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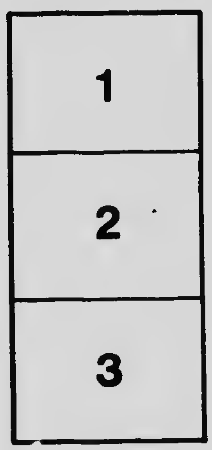

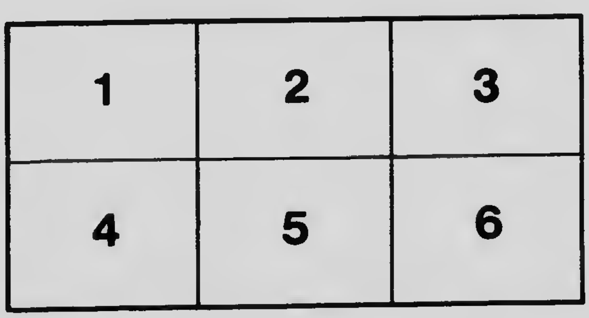

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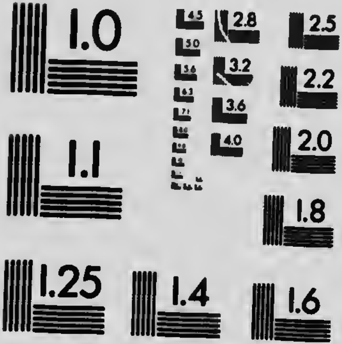

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BULLETIN 267]

[OCTOBER, 1918

Ontario Department of Agriculture

ONTARIO AGRICULTURAL COLLEGE

The Farm Water Supply and Sewage Disposal

WHY PURE WELL WATER PAYS.

The desirability and importance of an ample supply of pure water on every farm can hardly be over-emphasized. Perhaps more than any other food element, it determines the healthy and robust development of the body. Inversely, deadly disease germs finding access to poorly protected or unfortunately located wells may bring death, with little warning, into the family circle. Without great expense the water supply on the average farm may be so protected as to prevent contamination and it surely seems the part of wisdom in every case to ensure an abundant supply of pure water for man and beast—and to have lavish use made of it.

But even though the water be pure there are obstacles in thousands of cases, which prevent its convenient use. Where the household supply is drawn from a well or a stream at some distance from the dwelling the physical labor involved is great. It may be assumed that when no plumbing is installed ten gallons per person per day for all purposes is necessary. With a family of four, some one—often the housewife—must carry 400 pounds of water a day, or over one ton a week. Considerable danger from exposure during inclement weather is also involved, especially when in the haste of the housework, womenfolk leave hot kitchens to carry in water without taking sufficient precaution against the cold.

In the stable much the same conditions exist. The task of pumping water by hand for a large number of live stock is slow and arduous—wasteful of time and trying to the temper. And in cold, stormy weather the stock, when driven to an outside tank or an ice-covered stream, will rarely drink sufficient for their best performance or development. Indeed, so generally are these facts realized, that thousands of stables have been equipped in later years with modern water systems which provide the stock with an abundant supply under the most favorable conditions. It is unfortunate that far fewer houses than stables are thus equipped. Water systems in each case pay their way in dollars as well as in convenience, comfort and health.

This latter argument has been well developed by a practical farmer, who also has lived in a city, and whose experiences in this regard were published recently in an Ontario farm journal. He writes as follows:—

"Our water system, more than any other improvement that we have made around the place, gives us unending satisfaction and has robbed the city home of what was once its leading point of superiority. Not only have we found it quite possible to have running water, hot and cold, in a farm home, but the installation is less expensive than it is in the city. Our city installation cost us $225, a large part of which was plumbers' bills. Our farm bathroom represents an outlay of not more than $150.

"The difference in cost as between city and country is due to two factors—the cost of equipment and reduced labor charges. When we installed our country system we first sent a rough sketch of the proposed installation to a couple of supply houses and to a well known mail order house in Toronto. The latter firm gave us quotations from 25 to 50 per cent. lower than we could have secured from the nearest retailer, and they paid the freight in addition. Through the same source we purchased a pipe wrench, pipe cutter and stocks and dies for threading pipe. We did practically all of the work

Washing Dishes. Hot water on tap at sink.

ourselves. Home plumbing is not so difficult as it once was. It is now possible to buy equipment that can be installed complete with iron pipe and threaded joints.

"And what a comfort is a bathroom. I enjoy it to the full. I wouldn't be without it if the cost were twice as great. But the women folks are the chief beneficiaries. No more longings for the comforts of the old city home. They have them right on the farm. I don't anticipate that they will be instrumental in furthering rural depopulation, for, if all reports be true, rural women who live without city conveniences have a habit of sowing seeds of discontent and taking the whole family off to town."

The question of cost which this farmer mentions is important. There are few indeed but will admit that a complete water system for the farm is highly desirable; but many are deterred because of the expense involved. Many improvements may be made, however, such as safeguarding the well from pollution, installing an hydraulic ram, septic tank, gravity system, etc., which are not very expensive. And when the farmer is able to do a good deal of the work himself the cost is reduced to a point where thousands can afford the installations. Many different systems and devices, or modifications o… …se, may also be used according to local requirements and the peculiar circumstances of each case. With a practical working knowledge of the principles of farm water supply, water systems, equipment and sewage disposal, few indeed who have impure well water and are without household and stable water conveniences but can make improvements of a most beneficial nature and at a cost which they can afford to pay.

Winter scene without water system.

…ve such information is the purpose of this bulletin now presented to the …blic of Ontario. Practical information, as complete as possible and so … as to enable each reader to find quickly the particular problem he is …terested in, is given regarding every phase of the water question. To further assist those who may wish to make improvements or installations the authors of this bulletin will gladly give personal attention to any question or problem which may be sent to them. All are invited to make use of the appendices at the back of the bulletin, to fill them out carefully and to forward them as directed.

The Farm Water Supply

W. H. Day and R. R. Graham.

WELLS, PUMPS, POWER PUMPING AND WATER SYSTEMS.

In gaining an appreciation of water supply problems, and a knowledge of how to solve them it is desirable first to make a brief study of the occurrence of underground water. The earth is composed of a number of layers or strata. Some are loose, open, porous and water passes through them readily; others, like heavy clay, hardpan and rock, are so compact and the pores therefore so small that water passes through them very slowly if at all. These pervious or porous layers and impervious or non-porous ones are very important from the standpoint of water supply. Frequently they are distributed somewhat as follows: First, a pervious layer of soil on the surface, thin in some places and thick in others. Secondly, an impervious layer of clay, hardpan or shale rock. Thirdly, a pervious layer of sand, gravel or shale, and, fourthly, an impervious one of solid rock. But the number may be even greater than this, or the solid rock may extend right to the surface. Fig. 1 shows a possible distribution.

When rain falls upon the land shown in Fig. 1, part of it soaks into the porous layers, as at A or C, and part may run off over the surface. Also that which falls on the impervious layer as at B must find its way over the surface to the porous layers and into them or over their surface to a stream or pond. When the porous layers at the surface are saturated in part, the ground water-level would be somewhat as shown by the dotted lines. At A, A', and C dug wells sunk in the porous layers would give a supply of water, and the level in the wells would be the same as the ground water level. At B the impervious layer comes to the surface and a well sunk in it would give no water until the porous layer beneath it was struck. Then the water would rise to the same ground water level as in the well at C. A well drilled at A deep enough to strike the second porous layer would produce a flowing or artesian well. At D where the surface layer becomes quite thin the water would in all probability break out forming a spring, or saturate the soil all round, causing a "springy spot." And indeed it would be possible for the water from the second porous layer to find a crevice or channel through the upper layers and produce a spring as at E.

The origin of water in the earth is not always so evident as in Fig. 1. Particularly in arid and semi-arid regions is this the case, e.g., in Saskatchewan and Alberta and in parts of Australia and India. In many such localities the precipitation is not sufficient to saturate the surface layer and produce a ground water level in it. And drilling even to a depth of hundreds of feet may fail to locate a water-bearing stratum farther down, and yet occasionally shallow wells sunk in these areas tap veins or underground streams, rivers or lakes, whose sources we do not know, nor their outlets.

Locating Underground Streams.

These subterranean streams usually provide the very best supplies of water, both as to quality and quantity. The difficulty is that the striking of them is

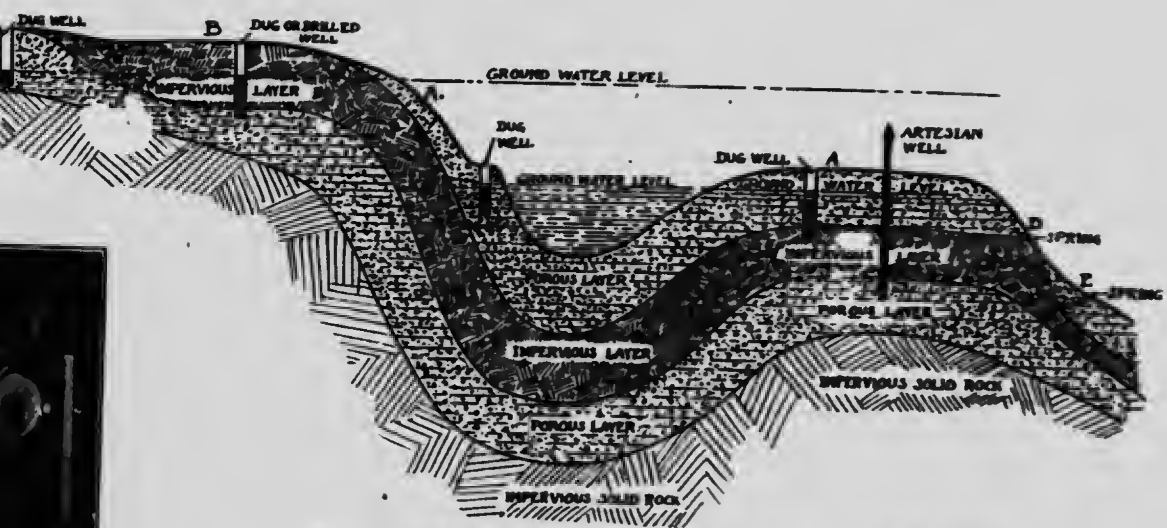


Fig. 1.—Showing soil layers, ground water levels, wells and springs.

Fig. 2.—Face water finder, about 12 inches high.

generally a matter of pure accident. From early ages certain individuals have claimed the power of being able to locate such streams by aid of a forked twig from various trees, such as plum, cherry, hazel, etc. And it is undeniable that in many instances phenomenal wells have been struck by digging or drilling on sites selected by these "water diviners" in spite of previous failures in the locality. For many years scientists as a class have stoutly denied the possibility of there being any virtue in this method of locating water, but in recent years as the result of some investigation on the subject a considerable change has come about, many not only admitting the possibility of the method being genuine, but actually expressing their belief in it. We understand the French Department of Agriculture has a staff of diviners, whose services are available on application. So also has the Department of Lands in Queensland, Australia.

Another method has come into vogue recently, viz., by using an instrument known as a water-finder, a photograph of which is shown in Fig. 2. This is an electro-magnetic instrument, patented by an English firm. In the lower compartment, according to the English letters patent, is a coil of fine iron wire about six inches long and five inches in diameter. The coil has no metallic core. The ends of the wire are free. The layers are separated by paraffin wax and interspersed occasionally by sheets of lead foil. In the upper chamber is a very slender delicate magnet five inches long turning on a pivot at its centre. It is magnetized so as to have a north pole at each end, one being the least shade stronger than the other. This method of magnetizing the needle is patented. When preparing for a test the coil is set by a compass with axis north and south. The needle is then placed on the pivot and points in a northern and southern direction when it becomes steady. If no underground stream runs below, the needle will lie almost motionless, but if there is a stream underground then the needle will suddenly swing out to one side and then oscillate back and forth, the oscillations gradually diminishing in amplitude. It may come back to rest or may receive another impulse before doing so. There is no regularity of impulses either in time or strength.

The principle of the instrument apparently is not definitely established. Those who have studied it are pretty well agreed that the action is in some way due to fluctuations in the earth currents of electricity which follow the underground streams of water. Some believe that these fluctuations cause momentary changes in the magnetism of the coil, which disturb the magnetic equilibrium of the needle, causing the oscillations. The makers of the instrument claim that the oscillations are due to "earth air currents of electricity"—perhaps electric waves would be a better term—originating in the fluctuations of the electric current in the stream. And some even claim that there is no virtue in the instrument whatever. Water Supply Paper 416, U. S. Geological Survey, Washington, pages 23-25, concludes with this opinion: "In the present state of knowledge any claim that the oscillations of a magnetic needle indicate the occurrence of available ground water is purely speculative." If the author of this paper had related details of tests with the water-finder made by himself or others and which resulted negatively his opinion would have carried more conviction. One thing is certain, the needle does oscillate in some locations and not in others—we have proven that over and over again by actual trial. And in India, under the direction of Dr. Harold H. Mann, Principal of the Poona Agricultural College, at least sixteen wells have been sunk on sites selected by the instrument in the Trap Region of Western India where water is proverbially hard to find, water being struck in every one of the sixteen, and Dr. Mann's conclusions, quoted from his

Bulletin No. 72, of 1915, entitled "Experiments with the Automatic Water-Finder," is as follows:

"The position, as a result of our work, is, therefore, that in a country where at least forty per cent. of wells under normal circumstances are failures even in selected sites, wherever the automatic water-finder has indicated water, and a careful test, including boring, has been made, water has been found. As a rule the supply indicated has been within the depth of well sinking; in a few cases, sub-artesian water has been found by boring, at depths varying up to 126 feet. Only one criticism can be made of these results, I think, and that is, that similar boring would, under almost all circumstances, reach a water supply of some sort. Other borings, in what were considered likely sites, do not justify this conclusion. These have only given 66 per cent. of successes, as against complete success when the water-finder has been used and has indicated water.

"It must be confessed, however, that we have so far found no method of using the instrument which enables us to say with certainty the depth at which the water will be found, or its quantity. Messrs. Mansfield & Co., the makers of the instrument we have used, state that they can tell, within small limits, the quantity of water to be obtained, but we have not been able to do this.

"It would seem, however, sufficiently proved that under the conditions which prevail in the trap areas of Western India, where underground water occurs in well-defined streams flowing in rock fissures, sometimes under little or no pressure, and sometimes under considerable pressure, the automatic water-finder can be used with advantage in locating streams of water which can be tapped, either by well-digging or b boring."

In June, 1918, Dr. Mann, writing the authors of this bulletin, says that after many additional borings in the interval the situation remains as stated in his bulletin. He also says that with extended use they are able to form a pretty close estimate of the depth to the water.

Mr. G. B. Brooks, of the Department of Agriculture, Queensland, Australia, has also done some very interesting work with the water-finder, combining it with the divining rod method, and tracing underground streams by both. In spite of the fact that water is very scarce in the areas where the water-finder has been used by him, no failures are recorded on sites selected by the instrument. So successful was his work that the Department of Lands appointed two officers solely as water diviners.

The Department of Physics at the Ontario Agricultural College has one of these instruments, with which it is intended to make tests fo those wi ing such, the party for whom the tests are made paying the travelling e ses of the operator. It is not an instrument that can be loaned.

DIFFERENT TYPES OF WELLS.

Throughout the rural districts of Ontario the almost universal source of water is a well of one type or another. There are three types in common use, viz., the dug, the driven and the drilled well, each adapted to conditions with certain characteristics.

Shallow Dug Well.

The dug well is suitable where water is available at shallow depths, the surface layer being soil. It has the advantage of always having a considerable reserve of water available. On the other hand, being shallow, and therefore frequently drawing its supply of water from soil near the surface, there is great danger of contamination from barnyards, privies, cess pools, etc. To be pure it is generally considered that water should filter through at least ten feet of soil, and even this may be insufficient if a strong supply of polluted liquid is constantly seeping into the same soil, as from a cesspool. Hence great care should be exercised in locating the dug well. It should be on higher land than any possible source of pollution and at least 100 feet from them. And even this is not sufficient precaution: The well after being dug should be so curbed, and so finished above ground that no surface water can enter it. And the top should be tight so that earthworms, toads, frogs, etc., cannot enter.

Fig. 3 shows two dug wells, that on the left poorly located and poorly protected, that on the right well located and protected.

Regarding the poor well note:

1. It is located in a hollow, so that surface water flows towards it.
2. The curbing is open so that water from the soil may enter anywhere below the surface, possibly having filtered through only a few inches of soil.
3. The top is open, admitting any vermin that may happen along.

Regarding the good well note:

1. It is located on high land, so that surface water flows away from it.

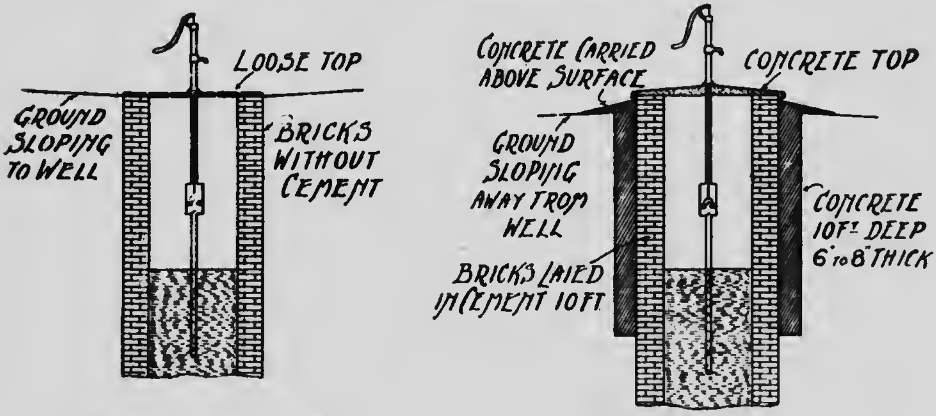


Fig. 3.—(*a*) Poor dug well. (*b*) Good dug well.

2. The curbing extends above ground, and the top ten feet is laid with cement mortar, making it impervious to water, the curbing lower down being open to admit the water.
3. The top ten feet of curbing is surrounded by a shell of concrete, slush, mixed, and tamped in so as to make close contact with the soil and prevent surface water trickling down to enter the well through the open curbing below. Puddled clay is sometimes used for backing instead of the concrete.
4. The top is elevated above ground, being tight and curved, thus excluding vermin and shedding any water that may be spilled.

Pump in Kitchen or Stable.

The good dug well may sometimes be rendered even better by the simple device of placing the pump some distance to one side of the well. It may be located anywhere provided neither the sucker nor any point in the pipe line be more than 25 feet above the surface of the water. (See section on pumps, page 15.) This may be turned to great convenience by placing the pump in the kitchen or stable, while the well is a hundred feet or so away. And when so placed the well itself is free from danger of pollution by impurities being washed from the cover into the well. In fact, all the surroundings may be kept much more sanitary than is frequently the case when the pump is placed directly over the well. In days gone by many wells have been dug in barnyards, and in other improper locations in order to have the pump near the stable or yard, when in reality sanitary sites might just as well have been chosen some distance away and the pumps even more conveniently located. This arrangement saves much labor, time and severe exposure for those carrying the water, especially in the winter-time. If the pump is in good order, and a check valve attached to the suction pipe in the well, one can easily draw the water 200 or 300 feet by hand pumping, much farther of course if power be used.

Improving Poor Wells.

Poor wells may be improved by correcting the mistakes made in their original construction. If the lining is bad it may be removed and replaced by a new one as described above. If this is not practicable, another lining may be put inside the old one, leaving a space between them, the top ten feet of this lining being laid in cement. The space between is then filled up to the cemented portion with coarse gravel and the rest of the way with sand. Sewer tile, either glazed or concrete, make a good inner lining. In either case the top should be properly protected. Should neither of these methods be applicable the well may be drilled deeper as described later under drilled wells.

Driven Wells.

Where the strata of the earth are such that a pipe can be driven down into a porous water-bearing stratum such as sand or gravel, then driven wells may be constructed much more easily and cheaply than dug wells. The method of procedure is as follows:

1. A well point (such as shown in Fig. 4) is procured.
2. The point is screwed on a pipe of the proper size, and a drive cap on the top of the pipe. Usually 1¼ or 1½-inch pipe is used for ordinary farm wells.
3. The point and pipe are driven into the ground by sledge, maul, or drop weight, until the end is just above ground. Care should be taken to have the pipe perpendicular. Sometimes when a hard layer of soil is struck the pipe is withdrawn and a hole bored through the hard layer by a special auger, and then the driving continued.
4. Another length of pipe is then put on, and the operation repeated.
5. Tests for water are made from time to time. This is done by letting down a plumb bob inside the pipe.
6. For a satisfactory supply of water the point should be driven a considerable distance into the porous layer, but care must be taken not to drive through it into the non-porous layer beneath. To ascertain whether the supply is adequate a pump is attached to the top of the pipe and pumping is continued for several hours. If the supply fails under this test, the point should be driven deeper in the porous layer. Where the water-level is more than twenty-five feet down the pipe would have to be large enough to admit the pump cylinder to the required depth.
7. The pump is then fixed permanently in place. There are three methods of doing this: If there is no danger of freezing, the pump, including cylinder

and sucker, may be placed entirely above ground, the cylinder being screwed directly to the pipe when the drive cap is removed. Or the pump may be placed in kitchen or stable, as described under dug wells. If there is danger of freezing, a shallow dry-well may be dug as far down as the first joint in the pipe, when the top length is removed and the pump placed in its stead, the cylinder being down near the bottom. This dry-well for the pump should be curbed and a tight cover provided as described above, but the curbing need not be backed with cement or puddled clay. The third method is to put the cylinder in the drive pipe.

The driven well is sometimes constructed without a drive-point. In this case the open pipe is driven down until driving becomes difficult, when the cap is removed, water poured into the pipe and the soil after being loosened by a drill is removed by means of a sand pump. When the water-bearing layer is struck the pipe is driven a short distance into it and then the hole sunk somewhat further by means of the drill and sand pump.

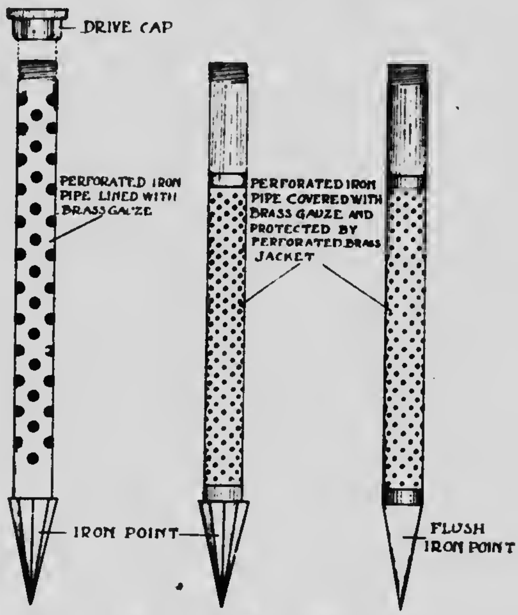


Fig. 4.—Types of well points.

The water from a driven well is turbid at first, but after a time becomes clear, as the finer particles of soil are gradually removed from the areas about the point.

The advantages of the driven well are:

1. Its cheapness.

2. Its sanitary qualities. Surface water cannot reach the point without filtering through twenty to twenty-five feet of soil.

