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WATER SUPPLY, PLUMBING, AND SEWAGE DISPOSAL FOR COUNTRY HOMES.

By Robert W. Trullinger,
Rural Engineer, Office of Experiment Stations.

INTRODUCTION.

It is the purpose of this paper to treat in a simple manner that portion of the subject of farm home sanitation relating to pure water supplies, the safeguarding of the same against contamination, and the safe disposal of sewage. A few suggestive drawings and illustrations are given to fit average cases, together with information intended to aid the farmer, if necessary, to modify the designs in order to apply them to his particular needs.

The greater part of this work is based on accepted scientific and sanitary principles, and many facts have been drawn from the works of authorities, to whom due acknowledgment is given.

THE FARM WATER SUPPLY.

DANGERS FROM CONTAMINATION.

Without doubt many of the germ diseases may be transmitted by means of water; and some of the diseases are so uniformly transmitted by water that they are known as "water-borne" diseases. Typhoid, dysentery, and other intestinal disorders are such diseases, and if they may be carried by water it is of the greatest importance that every precaution be taken to insure a pure water supply.

Farm water supplies may be divided into three classes, which in the order of their liability to pollution are surface supplies, shallow underground supplies, and deep underground supplies. The surface supplies are obtained from streams, ponds, reservoirs, and cisterns; both shallow and deep underground supplies are obtained from dug, bored, driven, or drilled wells, and from springs.

That farm water supplies are very subject to pollution is evidenced by the investigations of various authorities. The investigations of K. F. Kellerman and H. A. Whitaker,[1] of this department, in coopera-

[1] U. S. Dept. Agr., Bur. Plant Indus. Bul. 154.

tion with the Minnesota State Board of Health, indicate that of 79 carefully selected and typical water supplies in Minnesota 20 were good and 59 were polluted. Of the polluted wells 11 were so located that even extreme care would not make them safe; 10 were poorly located, but improvements in the protection from surface wash and infiltration would make them safe; 25 were bad only because of poor surface protection and could easily be made safe. Practically all the surface supplies investigated were polluted. During these investigations 23 of the farms examined showed a record of typhoid fever.

F. T. Shutt,[1] of the Canada Experimental Farms at Ottawa, reviewing his study of the subject since 1887, states that of the farm water supplies examined 30 per cent may be classified as safe and wholesome, 25 per cent as suspicious and probably contaminated, 36 per cent as seriously polluted, and 9 per cent as nonpotable through high salinity.

SURFACE SUPPLIES.

CONTAMINATION.

Surface water supplies are those most liable to pollution, and authorities agree that they are the most unsatisfactory for farm use. Streams and ponds receive the greater part of the surface wash from the immediate neighborhood, and in many cases barnyard or stockyard drainage from points remote from where the water is taken for household use. Streams or ponds located in pastures, manured fields, or where stock can gain access to them are polluted. Sometimes sewage and house drainage are emptied into streams and ponds. In fact, since they are open and unprotected, there are a thousand and one different sources of pollution for such supplies. Rain waters from the roof are polluted by dust, dirt, and leaves, which collect in the eaves trough, and by the droppings from birds.

Surface water supplies should therefore not be used for household purposes, not even for washing milk cans or for laundry purposes, unless no other supply is available. And it may be safely assumed that the person who drinks water from surface supplies endangers his health if such supplies are not first protected from the sources of contamination as far as possible and then purified.

CISTERNS.

In localities where underground waters are hard to obtain, cisterns may be used for the filtration, partial purification, and storage of rain water, and surface supplies. The size of the cistern will depend on the number of persons in the house and on the general water consumption, as discussed hereafter, under "Pumping, storage, and distribution."

[1] Reprint from Pub. Health Jour., State Med. and Sanit. Rev., 1912, April.

The cistern should be of water-tight construction, to prevent leakage and to prevent pollution from the neighboring soil. It should have an overflow drain and a tight cover. There should also be suitable provision for straining or filtering the water previous to its entrance to the cistern.

The cistern should ordinarily be in two compartments, with a filter wall of porous brick between. One compartment serves then as a settling chamber and the water receives a final filtration before entering the storage compartment.

