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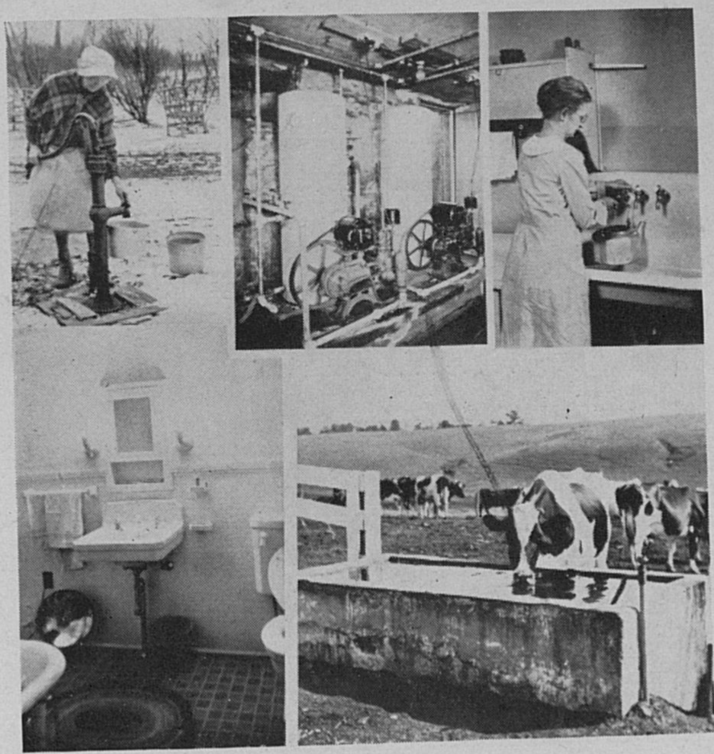
CIRCULAR NO. 319

ELECTRICALLY OPERATED WATER SYSTEMS FOR FARMS



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ELECTRICALLY OPERATED WATER SYSTEMS FOR FARMS

By J. B. BROOKS

Extension of rural electric lines in Kentucky has increased interest in the use of electricity for pumping water on the farm. This circular presents information which will be helpful in the selection and application of electrically operated water systems for farm use.

Conveniences that may be provided thru the use of a water system are:

A convenient water supply in the kitchen and bathroom.
A plentiful water supply for livestock.
Better sanitary arrangements for the dwelling.
A limited degree of fire protection.
Irrigation of vegetables and crops.

Advantages of electrically operated water systems over those driven by other forms of power are:

Automatic control.
Adaptability.
Safety.
Cleanliness.
Moderate initial cost.
Economy of operation.

THE COST OF PUMPING EQUIPMENT

The cost of an electric water system should be considered in terms of the conveniences provided thruout the life of the system. Thru proper care and operation, a pump and electric motor may be expected to last 15 to 20 years. Plumbing fixtures and piping have been known to last 40 to 50 years, depending upon the quality of materials from which they are made.

Pumps of 250 gallons per hour capacity, figure 2, for shallow wells, cisterns or springs where the water level at the source is not more than 22 feet below the pump, cost $60 to $70, complete with motor, 42-gallon tank and switches. Pumps of similar capacity, (figure 12), for wells where the lift exceeds 22 feet, cost from $140 to $190, motor, well cylinder, drop pipe and 42-gallon tank included. These prices differ in different localities and with different manufacturers. The cost of installation is not included.

The cost of piping can be determined after it is known where the water is to be pumped and the sizes of pipe that are to be used. The sizes of pipe may be calculated or this information may be obtained from pump manufacturers. Plumbing fixtures for the bathroom, kitchen and laundry differ in cost. Serviceable fixtures may be obtained at moderate prices.

If circumstances do not permit the installation of a water supply system for the entire farm, the system may be developed in units as finances permit. For instance, the first improvement may be a pump with water piped to the kitchen; later a bathroom may be added; and then water provided for livestock at other buildings. Future water requirements should be kept in mind when buying the pumping equipment.

COST OF OPERATION

The cost of pumping water varies according to the amount required, depth of well, pumping pressure, and the efficiency of the pumping equipment. Shallow-well outfits generally require 1 to 1½ kilowatt hours of electricity to pump 1000 gallons of water. Deep-well pumps use 1½ to 2 kilowatt hours in pumping the same amount.

By referring to table 1, the amount of water to be used on the farm can be determined; then the cost of pumping by electricity is found as in the following example:

5 persons at 35 gallons per day	175 gallons
4 horses at 12 gallons per day	48 gallons
30 sheep at 1 gallon per day	30 gallons
10 cows at 12 gallons per day	120 gallons
15 hogs at 2 gallons per day	30 gallons
200 chickens at 5 gallons per day per 100	10 gallons
Total daily requirement	413 gallons

That is, 413 gallons of water are required on this farm each day; therefore 12,390 gallons will be required per month. If a shallow-well pump is to be used which requires 1½ kw. hrs. of electricity to pump 1000 gallons of water, then 18½ kw. hrs. will be required to pump a month's supply. Assuming a charge of 6 cents per kw. hr. for electricity, the cost of pumping water for this farm would be $1.11 per month. With a good hand pump, it would take 31 hours to pump a month's supply for this farm. On this basis, a man's time is worth about 3½ cents an hour for pumping water.

SELECTING A WATER SUPPLY SYSTEM

Water Requirements. The quantity of water needed daily on the farm is an important factor to consider in determining the kind of water supply system that should be used. The amount of water required per day depends upon the number and kind of livestock, the number of persons, and sanitary arrangements provided (table 1). If the source is adequate, the use of water for livestock, sprinkling the lawn, and as a protection against fire should be considered in planning the system. The following table may be used in determining the average water requirement per day on a farm and the size of pump and storage tank that should be used.

Table 1. Average amount of water required for certain uses, per day.

Use		Gallons
If water is carried	per person	4 to 6
Pump at kitchen sink	do	6 to 8
Faucet at kitchen sink	do	10 to 15
Running hot and cold water in kitchen	do	15 to 20
Complete system in kitchen, bathroom, and laundry	do	30 to 40
One horse, mule or cow (drinking water)		10 to 12
One sheep or hog		1 to 2
100 chickens		3 to 5
Soaking the lawn, per 100 square feet		20
Lawn sprinkler	per hour	120
½-inch hose with nozzle, 20-40 pounds pressure	per hour	200
¾-inch hose with nozzle, 20-40 pounds pressure	per hour	300
Washing dairy barn and milk room floors and utensils	per cow	15

Source of Water. Electrically operated water systems may be used in pumping water from wells, springs, cisterns, farm reservoirs, or streams. Having determined the water requirement on the farm, a satisfactory and reliable source of water should be selected. In deciding upon a source, the purity of the water and the quantity that can be obtained are important factors to consider. The amount of water flowing from the source selected should be measured in gallons per minute, per hour, or per day. (To say that the source "furnishes enough water to fill a 3″ pipe" is no indication of flow, as the flow thru a pipe of a certain size depends upon the length and slope of the pipe.) The flow should be tested at a season when it is about average.

To find the flow of water in a well, a pumping test should be made, usually conducted for 12 to 24 hours. The flow of a spring may be determined by catching the water in a tub or other container.

The water from a spring or stream which has a small rate of flow may be piped to a reservoir which would collect a considerable amount of water, over a period of time. Often the flow of a spring can be improved by cleaning it out and building an enclosure of stone, brick, or concrete about it to prevent its getting filled with dirt and rubbish.

Table 2. Capacity of round cisterns or tanks and minimum square feet of horizontal roof area that must be drained into a cistern to fill it once in 4 months, based on average rainfall in Kentucky.

