

*Engineering in Balanced farming.*

## ENGINEERING IN BALANCED FARMING

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### WATER PUMPING SYSTEMS FOR THE FARM

HAROLD E. STOVER, EXTENSION AGRICULTURIST  
KANSAS STATE COLLEGE  
MANHATTAN, KANSAS

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ELECTRIFICATION 6

I. Classes of Pumping Operation. There are three classes of pumps. 1. Lifting water by suction operation to the level of a pump located above the source. Such an example is the pitcher pump where the piston and cylinder are located at the discharge point.

2. Raising the water by forcing it to an elevation above a pump which is located in the source. An example of this class is the deep well pump where the piston and cylinder are located in the water and a mechanism located over the well to operate the piston thus raising the water above the cylinder to the surface or discharge point.

3. A combination of both suction and force in discharging water at a discharge point above the well. An example of this class is the pump with the cylinder down in the ground not over 22 feet above the water source. Thus suction lift would raise the water to the cylinder and force would raise it from there to the discharge point.

II. Shallow Well and Deep Well Operation. 1. Shallow well operating pumps are those in which the piston and cylinder or other type of pumping mechanism has a practical suction lift capacity of 22 feet or less. Water is lifted by a partial vacuum being created within a cylinder or housing and the atmospheric pressure of air within the soil lifts it that distance. For any additional elevation the water must be raised by a positive pressure, such as a pump or air pressure.

These pumps are used in pumping water from shallow wells, springs, lakes, and streams. Theoretically, the suction lift capacity at sea level is 34 feet, but in actual practice is found to be 22 feet for the average case. This value is further reduced 1 foot for each 1,000 feet of elevation above sea level.

The shallow well pump can be located directly over the water source or offset any distance from it just as long as the suction lift of elevation concerned is not exceeded. A pump for this type of operation normally has the pumping and driving mechanism built into one unit. It is low in initial cost, requires a minimum of space for installation and requires the least motor size for the gallons per hour rate desired. Figure 1 shows a cross section of a typical shallow well suction water lifting mechanism.

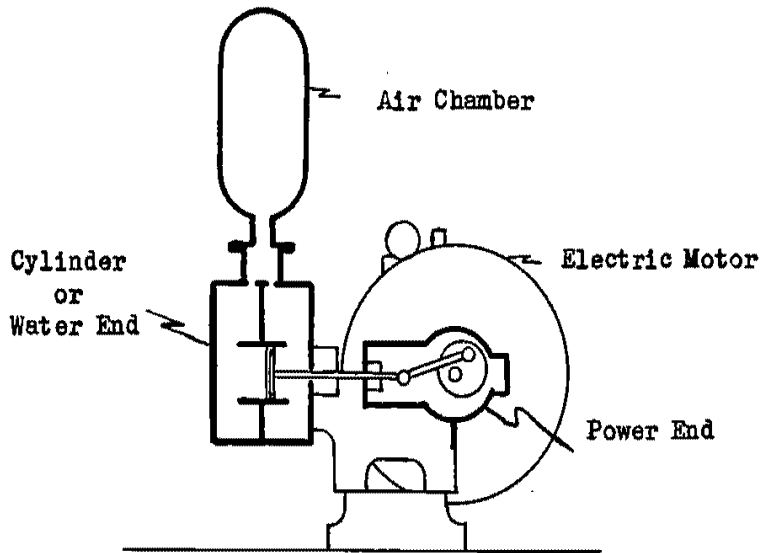


Fig. 1 - Shallow Well or Suction Pump

Some pumps have this mechanism operating in a horizontal position, others in a vertical position. Some pumps are single acting and others are double acting as Figure 2 indicates.