Concrete is probably the most sanitary and durable material for cisterns. In general, the walls and floor should be 6 or 8 inches thick and well reenforced and the concrete should be carefully proportioned

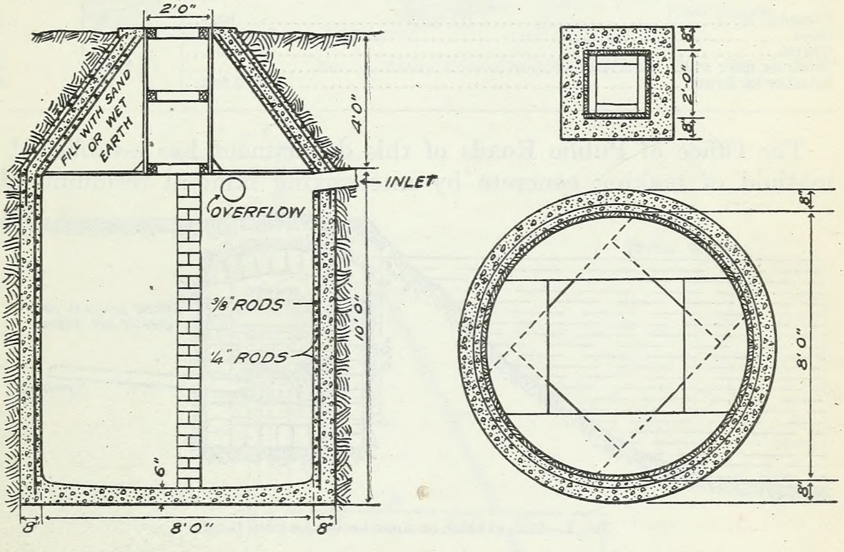

FIG. 1.—Reenforced concrete cistern, showing arrangement of forms and reenforcing.

and mixed. A mixture of 1 part cement to 2 or 2½ parts of clean sharp sand and 4 or 5 parts of clean and fairly small crushed rock or gravel is satisfactory for fairly water-tight concrete. The inside surface should be coated with a 1 to 2 cement mortar. Figure 1 shows a circular cistern of average size sufficient for a family of 6 or 8 people.

In constructing such a cistern, make a circular excavation 16 inches wider than the desired diameter of the cistern and about 16 inches deeper than the desired depth. Make a cylindrical form as shown in the figure, the outside diameter of which will be the inside diameter of the cistern. Mix the concrete in small batches fairly wet and tamp in between the form and the earth. To construct the conical portion, build a floor across the top of the cylindrical form, leaving a hole of the desired size in the center. Brace the floor well with uprights from the cistern bottom. Build a cone-shaped mold of wet earth or sand and lay the concrete and reenforcing on this cone. Allow it to set and harden well before removing the forms and earth. The following table gives an approximate bill of materials for two sizes of cisterns:

Cisterns—Material.

[Concrete: 1 part cement, 2½ parts sand, 5 parts gravel.]

Material.	14 feet deep (10-foot cylinder, 4-foot cone), 8 feet in diameter, capacity 3,800 gallons.	13½ feet deep (10-foot cylinder, 3½-foot cone), 6 feet in diameter, capacity 2,100 gallons.
Cement .... bags..	43	31
Sand .... cubic yards..	4½	3
Gravel .... do....	9	6½
Brick for filter wall	1,000	800
Lumber for forms .... board feet..	225	200

The Office of Public Roads of this department has established a method of making concrete by intermixing mineral residuum oil,

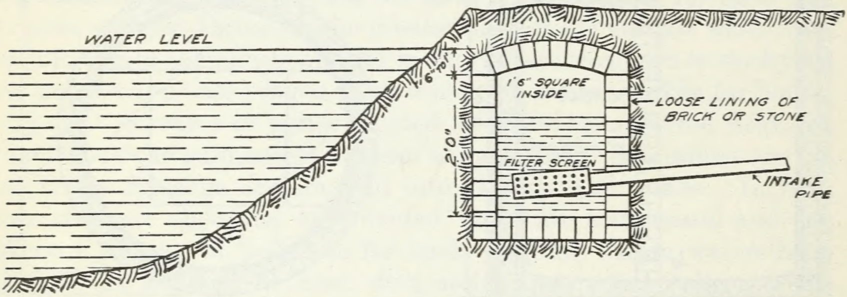

FIG. 2.—Crib of brick or stone for intake from pond.

which, according to their tests, makes a damp-proof and fairly water-tight concrete. Information may be obtained by writing to that office for their bulletin on oil-mixed Portland cement concrete.[1]

If water is piped from a stream or pond subject to pollution, the pipe entrance should be placed in a crib and screened, as shown in figure 2. The pipe can then empty into a receiving filter, made of concrete, which contains fine sand, gravel, and powdered charcoal in layers (fig. 3), and from which it empties into the cistern. The rain-water pipe from the eave trough should be provided with a switch or cut-off, so that the flow may be diverted to the outside—as, for instance, for a short time at the beginning of rains—to exclude the filth collected on the roof and gutters. An overflow pipe should be provided in the side of the cistern and should be screened to exclude rats and other vermin.

[1] U. S. Dept. Agr., Office Pub. Roads Bul. 46.