Depth feet	4 ft. diameter cap. gal.	Roof area square feet	6 ft. diameter cap. gal.	Roof area, square feet	8 ft. diameter cap. gal.	Roof area, square feet	10 ft. diameter cap. gal.	Roof area, square feet	12 ft. diameter cap. gal.	Roof area, square feet
4	376	67	846	150	1504	268	2350	418	3384	604
5	470	84	1058	187	1880	335	2938	522	4230	754
6	564	100	1269	226	2256	401	3525	628	5076	905
7	658	117	1481	265	2632	468	4113	732	5922	1054
8	752	134	1692	302	3008	535	4700	837	6768	1205
9	846	150	1904	338	3384	600	5288	941	7614	1355
10	940	167	2114	376	3760	670	5875	1046	8460	1506
11	1034	184	2327	415	4123	735	6463	1150	9306	1656
12	1128	200	2537	450	4512	804	7050	1252	10152	1810
14	1216	234	2962	530	5264	936	8226	1464	10844	2108
16	1504	268	3384	604	6016	1070	9400	1674	13536	2410
20	1880	334	4228	752	7520	1340	11750	2092	16920	3012

Twice the horizontal roof areas shown in this table would fill the cisterns once in 2 months, and 3 times the areas would fill the cisterns each month, except when drouths occur or during the late summer, when rainfall is below normal.

Where cisterns are the only source of water on the farm, it should be kept in mind that the quantity of water stored depends on their capacity and the area of the roofs that collect the water. Cisterns should be large enough to avoid a shortage of water during dry periods.

Table 2 shows the capacity of round storage tanks or cisterns and the number of square feet of horizontal area of the roof that must be guttered, in order to fill them at least once in four months, under average rainfall in Kentucky. In four months, approximately 5.6 gallons of water may be collected from each square foot of horizontal roof area. The horizontal roof area is equal to the product of the horizontal length and width of the roof at the eaves. The period of four months is used in preparing table 2 because most farmers prefer to fill the cisterns in the spring of the year, to last thruout the summer. Rainfall during late summer is below average. Moreover, it is often impractical to collect water from the many small rains that occur in summer, because roofs are dirty.

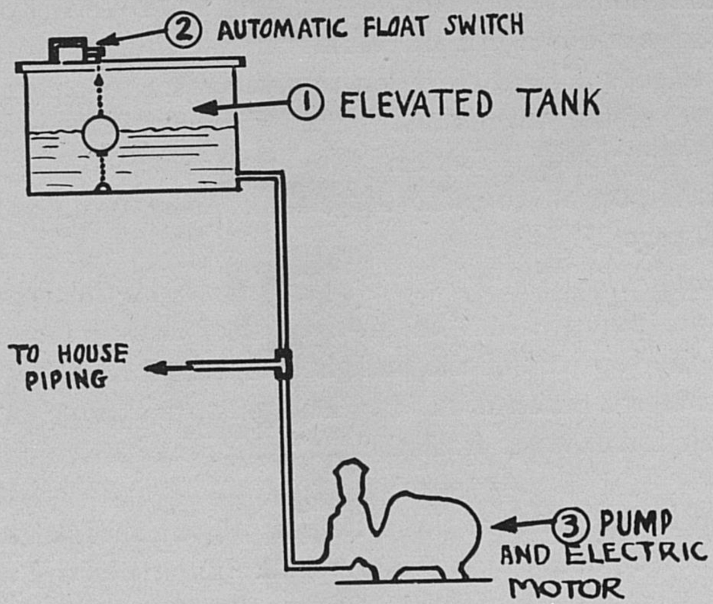


FIGURE 1. A typical gravity system.

TYPES OF WATER SUPPLY SYSTEMS

The gravity, the hydropneumatic, and the pneumatic water systems described below can be used to provide water under pressure. The type of system to use depends upon the quantity of water needed, the source of water, and other local conditions.

The Gravity System. In this system, water is pumped into a raised storage tank from which it flows by gravity to the various outlets. The principal parts of the system as illustrated in figure 1 are an elevated storage tank (1), an automatic float switch to start and stop the motor (2), a pump and electric motor (3).

The main advantage of the gravity system is that ample water may be stored by the use of a large storage tank to prevent a shortage during drouth or when an unusual amount of water is needed at once as in the case of a fire. A large storage tank also permits the use of a small pump where the flow of water at the source is small.

The disadvantages of the gravity system are: (1) water from a large elevated tank is warm in summer, (2) there is danger of the water in the tank freezing in winter, (3) heavy construction is required to support a large tank, (4) leaking and sweating of the tank may do serious damage if the tank is in a building, (5) it is often difficult to get sufficient elevation to give satisfactory pressure at all outlets, (6) if the tank is not properly covered, contamination of the water may occur. The first four disadvantages may be eliminated if it is possible to place the tank in the ground as shown in figure 23, page 25.

Hydropneumatic or Pressure-tank System. In this system, water and air are pumped into an air-tight steel tank. The air which occupies the top part of the tank is compressed as either more air or more water is pumped into it. The pressure exerted by the compressed air forces water from the tank thru the service pipes to the faucets.

The principal parts of this system as illustrated in figures 2 and 12, are a force pump (1), a pressure tank (2), an electric motor (3), an automatic pressure switch (4) to start and stop the motor at a predetermined pressure range, an air tube (5) thru which air is pumped into the tank with the water, an air-volume control (6) which automatically maintains the correct amount of air in the tank, a relief valve (7), which protects the system against excessive pressure, and a pressure gauge (8), indicating the pressure in the tank.

The advantages of the hydropneumatic system are: (1) a small, inexpensive storage tank may be used, (2) this tank may be located so that the water is cool in the summer, (3) the tank can be conveniently placed in the basement of the house, in a utility room or in a small pump house where it is protected against freezing, (4) frequent pumping, as occurs in this system, assures relatively fresh water, (5) ample pressure can be had to force water to outlets at some distance and height above the pump or tank. The disadvantages of this system are: (1) a large pressure storage tank

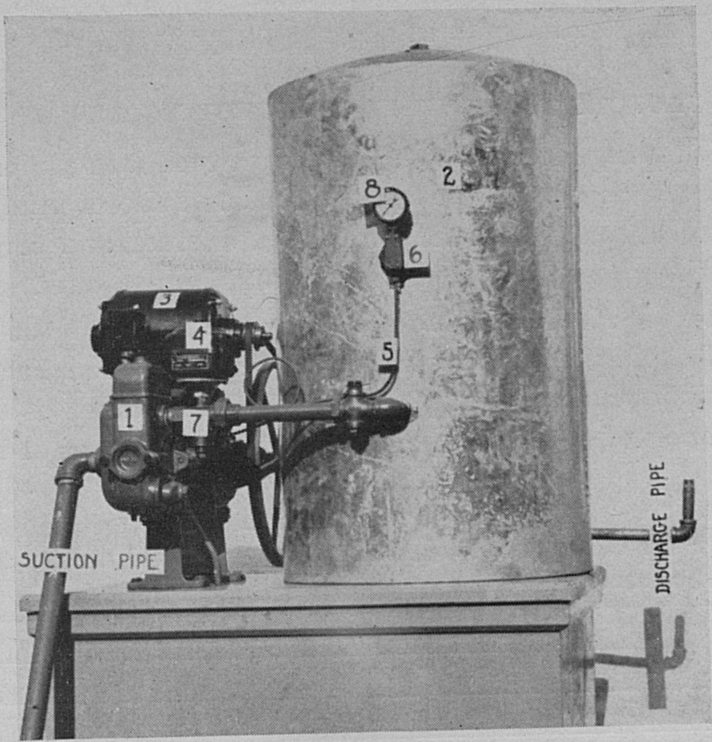


FIGURE 2. A typical hydropneumatic or pressure-tank system.

is expensive, (2) the cost of electrical energy for operation is slightly more than for the gravity system because of frequent starting and stopping of the motor.

Pneumatic or Air-lift System. Compressed air is used in this system to raise water directly from the well to the outlets. Compressed air is led thru a pipe down into the well into a submerged foot piece. The air lifts water by way of a vertical delivery pipe to the surface and to the outlets. The main advantages are durability, large capacity, fresh water supply, freedom from danger of freezing, and adaptability to drawing from a crooked well or from several widely separated wells, with one power unit. The disadvantages are high cost, low efficiency unless properly designed and installed, and the tendency of air to slip over the water where the horizontal discharge is great. This system should be installed by very competent workmen.