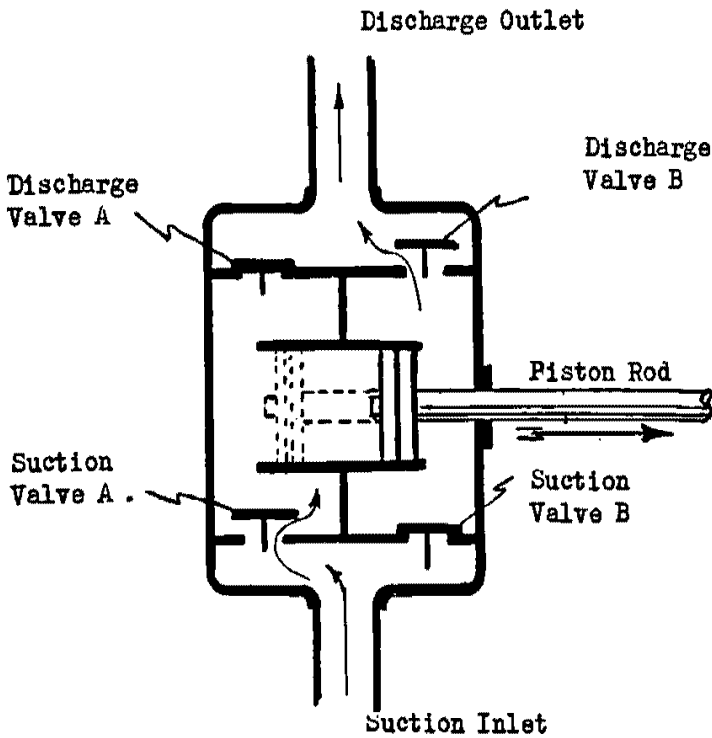


Fig. 2 - Water End or Pumping Mechanism  
Of a Shallow Well or Suction Pump  
Double Acting Pump

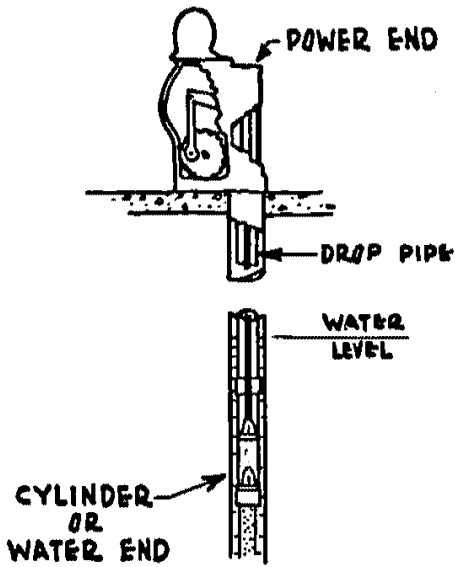


Fig. 3 - Deep Well Pump

2. Deep Well Operation: The deep well operating pump is one in which the driving mechanism (or power head) is separate from the pumping mechanism (or cylinder). The deep well operating pump must be located directly over the top of the water source, with the cylinder or pumping mechanism either submerged or within the suction lift (22 feet) of the water, as indicated in Figure 3. Due to the fact that the water table level changes at different seasons of the year it is best to have the cylinder in or very close to the water.

Figure 4 shows a typical deep well cylinder. This mechanism must be located in the drop pipe below the pumping head at the proper location such that water can be forced to the ground surface through the drop pipe.

The deep well principle of pumping can be used for pumping water from any depth, but generally is used where the lift is greater than 22 feet.

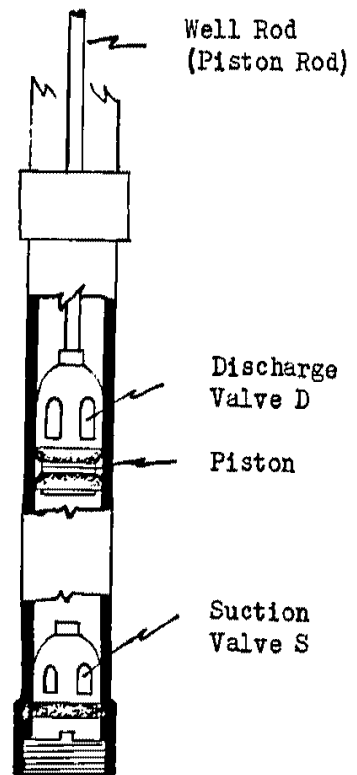


Fig. 4 - Single Acting Deep Well Cylinder

III. Types of Pumps. 1. Reciprocating Pump: This is a type in which a piston or plunger moves to and fro, either vertically or horizontally. A typical example of this pump is the kitchen pitcher pump. It may be located at any desired position as long as the vertical suction lift is not exceeded. A modern electric, shallow well, automatic, reciprocating pump is shown in Figure 5.