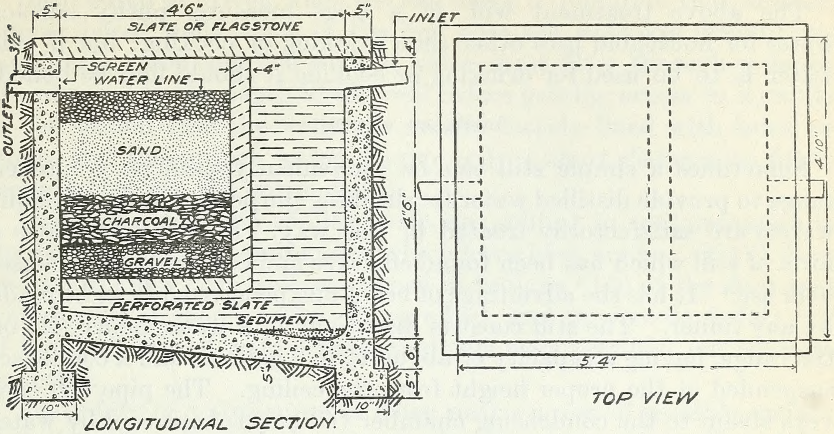

FIG. 3.—Cistern filter of concrete and stone.

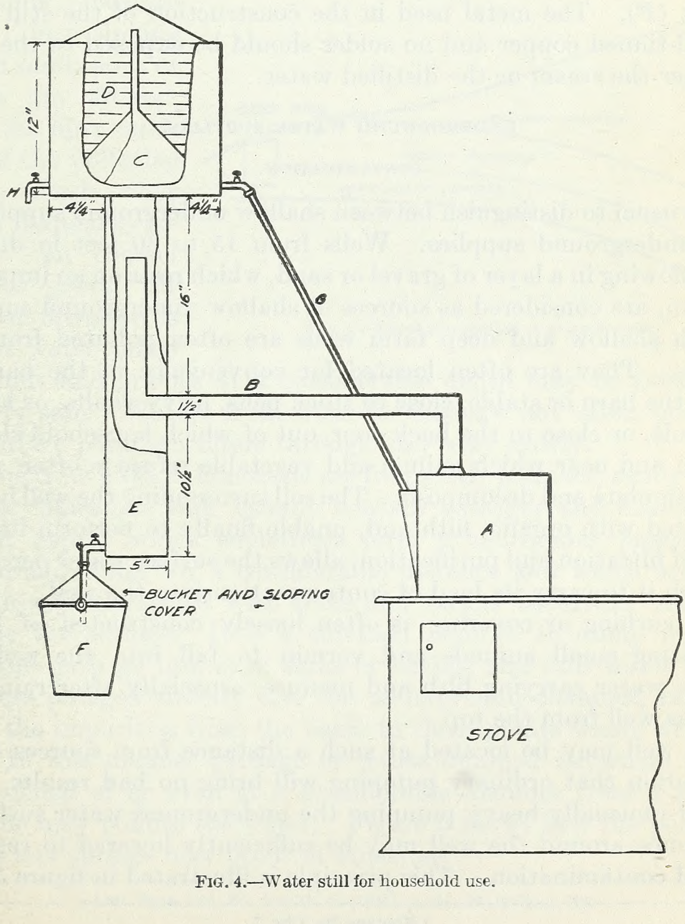

FIG. 4.—Water still for household use.

The above treatment will, in a large measure, purify surface water for household uses other than drinking or cooking; but if this water is to be used for drinking or cooking it should first be boiled.

DISTILLED WATER.

Sometimes a simple still can be conveniently used on a kitchen range to provide distilled water for drinking purposes. Saline (alkali) waters are satisfactorily treated in this way. Figure 4 illustrates a form of still which has been found effective and convenient for household use.[1] It has the advantage of being inexpensive and can be made by any tinner. The still consists essentially of a water boiler (*A*) on the range, having a capacity of about 1½ to 2 gallons, and a condenser suspended at the proper height from the ceiling. The pipe (*B*) conveys steam to the condensing chamber (*C*) and is kept cool by water in the compartment (*D*). The distilled water collects in (*E*) and can be drawn off from time to time or allowed to run continuously into the bucket (*F*). The metal used in the construction of the still should be well-tinned copper and no solder should be exposed to the action of either the steam or the distilled water.

UNDERGROUND WATER SUPPLIES.

CONTAMINATION.

It is usual to distinguish between shallow underground supplies and deep underground supplies. Wells from 15 to 30 feet in depth to water flowing in a layer of gravel or sand, which rests on an impervious stratum, are considered as sources of shallow underground supply.

Both shallow and deep farm wells are often polluted from local sources. They are often located for convenience in the barnyard, under the barn or stable, close to stock pens, privy vaults, or leaching cesspools, or close to the back door, out of which household slops are thrown and near which animal and vegetable refuse is often allowed to accumulate and decompose. The soil surrounding the well becomes saturated with organic filth and, unable finally to perform its useful work of filtration and purification, allows the surface water percolating through it to carry its load of contamination into the well.