Driven Well in Quicksand.

Sometimes in driven wells the sand is so fine that it blocks up the ordinary drive point. In overcoming this considerable success has been attained by using a special filter attached to the suction pipe as shown in Fig. 5. The filter is

Fig. 5.—(*a*) Sinking the open 10-inch drive pipe.

Fig. 5.—(*b*) Sand filter, to be placed in open drive pipe.

Fig. 5.—(*c*) Withdrawing open drive pipe.

made similarly to the drive point only being larger, about six to eight inches in diameter and three feet long. In this case an open drive pipe is used, and it must be large enough to admit the filter, and a jacket of gravel, usually about ten inches in diameter. A good pipe for this purpose may be made of very heavy galvanized iron sheeting, the sections being detachable and with a locking device. When the pipe has been driven down into the water-bearing area all the earth is removed from it, then a foot or so of coarse gravel placed in the bottom, the filter screwed to the suction pipe and set on the gravel, and enough fine gravel put in to fill the space between the filter and the drive pipe. The latter is then withdrawn, and the pump attached to the top of the suction pipe.

Drilled Wells.

Where the water-bearing stratum is overlaid by a layer of rock or impervious clay or hardpan the dug and driven wells are impracticable, and drilling is resorted to. This may commence right at the ground surface, or in the bottom of a dry well. That portion of the bore passing through soil is protected by watertight, wrought-iron casing, which is extended into the rock only far enough to prevent surface water entering. For this purpose it should be driven firmly into the rock. The drilled well provides the purest water of the three types, because of the depth of soil through which it has filtered and the distance it has flowed underground.

The pump cylinder in a drilled well, as in all others, must be within 25 feet of the surface of the water. See section on pumps, page 15.

Artesian Wells.

In drilling, sometimes a flowing well is struck. These are called Artesian wells, because of their being discovered in Artois, in France. The explanation of this phenomenon may be seen by referring to Fig. 1 where the head of water in the porous layer feeding the Artesian well stands much above the ground surface at the point where the well was sunk. Indeed, drilled wells in which the water rises from the second porous layer up near the surface as at B, Fig. 1, are frequently called Artesian, although they do not overflow.

Whatever the source, a pump of some kind is almost invariably required to deliver the water from the well to the point of use.

PUMPS—THEIR PARTS AND ACTION.

The parts of the ordinary pump are illustrated in Figs. 6 and 9, and are as follows:

1. The handle.
2. The standard, barrel, or body of the pump.
3. The plunger, or "sucker," as it is almost universally called on the farm. The sucker contains a valve which opens upward. It also has one or more "leathers." These are turned up cup-shaped around the plunger. They hug the side of the cylinder, especially on the up stroke of the piston. Shallow well pumps have only one "leather," but those for deep wells have as high as three or four.

4. The cylinder, that portion of the pump in which the sucker moves. Sometimes, as in many cistern pumps, the cylinder is situated in the standard but in well pumps it is situated down in the well within 20 or 25 feet of the water surface.

5. The suction valve in the bottom of the cylinder. This valve also opens upward.

6. The suction pipe, which extends from the cylinder down into the water.

7. The "set length" pipe, between the standard and cylinder, and which may be varied in length to set the cylinder the proper distance above the water. To prevent freezing a small hole is drilled in the set length to allow the water to run back into the well when the pump is not in use.

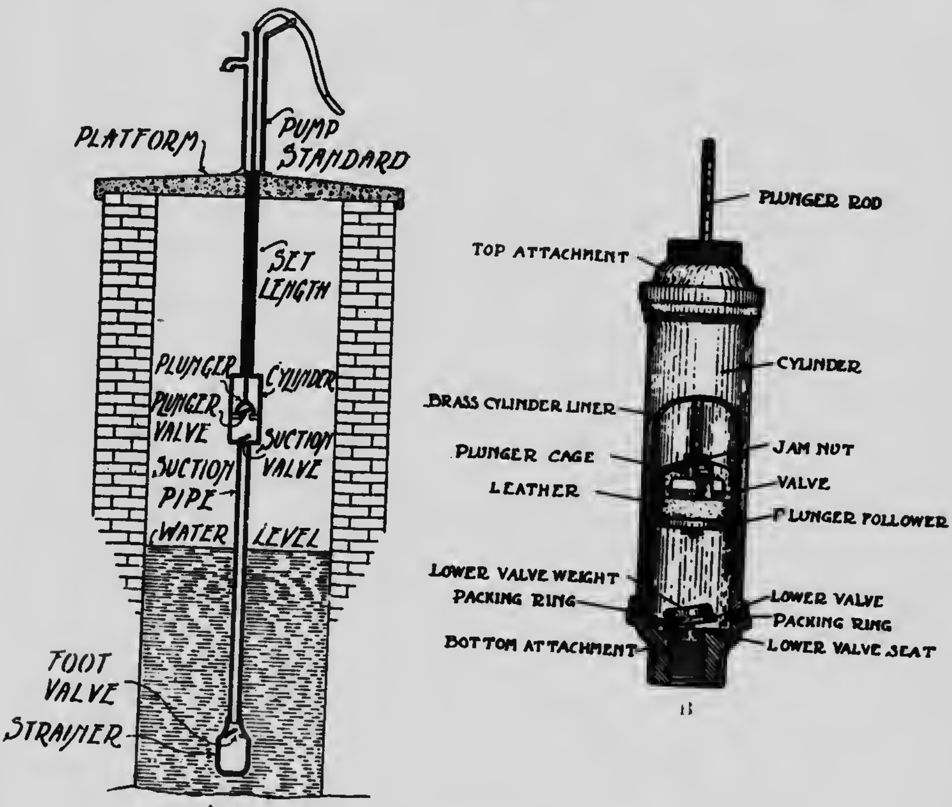


Fig. 6.—(*a*) Suction pump, showing parts.
(*b*) Cylinder and sucker, showing parts.

8. Foot valve and strainer, sometimes attached to the bottom of the suction pipe.

Most farm pumps are of the "suction" variety, which are installed with the "sucker" or plunger above the water surface. When the pump is being started the air must first be pumped out and while this is being done the water is "sucked" up to the plunger. Let us see how this is brought about.

Air has weight—their are 75 pounds of air in a room ten feet square and ten feet high under ordinary conditions, a surprisingly large amount to most of us. The atmosphere extends about 200 miles high, but gradually decreases in density as the height increases. If we could extend a pipe one foot square to the top of the atmosphere and weigh the air inside it we should find the weight to be more than a ton. How do we know this when we can't try it out? Because we have a method, and a very simple one, of weighing the atmosphere.

Principle of the Barometer.

To do this we take a glass tube more than 30 inches long, and seal one end.

Fig. 7.

Fig. 8.

Fig. 7.—The barometer. Note the mercury stands 28½ inches high in the tube. Note the glass dish in which the tube stands.

Fig. 8.—The same barometer as in Fig. 7, but the glass dish is placed in an air-tight jar, and some of the air exhausted through the pipe on the left—and the mercury now stands only 16 inches high. If all the air were exhausted the mercury in the tube would drop down level with that in the glass dish.

and then fill it with mercury, keeping the open end up and being careful to boil the mercury afterwards to expel all the air mixed with it during the pouring. When the tube and mercury are cool enough to be handled a finger is placed tightly over the open end, the tube inverted, and the open end thrust into a vessel of mercury, and the finger then removed. The tube does not empty itself—

the mercury only drops down till its surface in the tube is about 30 inches above the surface of the mercury in the open vessel. See Fig. 7. What holds up the 30 inches of mercury? The air pressing on the surface in the vessel. This is easily proven, for if we apply an air pump as shown in Fig. 8, and exhaust the air, the mercury in the tube drops. Hence that 30 inches of mercury must weigh the same as a column of air that size and extending to the top of the atmosphere. If our tube were an inch square we would have 30 cubic inches of mercury pressing on one square inch. And 30 cubic inches of mercury weighs 14.7 pounds, hence the atmospheric pressure when the barometer stands at 30 inches is 14.7 pounds to the square inch—speaking in round numbers we say 15 pounds. Some days the atmosphere is heavier than standard, some days lighter. At sea-level the average is about 30 inches, consequently that is taken as standard. At the Ontario Agricultural College, which is 1,100 feet above sea level, the average barometer is a shade under 29 inches. In a general way, an increase of 1,000 feet in altitude reduces the barometer reading one inch. Altitude, therefore, has to be kept in mind when setting the pump cylinder.

Water as a Barometer Liquid.

Now we can use water instead of mercury to measure the atmospheric pressure, but since mercury is 13.6 times as heavy as water the water column in the glass tube would be 13.6 times as high as the mercury column. Now 13.6 times 30 inches=34 feet. Hence the column of water that can be supported by the atmosphere at standard pressure is 34 feet high. Suppose we had an iron pipe 68 feet high, dipping into water, closed at the top, open at the bottom, but with provision for attaching an air pump at the top. If we exhausted every particle of air from the pipe the water would only rise 34 feet high; the top half of the pipe would contain only water vapour.

The Barometer and the Pump.

This has a very important relation to the suction pump. If the "sucker" is more than 34 feet from the water in the well, the pump will never work, the water will never rise up to the sucker even if it were perfect enough to remove all the air from the pipe. But the pump cannot be made so perfect as this, first on account of the weight of the valves and, secondly, because the valves or the collar of the sucker may allow some air to slip past them. Because of these imperfections and the fact that the water barometer may fall several feet below the standard when the atmospheric pressure is low or the well several thousand feet above sea level, practical pump men find it necessary to place the sucker not over 25 feet above low water mark in the well, and as a special safeguard some adopt only 15 or 20 feet. Even better results are obtained by putting the cylinder right in the water. This is always done in "deep" well pumps.

Action of the "Suction" Pump.

When installed with the cylinder above water the pump may be said to act by "suction" as distinguished from the action when installed with the sucker under water, although it will be readily understood from the explanations regarding the barometer that the term suction is a misnomer—the rise of the water in the pump is due to inequality of air pressure on the surfaces. Fig. 9 shows several stages in the action of the simple pump, as follows:

(*a*) The pump before use, handle still, both valves closed.

(*b*) The handle, being raised, which lowers the plunger, the air between the valves opens the top one by resistance against compression, and the air escapes through the open valve. This stroke continues till the sucker reaches the bottom of the cylinder, practically all the air between the valves being expelled.

(*c*) The handle being forced down, which lifts the plunger. The plunger valve immediately closes because of the pressure of air above it. Lifting the plunger lessens the pressure on the top of the suction valve, and when this occurs the air in the suction pipe expands opening the suction valve and part of the air in the pipe flows out into the cylinder. This expansion lessens the air pressure on the water in the pipe. Outside the pipe, however, the pressure on the water is the full atmospheric pressure, and because of this inequality the water is driven upward in the pipe by the outside pressure until the water column and the reduced air together exert a pressure just equal to that of the atmosphere, which occurs at the end of the up-stroke of the plunger.

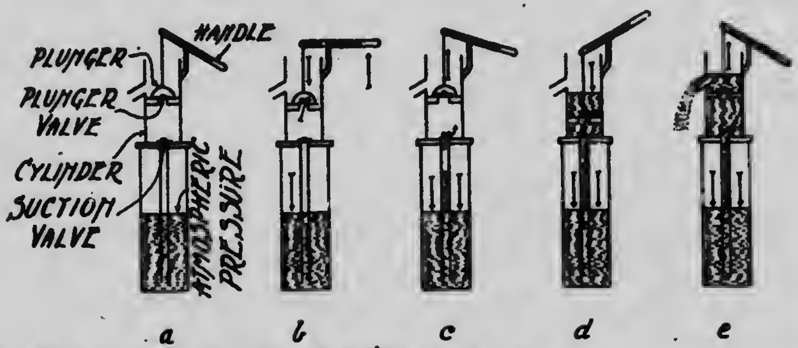


Fig. 9.—Stages in the action of the suction pump.
(*a*) The pump before use, both valves closed.
(*b*) First up-stroke—air in cylinder being forced out through valve in plunger.
(*c*) First up-stroke—air pressure in cylinder reduced. Atmospheric pressure on water in well drives water part way up the suction pipe.
(*d*) The water has reached cylinder, plunger moving down.
(*e*) Up-stroke—water begins to flow from spout.

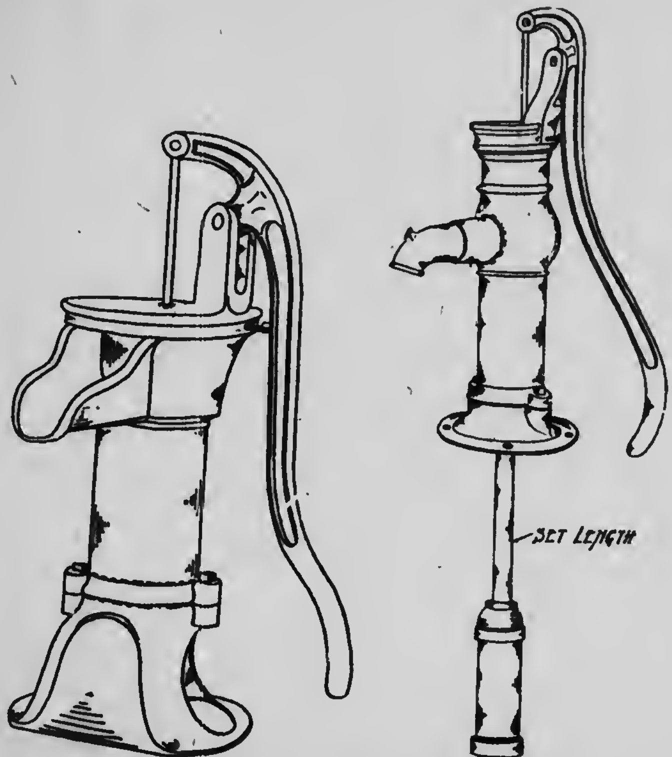
(*d*) On each upward stroke more air is expelled and the water rises higher until finally it reaches the plunger. With the water in the cylinder the valves act just the same as with air, only more pronounced, because the water is not elastic like the air.

Principle of the Lift Pump.

All pumps built for discharging the water only at the spout as shown in Fig. 6 are called "lift" pumps. In this type the pump head is not airtight, nor is the pump rod packed where it passes through the head. Pumps of this type when intended for cistern use, where compactness is very essential, frequently have the cylinder located in the body of the pump as shown at A in Fig. 10, although "set length" cistern pumps are also in use, as illustrated at B in the same figure.

Force Pumps.

Frequently, however, it is necessary to force the water higher than the spout, possibly to a tank situated high up in the house or barn, or it may be desired



10a. 10b.

Fig. 10.—(a) Cistern pump with cylinder in barrel.
(b) Set length cistern pump.

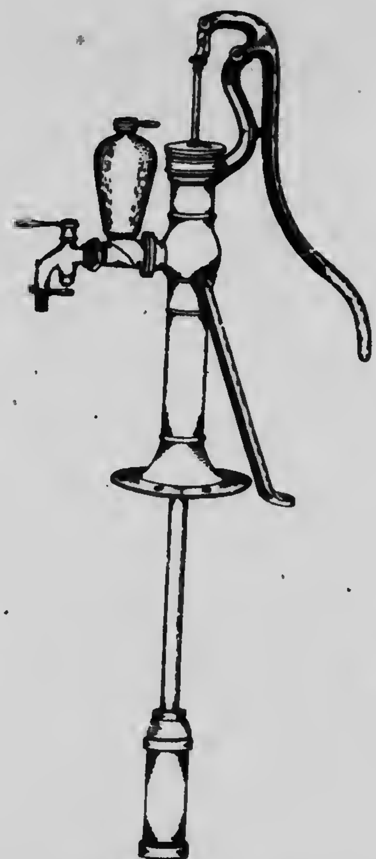


Fig. 11.

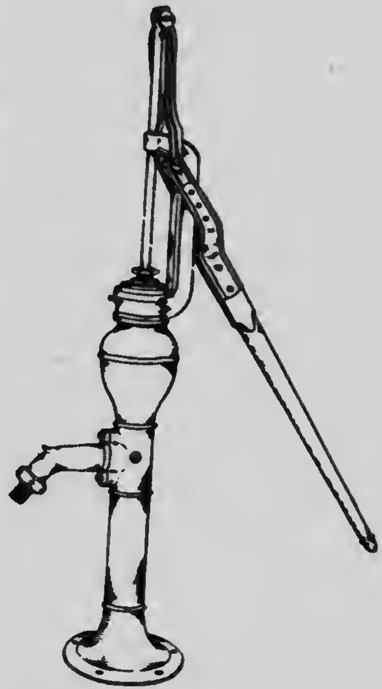
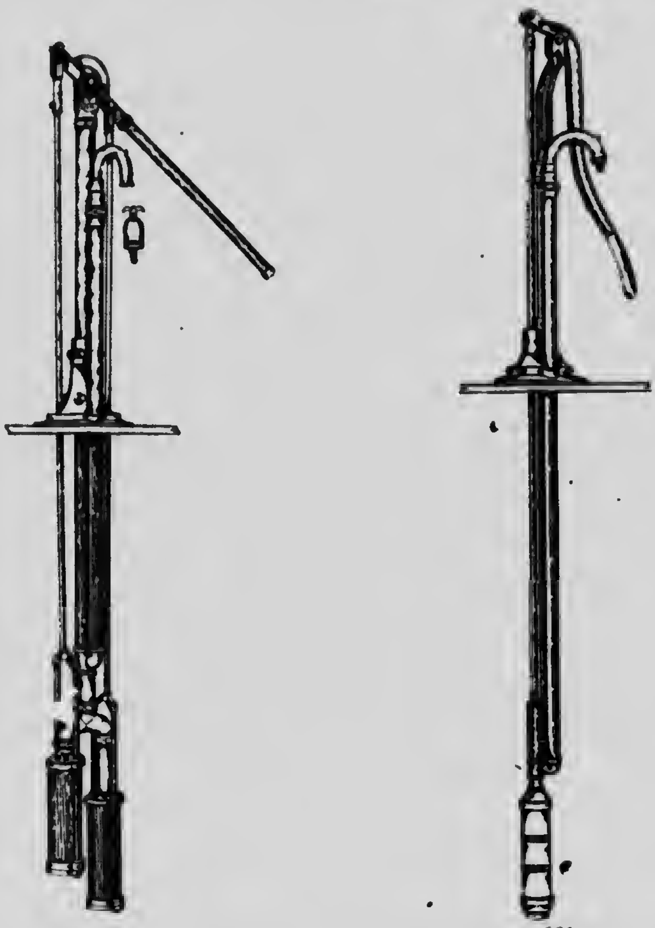


Fig. 12.

Fig. 11.—Force pump, with air-dome on spout.
Fig. 12.—Force pump, with air-dome in barrel.

to obtain water under pressure. Then a force pump is used, such as illustrated in Fig. 11. In this the head must be airtight, including the rod where it passes through the head. And there must be a means of attaching a pipe or hose to the spout. The air-dome on the spout (see Fig. 11) is not absolutely necessary, but yet desirable, because it reduces the labor of pumping very materially. Suppose there were no air-dome then the water would have to go up the pipe or hose as fast as de-



13*a*. 13*b*.

Fig. 13.—(*a*) Double acting force pump, with two cylinders side by side and two pump rods.
(*b*) Double acting force pump, with two cylinders, one above the other, the upper having about half the capacity of the lower.

livered from the cylinder, and while the sucker was on the down-stroke the water in the pipe would co a standstill, and on every up-stroke it would be necessary to start this long line water afresh. Every person who has driven a team knows the heaviest pull is in starting the load and getting up speed, and the same holds true here. With the air-dome, however, about half of the water delivered on the up-stroke is forced into the dome against air pressure, and this pressure keeps the water flowing from the nozzle during the down-stroke, thus givi a steady

14*a*.

14*b*.

Fig. 14.—(*a*) Double acting power force pump for shallow wells. It may be set some distance away from the well.
(*b*) Double acting power force pump for deep wells. Must be located at the well.

stream instead of an intermittent one. And on a fresh up-stroke the only water that has to be set in motion is the little bit delivered by that stroke. Nor is this the only difference. Without the dome, the water while flowing would have to move twice as fast in the pipes and this would make the friction *four* times as great, because the friction varies with the square of the velocity. Consequently, from the practical standpoint, the air-dome on the force pump plays a very valuable part in economizing labor. In some types the air-dome is merely an expansion of the pump barrel as shown in Fig. 12.

Where large quantities of water are required it is customary to install double-acting force pumps. These are of several types, two of which are shown in Fig. 13. Pump A uses two cylinders side by side, and two pump rods, attached to the handle, one on either side of the support. Pump B uses a small cylinder above a large one, the plunger in the top cylinder having no valve in it, the bottom plunger being of the ordinary type with a check valve in it, there also being a suction valve below it. There is no valve between the cylinders. On the up-stroke half the water in the bottom cylinder is forced into the top one and the other half is forced up the pump toward the tank. On the down-stroke the water in the upper cylinder is also forced up the pump.

Fig. 14a shows another type of double-acting force pump much used in connection with power pumping plants, where the water level is within 20 or 25 feet of the ground surface. There are two valves at each end of the cylinder, one a suction valve, connected with the suction pipe, and the other an outlet valve connected with the pipe leading to the elevated or compressed air tank. The plunger itself is solid. When a compressed air system is to be used the pump is supplied with an air compressor as shown in the figure. By turning the cap at the right of the compressor, the pump may be set to pump air along with the water or not, as desired.

When the well is a deep one and the pump must consequently be placed directly over it, a different form of pump must be used, as shown at B in Fig. 14.

Foot Valve and Strainer.

In many cases another valve is introduced, being what is known as a foot valve, at the bottom of the pump. It is frequently accompanied by a screen to prevent anything but water from being drawn into the pump. In case the suction valve may become somewhat defective the foot valve, if still good, would cause the pump to work in spite of the defective suction valve. Another function of the foot valve is to aid the suction valve in maintaining the pipe full of water at all times and the pump thus well primed.

Pump Troubles.

If you are not getting water, see if there is any in the well.

If the pump is not working properly there is a cause. Find it.

If it loses its priming (the water running down) the suction valve is defective, or some dirt or obstruction has lodged under it. Sand, gravel, or sometimes pipe-thread cuttings will cause this. Remove valve, and clean it off thoroughly.

If pump is discharging air bubbles with the water, there is a defect in the suction pipe, or it is not properly tightened in cylinder.

If the handle works up and down without apparent resistance, and delivers no water, it indicates that the plunger leather is worn and is not creating a vacuum in cylinder, or else suction valve is not working properly. Remove sucker and renew leather or release valve.

If pump works hard, or handle jerks up when pushed down, it is evident that something is preventing the water rising in suction pipe to cylinder. Perhaps the suction pipe is too long, or too small, or strainer (or drive point if used) is plugged up.

In a lift pump if water splashes out at top of pump (where rod works through) it indicates that cylinder is too large for capacity of head. If pump is taking air below cylinder it will also have a tendency to do this.

Capacity of Pumps.

To determine the capacity of a pump, square the diameter of the cylinder, in inches, multiply by the length of the stroke, in inches, multiply by the number of strokes per minute, and divide the product by 352. The answer will be the number of gallons per minute.