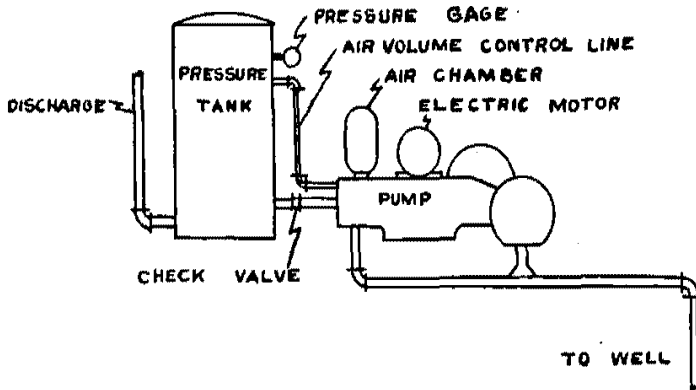


Fig. 5 - Automatic Reciprocating Type Shallow Well Pump

A deep well, reciprocating, automatic system is shown in Figure 6.

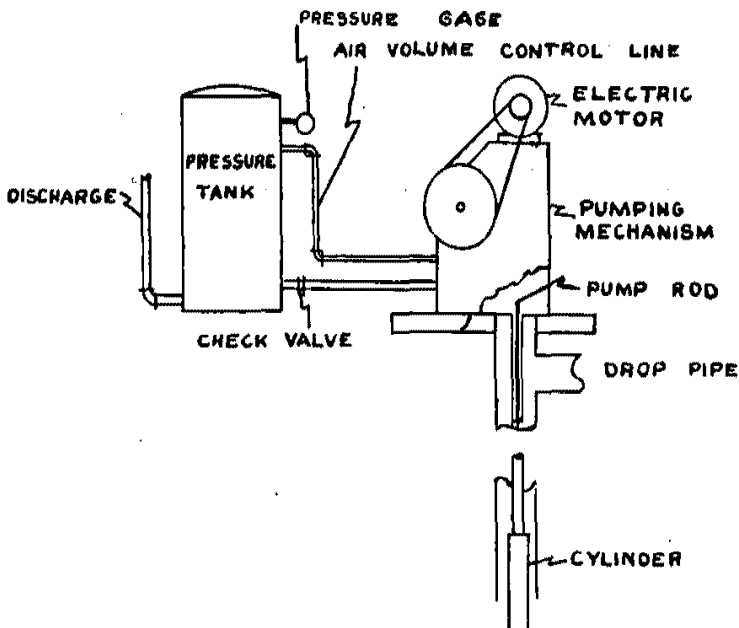


Fig. 6 - Electric Automatic Reciprocating Type Deep Well Water System

2. Centrifugal Pumps: This type pump is one in which an impeller operating on a shaft within a housing forces water to a discharge point by centrifugal action. The impeller is a device with many curved blades extending from a central shaft on which it is mounted. This impeller revolves at high speed within a specially designed housing. The water entering on one or both sides near the shaft is trapped between the blades and is thrown outward by centrifugal force so that it escapes from the discharge point under pressure. See Figure 7. The pump may be a single stage and consist of one unit, or multiple stage in which case several units are placed side by side to increase the pressure at the discharge point.

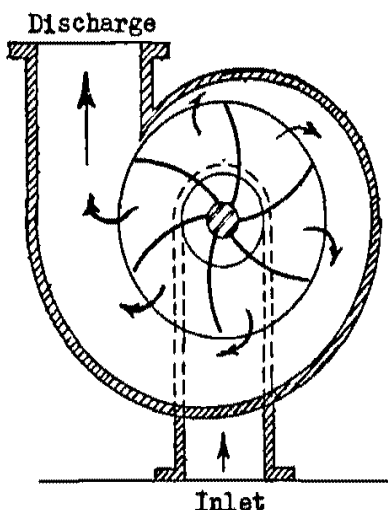


Fig. 7 - Centrifugal Pump

The centrifugal pump is very largely used in the equipment of buildings for water supply, pumping from streams, and sump and circulating pumps. They have also been developed for use in deep wells for irrigation purposes. The shaft is then operated in a vertical position and the pump is sufficiently small in diameter that it can be contained within the well casing. An electric motor can be used to operate these deep well centrifugal pumps very satisfactorily.