The curbing or covering is often loosely constructed of boards, permitting small animals and vermin to fall into the well; and surface water carrying filth and manure, especially after rains, runs into the well from the top.

The well may be located at such a distance from sources of contamination that ordinary pumping will bring no bad results, but in case of unusually heavy pumping the underground water surface for a distance around the well may be sufficiently lowered to reach the zone of contamination. This principle is illustrated in figure 5.

[1] Montana Sta. Circ. 7.

Deep bored or driven wells are less liable to pollution than shallow dug or bored wells, since in the first case the wells are usually imperviously cased and the surface water must filter through a depth of soil equal to the depth of the well before gaining access to it, while in the second case the wells are usually loosely lined with brick or stone, and the surface water, having only a short distance to filter, seeps in through the entire depth.

That both deep and shallow wells are subject to contamination is shown from many examinations which have been made. Of 177 deep and 411 shallow farm wells examined in Indiana,[1] 116 of the deep well waters were of good quality, 45 were bad, and 16 were doubtful; 159 of the shallow well waters were good, 209 were very bad, and 43 were doubtful.

The safety of water supplies when near sources of possible surface pollution often depends largely on the character and quality of the material in which the well is sunk. Surface waters in sinking through sandy soils or surfaces are filtered, and in the finer sands much of the polluting matter which they carry is frequently removed. In coarser sands or gravel the degree of filtration is less, but water taken from sands and gravels at a considerable depth may be considered relatively safe. Waters from wells in clay are not often polluted, since surface pollution filters through clay very slowly.

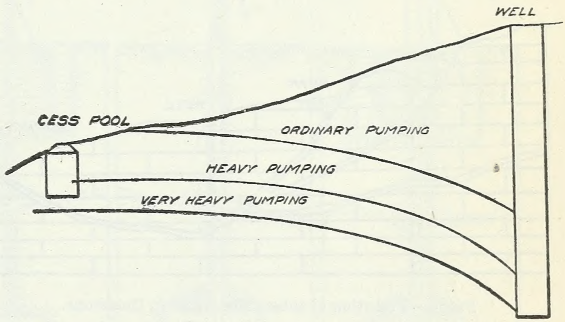

FIG. 5.—Effect of pumping on ground water.

Waters from wells in limestone are frequently polluted, owing to the fact that limestone soils usually contain passages and channels at different depths which sometimes form a continuous passage for underground water for a considerable distance and which are very often directly connected with sinks and basins occurring here and there on the surface. It is a common practice to dump manure, trash, and garbage into such sinks or basins, and rain water falling into these plunges directly into the underground channels, carrying with it the impurities from the basin to those points where wells are sunk. In this manner garbage or refuse dumped anywhere in the neighborhood of or even at a considerable distance from a well in limestone may pollute the water. Figure 6 shows how the pollution of wells and springs may occur in limestone.

[1] Ann. Rpts. Ind. Bd. Health, 27 (1908), p. 345; 29 (1910), p. 349.

Deep wells in granite or jointed rock are often polluted, although cased to a great depth, since polluted water may sink in a zigzag course along the rock joints until it reaches the bottom of the well casing. It is therefore necessary to exercise care in the location of the well and in the preliminary protection from pollution.

WELL LOCATION AND PRELIMINARY PROTECTION.

The farm well, especially a shallow dug well, should be located somewhat above the barns, buildings, yards, and stock pens, or at least in such a position that the surface drainage from all possible sources of animal and vegetable contamination is away from the well. The location should also be as far removed from these sources as convenience will permit.

To properly safeguard wells against outside contamination, first, all sources of contamination should be removed as far as possible. If local conditions and prices will permit, it is a good idea to provide impervious floors with water-tight drains for farm buildings and stock pens.[1] Under the same conditions concrete manure pits might well be provided to not only prevent the liquid manure from polluting the neighboring soil

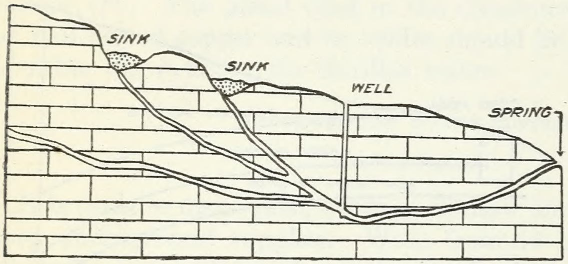

FIG. 6.—Pollution of subsurface water in limestone.

but to save the manure. No garbage, manure, or rubbish should be dumped into sinks or basins in the immediate neighborhood, and these should be fenced off and kept free from polluting matter. The house should be provided with some safe method of sewage disposal, while slops and garbage from the kitchen should be deposited in tightly covered garbage cans and disposed of by burying in the fields, burning, or feeding to pigs. The use of privy vaults and leaching or overflowing cesspools should be absolutely avoided, since they are likely to be sources of the worst contamination. Second, the farmer should become acquainted with the various types of wells and the best methods of protection, and the well should be so protected as to exclude filth from those sources of contamination which it has been impossible to remove or have been overlooked.