Work of Pumping Water.

The deeper the well or the higher the water has to be forced the more power is required to work the pump. On every up-stroke the plunger has to lift all the water in the pipe above it. In 100 feet of 1½-inch pipe the weight of the water and the pump rod together would be about 150 pounds. If one had a herd of 40 cattle and each drank 10 gallons or 100 pounds a day, which for the year round might be a fair average, the work of raising that weight of water 100 feet would be 10,000 foot-pounds and for 40 head, 400,000 foot-pounds; and the work of lifting the pump rod would be nearly as much more. If a man can do one-sixth of a horse-power of work then it would take him about an hour and a quarter a day to pump the water for the cattle. It is not surprising therefore that in these times of scarcity of labor, windmills, gasoline engines and electric motors are being more rapidly adopted than ever before for pumping purposes.

Power Pumping.

For many years the windmill held sway as the most popular power method of pumping water, the two chief reasons for this being:

1. Operating cost is practically nil.
2. Little attention is required, this being limited to an occasional oiling and throwing the mill in gear from time to time.

The mill is nearly always placed directly over the well, usually on a steel tower. Fig. 32 illustrates a typical windmill installation. The tank which may be located either in the tower or above the stable holds a supply sufficient to tide over a few days of calm weather. The price of mills for pumping ranges from $100 to $200 depending on size of wheel and height of tower.

The mill may be made to operate a pump at a distance by the use of windmill quadrants, which are illustrated in Fig. 15, and the operation of which will be readily understood from the drawing.

But the gasoline engine is rapidly coming into favor for pumping purposes. Where the wells are shallow the pump may be placed near the engine in the barn, drive-shed, or engine room as the case may be. A favorite type of pump for use under such circumstances is shown in Fig. 14a. Where the well is deep and the pump, Fig. 14b, has therefore to be set directly over the well, the engine may either be placed at the well or in a convenient room at the buildings and the power transmitted to the pump. There are numerous methods of doing this, three of which are illustrated in Figs. 16, 17 and 18. No. 16 shows the pump being operated from a line shaft in the same way as the knives of a reaper or mower are operated by the pitman shaft. In Fig. 17, the old-fashioned rope belt driven by the grooved pulley on the line shaft runs the grooved pulley at the pump, operating the plunger of the pump as before. Still a third method is shown in Fig. 18. The pitman wheel on the line shaft moves the pitman shaft back and forth, and this in turn works the L-shaped handle of the pump. Quadrants may also be used, as with the windmill. The authors have seen all these

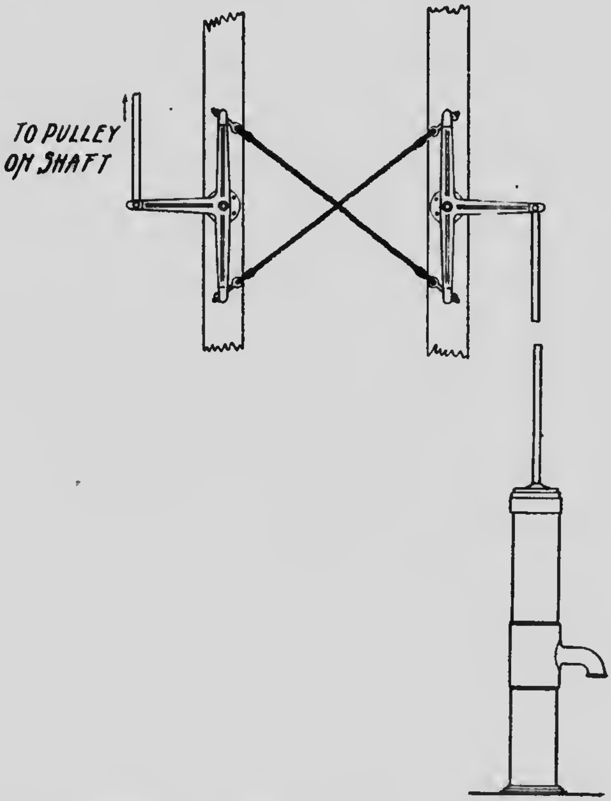


Fig. 15.—Windmill quadrants for operating a pump at a distance from the mill.

methods in satisfactory operation, and with these suggestions the reader should be able to adapt the principles to meet the circumstances of his own particular case. Ready-made pump jacks may be had from pump manufacturers.

Calculating Speed of Pulleys.

It is necessary to reduce the speed of the engine to the proper rate for pumping. In doing so one would be safe in assuming that the pump should run about as fast as when one is pumping by hand, say from 10 to 60 strokes per minute for shallow wells and 20 to 30 for deep wells. The calculating of pulley speeds would give little trouble if we would remember that all parts of the belt travel at

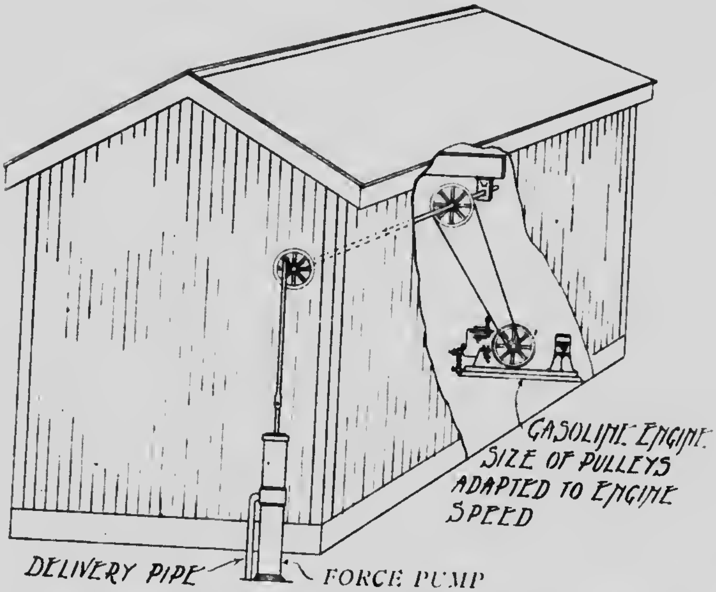


Fig. 16.—Pump operated by pulley on line shaft driven by gasoline engine.

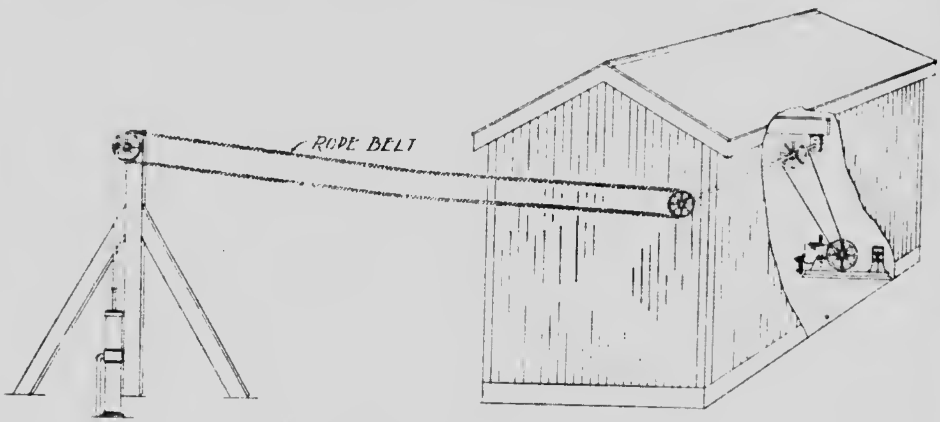


Fig. 17.—Pump operated by rope belt.

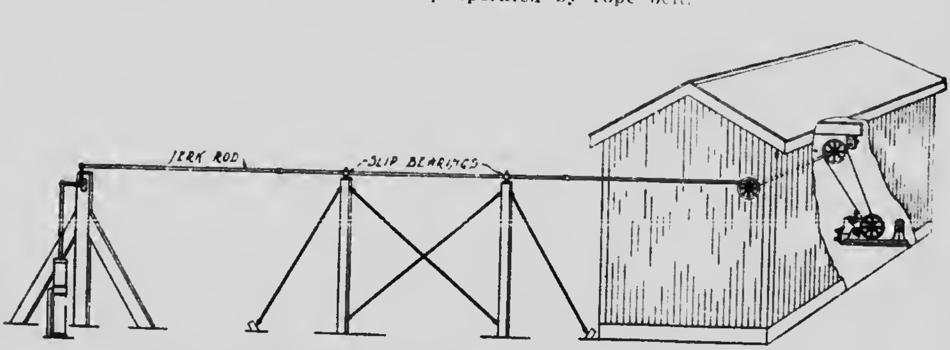


Fig. 18.—Pump operated by jerk rod.

the same speed. The length of belt that passes over the driver is equal to the circumference of the driver multiplied by the r.p.m. (revolutions per minute) of engine pulley. Therefore, belt travel = diameter of driver × 3 1/7 × speed of driver. Similarly the belt travel on the driven pulley = diameter of driven × 3 1/7 × speed of driven. But the belt travel is the same for the two pulleys. Hence we must have the following holding true:

Speed of driver × its diameter × 3 1/7 = speed of driven × its diameter × 3 1/7, and therefore

$$\text{Diameter of driven} = \frac{\text{speed of driver} \times \text{its diameter}}{\text{speed of driven.}}$$

This formula may also be reversed thus:

$$\text{Diameter of driver} = \frac{\text{speed of driven} \times \text{its diameter}}{\text{speed of driver.}}$$

Example:

An engine runs 400 r.p.m. Its pulley is 6 inches in diameter. What size of pulley should be used on the line shaft so as to run a pump at 60 strokes per minute?

$$\text{Diameter of pulley} = \frac{\text{speed of engine pulley} \times \text{diameter of engine pulley}}{\text{speed of pump.}}$$

$$= \frac{400 \times 6}{60}$$

$$= 40 \text{ inches.}$$

Cost of Engines.

For pumping purposes a small amount of power is all that is necessary. A 1½ horse-power engine may be had at from $60 to $100. The fuel requirements are not large—a pint an hour a horse-power. On page 21 we saw that the work to pump water for 40 head of cattle would average about ⅙ horse-power for 1¼ hours per day, so that the gasoline for pumping would be a small item.

Where electricity is available, pumping may be done by electric motors, and the same methods as adopted for the engine are applicable to the motor, except that since the speed of the motor is so great, usually 1,500 r.p.m. or more, one pair of pulleys may not reduce the speed sufficiently, in which case a jack-shaft is used between the motor and the line-shaft, one reduction being made from the motor to the jack-shaft and another from that to the line shaft.

Cost of Motors.

In Fig. 28, page 40, the reader will see a ⅙ horse-power motor installed for pumping water from a shallow well into a tank against 50 pounds pressure, which is equivalent to raising the water 100 feet high.

Motors are made in smaller sizes than engines. A ½ horse-power motor would do the pumping nicely on most farms, and it may be had at from $55 to $75 depending on type to suit conditions. Indeed, a ¼ horse-power would usually be of ample size. It can be had at from $40 to $50.

Rainwater and Cisterns.

Next to the well, perhaps the commonest source is the rainwater that falls upon the roof, and is conveyed by eave-troughing and conductor pipes to the cistern located either underground or in the cellar.

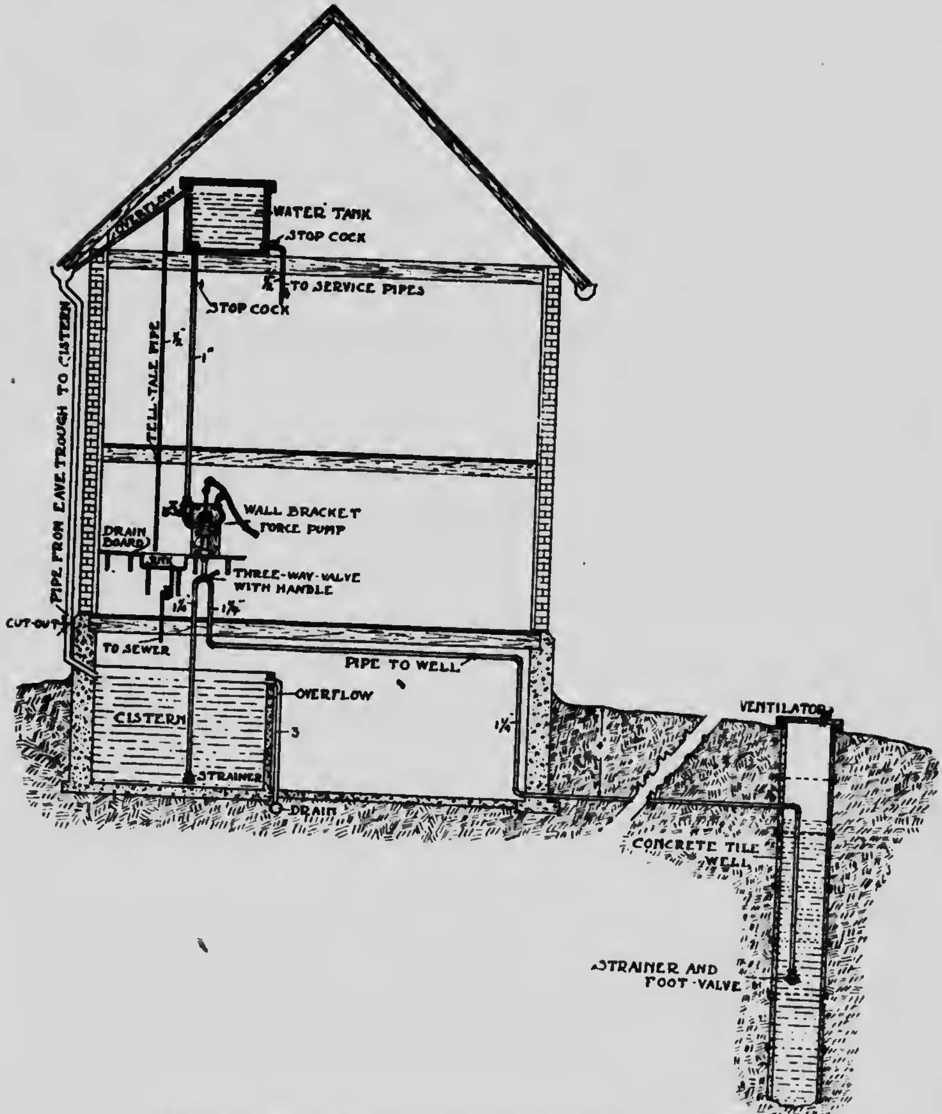


Fig. 19.—Cistern and attic tank system of water supply.

The value of a good cistern should be emphasized because the greatest demands for water in the home can be met by soft water which is supplied abundantly in this country by rains and thaws. In conjunction with an attic tank it can be made available to all parts of the house as detailed later. It is an easy matter to build a cistern and the cost is not great. The best material is concrete. The size varies with size of home or family and uses to which it is put, but it should be large enough to assure water all the year round, probably a tank about 7 ft. by 7 ft. by 5ft. would be ample in most cases. See Fig. 19 for further details.

GRAVITY SUPPLY FROM SPRINGS, STREAMS AND LAKES.

Springs, streams and lakes are frequently the source of water supply for various purposes. If the point of use is lower down than the source then a pipe may be laid and the water allowed to flow down by gravity, care being taken that the pipes are placed deep enough underground to escape frost. In this plan, trouble is occasionally experienced, the water running for a time but gradually stopping. Usually this is due to the lodgment of air somewhere in the pipe. This air comes from the water little by little. We have all seen a glass of cold water set in a warm room and later found the inside of the glass coated with innumerable small bubbles of air that had come out of the water as the temperature increased. Under certain conditions the same thing occurs in the water pipes, and by and by numbers of these small bubbles joining together form larger bubbles, and because of their lightness the large air bubbles try to flow back up the pipe toward the source. When they grow large enough and sufficient in number, the back pressure may entirely stop the water. And if there are any irregularities in grade the air tends to collect in the high spots from both directions. The slower the grade or the smaller the pipe the greater the danger from this source, because then the velocity of the water in the pipe is not sufficient to brush off the small bubbles and carry them along toward the outlet. If the trouble occurs in a pipe on a uniform grade it may be relieved by tapping standpipes into the waterline at intervals, or on an uneven grade, at the high spots. Generally it is not wise to use smaller than inch pipe for gravity systems. The end of the pipe in the source must be provided with a screen to keep back small stones, sticks or anything that might tend to choke the pipe line. The line should be laid as straight as possible, the joints in it well leaded and screwed up close so as to cover all the threaded portions of the pipes. This system is quite rare because very few places have the source of water supply high enough to make its adoption practicable. Fig. 20 shows details of such a system.

Use of the Siphon.

When the source and the house are on opposite sides of a ridge, and the source higher than the house, as shown in Fig. 21, the water can be siphoned over the ridge to the house in a pipe laid under the frost-line, if the perpendicular distance marked AB in the sketch does not exceed 20 to 25 feet, and the pipe is once filled with water. The pipe line should be made airtight and frost-proof, and it should be laid over the elevation with as gradual a bend as possible. The pet-cock at the highest point is installed for the purpose of pumping out any accumulation of air that may occur there from time to time and stop the flow. The pipe is filled with water in the beginning by means of a pump attached to

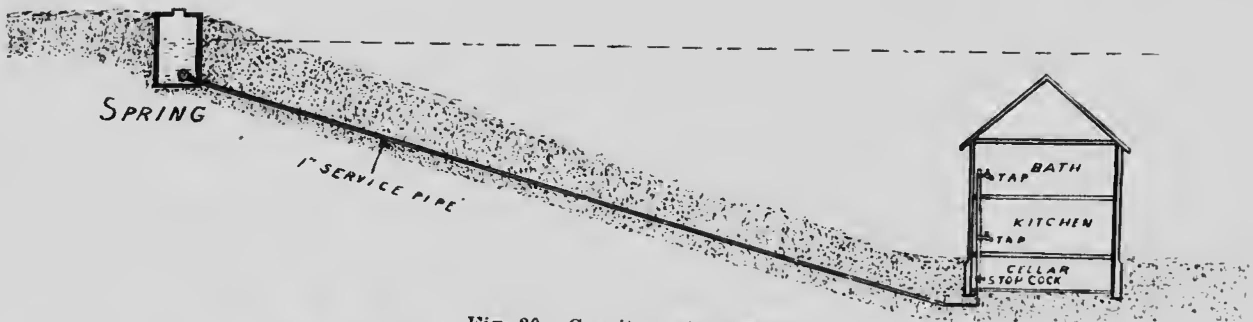


Fig. 20.—Gravity water system.

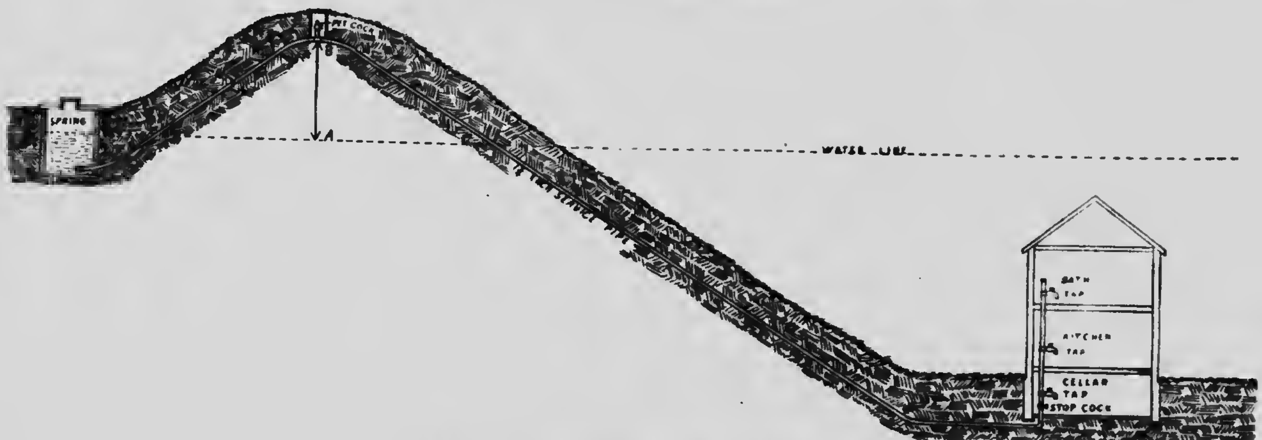


Fig. 21.—Siphon gravity water system.

the pipe in the house and once this is done the water will flow at the taps whenever they are opened. Occasionally this system is found in use. It also may give trouble by becoming airbound at the highest point, so some means as suggested above should be provided in order to easily remove the air and restore the normal flow.

Where the point of use lies at a higher elevation than the spring, stream or lake, then the pump may be used, in one or other of the forms already described, and operated either by hand, windmill, gasoline engine or electric motor.

THE HYDRAULIC RAM FOR ECONOMICAL SERVICE.

In many cases, however, it is possible to install an hydraulic ram, a variety of pump in which the energy of the water falling from the source to the ram is used to pump a portion of the water from the ram to the buildings situated at a much greater height. Fig. 22 (*a*) shows a sectional diagram of the hydraulic ram from which we may study its principle. S is the source of supply, being a spring, pond, lake or river, D the drive pipe, W the waste valve which opens downward, A the air chamber, C the check valve between the air chamber and the drive pipe which opens upward, and P the supply pipe by which the water is carried from the ram to the buildings.

When the water flows down the drive pipe it finds the valve C closed and W open on account of their own weight, consequently it begins to escape through the open waste valve. As soon as the velocity of the water is great enough to counterbalance the weight of the valve W, the latter closes, and very suddenly, too. If the drive pipe D is 1½ inches in diameter and 50 feet long, which is a length frequently used, the weight of water in the pipe is 38 pounds, and this is moving rapidly down the pipe. When the waste valve closes suddenly the 38 pounds of water strikes a blow on the inside of the pipe, including the valve C. Think of the blow a 38-pound hammer would strike, and you have some idea of the blow delivered by the water. The impulse opens the valve C and the water rushes suddenly and rapidly into the air-dome A. By and by, however, it comes to rest on account of the back pressure of the air. Immediately this happens the air begins to expand and starts the water backward up the drive pipe. This lasts only an instant, just long enough for the check valve to close, but this small recoil is a very important factor in the working of the ram. When the check valve closes the movement of the water backward in the pipe creates a suction on the waste valve, which, along with its own weight, opens the valve. Meantime, the air in A continues expanding and drives the water at a steady rate up the supply pipe toward the buildings. While this is taking place the water is wasting through W, and as soon as the velocity is great enough, W is closed again and another blow is struck, and thus the whole cycle is repeated over and over again.

