—i.e., rivers and streams, springs, lakes and ponds, shallow wells, deep wells, and rainfall—and the factors a landowner may use to evaluate their potential of development for use in a water system. Then we examined potential energy sources—human, wind, water, engines, electric motors, and combinations for the processes of extraction, transport, storage, and pressurization of water in systems. Finally, I detailed the energy requirements of lifting and pumping water and those factors related to the sizing of water storage for normal usage, source variance, gravity flow and pressurization, and emergencies like fire fighting and blackouts.

In this issue, we will continue with a closer look at those factors related to selecting and sizing the hardware of the water system, particularly tanks and pumps. Next, we will examine several examples of water systems and the accessories needed to complete any system.

## Tanks

Tanks are one of the best ways of storing water. The relatively high cost of storage by this means (compared with ponds or reservoirs) is often justified in light of convenience, better protection against contamination, effective shielding from sunlight, and the ease of determining the precise amount of water that has been stored.

Tanks come in all shapes, sizes, and materials. Four basic materials are used in tanks: wood, metal, plastic and concrete.

**Wood tanks**: One of the oldest materials used for tanks is wood. Typically these tanks are round-sided, flat-bottomed, and with a top that's open, flat, or sometimes fluted to shed precipitation, airborne dust, and other debris.

Not just any wood will do for water tanks. Typically, successful ones are fabricated from redwood, mahogany, or white oak. These woods, after an initial leaching of acids and resins, offer a sterile environment when in contact with water. Water in contact with other woods will warp or rot

## Sidebar A: Types of metal tanks

**Welded:** Welded tanks are used for smaller capacities than bolted tanks. Thicker steel is arced to the desired shape and welded to similar sheets. The component parts of the tank are welded together into a rigid tank. This type of tank may be easily manufactured in a shop and transported to the usage site **(Fig. 1)**. The limiting factor on size for this type is the carrying capacity of the transport system used to ferry the tank from the shop to the site. Of course, the shaped steel sheets could be transported "as is" along with the welding equipment to put it all together on-site.

**Bolted:** Another possibility is to use a steel tank designed to be bolted together; this eliminates the need for any on-site welding while solving the transport problem for thick-wall tanks of immense size. Tar or another petroleum-base sealant is sandwiched between the bolted sheets during assembly to prevent water loss.

**Soldered:** If the potential for on-site construction exists, a third option is to use very thin sheets of galvanized steel for the tank. Because of the thinness of the material, welding cannot be employed; instead, solder is used to seal the joints. The solder is a good sealant against water leakage. However, it is not strong enough to withstand the "shear"—the forces that tend to separate the joined sheets—when the tank is filled with water. For this reason, bolts or screws are also used to secure the sheets at the edges, along with crimping.

The thinness of steel or tin in galvanized sheet tanks is sometimes a disadvantage. In coastal areas, for example, the effects of the salt-laden air are all too evident.

While welded or bolted steel tanks may be transported about, the thin galvanized tin or steel tank usually can't survive transportation from one place to another or rough handling in any form. Out of necessity, then, they are constructed on-site.

Figure 1: Welded tanks are transported to the storage site.

them, leach undesirable chemicals and resins into the water, or promote the growth of bacteria and algae in the water supply.

Just as redwood or oak swells in the presence of water, it shrinks in its absence. Therefore any portion of the wood in a tank that is not covered with water will, after a few days, dry out and may lose its water-sealing function. In view of this, tanks constructed of either oak or redwood should be kept filled. Lacking this, they should be sprayed with water several times a day or excused from verbal abuse when they do leak.

Other woods are used in the construction of tanks. However, they must be treated so that, in effect, the water does not come into direct contact with the wood itself. Varnishes, resins, fiberglass, tar, or other coatings will be necessary. Or the water may actually be enclosed in some type of plastic or rubber bladder inserted in the tank.

**Metal tanks:** Water storage tanks may also be made of metal. This is usually sheet steel, and even very large tanks may have surprisingly thin walls. Since steel exposed to water rusts, it must somehow be protected. Paint, tar, and galvanizing are three common coatings.