TYPES OF WELLS AND METHODS OF SINKING.

In the selection, location, and sinking of a well it is always a good idea to consider permanence in addition to safety. This will depend on the kind of well used, and one should be acquainted with well

[1] U. S. Dept. Agr., Farmers' Bul. 481.

types and methods of sinking. The well should penetrate to levels below that of the ground-water surface in the driest seasons.

Figure 7 illustrates four different common types of deep and shallow wells. No. 1 shows a dug well, with pump, which may be lined with either concrete or cemented brick. No. 2 shows a driven well, which is constructed by attaching a point on the end of the pipe and driving the pipe into the ground until water is reached. The point is provided with a short length of pipe with perforations which permit the water to enter the pipe and keeps out the sand and gravel. This arrangement is best suited to shallow wells, as the cylinder is near the surface in a dry well. If the depth to water is greater than the suction limit, it is necessary to dig a dry well deep enough to place

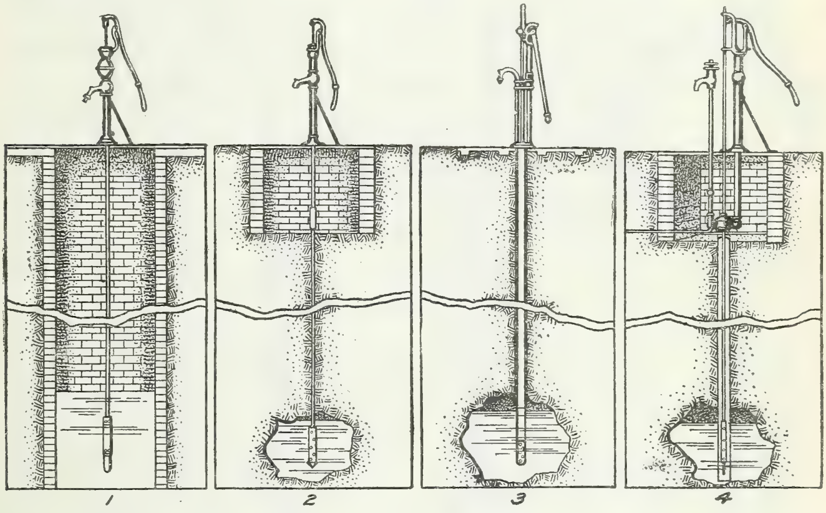

FIG. 7.—Types of deep and shallow wells.

the cylinder within the suction limit. Nos. 3 and 4 are drilled wells consisting of a small hole which may be from 3 inches to 15 inches in diameter. This hole is lined with an impervious iron casing which prevents caving in and keeps out all water, except that which enters at the bottom. This type of well can pass through as many water-bearing beds as desired and none but that from the lowest will enter. The casing is large enough to allow the cylinder to be placed below the water surface, or as near the water as is necessary. No. 4 shows a drilled well with a dry well installed above it to accommodate the lower half of a pump made for underground discharge.

M. L. Fuller[1] states in regard to types of shallow wells and conditions to which they are adapted:

Dug wells are generally circular excavations 3 to 6 feet in diameter. They are adapted to localities where the water is near the surface, especially where it occurs

[1] M. L. Fuller. Domestic Water Supplies for the Farm. New York and London, 1912, p. 68.

in small seeps in clayey materials, and requires extensive storage space for its conservation. Bored wells are wells bored with various types of augers from 2 inches to 3 feet in diameter rotated or lifted by hand or horsepower. They are usually lined with cement or tile sections with cemented joints and often with iron tubing. They are adapted to localities where the water is at slight or medium depths and to materials similar to those in which open wells are sunk. Punched wells are small holes usually less than 6 inches in diameter sunk by hand or horsepower by dropping a steel cylinder slit at the side so as to haul and lift material by its spring. They are adapted to clayey material in which water occurs as seeps within 50 feet of the surface, but not at much greater depths. These wells should also be lined with tile, iron tubing, or sheet-iron casing. Driven wells are sunk by driving downward, by hand or horsepower apparatus, small iron tubes, usually 1¼ to 4 inches in diameter, and provided with point and screen. They are adapted to soft and fine materials, especially to sand and similar porous materials, carrying considerable water at relatively slight depths, and are particularly desirable where the upper soil is likely to be polluted.