3. Turbine Pumps: The turbine is one of the simplest of all pumps. It is essentially a non-corrosive metal disk mounted on a drive shaft that revolves at high speed with a water-tight, close-fitting metal case. The disk has closely spaced impeller blades at the outer edge of it. The water enters the case at the outer edge, is picked up by the blades of the impeller and carried to the discharge opening. Close tolerances are required between impeller blades and housing so that water will be cleared from the suction to discharge side of the pump.

This type of pump is rapidly becoming more popular for irrigation purposes.

4. Rotary or Gear Pumps: The rotary pump is frequently called a gear pump. It is quite simple in design, but is subject to considerable wear, especially when the water contains an appreciable quantity of sand or other abrasive material. This type pump is used in many cases for pumping oil or liquids free from abrasives. Water enters at the bottom of the housing and is forced out at the outlet when the teeth of one gear mesh with those of the opposite one. See Figure 8. This pump delivers a steady flow of liquid without pulsation. It will operate against any pressure that the equipment will withstand.

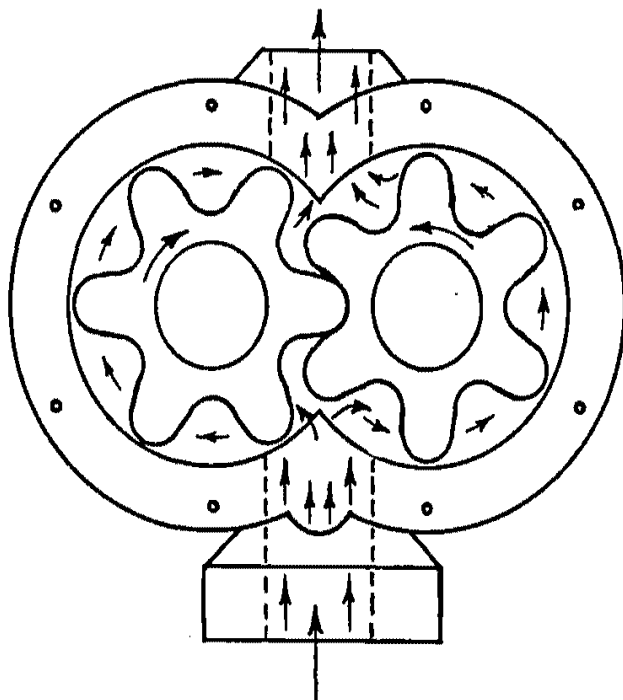


Fig. 8 - Rotary Pump

5. Ejector Operation Pumps: This principle of water lifting mechanism is relatively new as compared to all of the preceding methods of pumping. It is equipment that will operate for both shallow and deep well installations up to around 60 to 100 feet.

The ejector pumping operation consists generally of the same moving parts as the centrifugal or similar type pump, with an ejector or high velocity orifice inside a housing that is located adjacent to the pump for shallow wells and is located at or in the water for deep wells. Part of the water from the delivery side of the pump is piped down into the ejector assembly as shown in Figure 9. It is very similar to the manner in which live steam is used to force water into a steam boiler. Water flows in the directions indicated by the arrows. As the nozzle opening of the assembly becomes worn from abrasive materials and water passing through it, more water is used in the operation of the jet and hence it will need replacing when too large for efficient service.

The operation of the ejector principle is somewhat like the conventional hand fly spray. A centrifugal pump is substituted for the plunger and cylinder and a jet nozzle is substituted for the small spray tube. As the centrifugal pump operates, water under high pressure is delivered to the ejector nozzle within the ejector assembly housing. As this water at high velocity comes from the ejector nozzle and passes through the reduced area called the venturi tube, a partial vacuum is created around the nozzle within the housing. This partial vacuum permits water to flow from the source, if within the atmospheric lifting distance of water. The water passes the jet assembly and out through the expanded end of the venturi tube, where it is mixed with the water stream from the jet. As the venturi tube enlarges at the upper end, the velocity head changes to pressure head, which lifts the column of water in the pipe up to an elevation at which the partial vacuum created by the centrifugal pump at the top of the well can take effect. The centrifugal pump adds a pressure head to the water as it operates delivering some of the water to the storage tank or pressure tank and the balance of it is forced back to the jet to repeat the cycle.