The essential parts of this system are (1) a motor, (2) an air compressor, (3) a compressed-air tank, (4) an automatic, air-operated pump submerged in the well, and (5) pipes, gages and fittings.

FACTORS TO CONSIDER IN SELECTING A PUMP

The following factors which differ with each installation should be considered, as they bear upon the type and size of pump to use, the pressure against which the pump must operate, and the location of the pump with respect to the source and storage tank.

Friction in Pipes. Friction, or the resistance of the interior surface of a pipe to the flow of water, depends upon five factors: (1) rate of flow, (2) length of the pipe, (3) diameter of the pipe, (4) roughness of the inside walls, and (5) the number of bends or

Table 3. Loss of head, due to friction, expressed as feet and as pounds pressure per 100 feet of ordinary straight pipe, and length of pipe which would have the same friction as an elbow.

Flow, gallons per minute	SIZE OF PIPE											
	½ inch		¾ inch		1 inch		1¼ inch		1½ inch		2 inch	
	Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft.	Lbs.	Ft,	Lbs,
2	7.4	3.2	1.9	.82								
3	15.8	6.85	4.1	1.78	1.26	.55						
4	27.0	11.7	7.0	3.04	2.14	.93	.57	.25	.26	.11		
5	41.0	17.8	10.5	4.56	3.25	1.41	.84	.36	.40	.17		
6			14.7	6.36	4.55	1.97	1.20	.52	.56	.24	.20	.086
8			25.0	10.8	7.8	3.38	2.03	.88	.95	.41	.33	.143
10			38.0	16.4	11.7	5.07	3.05	1.32	1.43	.62	.50	.216
12					16.4	7.10	4.3	1.86	2.01	.87	.70	.303
14					22.0	9.52	5.7	2.46	2.68	1.16	.94	.406
16					28.0	12.10	7.3	3.16	3.41	1.47	1.20	.520
18							9.1	3.94	4.24	1.83	1.49	.645
Feet of pipe equivalent to a 90-degree elbow	5		6		6		8		8		8	

sharp turns. From many experiments it has been found that: (1) friction increases as the rate of flow increases, (2) friction is proportional to the length of pipe, (3) friction decreases as the diameter of the pipe increases, (4) friction increases with roughness of the pipe, and (5) with the number of bends.

Table 3 shows, in feet and in pounds pressure, the loss of head due to friction, per 100 feet of ordinary pipe, when discharging given quantities of water. At the bottom of the table is given the number of feet of straight pipe which is equal in friction to a 90-degree elbow. Friction in other pipe fittings is considered the same as in elbows, except that it is 50 percent more in valves. For example, if water is flowing at the rate of 5 gallons a minute, thru a 1 inch pipe, 100 feet long, table 3 shows that loss from friction is 1.41 pounds pressure. But if there is an elbow in the pipe, it amounts to the same thing as adding 6 feet to the length of the pipe, making it 106 feet. Then 106 times the friction loss for 1 foot, from the table, $\frac{1.41}{100}$, gives 1.49 pounds, the friction loss in the pipe with one elbow.

Example 1. What pressure in pounds or feet of head will be required to overcome pipe friction if the flow is 5 gallons per minute thru a 1 inch pipe 200 feet long, having three 90-degree elbows?

From table 3, note that the friction loss in three 90-degree elbows is equivalent to that in 18 feet of 1 inch pipe (3 x 6′) and that the friction loss in 100 feet of 1″ pipe (5 gallons per minute flow) is 3.25 feet of head or 1.41 pounds pressure. Therefore the feet of head or pounds pressure required to overcome the friction loss in 200 feet of straight pipe and three 90-degree elbows would be

$$\frac{218 \times 3.25'}{100} = 7.08 \text{ feet of head, or } \frac{218 \times 1.41 \text{ lbs.}}{100} = 3.07 \text{ pounds pressure.}$$

Lift by Suction. In figures 4, 5 and 6, it is shown that the suction lift of a pump is dependent upon atmospheric pressure which actually forces water into the pump cylinder as the piston is raised. For each pound of pressure exerted by the atmosphere on the outside of the pipe in figures 5 and 6, water can be raised 2.31 feet. Therefore, if a perfect vacuum could be obtained inside a suction pipe, water could be raised about 34 feet at sea level where the atmospheric pressure is 14.7 pounds per square inch. With elevation above sea level there is a reduction in atmospheric pressure

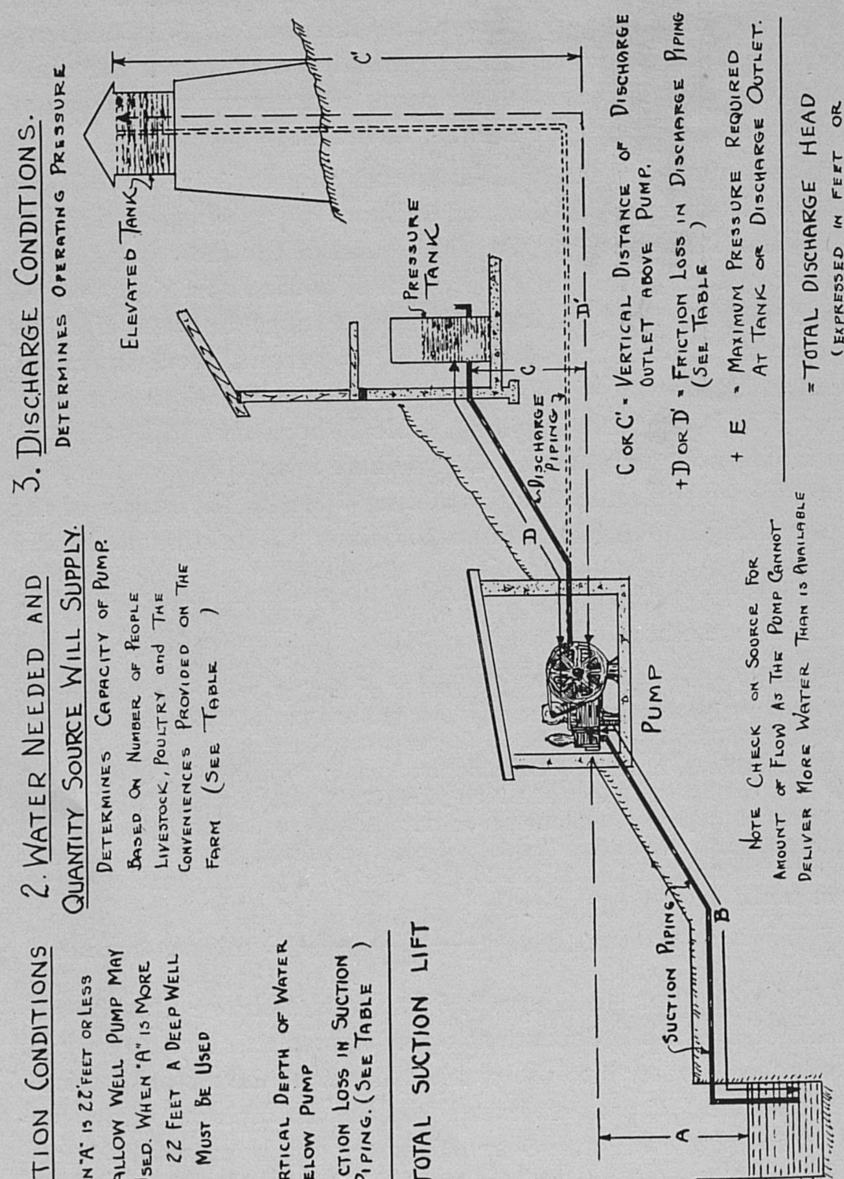
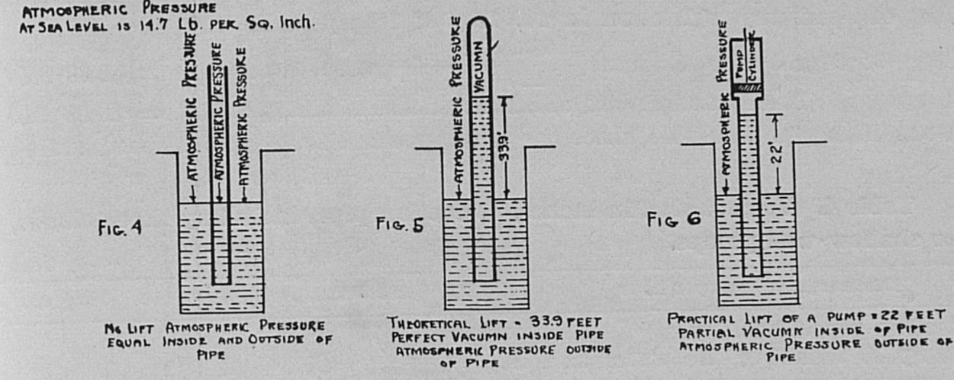


FIGURE 3. Factors to consider in selecting a pump.

and in the effective height to which water can be raised by suction. Under actual working conditions, it is found that the total suction lift of a pump is about 22 feet.