Steel tanks are characterized by one of three techniques used to secure the metal sheets together in tank construction. They may be welded, bolted, or soldered. **(Sidebar A)**

**Plastic tanks:** The high price of steel has prompted the production of plastic tanks in the 400 to 2,000-gallon range for water storage. Usually pale yellow or black and cylindrical, they have molded fittings for the inlet and outlet, and an access hatch in the top. These may be purchased and delivered to the water site.

**Concrete Tanks:** Concrete is also used. The basic setup is a poured slab for the base of the tank and poured, formed walls. Since this is similar to constructing a building's foundation, the resulting tank is square or rectangular sized. Or if a round tank is preferred, a slip form constructed in the shape of an arc can circumvent the many difficulties in producing a con-

## Sidebar B: Three methods of tank support

**Banding:** A band is a strong, continuous material that encircles the tank. It is demonstrated in banded wood barrels. The operating principle of banding is simple. Pressure is identical in all directions; therefore, the outward pressure of water at any point is opposed by the band's inward pressure on the tank wall directly opposite that side of the tank. Obviously the band material is under heavy tension and must be strong enough to withstand shear.

Bands work on circular tanks only. Square or rectangular tanks may also be banded, but the only points where the bands are really working is at the corners. The outward pressure at any point between the corners works perpendicularly to the tensioned band and is, therefore, rather ineffective. The weakest point is the midpoint between the tank's corners. The walls will bulge outward at these points.

**Buttressing:** One solution to tank support involves buttressing. It takes two forms. One is an external, angled support **(Fig. 2)**. Accordingly, if one buttress is used, it should be placed at the midpoint between the corners of the tank on each side. Long tanks may require several buttresses on each side.

A second buttress solution is to use an arced section of material along each side and to band it as you would a perfectly round tank. Either a square or rectangular-sided tank will be best supported if the selected arc describes a full circle.

**Burial:** Concrete, masonry, and concrete block tanks may also be supported by burial. There are two ways to do this. One is to dig the hole and insert a ready-built tank. The other is to dig the hole and build the tank in it.

This is no problem with standard concrete block or masonry construction. A poured-concrete wall will require forms. Putting them in is easy, but extracting the exterior portion of the form (facing the pit's walls) afterward may not be. Nevertheless, it should be removed. The wood could swell enough during the wetter season to crack the concrete wall.

There's a temptation simply to "form up" the inside surface of the tank and use the pit's wall in place of the exterior form. The penalty for such laziness is the cost of all that extra concrete. Also, concrete is heavy—a cubic yard weighs four tons—so it will readily compress the earth, particularly when it's stacked up for four to eight feet. Finally, concrete doesn't cure against dirt as nicely as it does against forms, which means that it won't be as strong.

Cisterns or reservoirs built into a slope may have a good percentage of the complete tank showing and, therefore, unsupported. Banding or buttressing will not be required if some of the leftover dirt is shoved up against the wall. The result is a "bermed" wall. Since this technique will work, no tank need be completely buried. While retaining the best aspects of a buried tank, a partially buried tank saves on cost, time, and materials and solves the problem of what to do with all that "extra" dirt displaced by the tank.

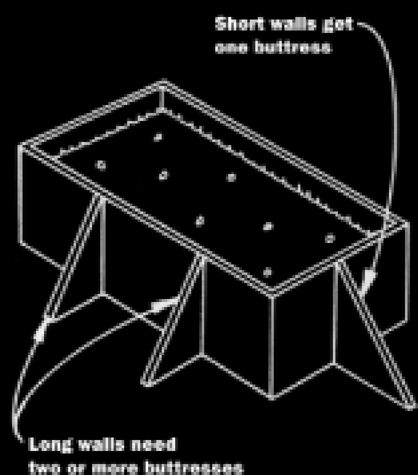


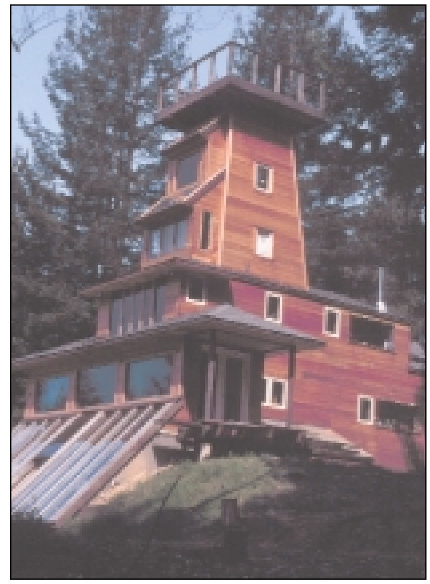

Figure 2: Buttresses provide additional structural support.