This type of pumping operation has the advantage that the centrifugal pump need not be installed directly over the well. It can be offset several feet from the well, such as in the basement or other protected location and yet lift water from a deep well by means of the two pipes. The well casing should be sufficient in size to install two pipes as shown in the sketch. This type of pump has few moving parts, very little vibration and is simple in operation. Many operators throughout the rural area are finding this principle of pumping water very satisfactory up to about 85 feet of depth. Some pumps will operate a little over 100 feet, but generally require a special installation.

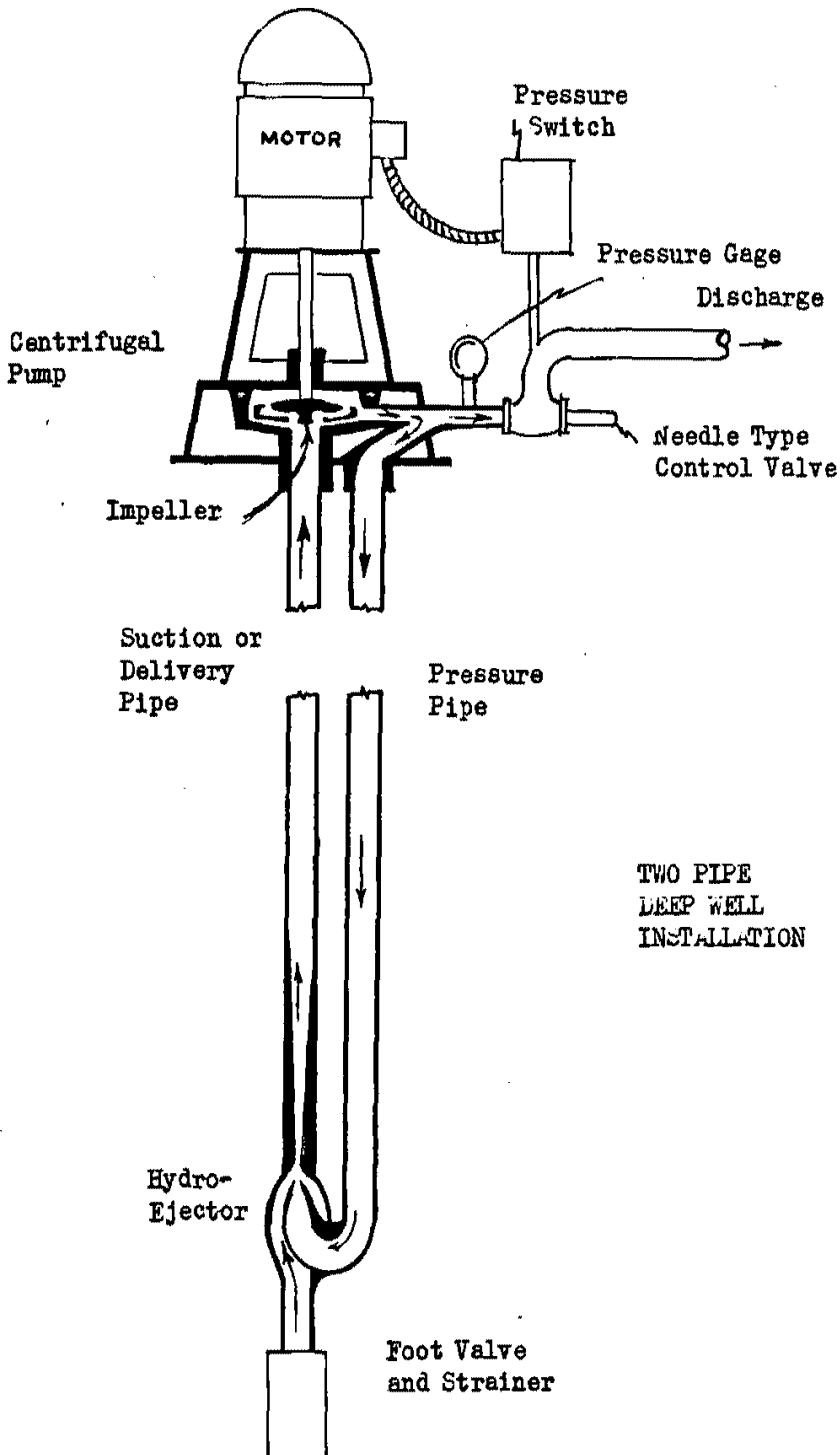


Fig. 9 - Ejector Type Pump



Selection of Pumping Equipment. 1. Determine the amount of water needed per day at the house and the barn and other buildings.

2. Next check the source of water supply. If there is a suitable source for both the house and other buildings, determine the amount of water available per hour of pumping rate. If there is not a sufficient quantity, other sources will have to be developed.

3. Next select the proper equipment for the existing conditions under which your pumping system must operate. If the water level in the well is within the shallow well suction lift, 22 feet total head including friction, any shallow well type pump can be used. If the total head is more than 22 feet, a deep well type of pump should be installed. Any of the deep well types previously explained can be used. If the maximum lift is over 80 - 100 feet, however, the ejector type pump is usually not recommended due to the lower efficiency. Normally the jet type pump is less efficient over 65 feet than the plunger type.

4. Pressure water system: This system consists of a water pump, electric motor or engine to operate the pump, a closed metal storage tank into which the water is pumped, and the necessary valves and switches. Any of the previously mentioned types of pumps may be used. For safe and best operation it should include in addition to the pump:

A. A closed rust and corrosion resistant tank capable of withstanding the necessary pressures for operating conditions together with the necessary pipe and fittings for connecting to the pump. A 42-gallon or larger size is recommended for normal daily operation. Where the well is sufficient in capacity for normal daily demands, a large storage tank is not needed. However, in many cases the water source is relatively slow or limited to a small rate of flow per unit of time, in this case a large storage tank to supply a day or two days requirements would be best.