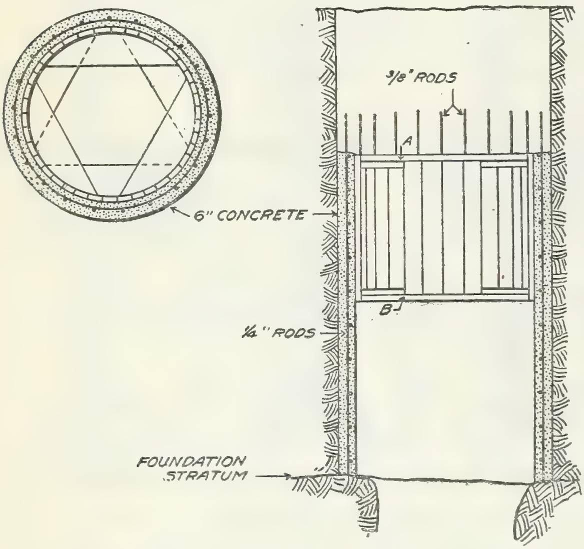

FIG. 8.—Concrete well lining, showing arrangement of forms.

Since most well-water supplies are obtained from sand and fine gravels, the cheapest and best method of well sinking is by driving. In a driven well the water can only be polluted at the depth of the strainer. In some materials, such as clay, it is necessary to bore the well, in which case it is absolutely necessary for safety that the well be lined with impervious casing to the strainer. Deep and shallow dug wells should also be lined.

PROTECTIVE WELL LININGS.

For lining shallow dug wells the latest practice has been the use of reenforced concrete. This has also been successfully practiced in lining deep dug wells. Concrete may be made practically impervious to water, so that a concrete-lined shallow or deep dug well can only be polluted from the bottom.

Figure 8[1] suggests a method of lining dug wells with concrete. Dug wells are usually about 6 feet in diameter. The concrete need be only about 6 inches thick with vertical steel reenforcing of ⅜-inch rods spaced 18 inches apart, and circular reenforcing of ¼-inch steel

[1] F. N. Taylor. Small Water Supplies. London [1912], pp. 34–36.

rods spaced about 9 inches. The two sets should be bound together by steel wire with the circular reenforcing placed inside the vertical. A carefully proportioned concrete mixture of 1 part cement and 2 parts sand to 4 parts of gravel or crushed rock should be used. A circular collapsible form is necessary, with diameter 12 inches less than the diameter of the well and about 5 feet long. The two rings, *A* and *B*, are cut to a diameter equal to that of the shaft, less twice the thickness of the concrete and 4 inches for the 2-inch lining boards. The rings are made by drawing a circle the size of the frame and laying boards around its circumference, as shown by the figure. The boards are then lightly tacked together and a circle of the same radius marked on three ends. Finally, around the circumference of the ring are fastened boards, each 2 inches thick and of the required length of the form. The concrete lining rests on the bottom of the well, which has been previously leveled to receive it. A wet mixture is advisable for this class of work. The form should be left in until the concrete has properly set before it is raised to construct the next section.

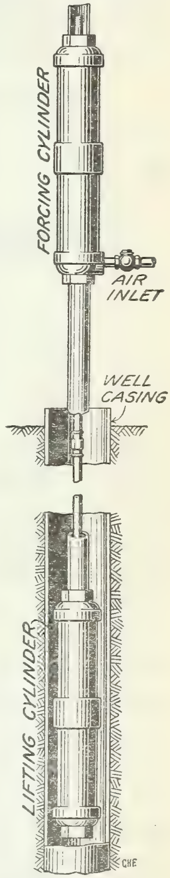

FIG. 9.—Iron well casing with pump and cylinder inside.

In regard to other types of well lining or casing M. L. Fuller[1] says:

> Cemented rock or brick linings protect the well from pollution, except at the bottom, as long as the walls are not cracked. They also prevent the entrance of sediments and animals and do not impart a taste to the water. Iron casings are used in both rock and unconsolidated materials. They are usually used in deep wells. They may be either iron tubing 1 to 4 inches in diameter, or sheet-iron casings 4 to 16 inches in diameter, with snug joints. They are adapted to wells of all depths in which water is obtained from a stratum below the casing or from a stratum between cased sections, or in case it is decided to procure water from a number of strata.

Iron casings may be obtained from manufacturers of pumping apparatus or from hardware dealers. Figure 9 shows a type of iron casing with pump inside.

PROTECTIVE WELL CURBINGS OR COVERINGS.