toured form. The use of rebar (a reinforcing bar used in standard concrete construction) is critical for either type to offset the water's weight and pressure when the tank is filled. A larger square or rectangular tank, even with internal rebar, will need additional external bracing to maintain structural integrity in use. **(Sidebar B)**

Bottom support of tanks: Irrespective of the type of tank used, it must have adequate support from below. Water hits the scale at 8.33 pounds per gallon. A thousand gallons, then, weighs over 8,330 pounds. At 2,000 pounds per ton, that's in excess of 4 tons. A 4000-gallon tank, then, holds a whopping 16 tons of water and that doesn't include the weight of the tank! The point? Never place a tank on rough ground or soft fill. If a tall and slim tank is desired over one that's short and squat, the problem becomes more acute. An analysis of the soil density may be needed to assure that it will not settle.

Wood tanks placed on bare earth will rot. Steel tanks (even galvanized) placed on bare earth will rust. How fast is anyone's guess, and it doesn't really matter. Don't do it! Large tanks are usually set on a bed of gravel over leveled earth. This takes care of the rust or rot problem—precipitation and condensation are drained away. This also lends a self-leveling feature. Use sand over gravel when the tank wall is thin plastic or metal. Otherwise, the bottom will be deformed or punctured by the smallest object when the tank is filled.

Figure 3: **(Left)** A tower will provide gravity pressurization.
Figure 4: **(Below)** A water tower can be converted into a house.



Wood and steel tanks may also get some help from treated wood beams. Old railroad ties spaced evenly over leveled ground will do the job. A raised platform also helps to lessen the probability of rot or rust in wet climes. Where it is desirable to use gravity flow and/or pressurization—but a higher elevation than the usage site is not available—the platform may be extended upward the needed distance to accomplish either or both. Obviously, this has a limiting effect on the type of tank used. A tank that can be constructed piece by piece on the tower will be preferable to one that must be raised to the top. Another drawback is that tank size is restricted. The tower, including footings, tower legs, and cross bracing must be sized to evenly support the tank's bottom area, its weight, and the weight of the water it can hold. Add in the extra problems of wind pressure on both tower and tank and any propensity for the ground to move through settling or earth tremors, and both the logistics and expenses are formidable. Nevertheless, tower raising can be a lot of fun **(Fig. 3)** And your tower might even become a house **(Fig. 4).**

Tank coatings: Redwood, mahogany, and white oak tanks have a built-in coating that prevents leakage, the formation of organic growths, and deterioration of the wood itself from rot. Water loss is prevented because it is the nature of these specific woods to swell and seal the tank. Newly constructed tanks, then, will leak like the proverbial sieve. For this reason, before the first filling, water is sprayed about the interior, wetting the wood uniformly to initiate the swelling and avoid the otherwise lengthy process of filling the tank. Another idiosyncrasy of these specific woods is that most of the harmful resins are leached from the wood during the initial period of use and will thereafter remain inert.

The scarcity and high demand for these woods make them prohibitively expensive for large tanks. However, other woods—pine, fir, oak—may suffice. But while these substitutes do give the nice wood appearance and provide the necessary structural support, they do not exhibit the self-sealing and preserving qualities of redwood. Moreover, once the resins are leached from the wood, fungus growth will occur.

For these reasons, the inside of tanks constructed of other types of wood must be sealed. Sealers and paint will counteract many of these problems, but preventing leakage is the tough one. So, a hard, completely watertight coating is called for, and that narrows the possibilities to some kind of epoxy, resin, or liner. Fiberglass is the usual choice because it may be used in conjunction with fiberglass cloth to make a tightly bonded, impenetrable finish.

In the presence of water, steel rusts. So, irrespective of the type of steel tank—whether soldered, welded, or bolted—a first requirement of a coating is to keep the water away from the metal. A waterproof paint or tarlike sealant is the primary choice. Pick one that prevents the growth of algae. Be wary—select a coating that meets your own standards in what you're willing to allow in your water in the way of chemicals, trace minerals, and elements.