B. An electric motor with an overload protection switch connected to it. The wiring to the electric motor should be installed so that in case of fire there would not be a failure of the pump due to the wires having shorted out in the circuit. An underground cable to the pump direct from the pole meter service would help prevent such a possibility.

C. An automatic pressure switch to automatically start and stop the motor at the pressure settings desired. Usually 20 pounds minimum and 40 pounds maximum are used.

D. An air volume control to automatically maintain the proper amount of air in the storage tank at all times.

E. A relief valve to protect the system against excess pressure with might damage it.

F. Pressure gage to indicate the pressure in the storage tank.

5. Gravity flow water system: This system permits water under pressure from elevated storage. An open storage tank is used instead of the closed pressure tank and must be located at high enough elevation to give the pressure desired.

An automatic float switch in the tank is used to start and stop motor instead of a pressure switch. The air volume control and pressure control is not necessary.

The open tank may be installed in the attic of the house, on a low and high ground elevation. An elevation of 2.3 feet is necessary for each foot of pressure desired in the water lines.

V. Typical Water Pump Installation. 1. Power requirements: The total net head or the head against which a pump operates, is the sum of three things: (1) the static head - the vertical distance or elevation in feet from the lowest water level in the well to the highest point in the discharge line; (2) friction loss in the pipe line; and (3) the pressure required at the end of the discharge line

A. Static head - The vertical distance between the lowest level of the water in the well and the highest point of delivery is fairly easy to determine. In case of an appreciable lowering of the water in the well during pumping operations, this increase in head or drawdown should be included.

B. Friction head - Much of the available pressure head is lost as water passes through pipes in overcoming frictional resistance of the pipe line and pumping equipment. The amount of power required to overcome this resistance depends upon the inside smoothness of the pipe, its length and diameter, the rate of flow of the water through the pipe, and the number of fittings and changes in direction encountered.