SUCTION LIFT OF A PUMP

Where the water level at the source is not more than 22 feet below the pump cylinder, pumps designed for shallow wells, as shown in figures 2 and 8, may be used. The total suction lift of 22 feet as used for shallow-well pumps includes the vertical height in feet of the pump above the water and the loss of head in feet due to pipe friction, figure 3.

Where the water level is below the practical suction lift (22 feet) of a pump, it is necessary to place the cylinder in the well as shown in figure 11. Usually the cylinder is submerged, increasing the efficiency of the pump and eliminating the necessity of priming.

The correct sizes of suction pipe for shallow-well pumps, where the horizontal and vertical distances from the water source to the pump, and the capacity of the pump are known, are given in table 4.

Example 2. Refer to figure 3. A shallow-well pump, capacity 300 gallons per hour, is to be used where the vertical distance (A) of the pump above the source is 16 feet, the pump is 100 feet from the source, and the suction pipe has three 90-degree elbows; what should be the size of the suction pipe so that the total suction lift will not be more than 22 feet, or within the limit of a shallow-well pump?

If a ¾″ pipe were used, the total suction lift would be:

Vertical distance (A) from source to pump .... = 16.00 feet

Friction head for 100 feet of ¾″ pipe and three 90-degree elbows = $\frac{118 \times 10.5 \text{ feet.}}{100}$ (See table 3.) .... = 12.39 feet

Total suction lift .... = 28.39 feet

FIGURE 3. Factors to consider in selecting a pump.

Since the suction lift is more than 22 feet, too great for a shallow-well pump, largely because of the friction in the ¾″ pipe, a larger pipe must be used.

If a 1″ pipe were used, the total suction lift would be:

Vertical distance (A) from source to pump .... = 16.00 feet

Loss of head due to friction in 100 feet of 1″ pipe and three 90-degree elbows equals $\frac{118 \times 3.25 \text{ feet.}}{100}$ (See table 3.).... = 3.83 feet

Total suction lift .... = 19.83 feet

A one-inch pipe would do, since the total suction lift does not exceed 22 feet.

Table 4. Correct size, in inches, of suction pipe, including three elbows, for shallow-well pumps.

Discharge, gallons per hour	180	250	300	350	400	450L	500	550	600
Suction pipe 50 ft. long,									
Pump 10 ft. above the water	¾	¾	¾	¾	1	1	1	1	1
Pump 15 ft. above the water	¾	1	1	1	1	1	1	1	1¼
Pump 20 ft. above the water	1	1	1¼	1¼	1¼	1¼	1¼	1½	1½
Pump 22 ft. above the water	1¼	2	2	2½	3	3	3	3	3
Suction pipe 100 ft. long,									
Pump 10 ft. above the water	¾	1	1	1	1	1	1	1	1
Pump 15 ft. above the water	¾	1	1	1	1¼	1¼	1¼	1¼	1¼
Pump 20 ft. above the water	1	1¼	1¼	1¼	1½	1½	1½	1½	1½
Pump 22 ft. above the water	1¼	2	2	2½	3	3	3	3	3'
Suction pipe 200 ft .long,									
Pump 10 ft. above the water	¾	1	1	1	1¼	1¼	1¼	1¼	1¼
Pump 15 ft. above the water	1	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼
Pump 20 ft. above the water	1¼	1¼	1¼	1½	1½	1½	2	2	2
Pump 22 ft. above the water	1¼	2	2	2½	3	3	3	3	3
Suction pipe 300 ft. long,									
Pump 10 ft. above the water	1	1	1	1¼	1¼	1¼	1¼	1¼	1¼
Pump 15 ft. above the water	1	1	1¼	1¼	1¼	1¼	1½	1½	1½
Pump 20 ft. above the water	1¼	1½	1½	1½	2	2	2	2	2
Pump 22 ft. above the water	1¼	2	2	2½	3	3	3	3	3
Suction pipe 400 ft. long,									
Pump 10 ft. above the water	1	1¼	1¼	1¼	1¼	1¼	1½	1½	1½
Pump 15 ft. above the water	1	1¼	1¼	1¼	1½	1½	1½	1½	1½
Pump 20 ft. above the water	1¼	1½	1½	2	2	2	2½	2½	2½
Pump 22 ft. above the water	1¼	2	2	2½	3	3	3	3	3
Suction pipe 500 ft. long,									
Pump 10 ft. above the water	1	1¼	1¼	1¼	1½	1½	1½	1½	1½
Pump 15 ft. above the water	1	1¼	1¼	1¼	1½	1½	2	2	2
Pump 20 ft. above the water	1¼	1½	2	2	2	2	2½	2½	2½
Pump 22 ft. above the water	1¼	2	2	2½	3	3	3	3	3

Capacity of Pump. The capacity or size of pump to use depends upon the present and future water requirements on the farm and the quantity of water the source supplies. If the source of supply is sufficient, a good rule is to figure on a total running time of two hours per day for the pump. Thus, if the daily requirement is 400 gallons, a pump with a capacity rating of approximately 200 gallons per hour would be required. If it is desired to have the added advantages of fire protection and lawn sprinkling, peak hourly demand must be determined as follows:

Average hourly requirements (400 gal. ÷ 24) .	=	17 gal. per hour
To supply 3/4″ hose with nozzle	=	300 gal. per hour
Peak demand	=	317 gal. per hour

The 200 gallon per hour pump would not be large enough to supply the amount of water required during periods of peak demand. A pump of approximately 320 gallons per hour capacity is required. The larger pump would cost more while running, yet it would not run so long nor so often as the smaller pump. If the source is adequate, the additional cost of the larger pump may be justified by the fire protection provided, the longer life of the pump, and the ability to meet an increased demand for water.

It is important to measure the flow of the source to see if it will furnish plenty of water for the pump when operating at maximum capacity. If the source is a spring or small stream in which the flow is small, a reservoir may be required to accumulate the necessary water supply for the pump. In a well of small flow, a pump of small capacity may be used in connection with a large pressure or gravity tank.

Discharge Head. An electrically operated water system, except the air-lift system, requires a force pump which forces the water to a height above the cylinder. The greater the elevation of the discharge outlet above the pump, the greater the pressure required (see table 5). The pressure against which a pump must operate depends upon the vertical distance of the discharge outlet above the pump cylinder, the frictional loss in the discharge pipe and the maximum pressure required at the tank or outlet (see figure 3 and tables 3 and 5).

Table 5. Vertical height in feet and equivalent pressure in pounds per square inch.

Height feet	Pressure pounds	Height feet	Pressure pounds	Height feet	Pressure pounds	Height feet	Pressure pounds
1	0.43	20	8.67	75	32.51	160	69.31
2	.87	25	10.84	80	34.68	170	73.64
3	1.30	30	13.00	85	36.85	180	77.97
4	1.73	35	15.17	90	39.01	190	82.30
5	2.17	40	17.34	95	41.18	200	86.63
6	2.60	45	19.51	100	43.35	220	95.23
7	3.03	10	21.67	110	47.68	240	104.32
8	3.47	55	23.84	120	52.02	260	112.55
9	3.90	60	26.01	130	56.36	280	121.21
10	4.33	65	28.18	140	60.69	300	129.90
15	6.50	70	30.35	150	65.03	350	151.55

Example 3 (see figure 3). What will the total discharge head be in pounds pressure when pumping 300 gallons of water per hour thru 200 feet of 1-inch pipe where the vertical distance (C) of the tank above the pump is 10 feet, a 40-pound tank pressure is desired, and there are two 90-degree elbows in the pipe line?