Provided that the solder or weld joints are good ones, steel tanks don't need leakage protection. The application of any type of paint or epoxy over these surfaces if they're even slightly encrusted with rust, dirt, or oil is cosmetic only. Don't do it! Wire-brush or sand off the rust, wet-mop the dust, and use something akin to alcohol or lacquer thinner to remove any trace of oil or grease prior to the application of a primer. Avoid the use of any rust-inhibiting primers not specifically approved for potable water. Fortunately, red lead primer is no longer available, but even zinc chromate primer would not be a good addition to drinking water. These are strictly weatherizing primers, for external use only. Apply the epoxy paint or other good water-base paint in one or two coats. Redo as required. Access to the tank will assure sufficient warning when a recoating is indicated.

Galvanized sheeting that is soldered for waterproofing should also receive a coating of some type. It's not usually done—the solder takes care of leaks, and the galvanizing takes care of the rust protection. However, long-term exposure of both solder and galvanizing to water, particularly soft water, can be dangerous. The water tends to leach lead from the solder—solder is lead and tin in various mixes, usually fifty-fifty. The water will leach both lead and cadmium from the galvanized coating. If

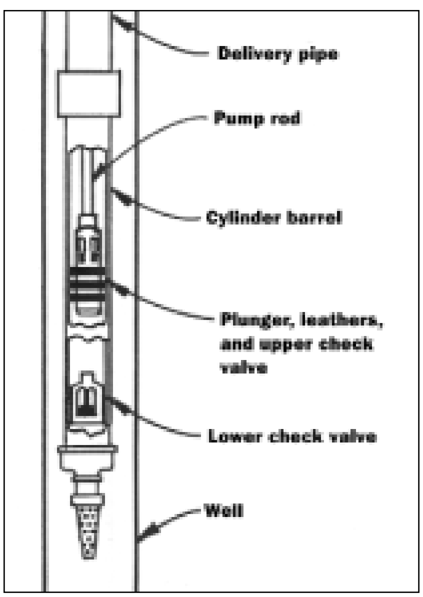



Figure 5: A deep well piston pump and cylinder.

you decide to cover the galvanizing with a coating that reduces this risk, choose it carefully. Many types of paint or epoxy will not adhere to galvanizing, and fewer still will meet potable water standards.

Concrete tanks will need a coating to prevent the escape of water and the formation of organic growths. A standard coating technique is that used for swimming pools: a mudlike, cement-rich plaster applied over the cured concrete, inside or out. An alternative is to use one of the newer concrete sealants such as cement paint or bituminous mastic. Both ways are expensive. Cement paint requires specialized labor in applying the coating. With mastic, the sealant itself is expensive.

## Pumps

There are three basic types of pumps that may be used in a water system to extract water from a source and deliver it to storage or immediate use. These are the piston pump, the centrifugal pump, and the hydraulic ram.

Piston pump: The piston pump, also known as the positive displacement pump, sees wide uses in water systems. It works on the reciprocating principle, or an up-and-down or back-and-forth movement. More specifically, a piston moves inside a cylinder **(Fig. 5)**, drawing water through an intake check valve on one part of a stroke and pushing it out through an outlet check valve on the second part of the stroke. Irrespective of the outlet or inlet water pressures, the same amount of water is pumped during each stroke; hence the term "positive displacement." This no-nonsense action also enables the unit to pump air efficiently. The air compressor and tire pump are both piston pumps. The piston pump can suck water up from as far as 25 feet below the pump.

There are two common configurations of the piston pump in water systems. In the first setup, the pump mechanism and its power unit—the motor or engine that drives it—sit atop a shallow well with a tail pipe reaching down below the water level. As long as this distance is not greater than about 25 feet, the pump's action will suck water up to the pump and then push it onward to usage or storage.

The second configuration handles well depths where the water level is more than 25 feet below the ground. The power unit and pump are separated. The power unit operates a converter—a device that translates the rotary motion of the power unit into the reciprocating motion needed in the pump mechanism—at the wellhead (ground level). Through a section of rigid rod, usually referred to as "sucker rod," this power is transferred to the piston pump mechanism situated deep in the well. The deeper the well, the longer the sucker rod. Since the water must be pumped to the surface through a pipe anyway, the sucker rod is designed to operate the piston pump from inside the delivery pipe, sharing this space with the upward-moving water.