Table I

FRICITION OF WATER IN PIPES. LOSS OF HEAD IN FEET DUE TO FRICITION PER 100 FEET OF ORDINARY PIPE.								
Gallons Per Min.	1/2 inch pipe	3/4 inch pipe	1 inch pipe	1 1/4 inch pipe	1 1/2 inch pipe	2 inch pipe	2 1/2 inch pipe	3 inch pipe
1	2.1							
2	7.4	1.9						
3	15.8	4.1	1.3					
4	27.0	7.0	2.1	0.6	0.3			
5	41.0	10.5	3.3	0.8	0.4			
6		14.7	4.6	1.2	0.6	0.2		
7		19.6	6.2	1.6	0.7	0.3		
8		25.0	7.8	2.0	1.0	0.3	0.1	
9		30.8	9.7	2.5	1.2	0.4	0.1	
10		38.0	11.7	3.1	1.5	0.5	0.2	
15			24.1	6.5	3.0	1.1	0.4	
20			42.0	11.1	5.2	1.8	0.6	
25				16.6	7.8	2.7	0.9	
30				23.5	11.0	3.8	1.3	

FRICITION OF WATER IN 90 ELBOWS. EQUIVALENT NUMBER OF FEET STRAIGHT PIPE						
Size of elbow	1/2	3/4	1	1 1/4	1 1/2	2
Friction equivalent:						
straight pipe	5	6	6	8	8	

fr  
pt  
will

A smooth pipe interior can be secured by using a good quality pipe, by reaming the ends of all pipes to remove the burr incident to cutting, and by applying pipe "dope" to male threads only. Bends and elbows diminish the effective head. For this reason, sharp turns should be avoided. When turns are unavoidable, use long turn fittings. This will reduce the friction and lessen the danger of "water hammer". It is advisable to make liberal allowances for friction in pipes since, in time, pipes may partially fill up, thus offering greater resistance to the flow. The loss in head through the pipe varies directly as the length of pipe, inversely as the diameter, and directly as the the velocity squared. Small pipes call for high velocities and high velocities increase the friction loss. For example, it will be noted by referring to Table I that the available head loss due to forcing 5 gallons of water per minute through 100 feet of 3/4-inch pipe is 10.5 feet. If 1 1/4 inch pipe had been used, the loss in head would have been about one-twelfth as great. If the water had been forced through the 3/4-inch pipe at a rate of 10 gallons per minute instead of 5, the loss in head due to the doubled velocity would have been 38 feet, almost four times as much.

w  
m  
i

C. Pressure head - When force pumps are used to pump water into pressure tanks, the maximum pressure against which the water is forced must be considered in calculating power requirements.

When the air in a pressure tank is compressed, each pound of air pressure will lift water 2.3 feet; that is, it requires a column of water approximately 2.3 feet in height to produce a pressure of 1 pound per square inch. Thus, in the case of a pressure tank operating on a cut-out pressure of 40 pounds per square inch, the equivalent vertical lift is 40 times 2.3, or 92 feet. The vertical height in feet and equivalent pressures in pounds per square inch are given in Table II.

II

HEAD AND PRESSURE EQUIVALENTS

Pounds per square inch		Pounds per square foot		Pounds per square inch		Pounds per square foot	
Head	Feet	Head	Feet	Head	Feet	Head	Feet
1	2.3	8.66	1	2.31	15	34.63	
2	4.6	17.32	2	4.62	20	46.16	
3	6.9	25.99	3	6.93	25	57.72	
4	9.2	34.65	4	9.24	30	69.27	
5	11.5	43.31	5	11.54	35	80.81	
6	13.8	51.98	6	13.85	40	92.36	
7	16.1	60.64	7	16.16	45	103.90	
8	18.4	69.31	8	18.45	50	115.45	
9	20.7	77.97	9	20.78	55	126.99	
10	23.0	86.64	10	23.09	60	138.54	

V. Calculation of Power. The actual horsepower required is readily determined by the following simple method: Multiply the gallons pumped per minute by the total pumping head, and divide the product by 1,000. The result will give approximately the actual horsepower needed to lift the quantity of water. This is based on a 25 per cent mechanical efficiency of the pump. An example will show the use of the tables and principles involved.