Vertical elevation, 10.00 feet (see table 5) .... = 4.33 pounds

Friction loss in discharge pipe, 200 ft. of 1″ pipe and two elbows (12 ft.) .... $\frac{212 \times 1.97 \text{ lbs.}}{100}$ = 4.17 pounds

Pressure wanted in the tank .... 40.00 pounds

Total discharge head, ... 48.50 pounds

TYPE OF PUMP

Pumps commonly used on farms are of two main types classified according to their design and operation.

Centrifugal Pumps, as illustrated by figures 7 and 8, may be used in pumping water from shallow or deep wells. Centrifugal pumps are efficient and their operation is not seriously affected by dirt or fine sand in the water. They are most efficient in pumping large quantities of water against relatively low pressure. The suction lift of this type of pump is generally considered to be about

15 feet, while satisfactory performance under higher lifts up to 22 feet are possible by the use of specially designed pumps.

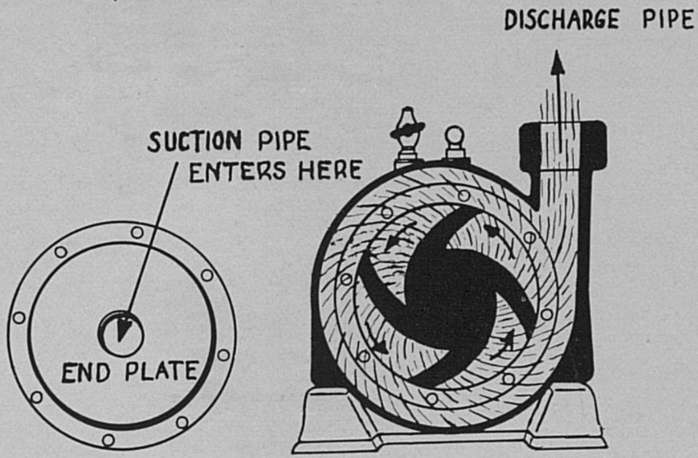


FIGURE 7. Centrifugal pump with end plate removed.

A deep-well centrifugal turbine type cylinder pump is shown in figure 9. It is used for farm water systems where larger quantities are required than are needed for the average farm.

FIGURE 8. A centrifugal pump for shallow-well operation. 1. Suction pipe connection. 2. Discharge pipe connection.

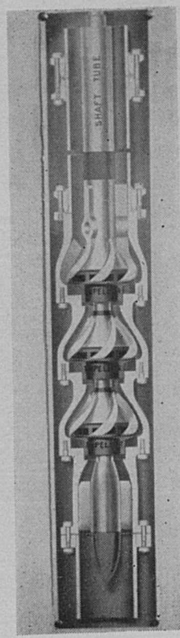


FIGURE 9. A centrifugal turbine type pump cylinder for deep-well operation.

Reciprocating Pumps, Plunger Type, as illustrated in figure 10 and 11, operate on the same principle as the pitcher, spout, and hand force pumps found on many farms. A piston operating in a cylinder, either horizontal or vertical, draws and discharges water on both strokes. This type of pump is used for either shallow or

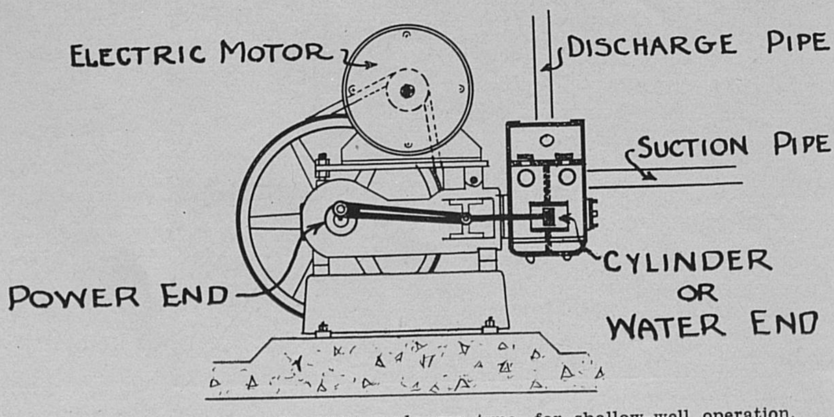


FIGURE 10. Reciprocating pump, plunger type, for shallow-well operation.

deep sources. The suction lift should not be more than 22 feet. For deep-well operation, the cylinder is placed in the well, as shown in figure 11. The working head is shown in figure 12.

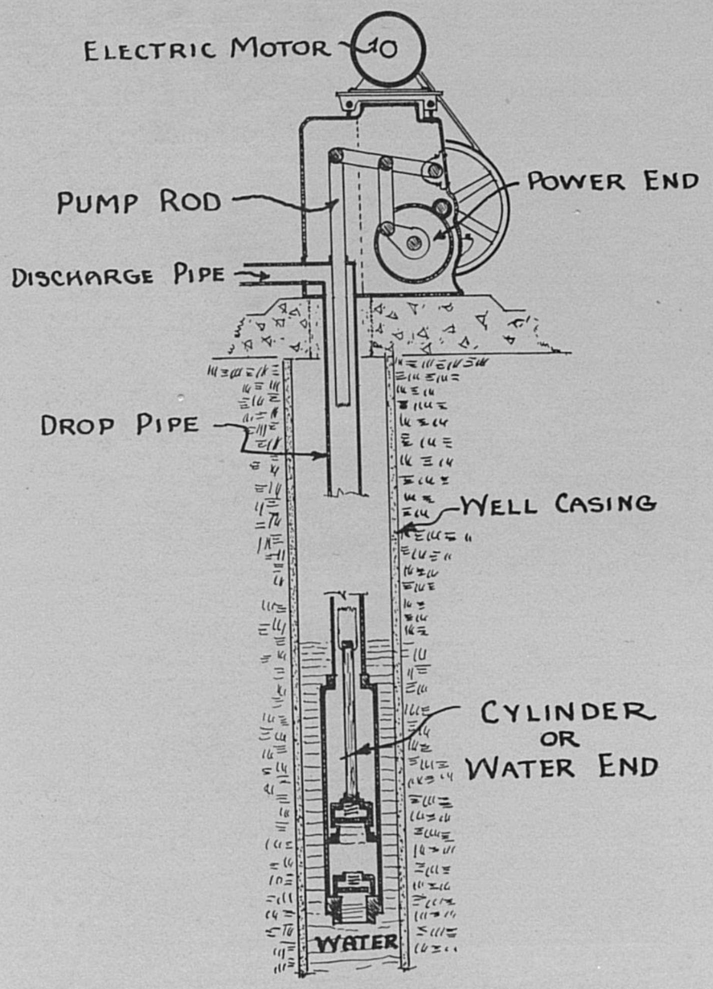


FIGURE 11. Reciprocating, plunger type, pump for deep-well operation.

Shallow-well pumps which operate against a maximum pressure of 45 to 50 pounds are equipped with electric motors of various sizes, depending upon the rated capacity of the pump in gallons per hour. This low-pressure pump is used where the source is fairly close to the buildings to be served.

The capacity of shallow-well pumps for higher than 50 pounds pressure varies according to speed of operation. These pumps are equipped with the proper sizes of motors to work against pressures ranging from 50 to over 350 pounds.

Reciprocating deep-well pumps are operated at various standard strokes and at fixed speeds. The capacity at a given speed is dependent upon the size of cylinder and length of stroke of piston. The horsepower requirements for different pressures and capacities are taken care of by the use of motors of different sizes.