The air-dome is absolutely essential to the working of the ram. In the supply pipe leading away from the ram up to the buildings there is a large weight of water, and even the blow from the 38-pound hammer in the drive pipe couldn't set all that water in motion so suddenly. But in the dome is a cushion of air, and when the blow comes that cushion is easily and quickly compressed, allowing a volume of water to rush in suddenly irrespective of the water in the supply pipe. However, since air is soluble in water the quantity in the dome gradually disappears and when nearly all exhausted the ram will stop working, and the only

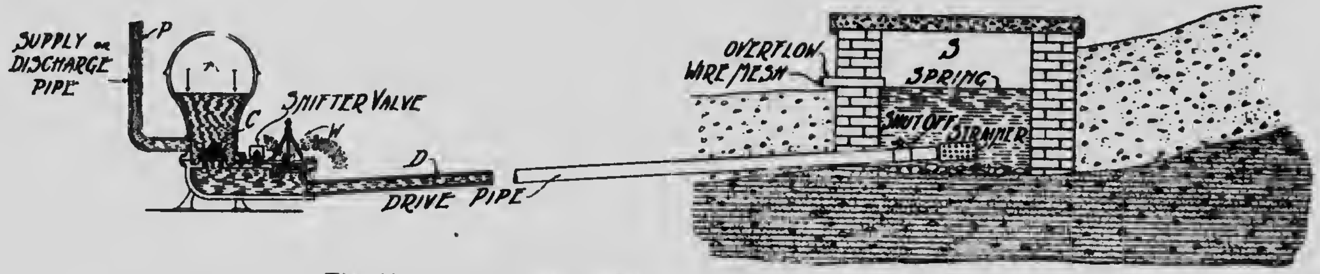


Fig. 22.—(a) Sectional diagram of hydraulic ram installation.

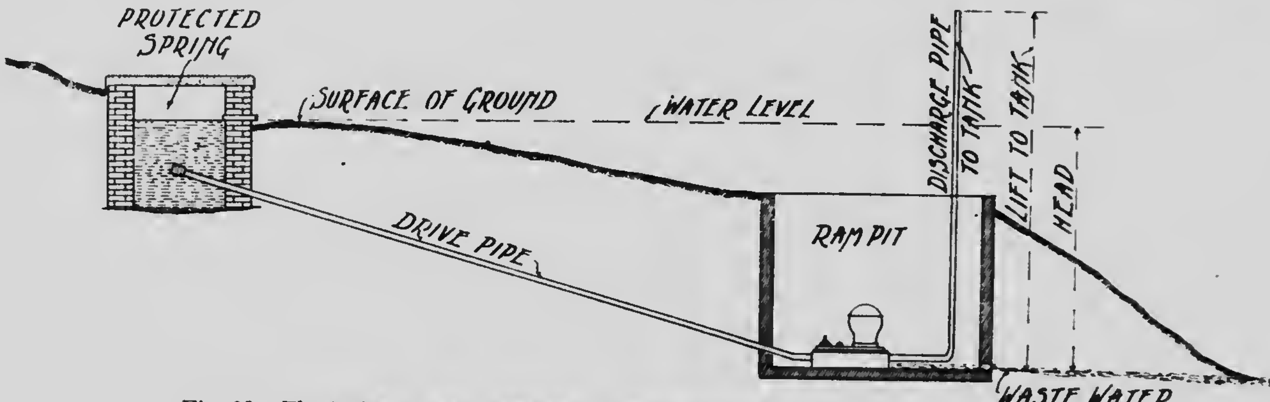


Fig. 23.—The hydraulic ram installation under ordinary conditions, ram close to spring.

way to start it again is to put fresh air into the dome. To do this it may be necessary to remove and empty it. Some drill a hole in it and put in an air valve similar to those used in bicycle or automobile tires, and then by means of a hand-pump force fresh air into the dome from time to time. However, it is possible to have air taken in automatically. It has already been pointed out that immediately after the valve C closes, a suction is created in the drive pipe. If a small hole is drilled in it, preferably on the top side, and essentially close to the ram, then at each suction a few bubbles of air will be drawn in, and this will keep the air in the dome constantly replenished. During the pressure portion of the stroke some water will waste through this hole, and, consequently, in new rams a check valve is fitted into it to prevent loss of water but admitting air. This is sometimes called a snifting, snifter, or sniff valve.

Fig. 22 (*b*) gives a sectional view of a ram, by which it will be seen that the

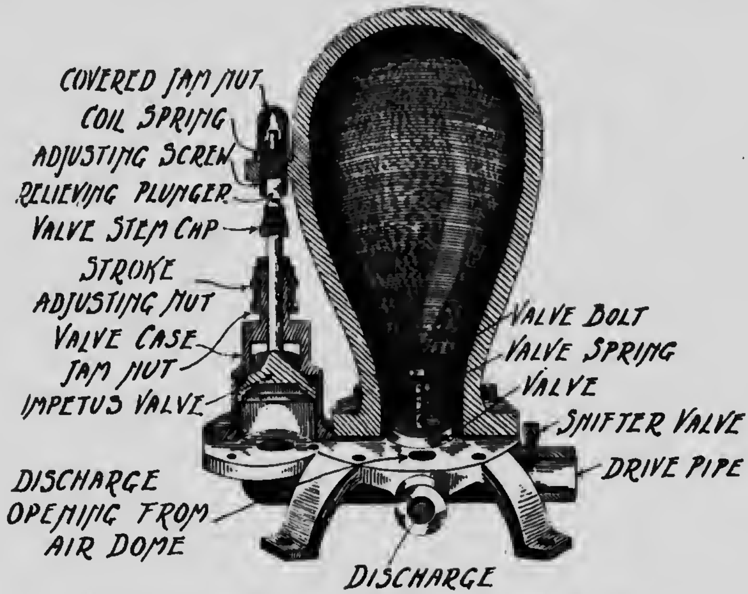


Fig. 22.—(*b*) Section of hydraulic ram, showing parts.

waste valve may be placed on the opposite side of the air-dome, in which case the drive pipe passes directly under the ram. As an additional help to open the valve W at the right time some rams are fitted with a relieving plunger operated by a spring. It is so set that the stem of W hits the plunger when at the top of its stroke.

What the Ram Will Deliver.

Where conditions are suitable for a ram it is without question the cheapest and most satisfactory method of pumping water. It has one drawback—it wastes far more water than it pumps to the buildings, and hence can only be installed where the supply is from five to twenty times as great as required at the buildings. The efficiency of the ram is from 65 to 90 per cent., i.e., it uses 65 to 90 per cent. of the energy of the falling water. Suppose the spring supplies 10 gallons per minute and the fall from the spring to the ram is 5 feet. Multiply these together and then take 65 per cent. of the product, and we have the energy available for driving water to the buildings.

$$\text{Energy in this case} = \frac{65}{100} \times 10 \times 5 \text{ foot-gallons.}$$
$$= 32.5 \text{ foot-gallons.}$$

Now divide this by the height of the buildings above the ram and we have the number of gallons the ram will deliver per minute at the buildings. If, for example, the height is 32.5 feet then

Number of gallons delivered per minute$= \frac{32.5}{32.5} =1$ gallon which is 1/10 of the water supplied by the supposed spring.

Therefore number of gallons per day=60 × 24=1,440 gallons=about 29 barrels. Consequently with 5 feet of head and 32.5 feet of lift the ram will deliver at the buildings 1/10 of the water in the spring. The quantity that will be delivered with other heads, lifts and spring-flows may be calculated in a similar way.

Generally speaking it is found that for each 10 feet of lift there should be 1 foot of head, but there is a limit—it is seldom advisable to install rams where the head is less than say two feet, although they have been known to work with as little as 18 inches. The length of drive pipe should not be less than three-quarters the lift to the buildings, nor less than five times the fall from the spring to the ram. It may, however, be longer, but seldom exceeds 50 feet, and 75 feet might be taken as an extreme length for sizes of ram suitable for farm conditions. If too long a drive pipe be used, the extra friction in it prevents the water from striking as heavily or as frequently as with a drive pipe just the right length.

Figs. 23, 24, 25 and 26 show how to install the ram under varying conditions. Fig. 23 illustrates the ordinary case where the conditions are such as to allow of building a ram pit within 35 to 50 feet of the spring, low enough to give sufficient fall in the drive pipe, and at the same time affording ample escape for the waste water. Note method of protecting the spring. Sometimes the ram pit must be built a considerable distance from the spring—say 200 feet. With such a long drive pipe the ram will not work satisfactorily unless fitted with an open stand pipe about 35 to 50 feet from the ram, as shown in Fig. 24. Sometimes a reservoir is used instead of the stand pipe, e.g., a barrel sunk in the ground. A long drive pipe is a detriment, for two reasons; first, in it friction is so great that it takes considerable time for the water to get up sufficient velocity to close the waste valve; secondly, the air-expansion in the dome would have to start all the water in 200 feet backward up the pipe before any recoil and suction could take place to aid in reopening the waste valve. The stand pipe overcomes both these difficulties—during the recoil the water in the lower section of the line recoils up the stand pipe while above it the water still keeps flowing down the line and raising the level in the stand pipe. When the waste valve opens again the supply and head in the stand pipe enables the water in the lower section to develop velocity quickly independent of that in the upper section. Thus the water level in the stand pipe pulsates up and down. On a stream, where head is not available under existing conditions it is sometimes possible to lead a portion of the water by a ditch or tile along the bank at a slower grade than the stream itself, and so obtain the necessary head.

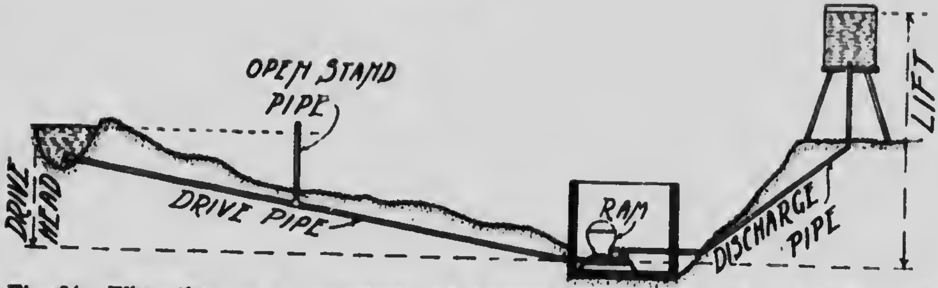


Fig. 24.—When the ram is at considerable distance from the spring, an open stand pipe or reservoir must be provided within 35 to 50 ft. from the ram.

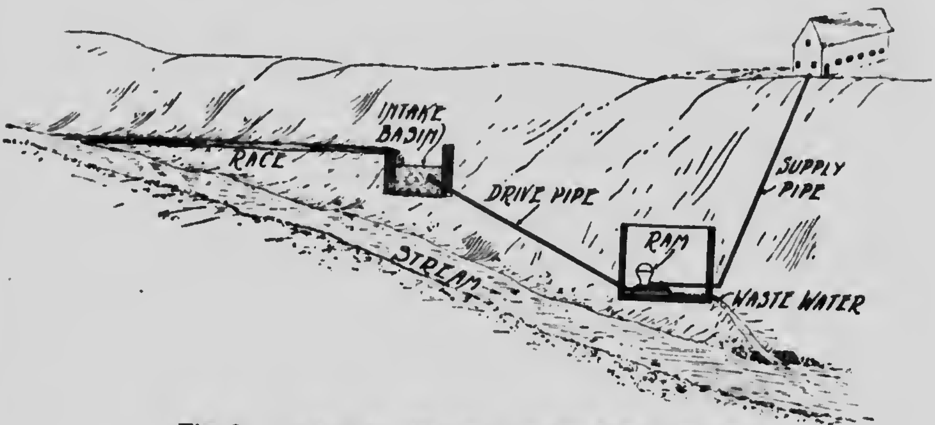


Fig. 25.—Obtaining head for ram along a river bank.

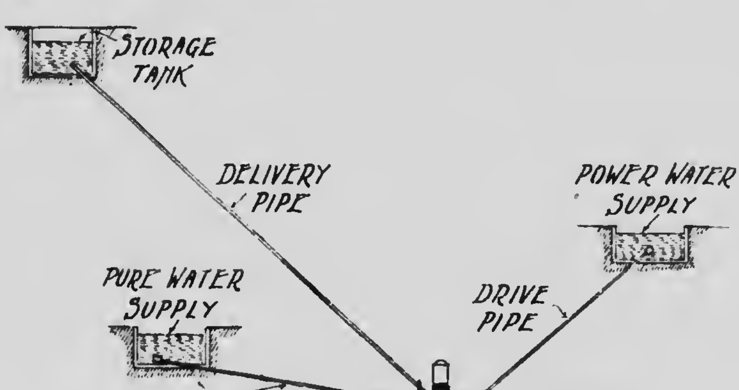


Fig. 26.—Double acting ram using impure water supply to drive pure water to the buildings.

This is illustrated in Fig. 25. Sometimes a small pure spring which does not supply sufficient water to operate a ram is situated near another source of water unfit for domestic use, as a pond, lake or stream. When the levels are such that the two supplies can be led together at a lower point, a double-acting ram may be used. This is so constructed that the impure water operates the ram and delivers nearly all the spring water at the buildings. Fig. 26 shows this installation.

When to Use Ram.

The steps to be taken in deciding whether a ram can be used are as follows:

1. Measure the flow of the spring. It requires 2 to 3 gallons per minute to operate the smallest size of ram. To measure the spring, construct a small dam with an opening in it and catch the water in a pail or tub noting the time it takes to fill it. Then measure the water in gallons.
2. See if thero is drainage for the waste water.
3. Determine the lift between the ram and the buildings.
4. Determine the head that may be procured from the spring to the ram-pit and see if this is great enough as compared with the lift—one foot of head to ten of lift.
5. Determine the amount of water required per day at the buildings, using as a basis the quantities mentioned on page 34.
6. Using the method explained on page 31, calculate the amount of water the ram will deliver. If this is as large as the quantity required the ram may be installed.

Appendix 1 contains a form which if filled out and submitted to any maker of rams will enable him to advise whether a ram is practicable, and if so, what size.

Cost of Installing Ram.

In February, 1917, we obtained prices on rams, piping, etc., and made an estimate of the cost of installing rams of different sizes to supply water to buildings situated 100 feet from the ram, and also the additional cost for each 100 feet additional distance between ram and barn. This estimate is presented in Table I. The prices are somewhat in excess of those obtaining before the war, but on the other hand are less than at the present time (May, 1918).

Table I, Showing the Approximate Cost, February, 1917, of Installing Hydraulic Rams.

Size of Ram.	Cost of Ram.	Drive Pipe.		Price of 35 feet	Supply Pipe.		Digging 135 ft trench and laying pipe, say	Filling trench, say	Ram pit, say	Intake, say	Total for delivery 100 ft. from ram.	Cost of each additional 100 feet.
		Length and size.	Rate per 100 feet black.		Length and size.	Rate per 100 feet black.						
	$	ft. in.	$	$	ft. in.	$	$	$	$	$	$	$ in.
No. 2....	9	35 x ¾	6.20	2.17	100 x ½	5.05	7.90	1.00	5.00	5.00	35.12	12.05—½
No. 3....	11	35 x 1	9.16	3.21	100 x ½	5.05	7.90	1.00	5.00	5.00	38.16	12.05—½
No. 4....	14	35 x 1½	14.83	5.29	100 x ¾	6.20	7.90	1.00	5.00	5.00	44.39	13.20—¾
No. 5....	22	35 x 2	19.94	6.98	100 x 1	9.16	7.90	1.00	5.00	5.00	5[illegible]4	16.16–1
No. 6....	40	35 x 2½	31.54	11.04	100 x 1¼	12.40	7.90	1.00	5.00	5.00	82.34	

Chief Features of a Good Water System.

But modern systems of farm water supply do not end with a suitable pump or other means for delivering the water at the buildings. They aim at providing the same conveniences as are enjoyed in city homes, viz., water on tap wherever required, whether on the lawn, in the kitchen or at the bath-tub. To do this, three elements are necessary in the system, first, a storage tank of some type or other, secondly, a method of providing pressure either by gravity or compressed air, and, thirdly, a distribution system from the tank to the points of use. Several methods are in vogue, according to the varying needs under different circumstances, but whatever the method there are certain general features that apply in all cases:

(1) The system should have capacity enough to meet the maximum requirements every day of the year.

(2) It should be simple in construction, compact, durable, not liable to leak, easy to operate and keep in repair.

(3) It should keep the water in a pure, fresh and cool condition for delivery at the taps at all times.

(4) It should be capable of rendering assistance in washing vehicles, watering the lawn and garden, and in fire protection.

Quantities of Water Required per Day.

In determining the capacity of systems for homes equipped with all modern conveniences it is the rule to allow at least 25 gallons per person per day, but where there is neither bath nor water-closet 10 gallons is sufficient.

For stock, the following quantities are allowed: cow 10, horse 10, sheep 2, and pig 1 gallon per day.

A knowledge of these amounts is an aid not only in calculating intelligently the size of water storage tanks for house or barn, but also determining type and capacity of pump to use, and size of septic tank required to take care of the sewage from the home.

THE ATTIC TANK SYSTEM.

Perhaps the simplest of all is the attic tank system, the distinctive feature of which, as its name implies, is a storage tank in the attic of the house for supplying water by gravity. The tank may be filled by kitchen pump, power pump, hydraulic ram or siphon, or by the rain water from the roof. This system is best adapted for utilizing the soft water from the roof or cistern for washing or bathing but for drinking purposes the water would become rather warm in summertime. The tank may be made of wood lined with galvanized iron, of metal, or of two or three oak barrels joined at the bottom by iron piping. A tank about 3 feet square is large enough for the ordinary-sized home. Other details as cover, overflow pipe, etc., are shown in Fig. 19. This system is giving good service in many homes to-day. One disadvantage is that occasionally the tank may spring a leak, causing damage to the house or furniture. As the quantity of water stored is usually not large, the system is not applicable for washing vehicles, etc., nor for fighting fire, especially as it will not deliver water higher than the tank itself.

THE ELEVATED TANK IN THE YARD.

A system somewhat akin to the one just considered is that of having a large stave or metal tank erected on a high tower in the yard usually in connection with the windmill structure. Water is pumped into it by one or other of the methods already noted and flows by gravity through pipes laid to the house, barn, lawn and garden.

The system has many obvious disadvantages for general use, but it is well adapted for lawn and garden watering, as the water has a chance of being warmed in the sun before being applied to the plants. Except for this particular advantage, it is doubtful if anyone would consider installing this system to-day when superior ones can be secured, for example, the compression system next to be described.

THE COMPRESSION WATER SUPPLY SYSTEM.

In bare outline this system consists in storing water in a steel tank under high air pressure, which drives the water out of the taps whenever they are opened.

The introduction of this system has made it possible for rural homes to have practically as good a water service as those in towns and cities. Since its advent a few years ago it has been installed in a great many rural homes, also in many suburban and village homes and summer resort cottages. Its popularity is due to its many distinct advantages over other systems, chief of which are given herewith:

1. The stored supply of water is kept clean, pure, aerated and cool in an air-tight tank underground or in the cellar, and always under sufficient pressure to render it available at all parts of the house and barns for ordinary service, and, if necessary, under extra pressure for fire protection, watering lawns and garden, and washing vehicles.
2. It is simple and compact in construction, durable, efficient, and easy to operate, the electric-driven outfit being entirely automatic.
3. Unlike the elevated tank system it is not a source of danger to life and property and the stored water is not subject to freezing in the winter and heating in the summer.

Farmers who have installed this system in their homes freely testify to the importance of these advantages. Indeed only those who have enjoyed the privileges of a good water system, like this one, can fully appreciate its value.

Construction of System.

As illustrated in Fig. 27, the system is composed of the following parts: One airtight metal storage tank, one force-pump with air compressor attachment, one pressure gauge, one water gauge, iron piping for connecting well to pump, pump to tank, and tank to faucets, and miscellaneous fittings such as check valves, unions, valves, etc. When the pump is power-driven there is also an engine or motor and their automatic controls.

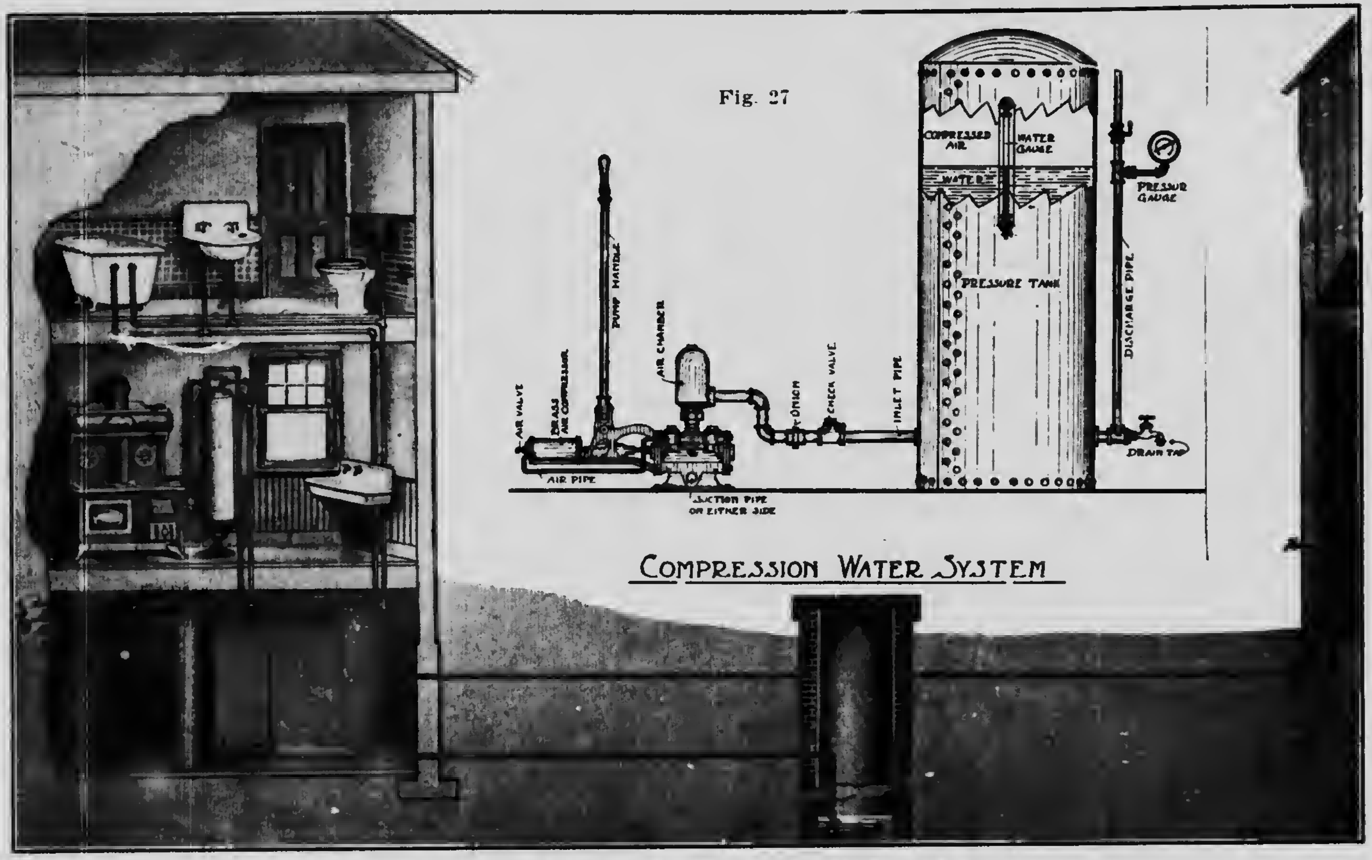


Fig. 30.—Water convenience for house and barn.

Fig. 27.—The compression water system, showing details of parts.

Storage Tank.