This arrangement seems odd, but in reality it is both simple and straightforward. It has two additional benefits related to servicing the pump and using a tailpipe. **(Sidebar C)**

There is a limit to the maximum number of strokes that this type of pump can withstand. A stroke is one cycle consisting of one up-and-down movement of the piston in the cylinder. This pump has a limit of 30-45 strokes per minute. In consequence, a system that uses a 6-inch stroke (total distance of movement) and a 3-inch cylinder (the biggest available) can supply up to 7.7 gallons per minute. **(Fig. 6)**

This is a low rate compared with other pump types such as the submersible centrifugal pump, and will barely cover most household needs directly. For this reason, the deep-well piston pump is utilized primarily in

## Figure 6: DEEP-WELL PISTON PUMP RATINGS

| Discharge Rate* | | Cylinder Size (I.D.) | Electric Motor Size Maximum Lift in Feet | | |
|---|---|---|---|---|---|
| GPH | GPM | in inches | ⅓ HP | ½HP | ¾HP |
| 146 | 2.4 | 1-11/16 | 228 | 336 | 513 |
| 157 | 2.6 | 1-¾ | 212 | 318 | 477 |
| 180 | 3.0 | 1-7/8 | 186 | 277 | 416 |
| 205 | 3.4 | 2 | 162 | 244 | 366 |
| 260 | 4.3 | 2-¼ | 128 | 192 | 289 |
| 321 | 5.4 | 2-¾ | 104 | 156 | 234 |
| 389 | 6.5 | 2- | 85 | 128 | 192 |
| 463 | 7.7 | 3 | 72 | 108 | 162 |

* Assumes 6-inch stroke and 42 strokes per minute.