Both shallow and deep wells should have water-tight curbs, in addition to impervious casings. The drip from the pump is often the cause of serious pollution. The casing or lining should extend 6 or 8 inches above the ground surface except when a dry well is used, and a concrete curbing should be built over the top with a slope away from the pump opening in the center. This cover should extend at least 2 feet beyond the edge of the well if a dug well, and if a bored or driven well the cover should extend 4 to 6 feet in all

[1] M. L. Fuller. Domestic Water Supplies for the Farm. New York and London, 1912, p. 70.

directions from the center. The outer edge should be raised to form a trough emptying into a tight drain, or a drain trough should be provided to catch the drip. E. Bartow[1] suggests that the earth be excavated for 4 feet outside of the regular casing to a depth of 4 feet and that an extra 4-inch coating of waterproof Portland cement mortar be placed outside this casing with 4 to 6 inches of mortar in the bottom of the excavation. This bottom should have a raised portion at its outer edge to divert the seepage water to a tile drain. This arrangement prevents surface water that has not been filtered through at least 4 feet of earth from gaining access to the well. Figure 10 shows a combination of these protective arrangements.

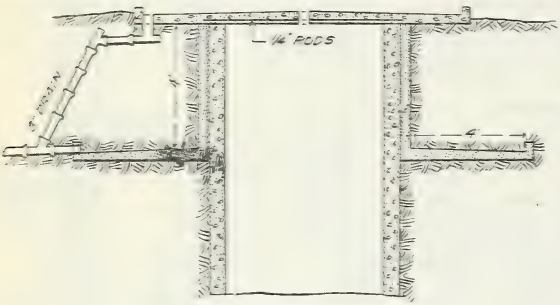

FIG. 10.—Well protection.

SPRINGS.

Springs are good sources of water supply, since they usually come from great depths within rock or are filtered through many layers of sand and gravel. However, they are subject to pollution from the same sources as wells and should be closely watched in this respect. Farm spring supplies are often polluted by the drainage from buildings and stock pens. Spring water supplies from limestone are also subject to pollution from distant garbage and sewage dumps in sink holes, as shown in figure 6. The same precautions should be taken for safeguarding spring supplies as in the case of wells, and in addition the spring should always be fenced to keep out stock. It should be cleaned of all trash and walled in to form a kind of reservoir, as shown in figure 11. The supply may then be conducted to the house by gravity or by means of a hydraulic ram. Where a spring is small a large vitrified tile may be so placed as to form a small storage reservoir. The reservoir should be covered and protected as much as possible from filth and vermin. After rains the spring should be noticed for any signs of turbidity which may indicate pollution from

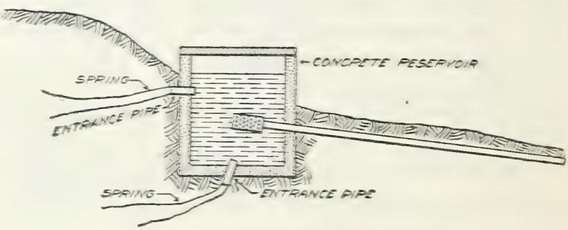

FIG. 11.—Method of walling in springs.

[1] Univ. Ill. Bul., 7 (1909), No. 2.

distant surface sources. Spring supplies should be frequently examined for pollution of any kind, and the water should be boiled before drinking, if possible, although this is not absolutely necessary in all cases.

PUMPING, STORAGE, AND DISTRIBUTION OF WATER.

After a pure water supply is made available the first things to be considered are the quantity of water needed, choice of pumping equipment, and means of storage and distribution.

QUANTITY OF WATER NEEDED.

The quantity of water needed depends on the power used and whether the service is for the entire farm or for the house only. Hand-operated systems are applicable where small quantities are required for house service only, but in case water is wanted for stock also the use of a windmill, engine, electric motor, or hydraulic ram is necessary. If a windmill is used the storage should be large enough for at least three days' supply, to provide water in case of calm weather. Where the other sources of power are used the storage capacity need not exceed one day's supply. The following table gives approximate quantities of water required per day:

Approximate quantities of water required per day.

	Gallons.
Each member of the family for all purposes will require	25–40
Each cow will require	12
Each horse will require	10
Each hog will require	$2\frac{1}{2}$
Each sheep will require	2

The water consumption will vary from day to day and with the seasons. Fire protection should also be considered, and in determining the size of tank the maximum amount likely to be required should be provided.

For a family of 6 persons a 200-gallon supply should be sufficient if the water is used in the house only. On a farm where water is supplied to a family of 6 persons, 10 horses, 12 cows, 25 hogs, and 15 sheep, the daily storage supply should be at least 500 gallons, with whatever additional amount, if any, the farmer deems necessary for fire protection.

There are three general systems of storage and distribution which may be readily applied to farm conditions, viz, the gravity, pneumatic, and autopneumatic systems.

THE GRAVITY SYSTEM.

In the gravity system water is forced into an elevated tank placed higher than the highest discharge cock. A storage tank may be placed in the attic, on the roof, or on a tower outside. The agricultural experiment station at Ames, Iowa, has designed a silo with the storage tank placed on top. Figure 12 shows a gravity system with the storage tank in the attic and figure 13 (p. 16) shows the storage tank placed on the windmill tower.