The storage tank is a cylindrical metal one having a guaranteed factory test of 125 pounds, and a working test of 75 pounds per square inch. The size depends upon the storage capacity required, and the power used for pumping, but for the average-sized home it is usually 30 in. by 6 ft. with hand, gasoline engine and windmill power, and 24 in. by 6 ft. with electric motor power; and when the same plant serves both house and barn 36 in. by 10 ft. is the common size. The accompanying table No. II may be found useful for reference on this type of tank.

Table II Compression Storage Tanks. Common Sizes.

Diameter in inches.	Length, feet.	Capacities.			Approximate weight in pounds.
		Barrels of 50 gals.	Gallons (Imperial), full capacity	Gallons, working capacity, ⅔ of full capacity.	
24	6	2.36	118	62	350
30	6	3.70	185	123	530
30	8	4.96	248	165	650
30	10	6.14	307	204	770
36	6	5.30	265	176	750
36	8	7.08	354	236	900
36	10	8.84	442	294	1050

For both hard and soft water two tanks are required, but each smaller than for the single installation, probably 24 in. by 6 ft.

The function of the tank is twofold, namely, the storage of water, and the retention of compressed air, which forces out the water when the faucets are opened. Since the storage tank contains both water and compressed air, the system is also known by the name "hydro-pneumatic water supply system."

The Pump.

The type and capacity of pump depends upon the kind of power used, class of well, whether shallow or deep, size of the installation, suction distance and so on, but it must always be a force-pump, being required to pump water against pressure. The reader is referred to the treatment of pumps in another part of this bulletin, for further information, and requested to note Figs. 11 to 14 as they show the common types of pumps used in connection with the compression water system.

The Air Compressor.

In the treatment of the hydraulic ram it was pointed out that air is soluble in water, and consequently unless fresh air was admitted to the dome the supply would become exhausted. The same is true here. To overcome this difficulty we require an air compressor by which fresh air can be forced into the tank from time to time. This is shown in Figs. 14 and 27. It consists of a small brass cylinder tapped at one end for a suction and a discharge valve, and containing a solid piston.

The piston is joined directly or indirectly, as the case may be, to the piston rod of the water pump, so that both pistons move simultaneously. A small iron pipe connects the compressor to the discharge side of the water pump, through which the air is forced to the pump, and thence with the water into the tank. When air is required a screw cap or tiny lever is turned one way to make the suction valve operative, and when air is not required this adjustment is reversed. Some authorities claim that the air pump should be used once or twice a week, but this is a matter for the attendant to find out by experience for his own particular case.

The Pressure Gauge.

This is the instrument resembling a small clock, that is seen in Fig. 27, attached to the discharge pipe at a point close to the side of the tank. This is the preferred location for it, being easily seen and convenient, but it may be placed anywhere in the system for either air or water will operate it. Its purpose is to indicate the pressure in pounds per square inch of the compressed air in the tank, in order that the attendant may know when to pump water into the tank, and when to stop, as he will know by experience what range of pressure gives the best satisfaction. This range will usually vary from 30 to 45 pounds.

The Water Gauge.

This is the glass tube on the front of the tank for indicating the amount of water and air, and as the water should be kept about two-thirds way up the tank this gauge is located near the top. Every height of the water records a definite pressure on the gauge as seen in pressure table on page 39. and if the height of the water is found to be above what it should be for the recorded pressure, the tank needs more air.

Piping.

All the piping should be A1 galvanized iron. The size of the discharge pipe is ¾ in., the suction and delivery 1¼ in. to 2 in., depending on the size of the installation, and the distance the water has to be drawn or forced. The service pipes throughout the house are ½ in. inside diameter.

Check Valves.

As shown in the illustration a check valve is located in the delivery pipe connecting the pump and the tank. Its function is to prevent the return of the water and air once they are pumped into the tank, and the pumping ceases. It should be installed so that the flapper or valve will open in the same direction as the water moves. It is advisable to put a check valve on the end of the suction pipe in the well whenever the suction distance is great, for the purpose of keeping the suction pipe full of water and the pump always primed. Combined with this check valve there should be a metal strainer to keep out things that might choke or destroy the pump valves. "Foot-valve and strainer" is the common name for this combination.

Drain Cock.

At the bottom of the tank is a drain cock. Its purpose is to drain the tank when necessary, for example, in cleaning, repairing or moving it.

Stop and Waste Cock.

In the discharge pipe above the pressure gauge is a stop and waste cock. Its purpose is to shut off the flow from the tank in case of repairs or alterations in the service pipe. It also drains the pipes.

Automatic Controls.

Speaking generally, the power-operated installations are equipped with automatic control switches for turning the power on or off at predetermined set pressures; for example, if the control be adjusted for a minimum pressure of 30 pounds and a maximum of 45 pounds the pumping will start and stop respectively whenever these pressures exist in the tank. This, of course, does not apply in full to the gas-operated plant, as the engine has to be cranked for starting. It is claimed that these controls are reliable and safe, and their advantages are obvious, but the attendant must take heed lest, just because it is automatic in this regard, he fail to give the plant the necessary care otherwise.

Kinds of Power Used for Pumping.

As already intimated, the power used may be hand, gas engine, electric motor or windmill. Probably the majority of the systems installed to date are operated by hand, but the power-driven are rapidly increasing, and are very much more satisfactory. One, or one and a half horse-power gasoline engine is adequate when used only for pumping, but in many cases it would be advisable to have a larger engine so that other work might be done as well. Since the electric-driven units are absolutely automatic they need not be so large and, consequently, less power is required, about 1/4 to 1/6 horse-power motor being large enough for small outfits for short suction distances. See Fig. 28.

Reference has already been made to the pressure gauge and its use. Now we shall see what the pressure is for different heights of water in the tank, and how high the various pressures will lift water in the pipes; first, when no air has been pumpe[illegible] the tank previous to the water; secondly, when enough air has been pumpe[illegible] t to make the gauge read, say, 10 pounds. The facts are given in the [illegible]ed form herewith.

Table III. Pressure in Pneumatic Tanks and Height Water Will Be Forced By It.

Amount of water in tar'	Gauge Pressure.		Actual height in feet water would be forced in pipes.	
	Nothing to start with.	10 lbs. to start with.	Gauge at 0 to start with.	Gauge at 10 to start with.
None.	0	10	0	20
1/4 Full	5	18 1/3	10	36 2/3
1/3 "	7 1/2	22 1/2	15	45
1/2 "	15	35	30	70
2/3 "	30	60	60	120
3/4 "	45	85	90	170

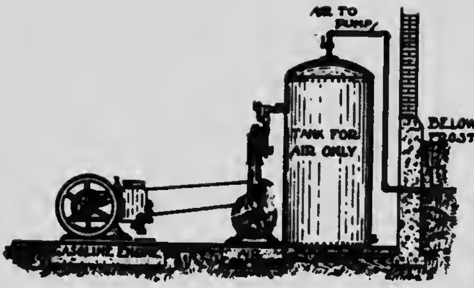


Fig. 28.—Demonstration pneumatic water system installed in Department of Physics, O.A.C. On the right is a 1½ h.p. gasoline engine. In front of the tank a double acting force pump of the same kind as shown in Fig. 14 (a). Note the pump handle. Just to the left of the tank is a ⅙ h.p. motor and pump of same type as shown in Fig. 14 (b). This motor is operated from the storage battery of the electric light plant on the left of the picture. The tank may be filled by hand, gasoline engine or electric motor.

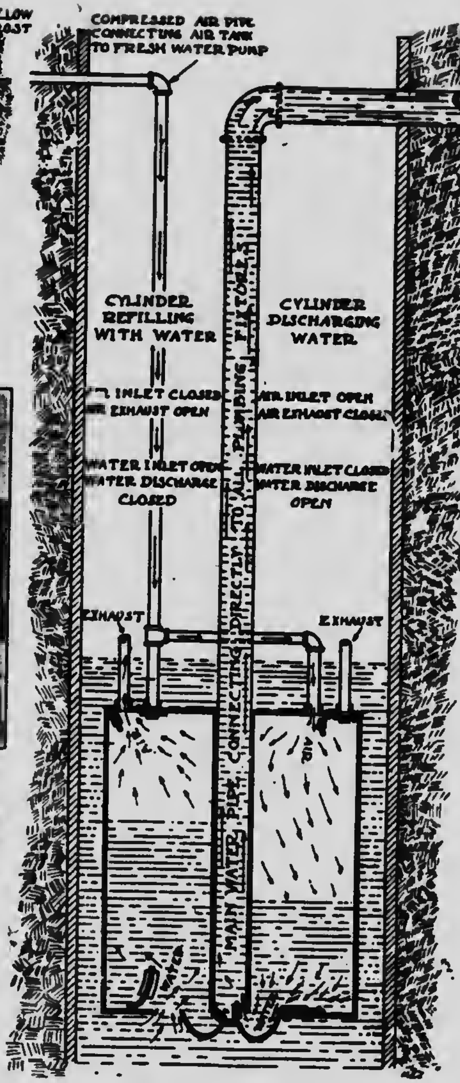


Fig. 29.—Fresh water system.

The heights recorded in columns 4 and 5 of the above table were calculated on the basis that when a tap is opened one pound pressure will lift water two feet in ordinary water pipes, friction included, but for stationary water under standard barometer, one pound pressure will support a column two feet four inches high.

In comparing the figures in column 3 with the corresponding ones in column 2 we note the decided gain in pressure by pumping some air into the tank first, a great advantage no doubt, in respect to fire protection, and in view of the fact that the tank could be entirely emptied at the highest tap in the house if necessary, but a disadvantage from the standpoint of pumping, especially by hand, as more power is required to pump against the higher pressure.

Additional Care of System.

1. Always keep the tank ½ to ⅔ full of water.
2. Pump a little air into the tank once or twice a week.
3. Keep pump, gasoline engine or electric motor well oiled, and otherwise in good working order.
4. Pump valves and valve seats will need cleaning and renewing occasionally. It doesn't pay to allow them to be old and badly worn.

Hints to Prospective Purchasers.

Names and addresses of companies handling this system may be secured from their advertisements in farm magazines and papers, from local plumbers and hardware dealers. It is a good plan to write the various firms for their catalogues describing the system, and make a careful study of the various types before purchasing. The companies will answer questions and give estimates of costs without any charge or obligation to buy.

Appendix 2 contains a form that will be convenient for sending information that will enable them to give you the estimates without delay.

General Statement of Costs.

The costs can be given only in a very general way as they vary considerably with size and type of installation, conditions under which the system is installed and so on.

1. Hand operated plants, $90 to $130. Size of tank 30 in. by 6 ft.
2. Gasoline engine operated, about $200. Size of tank 30 in. by 6 ft.
3. Electric motor driven unit, about $200. Size of tank, 24 in. by 6 ft.

All these estimates include tank, pump with air compressor, engine or motor for power, pressure and water gauges, connecting pipes, valves, unions, etc., but they do not include the service pipe throughout the house or barns, or from the pump to the well.

Pointers Regarding Installation of System.

1. The tank should be put in a frost-proof place, the cellar being the most common and best location, although it is sometimes placed underground. It may be set vertically or horizontally, depending on the height of the room.

2. The pump may be located inside the buildings and close to the tank if the well is shallow; that is, if the water is never more than 20 to 25 feet lower than the level of the pump cylinder. This arrangement is highly desirable if it can be secured.

3. If the pump is inside and operated by power, use the belt driven method of transmission as it is quieter than the direct drive.

4. Unless the purchaser has had some experience with plumbers' tools, or is a good mechanic, he had better get a plumber to install the system.

5. Insist on the plumber making a thorough test of the system before he leaves the job. This consists of pumping up the tank with air and water to about 50 pounds pressure and waiting to see if the pressure holds well or not, and if there are any leaks in pipe, connections, etc.

6. See that the check valve between the pump and the tank is put in as recommended in a previous paragraph.

7. Before starting the pump, open the suction valve or valves and pour in water enough to prime it well, and then screw the valve cap on again very tightly.

FRESH WATER SYSTEM.

There is another type of pneumatic system of water supply, a new one only just beginning to be introduced, known as the Fresh Water System, because no storage tank is used, the water being pumped direct from the well by compressed air whenever a tap is opened. It is illustrated in Fig. 29. Close to the engine or motor is situated an air pump by which air is forced into the air storage tank. The water pump, which is of special design, is located in the water in the well. The air tank and the pump are connected by a compressed air pipe and from the pump water-pipes lead to all points of use as in the system already described and which it resembles except in the respect already mentioned. When a tap is opened the water pump is operated automatically by the compressed air, which after being used by the pump is allowed to escape through the exhaust pipes just like the exhaust from a gasoline engine. The same automatic controls as used in the former system can be used here to keep the air pressure up to the desired limit.

HOUSEHOLD WATER EQUIPMENT.

The plumbing fixtures for the ordinary house consist of a kitchen sink, laundry sink or laundry tubs, and a basin, bath tub and water-closet for the bathroom. Good types of these, also their connection with the water service pipes and with the waste pipes, are illustrated in Fig. 30, page 36, and Fig. 35, page 58.

These fixtures may be secured in many different designs and qualities and at as many different prices. Your local plumber, or any dealer in them, should be qualified to give you all such information about them.

The Kitchen Sink.

The kitchen sink is made of plain galvanized or enameled cast iron, slate or porcelain, but the enameled cast iron is preferable for ordinary use. They are made in thre sizes, 18 in. by 36 in., 20 in. by 36 in., and 20 in. by 42 in., the first size mentioned being most common, and it is quite satisfactory for most cases. The sink should be set with its top about 33 in. above the floor to avoid undue stooping for those using it. It should be provided with a back, and also a drip or drain board, and a flexible wire, wooden or rubber mat that fits nicely in the bottom to protect the surface from scratches and as a preventive to breaking dishes against the bottom. The drain pipe leading out of the sink is 1½ inches in diameter, but for the farm kitchen sink the horizontal portion should be 2 inches, as there are such large amounts of waste water passing out of it. The trap below the sink is a very valuable part, as it prevents return of odors into the kitchen, and it should be opened at the bottom occasionally and cleaned out.

Laundry Tubs.

Laundry tubs usually consist of two tubs side by side, either separate or in one large tub with a partition at the centre. They are made of metal, porcelain or artificial stone, the last giving very good satisfaction if not allowed to freeze. They are a great convenience in washing. The clothes wringer can be attached to the partition wall, the clothes being washed in one tub and passed through the wringer into rinsing water in the other.

Bath Tubs.

The higher grades of bath tubs are made of porcelain or enamelled cast iron with a wide roll rim, those of lower grade of enamelled cast iron, or steel body with copper lining known as "steel clad" tubs, or steel body enamel painted. Of the cheaper grades the steel-clad gives the best service. The 5 ft. and 5 ft. 6 in. sizes are the common ones. It should be installed far enough from the walls to allow a person to clean around it easily.

Wash Basin.

Basins are made of enamelled cast iron and a good type is shown in Fig. 30, page 36. They are designed either for attaching to the wall or a corner of the room.

Water-Closet.

The water-closet consists of the bowl, the seat and the flushing tank containing a ball-cock device for regulating height of water in the tank. The bowl is enamelled cast iron and it is important that the enamel be good. The part that gives the most trouble is the ball-cock valve in the tank. To be satisfactory it should be noiseless, quick closing, easy to repair, simple in construction, and made of high grade material free from impurities, so that the valve seat will not be destroyed readily by chemical action of water on it.

Installation of the Fixtures.

1. Secure a capable plumber to do the work, and have him test the installations thoroughly for defects or leaks before you accept the work.

2. Discuss with him the question of best layout for the various fixtures, for instance, where should the kitchen sink, used so much, be installed in order to be most convenient.

3. So far as practicable, the fixtures and water pipes should be kept away from outside walls, doors and windows in order to protect them against frost. This is very important.

4. The water pipe should be made of the best galvanized iron and it should be ½-inch inside diameter.

5. The waste pipes from sinks, basins and bath tub should be 1½-inch diameter and each of these pipes must be provided with a trap or water seal.

6. The hot water boiler may be located in the cellar close to the furnace, in the kitchen, or in the bathroom, some preferring one place and some another, according to personal taste and the layout of the house.

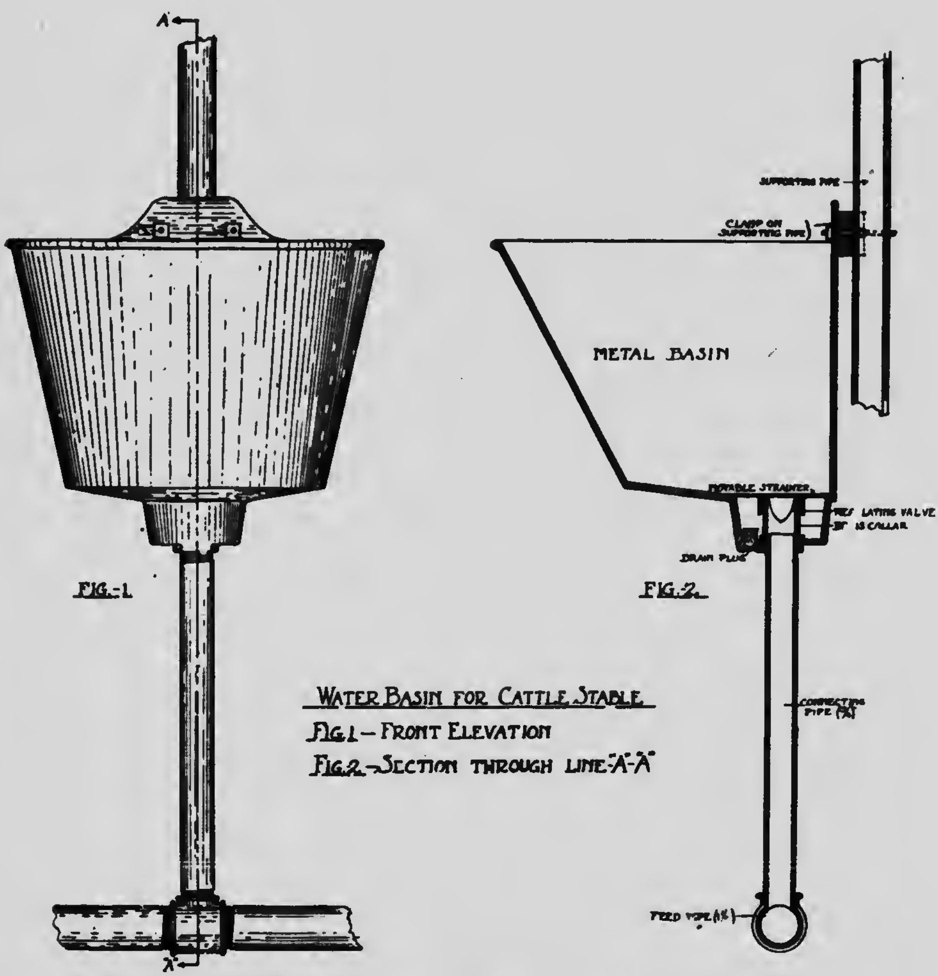


Fig. 31.—Water basin for stable.

WATER SYSTEMS FOR THE STABLE.

The best water system for the stable consists of a storage tank in the mow above the stable or suspended from the ceiling, and from which water gravitates to individual drinking basins in front of the cattle or horses. The water is maintained at a constant height in these basins by a float in a regulating tank in the pipe line between the main tank and the basins. The water is prevented from passing from one basin to another by a conical metal valve resting in a seat in the bottom of the basins, the advantage of this being that a diseased animal cannot affect the others through the drinking water, as is the case where the animals drink from a common water trough in front of them.

The tank may be of wood, metal or concrete. The metal tanks are usually suspended from the ceiling of the stable, while the wood and concrete are in the haymow or loft. If a windmill is used for pumping, the tank should be large enough to hold three or four days' supply of water to tide over the days that the wind may not blow. A tank 8 ft. by 4 ft. by 3 ft. will hold enough of water for 20 head of cattle for three or four days. The tank may be filled by windmill, gasoline engine or hydraulic ram. Some run the rain-water into it from the roof of the barn, but there is some objection to this practice on account of the dirt in the water, which may befoul it or choke up the pipes; however, if the tank be cleaned out occasionally the objection cannot be serious. An overflow pipe about 4 in. in diameter is required to take care of overflow in case of big rains. Tanks should be tightly covered and well protected from frost.

A very neat system sometimes found in use combines the house and stable systems, by having the overflow from the house tank lead to the control tank in the stable. In this way the water in the house tank is fresher than when the separate house system is used. This is only feasible where power pumping is used.

The design of the drinking basin needs emphasizing. It should be as simple as possible with no parts to get out of order, and be easy to clean and repair. The accompanying drawing, Fig. 31, shows a very desirable type, with all details named.

For a general outline of this system and for further details the reader is referred to Fig. 32. It could be extended to serve the horses with water in basins, but another regulating tank would be required since their basins would be higher than those for the cattle. It will be noticed that all water pipes are kept away from the walls of the stable in order to protect them from frost. The main pipe feeding the basins should pass from one row of cows to the other along the floor, not rise up to the ceiling and then over, as there would be a tendency for the highest point in the bend to become air-bound.

This system is the most common one to-day, but with the advent of the compression system described previously, we already know of some farmers using it for the stable as well as for the house, the one installation serving both duties. In a few cases the water is supplied to the stables by gravity from a spring, or pumped from a spring by an hydraulic ram, in either case a storage tank not being necessary.