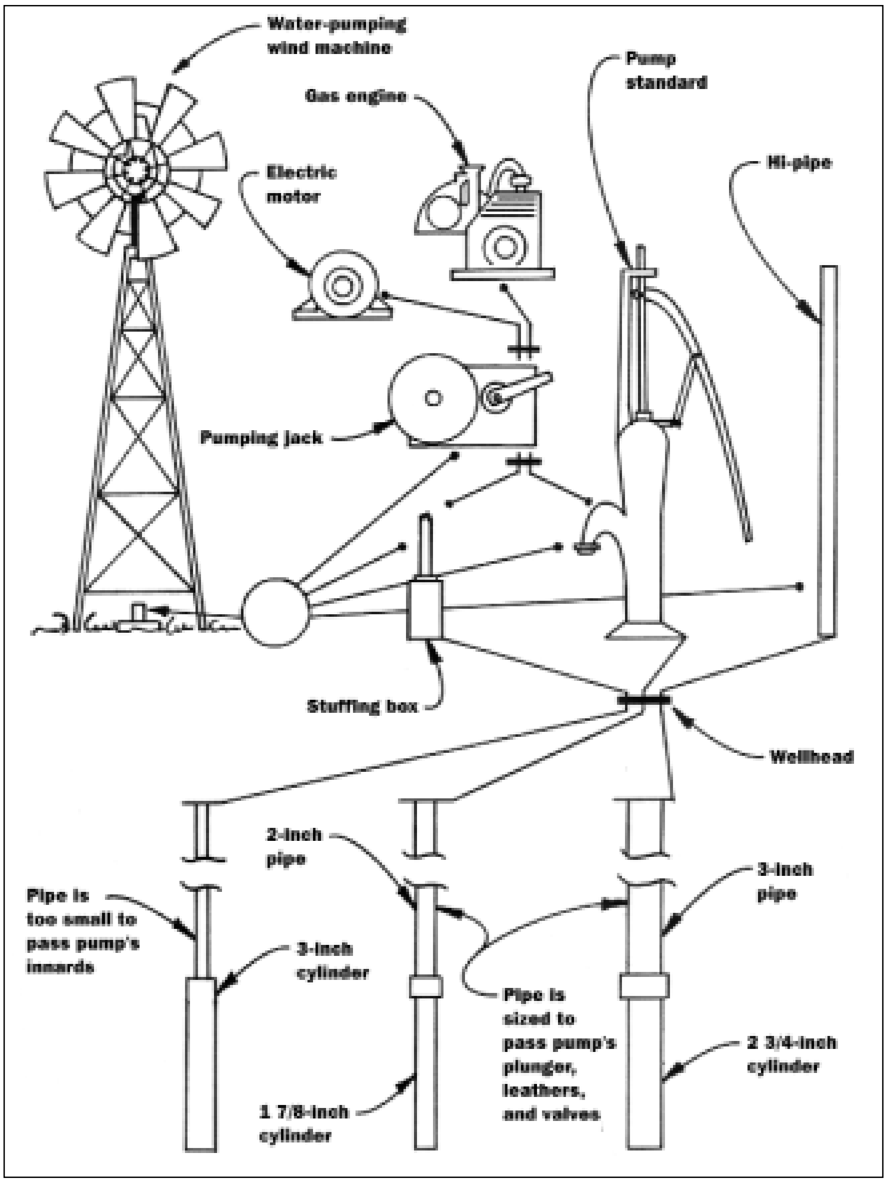



Figure 7: There are multiple ways to power a deep well piston pump.

the "store" type of water system where its only job is to pump water to storage. Hence, transporting and pressurizing water for usage is left to another means, i.e. gravity.

The deep or shallow well pump mechanism may be operated in four different ways. **(Fig. 7)** Pumping by hand is accomplished through use of the pump standard. An electric motor will drive the pumping jack—a unit that bolts to the pump standard—to operate the pump's sucker rod. A small gasoline engine will also operate the pumping jack. Finally, a wind machine will connect directly to the sucker rod to operate the pump. Frequently two or more of these pumping methods are combined, since the equipment is designed to accommodate multiple energy sources. **(Fig. 8)**

Centrifugal pump: The centrifugal pump works on the same principle as a rock on a string that you swing around your body. The rock wants to travel in a direct line, but the string prevents it from doing this. If, instead, you held a bottle with one end of a long section of rubber tubing secured through its cap and whipped the hose around in a tight circle, the water in the bottle would travel down the tubing. That's centrifugal pumping.

The centrifugal pump built for a water system uses impellers instead of tubing and is much more compact. Coupled to a high-speed electric motor, it is capable of delivering water at a very high rate.

A single set of impellers in a centrifugal pump can pump against only so much pressure (head). Hence, the pumping rate drops off as the pumping head increases. This limitation is alleviated in design by stacking individual impeller sections on top of one another, each with an outlet connected to the inlet of the stage above it and its own inlet derived from the outlet of the stage below. Standard centrifugal submersibles are available with as few as seven stages and as many as forty-

## Sidebar C: Features of the deep well piston pump

An above-ground positioning of well pumps is always preferable for the convenience it affords in servicing the equipment. However, with the deep well piston pump, careful selection of components will still allow the removal of the entire pump mechanism, including valves and leathers—the only section of the pump mechanism that is subject to wear—up through its delivery pipe for servicing without hassling with the pipe and cylinder itself. This is a nice bonus. All that 2-inch galvanized pipe is heavy, and removing it would add many hours and considerably more equipment to an otherwise fast and easy overhaul.

This magic works if the cylinder diameter is 1-7/8 inch and the delivery pipe is of 2-inch diameter. If a larger cylinder size is needed (or dictated) to increase the pumping rate or pump depth, there are two options. One is to install a pipe size larger than 2 inches to retain the servicing capability. The other is to keep the pipe size at 2 inches (or smaller) and lose the option of removing the wearable portions of the pump up through the pipe when servicing is needed.

A second benefit stems from the piston pump's ability to pump air and therefore suck water. With the addition of a tail pipe, the pump's reach for water is extended to 15 to 20 feet below the pump. This saves just this much expensive sucker rod and galvanized pipe. In addition, maximum use of the well's depth is assured. No type of pump can be placed close to the bottom of a well without sucking in a lot of sediment and doing itself irreparable harm. In this scenario, the bottom of the tail pipe can sit closer to the bottom of the well while the pump itself is safely 15-20 feet above it.

five stages, depending on the final in-well depth, total pumping head, pumping rate, and delivery pressure.

Note the difference in pumping rates of the centrifugal pump **(Fig. 9)** compared with the deep-well piston pump **(Fig. 6)** for equivalent motor horsepower, pumping head, and pressure delivery.