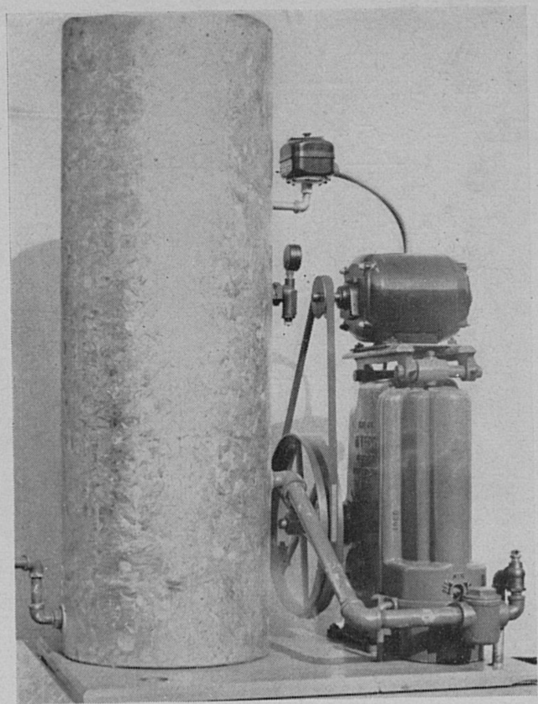


FIGURE 12. Tank and working head for reciprocating type deep-well pump. See also figure 11.

TYPICAL PUMP INSTALLATIONS

For Shallow Wells. Pumps designed for shallow-well operation are used for pumping water from cisterns, springs and reservoirs where the water level at the source is not more than 22 feet below the pump cylinder. The four common methods of placing shallow-well pumps are: (1) *Pump near source; elevated storage tank* (*figure* 13). In this type of installation the pressure against which the pump operates equals the pressure of a column of water as high as the elevation of the discharge outlet above the pump, plus the friction loss in the discharge pipe. Water flows by gravity from the tank to the faucets.

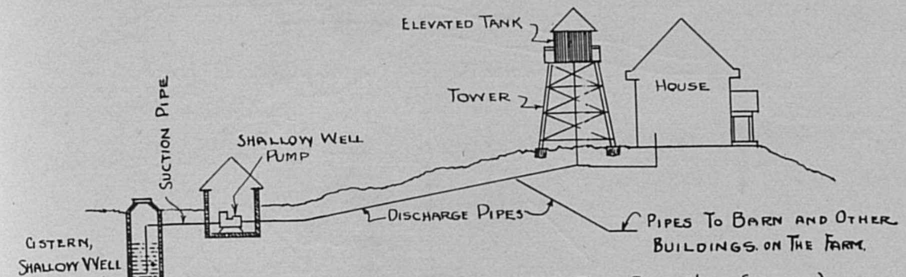


FIG 13 GRAVITY SYSTEM (ELEVATED TANK PUMP NEAR SOURCE)

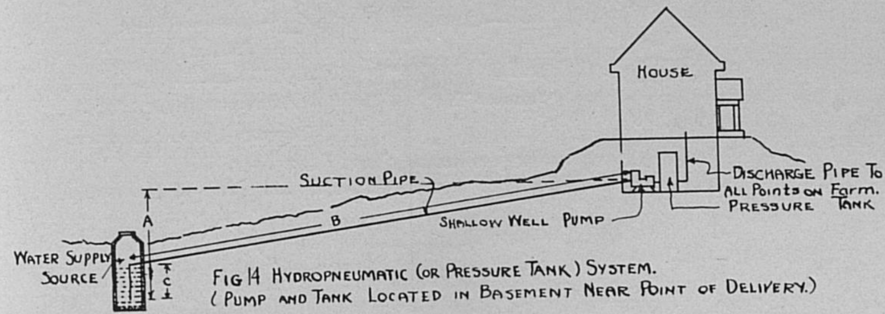


FIG 14 HYDROPNEUMATIC (OR PRESSURE TANK) SYSTEM.
(PUMP AND TANK LOCATED IN BASEMENT NEAR POINT OF DELIVERY.)

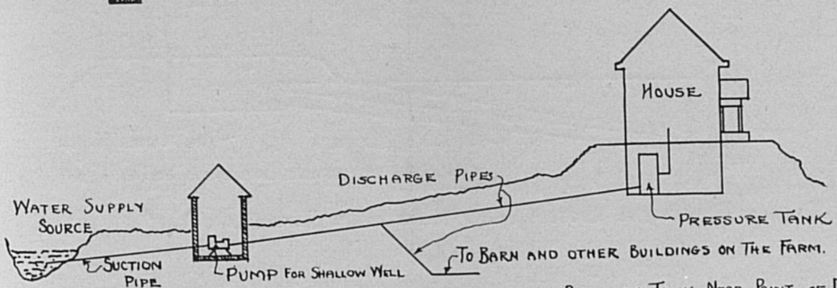


FIG 15 HYDROPNEUMATIC SYSTEM, (PUMP NEAR SOURCE - PRESSURE TANK NEAR POINT OF DELIVERY.)

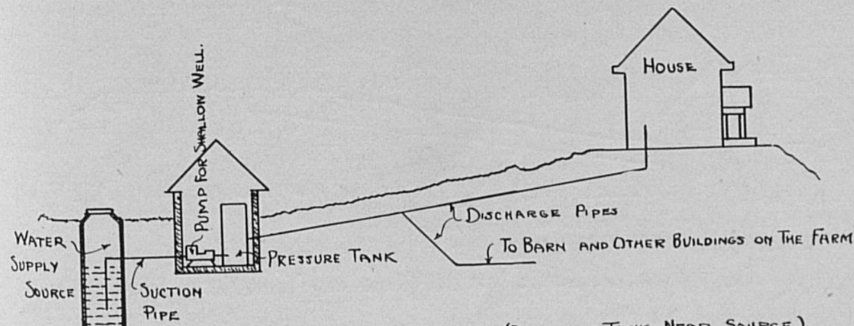


FIG 16 HYDROPNEUMATIC SYSTEM - (PUMP AND TANK NEAR SOURCE)

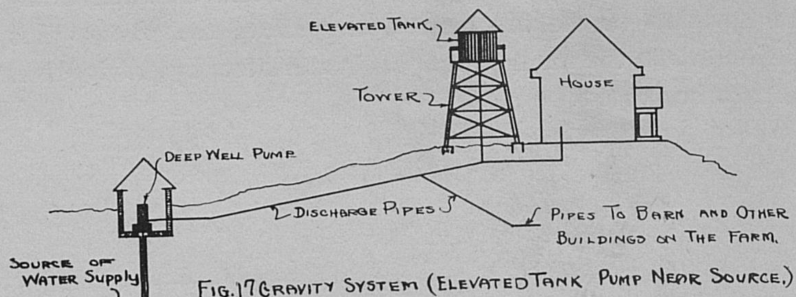
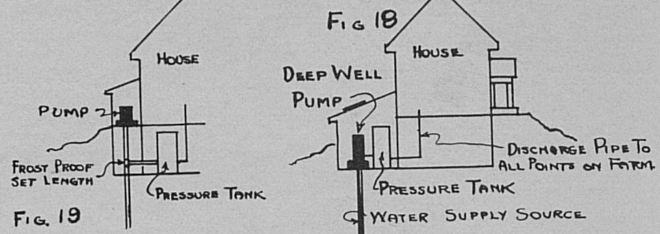


Fig. 17 Gravity System (Elevated Tank Pump Near Source.)



Hydropneumatic (or Pressure Tank) Systems
(Pump and Tank Located Near Source and Point of Delivery)

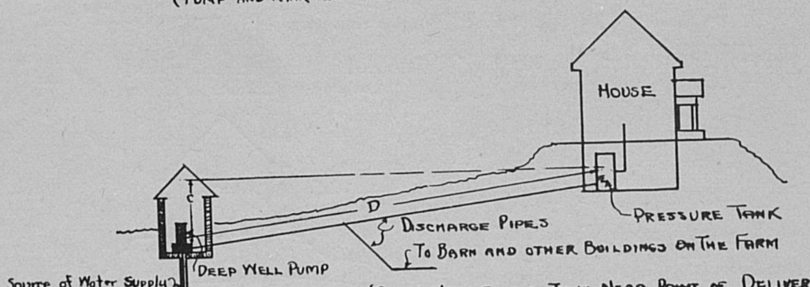


Fig. 20 Hydro-pneumatic System (Pump Near Source Tank Near Point of Delivery).