As to the actual installation of the water system for a stable, there is very little about it that a handy farmer cannot do himself if he knows how to go about it and has a few good tools. He can either make the tank or buy it, he

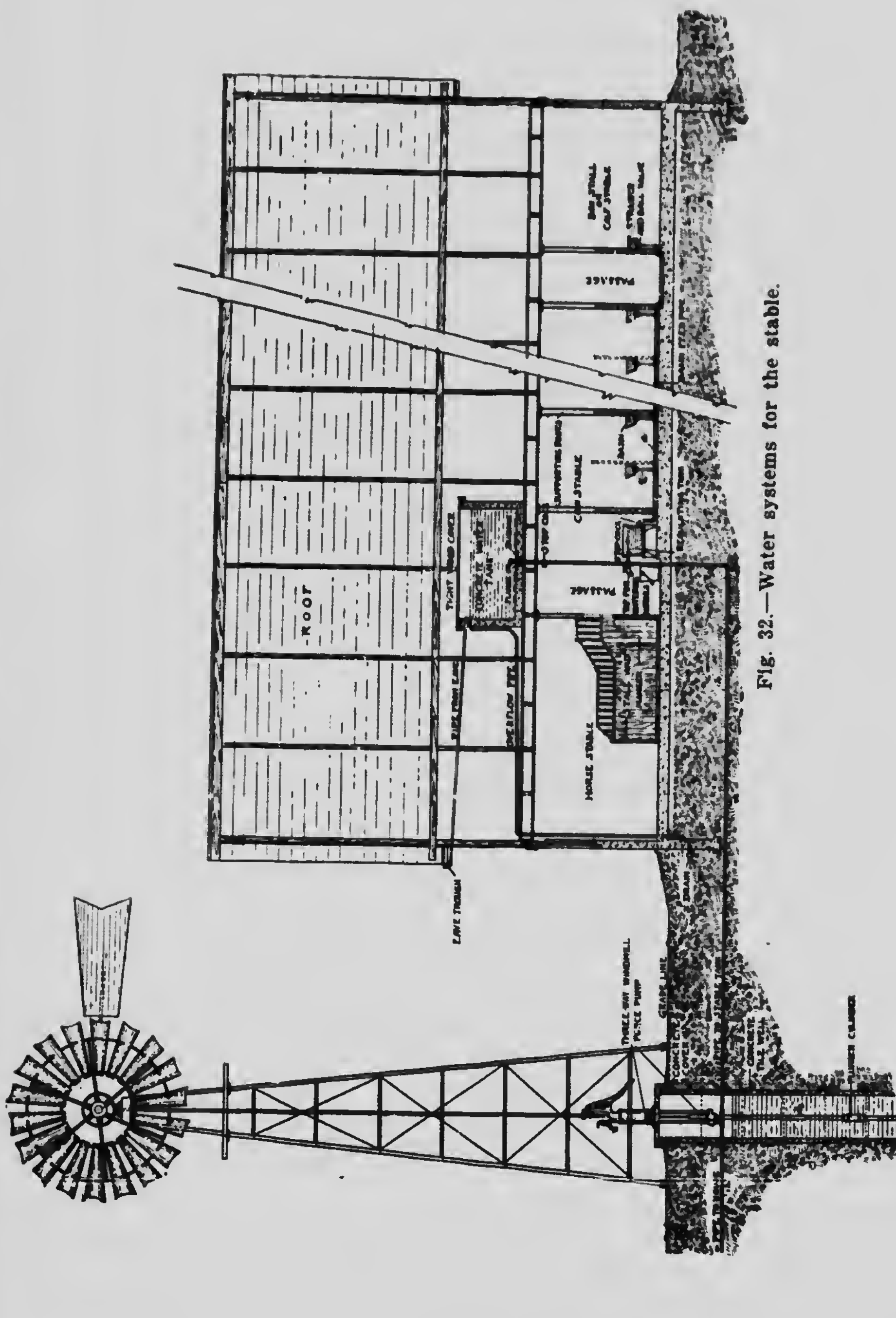


Fig. 32.—Water systems for the stable.

can buy all the pipe and fittings from a hardware dealer already cut and threaded. and the regulating tank and basins from firms dealing in stable equipment. With a couple of pipe wrenches and some white lead for the connections, and a boy to help him, he can install the system nicely.

Two types of regulating valves are used. These are shown in Fig. 33, A and B. The valve and lever in A may be bought for $1.00 to $2.00, depending on size. The float may be made by a tinsmith.

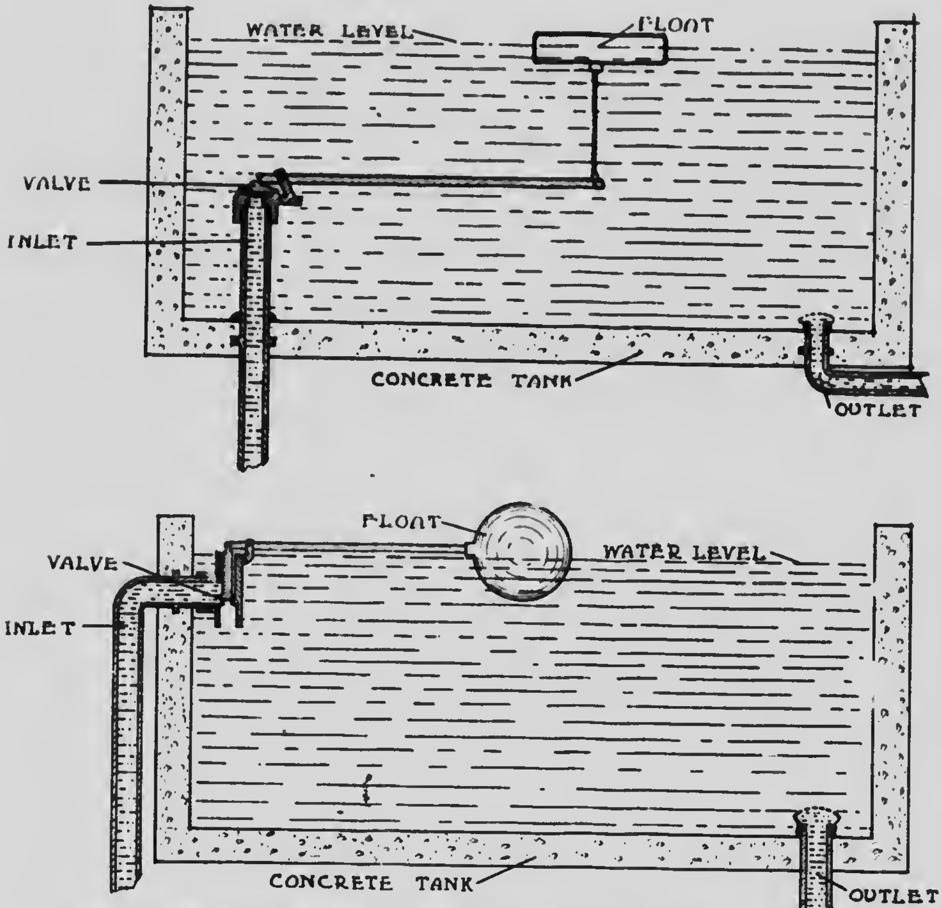


Fig. 33.—Regulating tank, showing details and valves of different types.

Bacteria and the Water Supply

D. H. Jones.

Bacteria are microscopical plants. They are the smallest living things known. They average about 1/5,000 of an inch in length and 1/15,000 of an inch in breadth. They are invisible except when viewed through a high-power microscope, hence the term microscopical. They are very simple in structure, being unicellular. In shape some are spherical, some are straight rods, and some are spiral. See Fig. 34, Nos. 1, 2, 3 and 4. Under favorable conditions for growth they multiply very rapidly. One bacterium may have a progeny of from ten millions to fifteen millions in twenty-four hours. They occur in large numbers wherever man, animal or plant life exists. There are many species of them, the majority of which are beneficial, but some species, however, are injurious. Amongst the latter are those which cause most of the infectious diseases of man and animals. Sometimes these injurious species get into the water supply and as a result an epidemic of infectious disease as typhoid fever is liable to occur.

All natural drinking waters, such as rivers, ponds, lakes, wells, etc., usually contain many species of bacteria. Other micro-organisms, such as algæ, diatoms and crustacea are also likely to be present. Some of the bacteria may be harmful to health, being liable to cause disease, but many of them are not. It is the presence of these dangerous species in the water supply that has to be guarded against.

The species of bacteria found in drinking waters are divided into three more or less distinct groups, as follows:

Group I. Natural Water Bacteria.

This group includes a number of species of bacteria which are not harmful to health. They are liable to develop and multiply in water in which there is a minimum of organic matter, but as they cannot cause disease their presence is not sufficient to condemn the water for drinking purposes.

Group II. Soil Bacteria Found in Water.

In the soil there are many different species of bacteria. See Fig. 34, Nos. 1 and 2. One ounce of soil will contain millions of them. These find their way into rivers, lakes, wells, etc., during rains, particularly at flood time, being washed from the soil both in the surface and drainage waters. These bacteria do not live and multiply in the water to any great extent unless there is a considerable amount of organic matter present in it. They do not produce disease, hence their presence alone in water is not sufficient to condemn it for drinking purposes, though if they are present in any quantity they indicate either that there is considerable organic matter present, or that there is danger of the water

Fig. 34.

1. *Bacillus fluorescens*, fairly common in well water.
2. *Bacillus subtilis* (hay bacillus), common on hay and in the soil; occasionally found in well water.
3. *Bacillus coli*, common in sewage and in polluted water; the danger signal in water examination.
4. *Bacillus typhosus*—showing flagella. Cause of typhoid fever.
5. Flask of culture media, test-tube cultures, inoculating needles, petri dish cultures, high-power microscope. (Edwards.)

being polluted from soil surface washings, which may have been contaminated with disease-producing bacteria coming from infected persons. Neither of these conditions is desirable.

Group III. Intestinal Bacteria Found in Water.

In the intestines of man and animals there are certain species of bacteria, particularly *Bacillus coli* normally present in very large numbers. See Fig. 34, No. 3. These are passed out by the million in the bowel discharges, so that when the water supply becomes contaminated with sewage from cesspools, drains, or seepage, there will be many contaminating bacteria present in the water. These bacteria do not multiply to any great extent in natural waters as the food and temperature conditions of the water are not usually suitable for their multiplication.

Thus, when *Bacillus coli* or any other species of intestinal bacteria is found in water it is an indication that the water has been recently polluted and may be dangerous. *Bacillus coli* itself is not, except under certain conditions, a disease-producing bacillus, but wherever it is found in water there is danger of *Bacillus typhosus* (Fig. 34, No. 4), which causes typhoid fever, being present. Many outbreaks of typhoid fever are due to the water supply being polluted with the discharges from either a typhoid patient or typhoid "carrier." A typhoid carrier is one who has had typhoid fever and has got better, but has not got rid of the typhoid bacteria from his system. Within his system the bacteria are constantly developing and being discharged in the urine and fæces. Water, milk, or any kind of food that becomes contaminated from such discharges is liable to establish typhoid fever in those consuming the food. Hence, great care is necessary to prevent water and foods from being so contaminated.

Shallow or dug wells are very liable to such contamination unless they are properly located and constructed. They should be so located that surface drainage cannot find entrance and the upper ten or twelve feet of the wall should be impervious to water, thereby forcing all water that enters the well to filter through soil to a depth of at least ten or twelve feet, a process which aids in purifying it.

When wells have become polluted from unsanitary seepage or drainage the cause should be found and removed and preventive measures taken so that the trouble should not recur.

The water so polluted should be sterilized, that is, should have all the bacteria killed before being used for drinking purposes. Sterilization may be accomplished either by boiling the water or by the addition of a suitable disinfectant. The disinfectant most suitable for this purpose is a hypochlorite solution. This hypochlorite solution may be prepared and applied as follows:

Stock Hypochlorite for Water Purification.

1. Mix ½ pound of chloride of lime (33 per cent. available chlorine) with 1 pint of water.
2. Then add sufficient water to make 1 gallon.
3. Dissolve 13 oz. of sal soda crystals in 2 quarts of luke-warm water.
4. Add sufficient water to make 1 gallon.
5. Mix these two solutions in a barrel or crock and allow the milky solution to settle over night.
6. Pour off the clear liquid from the white sediment into a jug and fill into bottles, well stoppered, and keep cool in a dark place. This "stock hypochlorite"

will contain approximately the equivalent of 3 per cent. of chloride of lime or 1 per cent. of available chlorine.

Application. Mix one ounce of this stock solution to 5 gallons of water that is to be used for drinking purposes. After mixing, allow to stand for half an hour before use.

The solution may be added in small quantities to water after it has been drawn from the well or the quantity of water may be estimated and the necessary amount of solution poured direct into the well and stirred in.

Free Bacteriological Tests Made.

Farm well waters suspected of being polluted will be tested upon application to the Bacteriological Laboratory, Ontario Agricultural College.

Taking a Sample of Well Water for Bacterial Analysis.

In procuring samples of water for bacterial analysis great care must be taken that they be not contaminated by bacteria from the hand, clothing, etc. To this end full directions for sampling are given in Appendix 3, and they should be followed in every detail. Also full information about the well should accompany the sample. For this purpose fill out the form in Appendix 5.

Chemistry of the Farm Water Supply

H. L. Fulmer.

Water, as we see and use it every day of our lives, is a very simple looking substance and most people through daily association with it undoubtedly come to look upon it, or consider it to be, as simple and as harmless as it appears.

In reality, however, water that we find in our wells, springs, streams, rivers, lakes and oceans is a rather complex liquid being often composed of many things mixed together. Some of the things present frequently are of a nature, or have in possession some property which they impart to the water as a whole, that makes the latter absolutely unfit for many of the domestic or household uses to which it is put. In many instances, in fact, serious accident, impaired health and strength and even death, have been directly caused by, or traceable to, the use of water of an undesirable or non-potable quality.

Some of the impurities nevertheless which are to be found in natural waters do not by any means render it non-potable; in fact, some are often desirable in that they make the water more palatable for drinking, or, as is the case with our so-called mineral waters, impart to it some decided medicinal value. Others again simply give it some objectionable taste or odor or property but do not render it unfit for the majority of farm uses, or make it unhealthful.

How Water Becomes Impure.

Pure natural water is an unknown thing except that which falls as rain toward the end of a very heavy shower. It is even doubtful if this latter is always absolutely chemically pure. The moment water comes into contact with the atmosphere near the surface of the earth, but more particularly with the soil and rocks, it begins to absorb the various impurities which it is afterwards found to contain. Because of its great and universal absorbent and solvent power it dissolves a certain proportion of some or all of the constituents of the soil and rocks and these dissolved portions are carried along in solution in the water wherever it goes unless, by some means or other, it is made to part with them. These dissolved substances frequently make water which we get in our wells or elsewhere, unfit for domestic use.

But even more dangerous and more objectionable are those impurities which find their way into our water supplies after they are located, such as dead and decomposed animals and plants, seepage from barnyards and out-houses, refuse from factories, sewage from towns and cities, and many things from other sources. All these latter can, and should be prevented from gaining entrance, in most cases, by proper safeguards. If not prevented, when possible, their presence can only be regarded as a straight case of adulteration.

Objectionable Impurities.

Objectionable impurities, or those constituents whose presence is undesirable for various reasons are of two classes, namely:

(*a*) Organic impurities.
(*b*) Inorganic impurities.

(*a*) Organic impurities, or in other words, the dead remains of plants and animais or their excretions, and the products of the decay of these, are the most dangerous ones with which water can be contaminated. Not only have these bodies the power, when taken into the alimentary tract of animals and men, to produce grave digestive and other disorders; but what is probably more important, their presence in water is a sure sign of the presence of numerous kinds of bacteria which feed upon them.

In addition to the above objections, the presence of organic matter in water ver[illegible] frequently discolors it and gives it a forbidding appearance; or imparts t[illegible] a [illegible]or or nasty taste. This is what happens when large quantities of r[illegible] barnyard drainage, or seepage from peaty swamps get into the water. Furthermore, such water is hard on utensils in which it is stored or boiled; causes frothing, incrustation and corrosion in steam boilers; and attacks destructively all metals with which it comes in contact.

Detection of Organic Ma[illegible]er.

The presence of organic matter is not always made evident by the mere color or odor or taste of the water—sometimes the clearest and brightest water, one that is palatable and sparkling, may be dangerously polluted. It is never wise, therefore, to depend upon appearance—a chemical examination should always be made. Such an examination in all its detail is not easy or simple, but useful information can be obtained by the following simple tests:

1. Pour half a pint of water to be tested into a wide-mouthed bottle or decanter which has been thoroughly washed, and scalded with pure boiling water; close it with the palm of the hand, or better, with a glass stopper; and shake it violently up and down. If an offensive odor is then perceived on immediately removing the hand or stopper, the water is probably contaminated with sewage, or other forms of decaying or decayed organic matter.

2. To a little water in an absolutely clean glass vessel add a drop or two of sulphuric acid, and enough permanganate of potash solution to tinge it to a faint rose color; cover the vessel with a saucer or glass plate and let stand. If the pink tinge is still visible after a quarter of an hour, the water is probably free of organic matter.

3. Pour a little solution of silver nitrate into a carefully cleaned and dry glass. See that it remains clear (if not the glass is not properly cleaned); then pour in some of the water. Should a strong milkiness appear that is not cleared upon the addition of a little nitric acid, the water is probably contaminated with sewage. This test is not conclusive in proximity of salt wells or in the vicinity of the ocean where the water may be influenced by spray or seepage from the sea.

The above three tests are only useful for determining whether or not it is advisable to have a more elaborate or costly analysis made by a skilled chemist.

If the water is found to be contaminated with organic matter then an inspection should be made to find, if possible, the cause. Most organically impure waters are so because of some preventable factor, and if this be located and removed the water then becomes pure. It occasionally happens, however, that a water is bad because at some time or other before it reaches the point from which it is drawn by the user, it has to pass through some naturally infested location such as a swamp or some other place possessing a mass of dead and decaying organic matter. In such circumstances it is necessary to locate a source of supply elsewhere.

How to Purify a Water of Organic Matter.

If a water is not too badly infected with organic matter it can often be purified in small quantities, sufficiently to make it potable. On the large scale, however, it can only be economically handled by large corporations such as cities or towns, or other governments.

One of the simplest methods of purification is to boil the water for a short time. This will kill bacteria, drive off bad odors due to any sewage gases that may be present, and render somewhat inert, physiologically, the small amount of partially decayed organic matter.

In case the water is colored this treatment will not clear it up, if the color is due entirely to organic matter (or to suspended particles of soil, iron, etc.). Under such circumstances in addition to being boiled, the water would have to be passed through a filter composed of a considerable depth of alternate layers of good clean sharp sand, gravel and charcoal. This filter would have to be re-charged every day with fresh sand, gravel and charcoal, or with some of these that have been previously used and then afterwards thoroughly aerated and cleansed by spreading out in the sun or by baking in an oven.

Another method of purification is by the use of disinfectants. The most satisfactory disinfectant to use is chloride of lime, provided it is fresh and of good quality (33 per cent. available chlorine) and used in sufficient quantity. The method of using this substance is to be found on page 50 of this bulletin and need not be repeated here. This treatment gives the water an odor of chlorine at first, but this finally passes off on standing or can be removed quickly by boiling for a few minutes. It also destroys the coloring in the water (if the latter be due to organic matter and is not present in too large quantities), and thus makes it unnecessary to filter.

The best plan, in cases of organic impurity, however, is to remove the cause, if it can be found and is removable; or, as before stated, if the cause is not removable to locate a new water supply.

Inorganic Impurities.

(*b*) Inorganic impurities, or those derived from the mineral constituents of the soil and rocks, are seldom dangerous unless present in large quantity. Sometimes poisonous minerals are to be found in water such as lead and copper and even iron, usually because of lead, copper or iron pipes, etc., through which the water has passed; sometimes sufficient mineral is present to give the water a decidedly salty or brackish taste, i.e., salt water and alkali water; but very seldom, under average conditions, does water contain sufficient mineral of any kind to make it unfit or objectionable for consumption by man or beast.

The chief objections to inorganic impurities are that the water is made "hard" by them and often quite unfit for cleansing, cooking some kinds of vegetables, laundry work, or boiler use; also useless for many industrial purposes such as the retting of flax; and sometimes destructive to metal pump connections and other metal parts coming in contact with it for any length of time.

Detection of Hardness.

The detection of hardness in water is a simple matter. Hard water does not form a lather readily with soap but instead produces a sticky, curdy substance which adheres to the hands or clothes washed in it with soap. Such water also turns milky when soap is put in it; and furthermore, usually forms a thick incrustation on the bottom and sides of vessels in which it is frequently boiled, such as a teakettle or boiler, or the flues of a steam engine. Also if the water is very hard, it is found that some kinds of vegetables, as beans and peas, do not soften properly, but rather become harder and tougher and hence less easily digested, when cooked in such water.

Removal of Hardness.

Hard water, on a small scale, can often be somewhat remedied for domestic use by various treatments. To do this intelligently one should understand that hardness of water is of two kinds, namely:

(1) Temporary hardness.
(2) Permanent hardness.

Temporary hardness is caused mainly by the bicarbonates of calcium magnesium and iron. This is the kind of hardness which causes a water to form a whitish scum on top when boiled for a short time, or which produces a sediment in the bottom, or on the sides, of a vessel after boiling for a short period.

This kind of hardness can, fortunately, be easily remedied. If a gallon of water be boiled until about a quart of it has boiled away, it will usually be found that it has lost all its temporary hardness; and if a water so treated had nothing but temporary hardness in it originally, straining now to remove the scum and sediment will give a water almost perfectly "soft."

Permanent hardness is a kind of hardness which is caused principally by the dissolved chlorides, nitrates and sulphates of calcium, magnesium and iron and can only be easily detected after the temporary hardness has been removed by boiling. If the water is still hard after boiling and straining it is quite safe to conclude that it contains permanent hardness. Or if a water is hard, and on test is found not to contain temporary hardness, it is then safe to assume that its hardness is of the permanent variety.

There is no simple method for removing permanent hardness. The only way to remove it is to treat the water with some kind of chemical, such as washing soda or phosphate of sodium, and the amount of these chemicals to use can only be determined by a rather complex chemical analysis. However, boiling for a short time, after the addition of a small spoonful of either of these to two gallons of the water, will probably be about the average amount to use to remove the permanent hardness more or less completely from most waters. After this treatment straining will give a water practically soft.

Most hard waters have both kinds of hardness, particularly waters to be found in limestone formations or districts, or in districts containing rocks with considerable calcium in their makeup. Usually, in this case, the hardness is about equally divided between the two classes, sometimes one predominating, sometimes the other. In this case a combination of the boiling and chemical treatment will completely soften the water.

Many elaborate methods have been worked out and put into operation for softening water on the large scale. But these are only available to large industrial concerns that can employ a chemist to oversee the work or to constantly advise them. The farmer needing much soft water should aim at providing means for catching rain water and storing it in sufficient amount to supply his need.

Chemical Analysis Offered.

Anyone desiring chemical analysis of his water supply will be willingly aided in every way possible, through analysis, advice and otherwise, by application to the Department of Chemistry of the Ontario Agricultural College. Directions for taking and shipping samples of water to this laboratory will be found in Appendix 4. Also information sheet re well, Appendix 5, to be filled out and sent with the sample.

Farm Sewage Disposal

W. H. Day and R. R. Graham.

Sewage disposal systems for the farm may be divided into two general classes; one adapted to homes equipped with water systems and plumbing fixtures, the other to homes without these modern conveniences. In the former we have two types, the septic tank system and the cesspool; in the latter, the ordinary outside closet and the chemical closet.

THE SEPTIC TANK SYSTEM.

The elements of the septic tank system may be seen from Fig. 35. They are as follows:

1. The collecting system, composed of the water-closet, bath and wash basins, and soil pipes.
2. The tank, from which the system derives its name, and having two compartments, the first called the receiving or settling chamber and the second the discharge or flushing chamber.
3. The absorption bed, being a system of tile connected with a main drain from the tank, and into which the sewage from the discharge chamber is carried by the main tile.

The details of the tank may be seen from Fig. 36 (*a*) and (*b*).