With such a difference in performance, why then isn't the piston pump retired to dusty shelves alongside other antiques? A major reason is that the centrifugal pump can't suck or pump air. For this reasons, it must be submerged. The water level in a well enough in the well so that the point of greatest drawdown will not fall below its inlet.

This is no particular problem for the pump mechanism, but it does raise a few engineering nightmares for the power unit. Since both operate in a rotary fashion, coupling the two units together over a distance of more than a few feet is difficult. At the kind of rpm the pump works best, there's also a real problem with balance.

There are several solutions to this problem. In shallow wells, the pump may be mounted over the wellhead. Equipped with an injector mechanism,

Figure 8: A pump jack mounted on a pump standard offers hand and powered pumping.

ram is a water-powered device. **(Fig. 10)** It has one function: to pump water.

How does it work? The ram uses the energy of moving water to pump a small portion of that water to a higher point. It starts when we let water flow through a drive pipe into the ram and suddenly shut it off. Water, once moving, doesn't like stopping so abruptly, so it piles up. And because it's virtually incompressible, it builds up pressure. If we put a check valve in the chamber, the pressure will pop it open, moving a small amount of water into the vertical pipe beyond. Once the penned water has spent its pressure, the check valve closes and the flow automatically resumes. Preset adjustments again shut off the flow, and the pressured water acts again on the check valve. The water in the pipe behind the check valve climbs higher and higher with each cycle. You can

## Figure 9: Centrifugal Pump Ratings

| Electric Motor Size | No. of stages in pump | Total Pumping Head 20 | 40 | 60 | 80 | 100 | 120 | 140 | 160 | 180 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Discharge Rate* in GPH/GPM | | | | | | | | | |
| 1/3HP | 10 | 745/12.4 | 690/11.5 | 620/10.3 | 535/8.9 | 430/7.2 | 285/4.8 | 65/1.1 | — | — | — |
| ½HP | 13 | 820/13.7 | 775/12.9 | 735/12.3 | 690/11.5 | 635/10.6 | 580/9.7 | 505/8.4 | 415/6.9 | 300/5 | 125/2.1 |
| ¾HP | 18 | 870/14.5 | 845/14.0 | 820/13.7 | 795/13.3 | 760/12.7 | 730/12.2 | 700/11.7 | 665/11.1 | 630/10.5 | 585/9.8 |

* Assumes 30 psi at delivery point.

Figure 10: A hydraulic ram is a simple, water-powered pump.

pipe and deliver any more water through the check valve. That's the limit of the ram, and it can be increased beyond that point only with a larger inflow of water (larger diameter of drive pipe) or a higher pressure of incoming water (greater initial drive head).

Theoretically, the ram pumps 1/10 of the water 10 times as high, 1/5 of it 5 times as high, and so on. As we might suspect, in practice the results are much lower because of friction in the working parts such as valves and inlet and delivery pipes. Nevertheless, the results are impressive and beneficial if you want to fill a reservoir or get water to your homesite on the hill from the stream in the canyon below. If you have gross amounts of water in the stream or river, you can use the hydraulic ram to pump water to an elevation and then let it drop into a water turbine that's back down the hill, thereby producing electricity. Sort of roundabout, but undeniably practical under the right conditions.

The standard ram is a single-acting unit. It pumps the water that powers it. A double-acting ram will pump a different source of water than the one which provides the pumping action. In this way, a stream may operate a hydraulic ram to pump water from a spring or well.

The hydraulic ram is manufactured worldwide. Commercial units are simple and easy to maintain and operate but relatively expensive. Owing to its simplicity, a multitude of do-it-yourself ram designs exist for the owner-builder or person with an ability to work with standard plumbing hardware.

## Pump evaluation

The two most popular pumps are the deep-well piston pump (hereafter the piston pump) and the submersible centrifugal pump (hereafter the submersible pump) and we will focus on these two. [This is not meant as a judgement against the hydraulic ram. The hydraulic ram needs running water which, over the length of your property, must drop in elevation at least 10 to 15 feet to be useful.]

What factors affect the selection of a piston pump or a centrifugal pump? Let's examine well size, pumping capacity and head, positioning in the well, the power unit, pumping vs usage rates, and energy vs pumping rates.