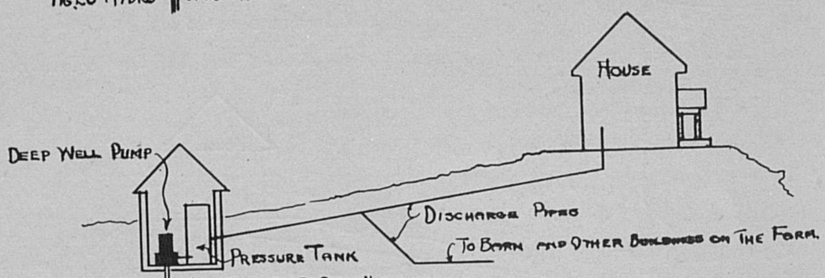


Fig. 21 Hydropneumatic System -(Pump and Tank Near Source).

(2) *Pump and tank near point of delivery (figure 14).* This type of installation is recommended where the vertical suction lift plus the friction loss in the suction pipe does not exceed 22 feet. Usually, the pump and tank are placed in the basement of the house.

(3) *Pump at source of supply; tank at point of delivery (figure 15).* In this type of installation the pump operates under higher pressure than is shown on the pressure gage in the tank. The automatic pressure switch gives best results when placed on the tank rather than in the discharge line near the pump, since pulsations (or water hammer) occur in the discharge line and the smooth operation of the device is not possible. A special air chamber and check valve placed in the discharge line near the pump would partially overcome this trouble; then the pressure switch may be placed on the air chamber. In this type of installation, the automatic air control device shown in figure 2 could not be used.

(4) *Pump and tank near source of supply (figure* 16). In this case, the pump and tank are housed in a separate building near the source. The total suction lift should not exceed 22 feet. Careful consideration must also be given to the height to which the water must be raised. Pressure maintained in the tank must be sufficient to overcome pipe friction in the discharge lines and force the necessary flow at the required pressure to the various outlets.

For Deep Wells. Deep-well pumps must be placed directly over the well, as shown in figure 11. The tank may be placed near the pump or at a distance. If the well is within a few feet of the house, the most satisfactory location for the pump and tank is in a frost-proof annex to the basement, figure 18. In figure 19 another arrangement is shown for a well just outside the house in which an anti-freezing device called a frost-set-length permits the discharge to be placed below the frost line and the pump in the upper part of an annex where moisture cannot injure the motor. If the well is not near the house, the pump and tank may be placed in a frost-proof pit as shown in figure 21. If a large pressure tank is used, it may be buried horizontally in the ground with its end extended into the pit, in order to save space and permit the use of a smaller pit. If the pump and tank are not close together (see figures 17 and

20), a check valve and air chamber should be placed in the discharge line near the pump to reduce the pulsations from the pump. The pressure switch is attached to the air chamber or to the pressure tank.

Pump Jacks for Hand Pumps Already in Place. If a good hand force pump is already in the well, a pump jack with electric motor as shown in figure 22 is one of the cheapest and most practical ways of using electric power for pumping water. The motor may be portable or stationary. If the motor is stationary, it should be amply protected against the weather.

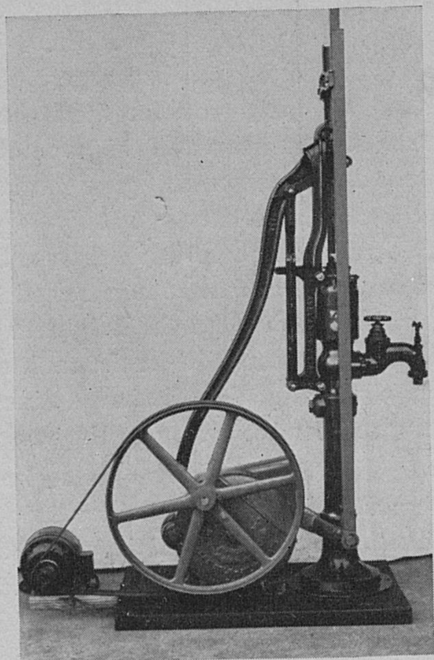


FIGURE 22. Hand pump operated with pump jack and electric motor.

STORAGE TANKS

For the Gravity System. Elevated tanks are built of concrete, brick, wood or steel. If a hill of sufficient elevation is near the house, the tank may be placed on it, figure 23. A tank of concrete or brick, on a good foundation, a few feet below the ground level, is more secure than one on a tower. Water in such a tank remains cool in summer and does not freeze in winter, and the pipes are protected against freezing by being under ground. A tank of wood or steel usually is placed on a tower or in the attic of a building, above the highest faucet in the water system. Objections to placing the tank in the attic or on a tower are leakage, sweating of the walls, insecurity, and that the water is warm in summer and may freeze in winter.

The size of a storage tank for the gravity system depends upon the water requirement, the water flow at source, and how often the water is to be pumped. It is well to consider a tank large enough to provide for unusual demands such as for sprinkling the lawn and protection in case of fire. Generally a tank large enough to hold a week's supply is recommended.

FIGURE 23. Concrete gravity tank on a hill near and slightly above the buildings to be supplied. It should be covered to keep out dirt and birds.

If the rate of flow of water at the source is such that a pump of small capacity must be used and if the flow is affected by drouth, it is advisable to provide a storage tank of large capacity. Some farmers, under these conditions, build a tank large enough to hold a two-months' supply. The capacities of round storage tanks are given in table 1.

For the Hydropneumatic System. This system, with automatic control, requires only a small pressure storage tank. In one type of installation, water is pumped direct from the source to the faucet without the use of a tank. Whenever a faucet is opened, the electric motor automatically starts the pump. In this case, the pump must be large enough to supply all the water required at any one time.

The disadvantages of this type of installation are the frequent starting and stopping of motor and pump, and the lack of storage.

Generally it is desirable to have a storage tank of such size that the system is not entirely dependent on the pump capacity to meet the usual water requirements. The size of pressure tank to use for the hydropneumatic system depends upon the flow of water at the source, size of pump, and the greatest demand for water that is likely to occur as in the case of a fire or lawn sprinkling. If the source is small in flow or a small pump is used and the demand

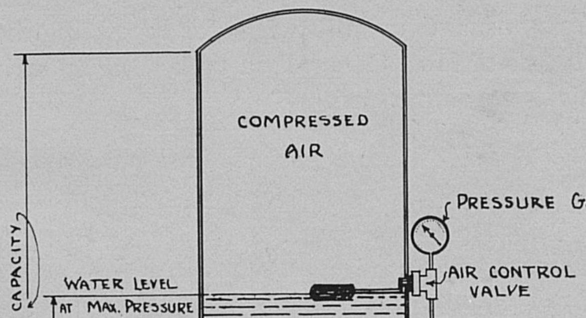


FIGURE 24. Hydropneumatic or pressure tank.

is large, a storage tank of size to allow for a reserve supply is desirable. In general, the working capacity of a pressure tank is from $^1/_4$ to $^1/_3$ of its total volume (figure 24). About $8^1/_2$ to 10 gallons may be drawn from a 42-gallon tank between stopping of the pump at 40 lbs. and starting again at 20 lbs. pressure. This is known as the working capacity of the 42-gallon tank.

The control apparatus for the hydropneumatic or pressure-tank system is usually set so that the motor and pump start when the pressure drops to 20 pounds in the tank and stop when the pressure reaches 40 to 45 pounds. The control apparatus should not be set for pressure above that recommended by the manufacturer. Figure 24 shows a pressure tank with control apparatus. The walls of a pressure tank are made of steel of thickness depending upon the working pressure that is to be maintained. Range boilers or other thin-walled tanks should not be used.