This is nature's own way of disposing of sewage, and if the proper conditions are provided, the results are very complete and satisfactory. The process is as follows: From the collecting system the sewage is flushed into the dark water-tight settling chamber where it is partly decomposed by a certain class of bacteria. This chamber remains full at all times, and overflows into the discharge chamber whenever fresh sewage is received. The sewage which passes over is not fully decomposed and it carries with it some solids in fine particles held in suspension by the liquid. Further decomposition occurs in the discharge chamber, which is fitted with a valve or siphon so adjusted that when the liquid reaches a certain height the contents of the chamber are discharged automatically into the system of tile called the absorption bed. This may occur perhaps once or twice a day, or maybe not oftener than once in two or three days, according to circumstances. The liquid then seeps through the joints of the tile into the soil where the decomposition of the sewage is rendered complete by other classes of bacteria. For the full treatment of the bacteriological conditions the reader is referred to page 70. Too much agitation of the contents of the settling chamber would interfere with the action of the bacteria, so the inlet pipe is turned down into the liquid about a foot in order that the sewage may enter as quietly as possible. The overflow pipe in the partition wall also turns down into the contents of the receiving chamber so that solid particles cannot pass over before being acted upon by the bacteria. It should be emphasized that the intermittent discharge, contrary to the opinion of those who have not given the matter careful study, plays a very important part in the operation. The interval between the flushings allows time for the air to enter the soil, thereby enabling the bacteria to complete the work of purification and the pure water has time to soak away thus preventing the soil from becoming water-logged with unpurified sewage, as often happens with con-

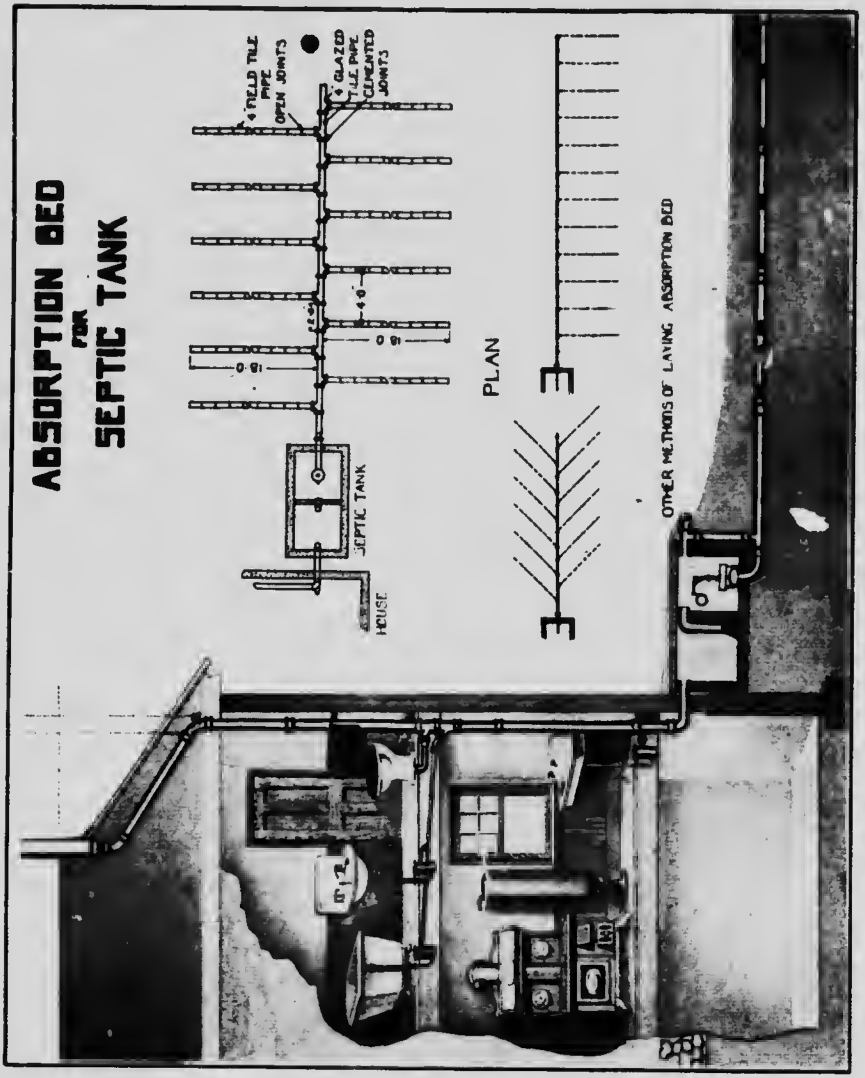
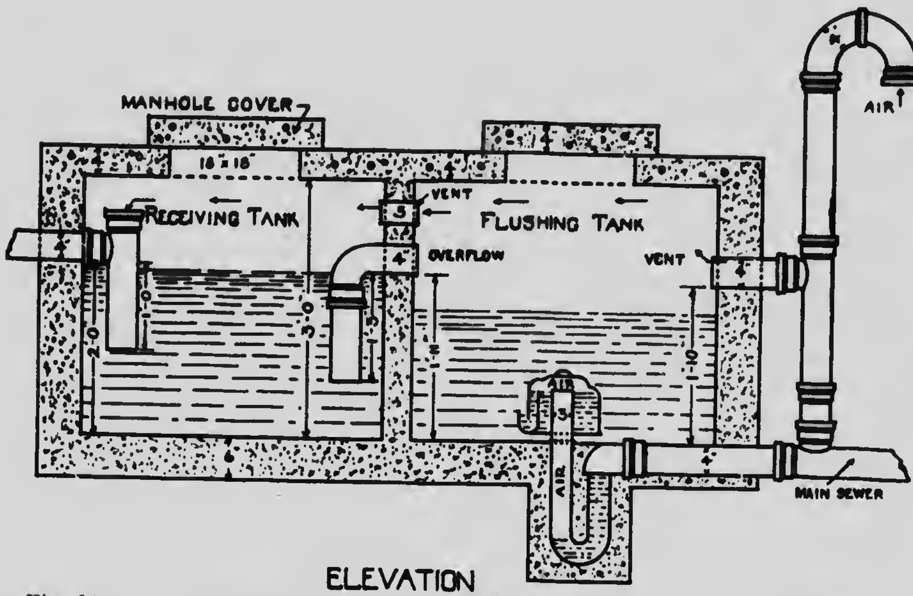


Fig. 35.—Septic tank system of sewage disposal showing
(*a*) Collecting system.
(*b*) The tank with Quinn valve.
(*c*) The absorption bed.

tinuous discharge. The siphon illustrated in the drawings and photographs is a very reliable and durable type, and is therefore highly recommended for septic tanks. There are also on the market reliable valves that work by a float, and trip automatically at the proper depth of liquid.

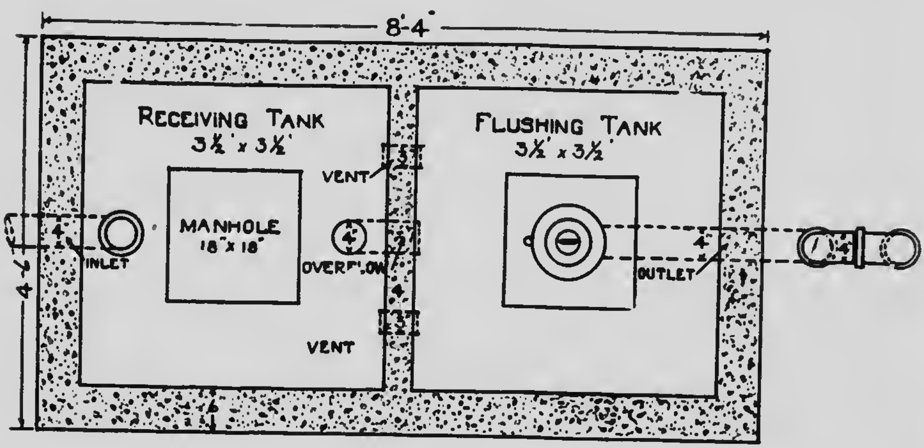
Action of the Siphon.

The reader will perhaps be interested in an explanation of the action of the siphon. Look at Fig. 36 (*a*). Note that there is air in the "bell" of the siphon and also in the long arm of the U. As the water slowly rises in the tank more of the air in the bell is forced down into the long arm, driving the water in the U before it. By and by the air reaches the bend in the U, and when the water rises a little higher in the tank a bubble of the air will be forced around the



ELEVATION

Fig. 36.—(a) Section of septic tank with Miller siphon valve, showing details of construction.



PLAN

Fig. 36.—(b) Plan of septic tank, showing details.

bend—and that one bubble is enough to "trip" the siphon. Once it passes the bend it begins to rise in the short arm. As it does so it begins to expand because the pressure is less, and as it expands it forces some of the water in the short

Fig. 37.—(*a*) Types of sewer tile fittings for septic tank installation, and parts of the Miller siphon.

Key to parts:

1. 4-inch T sewer pipe.
2. 4-inch Y sewer pipe.
3. 4-inch plain sewer pipe.
   (Each of these is 2 feet long.)
4. U-shaped or lower portion of siphon.
5. Bell or upper portion of siphon.
6. 4-inch land tile (1 foot long).
7. 4-inch quarter bend sewer pipe.

Fig. 37.—(*b*) Prepared sewer tile fittings for septic tank.

Key to parts:

1. Inlet and vent pipe for receiving chamber.
2. Overflow pipe for receiving chamber.
3. Vent pipe for discharging amber.
4. Bend made of two quarter ds for installing on top of the vent pipe that projects above the ground.

Note.—See Fig. 38 for installation of these fittings.

arm out into the main drain. The air being lighter than the water it displaces both because of its nature and its expansion, this immediately reduces the pressure in that arm, thereby disturbing the balance and allowing larger bubbles of air to escape rapidly round the bend and force more water out of the short arm. Almost instantly the water in the dome reaches the top of the long arm and begins to flow rapidly down it and up the short arm and out into the tile. This continues until the water in the tank reaches the bottom of the bell. And when the tank is empty both arms of the U remain full of water up to the level of the main tile. The purpose of the air passage around the left side of the bell is to admit sufficient air to drive the water out of the U at the next discharge. Before this air passage was provided it was found that after a time the siphon would reach a state where instead of tripping it would just allow water to dribble through as fast as it entered the second tank, thereby producing a constant slow discharge into the tile instead of an intermittent one. The introduction of the air passage overcame the difficulty—it completely "breaks" the siphon every time. Understanding the action of the siphon the reader will appreciate the direction given later that the U of the siphon must be filled with water before the bell is put on. This is called "priming the siphon."

Capacity and Construction of the Tank.

In computing the size of tank, allow about 3 cubic feet in each compartment for each person in the family. Any variation in size should be made by altering the length or width. The depth should always be in the neighborhood of three feet, although in some cases the receiving chamber is made about 18 inches deeper than the discharge chamber. This device is especially valuable where space is limited, as by it the capacity of the receiving chamber can be made as great as desirable. The best material for the tank is concrete of rich strength, and the pipes or fittings may be either iron or vitrified sewer pipe. The accompanying drawing, Fig. 36, and photograph Fig. 37 (*a*) and (*b*) give all the required measurements and details of construction.

Some points, however, should be emphasized, namely: First, that the tile used in making the fittings shown in Fig. 37 (*b*) should be cemented together a few days before the tank is built, so that they will be ready for setting up with the forms; second, only single forms are required; third, that the fittings and siphon should be placed in the forms according to the measurements given in Fig. 36 and these measurements should be carefully verified before the concrete work is begun; fourth, the forms should be made tight, true to shape, and braced securely in position; fifth, the concrete should be made in the proportions of 1 part cement to 6 parts of clean, sharp gravel, thoroughly mixed while dry and again after wetting. Use mixture medium wet and tamp it slightly in the forms; sixth, build the floor and walls at the same time in order to get a good bond between them; seventh, plaster inside of tanks with neat cement mortar in order to make them watertight, smooth and well-finished before the top is built on; eighth, reinforce the top and the manhole covers with old pieces of iron or heavy wire; ninth, keep the concrete work moist and protected from the sun for a few days so that it will cure well before being put into use; tenth, be sure to prime the siphon.

Installing the Absorption Bed.

The details of the absorption bed are shown in Fig. 35, upper right hand corner. The purpose of Fig. 38 is to emphasize the fact that the absorption bed must be on a lower level than the tank, so that it will be possible to keep the lines of tile near the top of the ground, while the tank is below the ground entirely or nearly so. If a sufficient slope from the house does not exist, the tank may be kept partly or wholly above ground level, and banked and covered with earth, and if necessary specially protected in the winter by strawy manure. When the absorption bed has to be installed on a steep slope or on terraced ground it is necessary to adopt some such system as is shown in Fig. 39 in order to secure a uniform distribution of the liquid in the tile. Fig. 35 shows the various layouts of the absorption bed, and most of the important details, but some others should be mentioned, chiefly, first, that if the soil is very heavy or wet it should first be underdrained: second, 4-inch tile is preferred to 3-inch for the laterals, and about 35 4-inch or 50 3-inch tile should be used for each person of the home: third, that all the tile

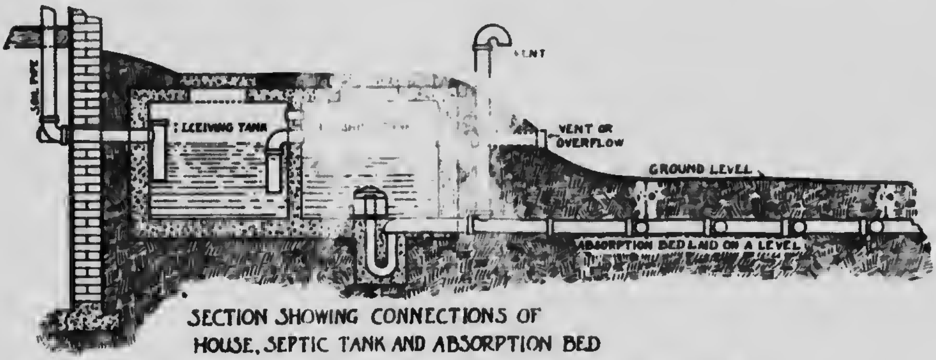


Fig. 38.—The absorption bed in relation to the tank.

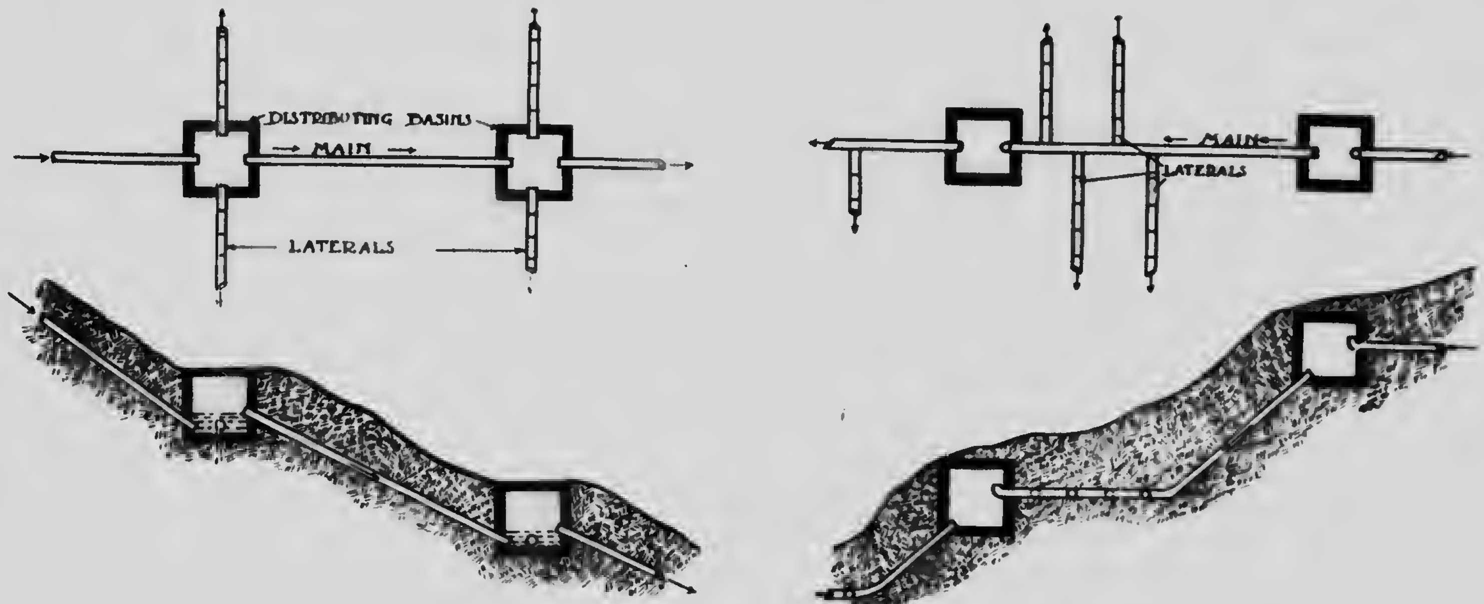
should be laid as level as possible, main included from point where laterals begin to branch off, and they should not be laid deeper than 12 or 15 inches; fourth, the laterals may be placed 4 to 6 feet apart depending on whether the soil is heavy or light: fifth, if possible the tile should be kept away from trees, shrubs or bushes, as the roots may in time choke them; sixth, the lines of tile should not exceed 30 feet in length; seventh, the absorption bed may be located close to the tank or any distance away, depending on circumstances.

Bill of Material and Costs.

The following estimate will serve to give the reader a general idea of the amount of material, the labor and the cost of the septic tank installation described and illustrated herein:

4 bbls. Portland cement at $2.25 per bbl.	=	$9.40
4 loads of gravel at $1.50 per load	=	6.00
8 plain 4-inch vitrified sewer pipe at 30c. each	=	2.40
15 "T" 4-inch vitrified sewer pipe at 65c. each	=	9.75
3 4-inch vitrified quarter bends at 65c. each	=	1.95
216 4-inch field tile at 5c. each	=	10.80
1 3-inch siphon	=	12.00
		$52.30

It would require the labor of two men for probably four days to complete the work, and as all the work can be done by the farmer and his assistant no estimate will be submitted to cover the labor.



A

B

Fig. 39.—Plan and section of the absorption bed installed on terraced land.

(a) Where there is room for only one line of tile on each level
(b) Where two or more lines may be laid on a level.

In regard to the bill of material, the estimate of the gravel and the field tile may be too high for many cases as the gravel may be available on the farm or in the immediate vicinity of the builder at a cheaper rate than quoted above, and the tile may have been bought in large quantities for drainage purposes. Also the item of 15 "T" 4-inch vitrified pipe might be reduced to 9 in number by making the laterals twice as long as shown in Fig. 38 which would reduce the cost by about $4. When these probable reductions are taken into consideration the actual cash outlay would not much exceed $40.

Care of Tank.

The septic tank should be carefully inspected twice a year to make sure that everything is working properly, once just before winter sets in, and again in the spring. And once in two or three years the accumulation of sludge at the bottom of the receiving tank should be removed. The covers should always be replaced tightly, and covered up with soil or turf.

THE CESSPOOL.

Before the advent of the septic tank the cesspool was the only method of sewage disposal for farm homes equipped with plumbing fixtures. In its original and simplest form it is a hole in the ground 8 to 10 feet deep and 4 to 6 feet in diameter, lined up with field stone and safely covered with timbers, plank and earth. Into this pit the sewage is discharged through the inlet pipe and partly decomposes, and in the liquid form slowly seeps away in the surrounding soil. As it was a frequent occurrence for this form of cesspool to overflow, the idea was conceived of improving it by building an enclosed trough around the edge of the pit near the top of the ground and connecting it to rows of field tile, radiating out like the spokes of a wheel, and the liquid was conveyed from the pit to this trough by a 3 or 4-inch pipe between them and turning down a foot or so into the contents of the pit. This is the second form of the cesspool.

Objections to the Cesspool.

One serious objection to the cesspool has already been referred to, namely, its overflowing. This condition may be due to a very heavy and poorly drained subsoil, or to too small a pit, or both. The installation of tile already referred to will prevent this trouble for a while, but they soon fill up by the constant dribbling into them of liquid and fine solids. Another bad feature is that wells may be contaminated by the underground seepage from it, and as this seepage may be carried great distances through small channels and the various forms of passages through the soil and rocks below the surface there is ever a lurking danger not only to the water supplies nearby but even to those more remote. If the subsoil be very gravelly and well drained and one could be absolutely certain that there was no chance of the seepage endangering the water supply or reappearing somewhere at the surface as a public nuisance, there could be no serious objection taken to the building of a cesspool, but as the possibilities of trouble with it are so great we cannot recommend it to the general public as a safe and satisfactory method of sewage disposal.

WASH WATER AND KITCHEN SLOPS.

In farm kitchens there are large quantities of waste water to be disposed of daily in some way or another. In homes equipped with septic tank or cesspool these wastes may be discharged into them, although there is some objection to this practice, in the case of the wash water for the reason that it contains much strong alkali material which is injurious to the sewage bacteria both in the tanks and in the soil. For homes without septic tanks these forms of waste may be disposed of in a convenient and sanitary manner in a grease trap or miniature cesspool, two types of which are illustrated in Fig. 40. The upper type is best adapted to heavy soils, and it will be necessary in this case to install a small absorption bed of 30 or 40, 3-inch or 4-inch drain tile on the

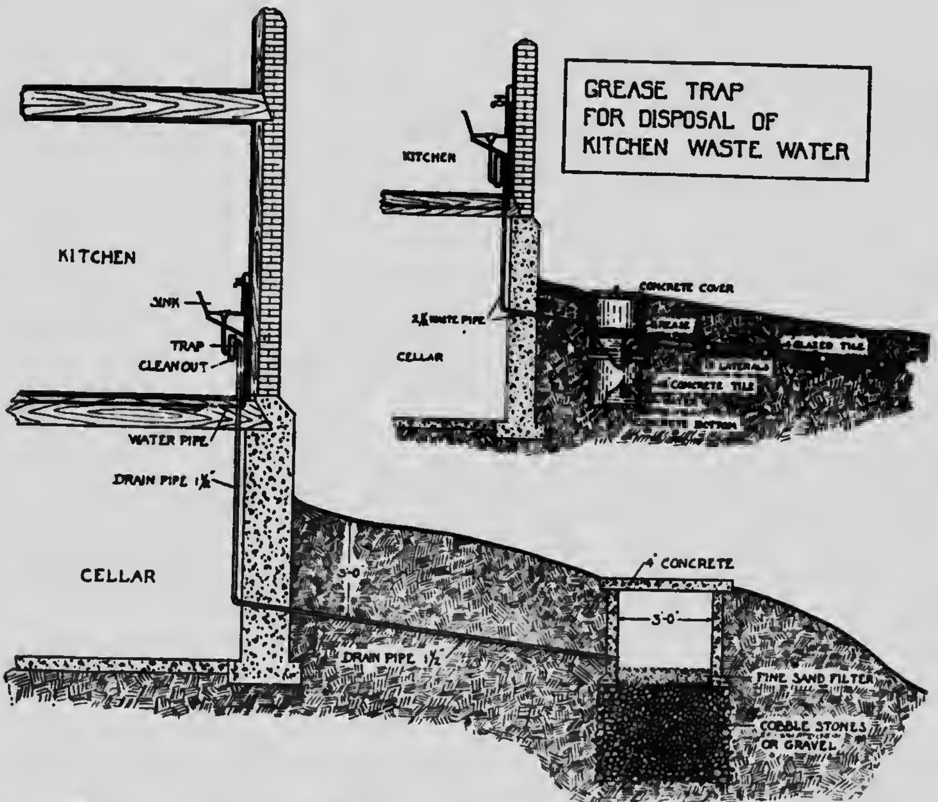


Fig. 40.—Two types of grease trap for disposal of kitchen waste water.

same principle as for a septic tank. The trap may be located close to the cellar wall and the tile ten or more feet away. The lower type is adapted to light, gravelly soil or any soil with a very porous subsoil well drained. It should be built 15 or 20 feet away from the house. The top of the trap in either case should be strong, tight fitting and removable in order that the trap may be readily accessible at any time for cleaning out the accumulation of grease and sediment whenever necessary. Neither one of these types is difficult or expensive to construct and their installation at any farm home not having sewage disposal systems would aid materially in making conditions tidy and sanitary.