Well size: A submersible pump is not made for well sizes below 4 inches in diameter. The piston pump can be utilized in well sizes as low as 2 inches.

Pumping capacity and head: The pumping capacity (rate of flow) of the submersible pump decreases rapidly with drawdown, particularly if the water approaches the level of the pump's intake. Effectively, the pumping head is increasing, too, since it's measured from the level of water in the well. This situation may be accommodated in three ways. First, the well can be dug deeper to reduce the effect of drawdown; this also increases in-well storage. Second, a submersible pump with more "stages" and a higher horsepower rating may be selected for the job. And third, a higher-capacity well—one that won't experience much drawdown—can be dug. In terms of both energy and money, all three are expensive solutions.

A piston pump's efficiency, on the other hand, is not affected by drawdown. Positive displacement always assures the delivery of the same amount of water. So if the pumping head increases because of normal drawdown, the only effect it can have is to increase slightly the load on the above-ground power unit.

Positioning in the well: The submersible pump must at all times be submerged, and a tail pipe will not work with this type of pump. This necessitates a deeper well, both to maintain the pump's clearance above the bottom of the well and to assure that the drawdown will not uncover it.

A piston pump, at the slower pumping rate, causes less drawdown, can pump water from as much as 25 feet below the pump level (using the tail pipe), and requires less clearance above the bottom of the well.

The power unit: The power unit of the submersible pump is limited to an electric motor (gas engines won't run underwater) that is built for 110V or 220V, 60-cycle A.C., single-phase or a variety of DC voltages.

The piston pump can utilize a number of "power" units—muscle power, solar power, wind power, gasoline-engine power, and electrical power. If an electric motor is used, it can be wired for high or low voltage, A.C. or D.C. Additionally, if the pumping equipment cannot be positioned directly over the well, an offset system may be installed.

**Pumping versus usage rates:** In the "demand" system, the water pump must be closely matched to the rate at which water is used. At the very least, the pump must have a capacity equal to the largest single rate of use. Better yet, it must allow simultaneous rates of water usage. Finding the pumping rate requires thought and consideration.

The store system's pump capacity is not affected by usage rates, singularly or in combination. Instead, it is concerned only with equaling the total quantity of water that is used daily. However, storage must be sized to handle this amount of water, pipes must be sized for the use rates, and the energy source must be selected so that, at whatever rate, the pump will replenish the water. Fortunately, though the water is at times used at high rates, the pump has a 24-hour period in which to restock the water in storage for the next day.

**Energy versus pumping rates:** It could be argued that for deeper wells, the submersible pump is capable of handling the needs of a "store" system, whereas the piston pump cannot function in the "demand" system. This is a clever observation, yet it's flawed. Why use excessive amount of energy required to do a job quickly when there's normally lots of time to do it slowly. Nevertheless, it brings up an interesting point: There are times when it would be nice to have both pumping rates.

**Conclusions:** The inherent advantages and disadvantages of the submersible pump and the piston pump are as distinct as the differences between the deep-well systems they commonly serve—that is, the "demand" system and the "store" system, respectively. In a nutshell, we could say that the piston pump works best in situations where only low energy levels are available, high pressure (head) exists, and the water source has a low yield. Conversely, the submersible pump shines in situations where high flow rates are required, low head exists, and energy availability is not an issue. For shallow wells, these differences lessen. The piston pump can approach the highest pumping rate required for the household without suffering the submersible pump's wildly varying pump rates for the same water drawdown.

At this point, it will probably be helpful to look at some examples of commonplace water systems. Three major design concepts are reflected in the Gold, Silver, and Gold-Silver systems. The Gold system is based around the "store" theme of water system design, the Silver system around the "demand" theme, and the Gold-Silver system is a hybrid of the two.

We'll discuss these three water systems next issue in the final installment of this three-part series.

**(Some text and drawings in this article were taken from Waterworks: An Owner-Builder Guide to Rural Water Systems (Michael Hackleman, Peace Press, 1983, 172pp), The Homebuilt Wind-Generated Electricity Handbook (Michael Hackleman, Peace Press, 1975, 194pp), and At Home with Alternative Energy (Michael Hackleman, Peace Press, 1980, 146pp) For a publications list, send an SASE to: Michael Hackleman, P.O. Box 327, Willits, CA 95490.) Δ**