What size of motor will be required to pump 5 gallons per minute well 40 feet to water into a hydropneumatic tank, which is at a vertical distance of 5 feet above the well curb. The well contains 10 feet of water which lowers 5 feet when pumped at the desired rate of 5 gallons per minute. The hydropneumatic tank operates between pressures of 20 to 40 pounds per square inch gage pressure. The water is to be conducted through 520 feet one-inch pipe and two 90° elbows. The static head is 50 feet, to which must be added the friction and pressure heads. The total length of pipe through which the water is conducted is 50 plus 520 equals 570 feet. The number of feet of straight pipe equivalent to two one-inch, 90° elbows is 12 feet. (Table I). This amount must be added to 570 feet. Hence, the total length of pipe to be considered in calculating the friction loss is 582 feet. Referring to Table I, it will be determined that the friction loss in feet of head per 100 feet of one-inch pipe, carrying water at five gallons-per-minute rate is 3.3. To find the friction loss for 582 feet, multiply 582 by 3.3 and divide by 100. The result is 19.20 feet, friction head. It is necessary to find the equivalent head in feet for 40 pounds pressure. Referring to Table II, it will be determined that 40 pounds per square inch pressure is equivalent to 92.36 feet of head.

The loss of head due to friction (19.20) plus the vertical lift (45) plus the five feet which the water lowers when pumping, plus the pressure (92.36) gives a total pumping head of approximately 162 feet. The horsepower required, according to the rule stated above, would equal 162 times 5, divided by 1,000, or .81 horsepower. This value is for an efficiency of 25 per cent.

VII. Make of Water Pumping System to Purchase. There are many first-class hydropneumatic water systems on the market, any one of which will give satisfactory service. The following general rules may be helpful as a guide for the purchase of a satisfactory system for the farm:

1. Buy a system manufactured by a reputable and well-known manufacturer.
2. Buy from a reliable dealer who is in a position to render adequate and prompt service.
3. Buy the type of system that is best suited to your own particular needs with respect to type and capacity of pump, type of power available, size of pressure tank, safety features, location requirements, etc.
4. Buy the system that will come the nearest to meeting all the preceding requirements and yet whose cost is not out of line with old line company prices.

VIII. Capacity of Pump to Install. If there is a sufficient supply of water available, a pump of from 500 to 600 gallon per hour is recommended. This size provides capacity for full household use, livestock use, some garden irrigation, and a reasonable capacity for some fire fighting purposes.

IX. Size of Pressure Tank for Full Automatic System. The average size pressure tank is 42 gallon. A larger one can be provided if greater storage is needed; however, one smaller than this is not recommended for average farm use. A small cistern pump could use a smaller tank. Too large a tank requires considerable space, and unless it is buried in the ground or otherwise protected from heat, the water within it may become quite stale. The tank should be made of material heavy enough to stand the maximum pressure to be used and preferable a non-corrosion type metal. It should also have a safety valve for protection against excessive pressures.

Trough	Trouble	Remedy
Pump starts stops frequently	Pressure tank may be water-logged.  Valves in pump may be leaking.  Switch diaphragm may be leaking.  Safety valve may be leaking.	Pump more air into tank by hand or with automatic air volume control.  Repair pump valves. If pump valves cannot be repaired, drill a small hole through the check in the check valve, and install a good foot or check valve on the lower end of the suction line.  Renew diaphragm.  Clean and adjust safety valve.
Pump runs for long periods of	Badly worn mechanism of pump such as leathers and valves.	Repair or buy a new pump.
Water leaks through air line	Air valve core not functioning.	Renew air valve core. On small pumps a special light spring is required in the core. An automobile valve may be too strong.
Air blows out through the faucets when the water flows	Too much air pressure in tank.	Reduce the amount of air being pumped into the tank by proper adjustment of the air volume control.
Pump well water stops	Tank water-logged or valves bad.	Repair air pump control or pump valves.
Pump runs for long periods of time	Pump badly worn.  Well pumped dry.	Repair or renew pumping mechanism.  Stop operation of pump until water supply is again available.
3. Water leaks out through air pump	Check valve between air pump and water line not functioning.	Repair air check.
Air blows out through faucets when opened	Too much air in tank.	Open relief valve on air pump or repair air volume control mechanism.