CHEMICAL CLOSETS.

The chemical closet in its simplest form has a small wooden or metal chamber enclosing a pail-like receptacle, the top of the chamber constituting the seat. The firms that manufacture the closets supply their own chemicals. The chemical substance added to a little water is put into the receptacle as it is required, and this solution changes the raw sewage into a harmless and inoffensive product called sludge. The receptacle is removed and the product emptied out upon the ash-heap whenever it becomes full or the chemical is exhausted. See type B. Fig. 41. Another type that has recently come upon the market is illustrated in A. Fig. 41. Its principle is similar to the other, but it is more elaborate, and may be extended to capacities large enough to serve

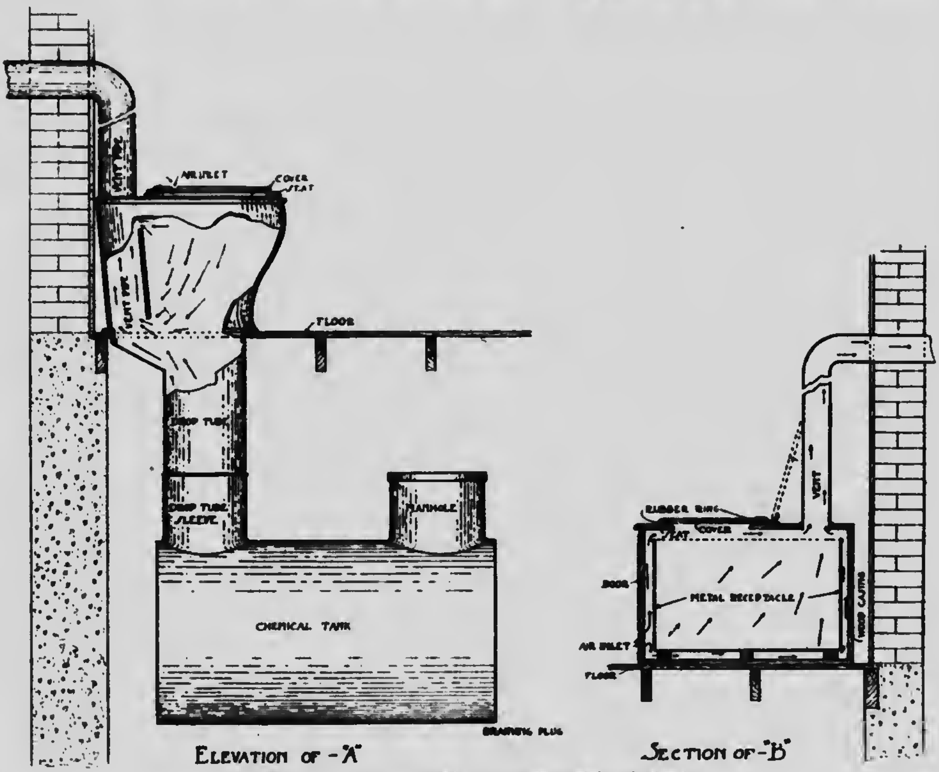


Fig. 41.—Two types of chemical closets.

large institutions, hospitals, summer resorts, etc. The smallest size made has a tank of 125 gallons capacity. A new feature about it is an agitator in the tank for stirring up and mixing the sewage and chemical solution, thereby promoting more rapid destruction of the sewage.

The chemical closet has many advantages over the outside privy. It is located inside and for this reason is greatly appreciated in the winter time, it is more sanitary, it is not infested with flies that may carry disease germs about to endanger health, and it is cheap to install and easy and cheap to operate. Since Boards of Health recognize their value and recommend them—as do those who have used them in their homes—they surely deserve favorable consideration in this treatment of methods of sewage disposal for rural homes. Ask your plumber or hardware dealer about them.

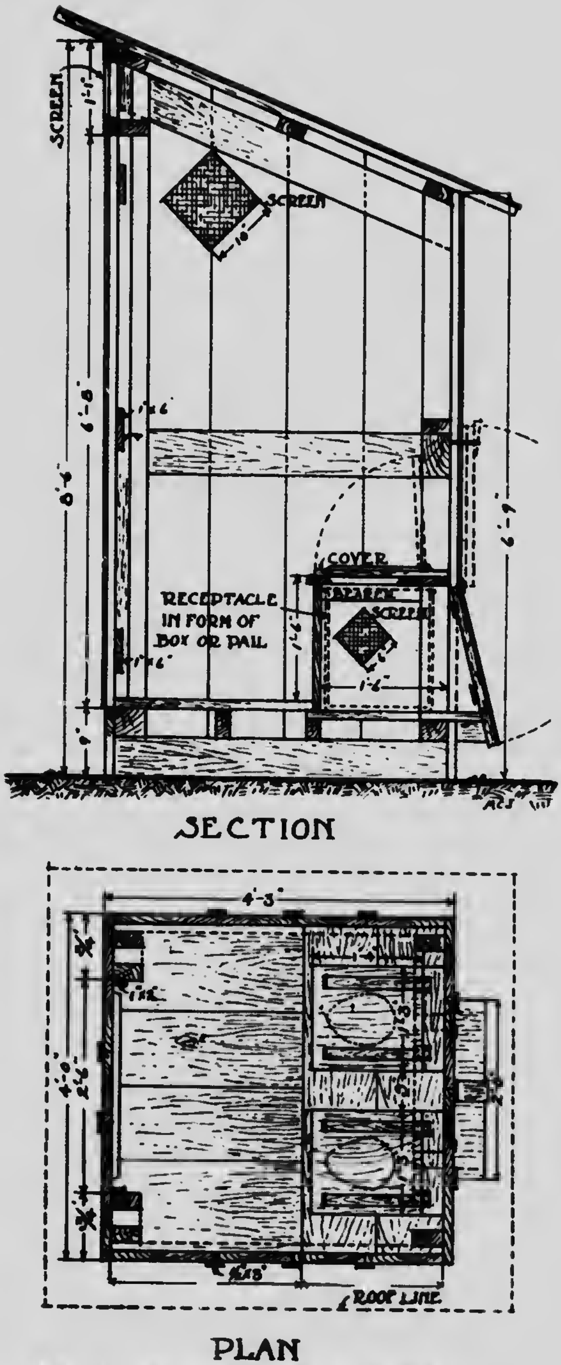


Fig. 42.—Section and plan of outside privy.

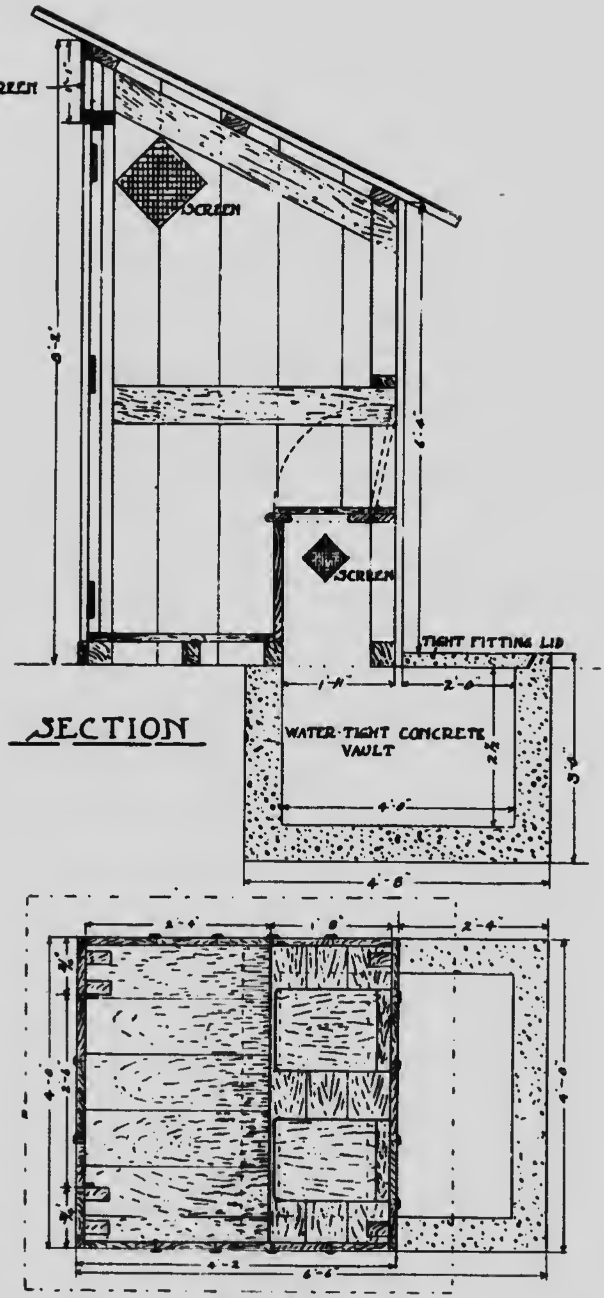


Fig. 43.—Section and plan of outside privy.

OUTSIDE PRIVIES.

The two most satisfactory types of outside privies are illustrated in Fig. 42 (*a*) and (*b*). The chief difference between them is in the kind of receptacle used; in the former it is a pail or box, while in the latter an underground watertight vault. The designs are recommended by the Provincial Board of Health, Toronto, and a full treatment of the subject is given in their circular No. 39, entitled "Sewage Disposal," which may be had on application to them. As the accompanying figures give all the details and measurements no further description is necessary.

In order to make these privies as sanitary as possible they should be built fly-proof and screens put in the door and on opposite sides, as shown in the drawings, for purpose of ventilation. The receptacles should be cleaned out often and they should be disinfected each time with chloride of lime, and dry ashes should be used liberally on the contents of the receptacle or vault while it is in use. If the privy is built and attended to as herein specified it may be located quite close to the house, preferably inside or attached to the woodshed to avoid undue weather exposure to those using it. The purposes of the waterproof underground vault are threefold: to prevent the seepage of contamination underground to the well, to increase the storage capacity for sewage and make less frequent cleaning possible, and, lastly, to keep out flies.

SEWAGE DISPOSAL IN RELATION TO WATER SUPPLY.

Those who intend to install sewage systems should bear in mind carefully the fact that our water supplies are protected by law against sewage contamination. The articles in the Public Health Act that pertain to this case are given herewith as follows:

"*Article 90.*—The Provincial Board shall have the general supervision of all springs, wells, ponds, lakes, streams or rivers used as a source for a public water supply with reference to their purity together with the waters feeding the same, and shall examine the same from time to time when the necessity for such examination arises, and inquire what, if any, pollution exists and the causes thereof. 2 Geo. V, c. 58, s. 90.

"*Article 91.*—(1) No garbage, excreta, manure, vegetable or animal matter or filth shall be discharged into or be deposited in any of the lakes, rivers, streams or other waters in Ontario or on the shores or banks thereof."

Therefore it is the duty of all parties putting in any form of sewage disposal systems to strictly guard against any possibility of them directly or indirectly contaminating the sources of public water supply.

Bacterial Action in the Septic Tank System of Sewage Disposal

D. H. JONES, PROFESSOR OF BACTERIOLOGY.

The private house septic tank system of sewage disposal may be considered to consist of four sections. First, there is the collecting system composed of the toilet basin, bath and wash basins (laundry water should not be allowed in); second, the first compartment of the septic tank, known as the settling chamber; third, the second compartment of the septic tank known as the discharge chamber, and, fourth, the sub-irrigation tile system into which the sewage from the tank is discharged. Bacterial action in these various sections differs to some extent and is very marked in all but the first. To gain an idea of what bacteria are, their nature, size, etc., the reader is referred to page 48 and Fig. 34, Nos. 1, 2, 3 and 4.

Crude sewage consists of water, plus organic and mineral solids, both in suspension and solution. Purification of the sewage implies the removal or destruction of these organic and mineral substances, leaving an effluent of pure water. In the septic tank system this purification is induced by the bacteria present.

Sewage has a very rich and complex bacterial flora. It contains millions of bacteria in every cubic centimeter, and many species are represented in this number. When the action of these bacteria is properly controlled, it results in the complete purification of the sewage. The septic tank system has been devised for the purpose of adequately controlling the action of the sewage bacteria to the end, first, that the sewage may be purified, and, second, that as much manurial value as is possible under the circumstances may be obtained from the sewage.

The bacteria responsible for this purification process may be divided into three main groups, according to their oxygen requirements: First, the anaerobic bacteria; second, the aerobic, and, third, the facultative bacteria. The anaerobic bacteria are those species which are active only in the absence of oxygen: the aerobic bacteria are those which are active only when oxygen is present, and the facultative bacteria are those species which are active either in the presence or absence of oxygen.

The settling chamber of the septic tank remains always full. As the sewage enters this chamber at one end the heavier solids settle to the bottom and the excess liquid from the tank passes over into the discharge chamber at the other end. The bacterial action which takes place in the settling chamber is mostly due to the action of the anaerobic species of bacteria which find favorable conditions for their work in the lower depths of the sewage, where free oxygen is not present. Here they accumulate in large numbers and their work consists mostly in reducing or partially breaking down or digesting, by extraction of oxygen the complex organic matter present in the solids, changing it to simpler and soluble substances which are then ready to pass over in liquid form into the discharge chamber. In this action, gases such as carbon dioxide and hydrogen sulphide are produced, which bubble up through the liquid. In the surface layers of this chamber the aerobic and facultative species of bacteria are also active, to some extent, as oxygen is there available. Their action results in a digestive process, mostly by oxidation of the organic materials present. As a result of their activities in the surface layers using up the oxygen that is present, they ensure strict absence of air in the lower depths, thus making ideal conditions for the anaerobic bacteria.

In the discharge chamber the bacterial action is not so decided as in the settling chamber, for the simple reason that the oxygen requirements are not at the maximum and the contents of this chamber are discharged once or twice daily. Nevertheless, bacterial action is progressing constantly in the sewage of this tank as it slowly increases in volume to the time when it is discharged. The classes most prominent in this chamber are the aerobic and facultative bacteria. Their action is a further breaking down or digesting by oxidation of the organic material still present in the sewage, both in soluble condition and also solids in suspension.

As soon as the contents of the tank are discharged into the sub-irrigation tile system, the liquid is slowly absorbed by the soil around the tiles and by capillary action a film of the liquid covers the individual soil particles, and through this thin film the oxygen of the soil air is readily available to the bacteria in the film, enabling them to complete their action in breaking down the complex organic substances still remaining. Then, the nitrifying bacteria and others, some of which are in the sewage, but more of which are in the soil, recombine the elements and simple compounds thus formed into fresh compounds, as nitrates, which may then be utilized by growing plants. In this way much of the manurial value of the sewage is reclaimed in the soil and the drainage water from such soil, if there is any, should be relatively, if not absolutely, pure, providing the system is working properly. Needless to say the tile system should not be allowed to clog up and the soil surrounding it should be more or less porous and not heavy clay.

Bacterial Action in the Dry Closet.

The satisfactory disposal of human excreta is frequently a troublesome problem both in individual houses in the country, and in dense town or city communities. The excreta contains considerable manurial value, as it is composed almost entirely of organic material in process of decay. It contains millions of bacteria to the ounce and it is the activities of these bacteria that are responsible for its putrefaction and decay. If allowed to accumulate as in dry closets or outhouses, it becomes a decided nuisance with objectionable odors and serves as a breeding place for flies and other insects. If these closets were kept clean, the contents being removed weekly and buried six inches to a foot beneath the surface of the soil in field or garden, the nuisance would not occur. When the excrement is allowed to accumulate, the action of the various anaerobic species of bacteria within the mass results in the production of the strong smelling gases, whereas if it is not allowed to accumulate but is buried in small quantities just beneath the surface of the soil, the aerobic species of bacteria bring about its decay without the production of the strong odors and its full manurial value is recovered in the soil.

Bacterial Action in Cesspools.

In the cesspool, sewage is not thoroughly purified, as the bacterial action is incomplete, being mostly anaerobic and very similar to that in the settling chamber of the septic tank. As the walls of the cesspool are permeable to water, the sewage soaks away directly into the surrounding sub-soil. When this becomes water-logged the sewage rises more or less to the surface, thus becoming a nuisance, giving foul odors and bogginess. As the bacterial action in the cesspool is mostly if not altogether anaerobic, the decomposition of the sewage is only partial. If the surrounding soil is fairly porous and does not become water-logged, there will be some aerobic bacterial action in the upper layers of the soil which will tend to purify the sewage should it reach those upper layers. But this action cannot be regulated or depended on and the drainage water from such soil is liable to be heavily contaminated with undesirable sewage bacteria with sewage only partially purified. Hence wells should never be located near a cesspool.

Appendices

APPENDIX I.

INFORMATION BLANK RE HYDRAULIC RAM

Persons wishing advice re hydraulic ram installations should fill out every blank and forward this sheet with their letter to the Department of Physics, O.A.C., Guelph; or, if writing for quotations, all these points must be given before the firms can quote on proper outfit.

Name ....

Address ....

Date ....

1. How many gallons per minute flowing from the spring or stream can be supplied to the ram? ....

   NOTE.—Do not say supply fills a certain size pipe, as the flow through a pipe varies with the fall. See page 31 for method of measuring flow of spring.

2. How many gallons per 24 hours do you need at the tank? .... See page 34.

3. What is the vertical fall in feet from the spring water level to the point where the ram will be located? ....

4. What is the distance between the source and the point where the ram will be located? ....

5. What is the vertical height, in feet, the water must be lifted from the ram to the tank? ....

6. What is the length of pipe necessary between the ram and tank? ....

7. Is there good drainage for the waste water? ....

8. Do you expect to use an elevated or a pneumatic steel tank? ....

9. Make a sketch of the proposed lay-out on the back of this sheet.

APPENDIX II.

INFORMATION BLANK RE WATER SYSTEM

Persons wishing information in regard to the installing of water supply systems would do well to fill out this form and enclose with their letter to the Department of Physics, O.A.C., Guelph; or if writing a firm for quotations on a system this information if sent direct would enable them to decide what equipment, both as to kind and capacity, would be most suitable.

Name ....

Address ....

Date ....

1. What is the source of your water supply? ....

2. (a) If well, state: Type .... Depth ....Lowest level of water ....

   Whether well ever goes dry ....

   (b) If spring or stream, state gallons per minute ....

3. Which is higher, source or buildings? ....

   How many feet fall between them? ....

4. Distance between source and buildings ....

5. For what service is the water required—house, barns, lawns, gardens, etc.?....

   If for stock, what kind and how many? Horses...... Cows...... Pigs......

   Sheep ....

6. How many persons will use the service? ....

7. Do you require both hard and soft water services? ....

8. What is your estimate of the gallons of water required per day? ....

9. Is the pumping to be done by hand, windmill, gasoline engine, electric motor, or hydraulic ram? ....

   If electric motor, give the following information:

   (a) Direct Current? ...... If so, what voltage? ....

   (b) Alternating Current? ...... Cycles ...... Phase ...... Voltage ......

   NOTE.—If in doubt about these, ask the company that supplies your electric current.

10. What system do you propose to use?

11. Describe your present pumping machinery, if any, and we will advise you whether it can be used in connection with your proposed system or not.

12. Make on the back of this sheet a sketch showing relative positions of source of water supply and pumping machinery, tank, etc., marking in the distances vertical and horizontal.

APPENDIX III.

DIRECTIONS FOR TAKING A SAMPLE OF WELL WATER FOR BACTERIAL ANALYSIS

1. It is essential that the bottle to contain the sample and also the cork stopper for the same be sterilized by boiling in water 30 minutes.

Care should be taken not to touch the neck of the bottle nor that part of the cork that goes into the bottle with the hands, or anything that has not been just previously sterilized.

A small bottle, as a medicine bottle, will hold sufficient for the test.

NOTE.—A sterile bottle, in a mailing case, ready for taking the sample, will be forwarded on application to the Bacteriological Department, O.A.C., Guelph.

2. Pump for one or two minutes or until all local laterals are emptied of water that has been standing in them.
3. In removing the cork from the bottle do not touch the part of the cork that goes into the neck of the bottle against anything, and do not remove cork until ready to take the sample.
4. Do not touch the mouth of the bottle with the hands or anything else.
5. Let the water from the pump run directly into the bottle, then cork tightly with the same cork that is removed from the bottle, place the bottle in the mailing case, stamp the case and mail it immediately to the Bacteriological Department, O.A.C., Guelph.
6. Write a card stating date and time of day the sample was taken.

APPENDIX IV.

DIRECTIONS FOR TAKING A SAMPLE OF WATER FOR CHEMICAL ANALYSIS

CONTAINER.—A bottle of not less than one quart capacity is to be used, preferably one with a glass stopper. If there is no glass stopper, the bottle must be stopped with a new cork.

PREPARATION.—The bottle must be thoroughly cleaned, all foreign substances removed, and scalded out with boiling hot water and then allowed to drain until cool.

TAKING OF SAMPLE.—If the sample is to be taken from a well, the water must be pumped out for about five minutes, or long enough to empty all pump connections before the sample is taken; if from a tap, the water must be allowed to run to waste for about ten minutes, or long enough to empty all local laterals, before sampling. If the sample is to be taken from a lake or stream, it must be taken some distance from the shore, the sampling vessel being plunged a foot and a half below the surface, to avoid the surface scum. Samples are not to be taken immediately after a storm.

From wherever the sample is taken, the bottle must be rinsed out several times with the water to be analyzed. The bottle must not be filled quite full, a small space must be left for the expansion of the water. Cork, and tie a piece of cloth over the neck to keep the cork in place. Do not use sealing wax.

NOTIFICATION.—Send notice by mail stating by what express company you are sending the water, and the date of the shipment. Also give, as fully as possible, the history of the well or source of the water, and remarks on the sanitary surroundings. Address the package to Chemical Department, Ontario Agricultural College, and prepay express charges on the same.

APPENDIX V.

INFORMATION BLANK RE WELLS

Persons enquiring about wells, either from the standpoint of construction, improvement, bacteriological analysis or chemical analysis, should fill out this form in full and enclose with their letter to the proper Department.

Name ....

Address ....

Date (when sample is sent) ....

WELL:

1. **Distance to rock** .... 2. **Depth of well** ....
3. **Nature of soil (gravel, clay, sand or loam)** ....
4. **Whether the well is fed by a spring** ....
5. **The mode of construction of the well, including its wall and covering:** ......
   ....
6. **Is the cover tight?** ....
7. **Depth of water in the well** ....
8. **Whether the appearance or depth of the water is affected by heavy rains....**
   ....
9. **Date of digging**............... 10. **Date of last cleaning**.................
11. **Any indications of pollution, discoloration of sides, etc.** ....
12. **Amount of water used from well** ....

SURROUNDINGS:

1. **Proximity to dwellings, outbuildings, stables, drains, sewers, etc.** ....
2. **Drainage of surrounding soil: Is slope towards or away from well?** ....
3. **Is surface drainage from house or barns to or away from well?** ....
4. **Are surroundings clean?** ....

WATER:

1. **Has the water been healthful?** ....
2. **Have there been any cases of typhoid fever?** ....
   If so, how many in last five years ....

REMARKS ....
....
....

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