ELECTRIC MOTORS FOR WATER SYSTEMS

The advantages gained thru the use of electricity as compared with other sources of power are as follows:

1. Electric current supplied by the central stations is a cheap and convenient source of power.
2. The electric motor lends itself to automatic and dependable operation, requiring very little care, other than oiling. It is not likely to need oiling oftener than once in 6 months.
3. The electric motor does not require the use of inflammable fuel and gives off no objectionable or dangerous fumes.

Electric motors are designed for operation at standard voltages from direct or alternating current. Alternating current is usually furnished by central-station plants and direct current by individual lighting plants. Always specify the type, voltage, cycle and phase of current available, when buying a motor. Standard water systems are usually provided with 110-220-volt, alternating current 60-cycle, single-phase motors.

The motor should be one that is capable of starting and operating against a heavy load. The speed should be fairly constant for different loads. On a single-phase alternating-current power line, a repulsion induction motor should be used. If the current is three phase, a wound rotor type of induction motor is most suitable, particularly for the larger systems. For small units operating on a three-phase current, a squirrel-cage type induction motor is satisfactory. A compound motor is used with direct current. The ordinary 32-volt farm lighting plant generally supplies up to ¼ horsepower. When more power is desired the use of the farm plant is not generally recommended.

Electric motors must be properly wired and supplied with ample voltage if they are to operate efficiently. A motor of $^1/_3$ horsepower or larger should be used on a 220-volt circuit, if possible, for most efficient operation. The motor wiring should be separate from the lighting circuit in all cases. A cut-off switch should be placed in the line close to the pump in order that repairs or inspection of the system can be made when necessary. The wiring should be done in accordance with local codes and inspected for safety by a reliable inspector. Diagrams and instructions for wiring electric motors are usually furnished by manufacturers of electrically operated systems.

The power rating of a motor required for the water system depends upon the capacity of the pump, the pressure against which it is to operate and the efficiency of the pumping equipment. The theoretical horsepower required to pump water is found by multiplying the gallons pumped in one minute by the total lift in feet, including suction lift, discharge head, and pipe friction, and dividing the product by 4000. Formula:

$$\frac{\text{Gallons per minute x total lift in feet}}{4000} = \text{theoretical horsepower.}$$

To overcome the losses in the pumping equipment, the theoretical horsepower as computed is generally multiplied by 2 for a shallow-well pump or by 3 for a deep-well pump, to determine the actual horsepower requirement. Table 6 shows the theoretical horsepower required to pump water where the total lift and pump capacity are

Table 6. Theoretical horsepower required to pump water.

Gallons per minute	2	3	4	5	6	7	8	9	10
Total lift, feet*	Horsepower								
50	.02	.03	.05	.06	.07	.08	.10	.11	.12
60	.03	.04	.06	.07	.09	.10	.12	.13	.15
70	.03	.05	.07	.08	.10	.12	.14	.15	.17
80	.04	.06	.08	.10	.12	.14	.16	.18	.20
90	.04	.06	.09	.11	.13	.15	.18	.20	.22
100	.05	.07	.10	.12	.15	.17	.20	.22	.25
125	.06	.09	.12	.15	.18	.22	.25	.28	.31
150	.07	.11	.15	.18	.22	.26	.30	.33	.37
175	.08	.13	.17	.22	.26	.30	.35	.37	.43
200	.10	.15	.20	.25	.30	.35	.40	.45	.50

* Total lift in feet includes suction lift, discharge head and pipe friction.

known. It is safest to get the advice of a reliable pump dealer before deciding upon the size of motor to use. The pounds of pressure to be maintained in the tank should be converted to equivalent feet of head, table 5, and added to the total lift of the pump. Forty (40) pounds maximum pressure is generally considered satisfactory for common uses on the farm, if the tank is near the point of delivery or faucets.

Example 4. From the suction and discharge conditions as found in examples 2 and 3, pages 13 and 16, estimate the size of electric motor required to operate the 300-gallon-per-hour pump. Assume that the 1 inch suction pipe is used and that low water level at the source is 16 feet below the pump, as in example 2.

From example 2. Vertical distance of water level below pump	=	16.00 ft.
Loss of head due to friction in suction pipe	=	3.83 ft.
Total suction lift	=	19.83 ft.
From example 3. Vertical distance of tank above pump	=	10.00 ft.
Loss of head due to friction in discharge pipe	=	9.64 ft.
Tank pressure in equivalent feet of head	=	92.00 ft.
Total discharge head	=	111.64 ft.
Total lift = suction lift + discharge head = 19.83 ft. + 111.64 ft.	=	131.47 ft.

From page 28.

$$\text{Theoretical horsepower} = \frac{5 \text{ (gallons per min.)} \times 131.47 \text{ (feet lift)}}{4000} = .164$$

Theoretical horsepower × 2 = .33 horsepower actually required, based on 50 percent mechanical efficiency of the pumping equipment. Under these conditions, a one-third horsepower motor might be satisfactory, but since a slight reserve of power is desirable a ½ horsepower motor should be used.

Example 5. From a well 100 feet deep it is desired to pump water 20 feet above the pump to a pressure tank located 200 feet away. A maximum pressure of 40 pounds is to be maintained in the tank. A 2½ inch drop pipe and 1¼ inch discharge pipe are used. The capacity of the pump is 6 gallons per minute or 360 gallons per hour. Find the size of motor required to operate the pump. 40 lbs. tank pressure × 2.3 = 92.0 feet head. 100 feet + 20 feet = 120 feet vertical elevation of discharge outlet above water level at the source. By referring to table 3 note that with a flow of 6 gallons per minute thru the 2½ inch drop pipe friction is negligible. With the same flow thru a 1¼ inch pipe there is a loss of 1.20 feet of head due to friction for each 100 feet of pipe. Therefore in 200 feet of 1¼ inch discharge pipe the loss would be 2.40 feet of head. Then 92 feet + 120 feet + 2.4 ft. = 214.4 ft. total head, including pipe friction. The theoretical horsepower requirement =

$$\frac{6 \text{ gallons per minute)} \times 214.4 \text{ (total ft. head)}}{4000} = .32 \text{ horsepower.}$$

.32 horsepower x 3 = .96 horsepower actually required considering the mechanical efficiency of the motor and pump as 33⅓ percent. A one horsepower electric motor should be used under these conditions.

PROTECTING THE WATER SUPPLY SYSTEM

Pumping equipment must be properly housed to protect it from the weather and to prevent freezing. The size of pit or pump house and the arrangement of the equipment should be such that repairs, oiling, and inspection can be easily made. Pits and pump rooms should be well drained and ventilated. Pits should have water-tight walls of either concrete or masonry. The pump should be set on a base raised a few inches above the floor to permit draining of oil into a shallow container. Placing tanks on piers or blocks provides ventilation underneath and retards corrosion. Pipe lines should be laid 3 feet deep to prevent freezing. Pits about four feet deep should be amply frost proof.

SEWAGE DISPOSAL

No farm water system is complete without means for disposing of sewage. To provide a safe disposal system, a septic tank with the proper filtering system is recommended. For further information on this subject, refer to Kentucky Extension Circular, No. 131, "Septic Tanks for Sewage Disposal."

DATA BLANK

The source of water may be a shallow well, cistern, lake, pond, spring or stream, or a deep well.

1. Source .... Flow .... gallons per hour.
2. Amount required per day .... gallons. Peak demand (table 2) .... gallons per hour.
3. Height of proposed pump location above water.....feet.
4. Elevation of tank above pump ..... feet.
5. If tank is near pump, elevation of the highest faucet above the tank ..... feet.
6. Length of suction pipe ..... feet.
7. Length of discharge pipe ..... feet.
8. Electric current available. Direct ...., volts ....

   Alternating .... volts .... phase ....

   cycles ....
9. Is automatic control desired? ....
10. Must provision be made to prevent freezing? ....
11. Depth of a deep well to low water level .... feet.
12. Inside diameter of a deep well, or the casing ....

Remarks: ....

....

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Date: ....

Name ....

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