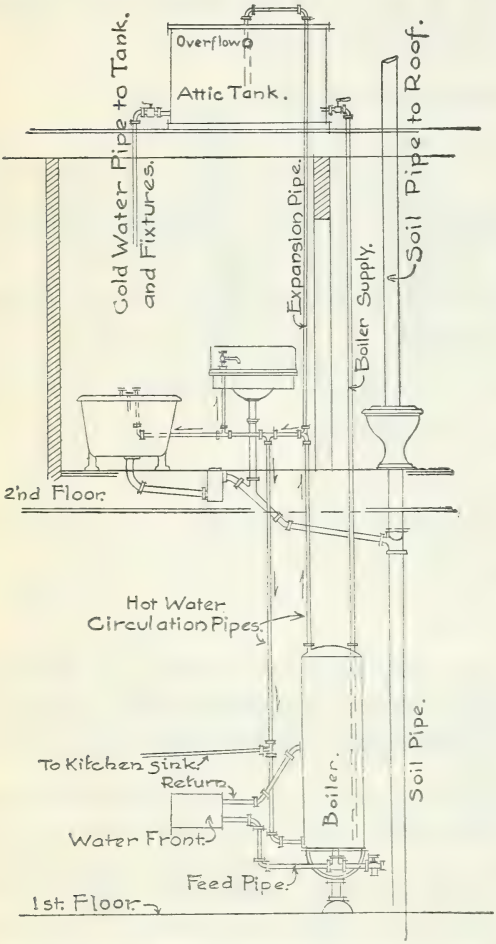

FIG. 12.—Gravity supply system with storage tank in attic.

Since there is considerable frictional resistance to the flow of water through the distribution pipes, the tank should be placed at least 10 feet higher than the highest discharge cock to insure a flow under pressure.

Water weighs 62.5 pounds per cubic foot, or about 8.4 pounds per gallon, so that in placing a tank in the attic or on the roof the supports should be made sufficiently strong to uphold this weight.

Either wooden or galvanized metal tanks may be used. Wooden tanks may be obtained of almost any size, either circular or rectangular in shape. They are generally built of cedar or cypress, and are slightly conical. They are usually knocked down when shipped, and should be set up and filled with water as soon as received. The foundation should be good and solid and the weight of the tank should rest on the tank bottom and not on that part of the stave which projects below. The capacities of circular tanks may be found by the following: Capacity in gallons equals diameter in feet, squared, multiplied by 0.7854, multiplied by the depth in feet, multiplied by 7.48. One cubic foot equals 7.48 gallons. When located in buildings wooden tanks are commonly made rectangular.

They may be lined with tinned copper, but never with lead. To obviate the use of heavy planking, rods are used to rigidly tie together the end and side braces.

Steel tanks may be purchased in circular, round end oblong, and rectangular shapes. Commercial sizes of these tanks are given in the following tables:

Round storage tanks.

Diameter.	Height.	Capacity.	Diameter.	Height.	Capacity.
Feet.	*Feet.*	*Gallons.*	*Feet.*	*Feet.*	*Gallons.*
3	2	106	5	3	440
4	2	189	5	4	588
4	2½	235	5	5	735
4	3	283	5	6	880
4	4	378	5½	8	1,400
4	5	470	6	2	423
4	6	567	6	2½	528
4	8	756	6	3	635
5	2	299	6	4	845
5	2½	368	6	5	1,056

Round end storage tanks.

Width.	Height.	Length.	Capacity.	Width.	Height.	Length.	Capacity.
Feet.	*Feet.*	*Feet.*	*Gallons.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
2	2	4	118	4	2	14	820
2	2	5	150	4	2	16	945
2	2	6	181	4	2½	8	536
2	2	7	202	4	2½	10	756
2	2	8	236	4	2½	16	1,200
2	2	10	299	4	3	8	725
2	2½	8	299	4	3	10	915
2½	2	8	299	4	5	10	1,480
2½	2	10	378	5	2	16	1,200
2½	2½	8	378	5	2½	16	1,480
3	2	8	362	6	2	8	740
3	2	10	440	6	2	10	900
3	2½	8	440	6	2	16	1,420
3	2½	10	567	6	2½	8	900
3	3	10	662	6	2½	10	1,120
4	2	8	473	6	3	10	1,340
4	2	10	598	6	4	10	1,760
4	2	12	693	6	5	10	2,200

Tanks 4 feet long, 1 top brace; 5, 6, and 7 feet, 1 side and 1 top brace; 8 feet, 2 side and 1 top brace; 10 feet, 3 side and 2 top braces; 16 feet, 5 side and 3 top braces.

Square end storage tanks.

Width.	Height.	Length.	Capacity.	Width.	Height.	Length.	Capacity.
Feet.	*Feet.*	*Feet.*	*Gallons.*	*Feet.*	*Feet.*	*Feet.*	*Gallons.*
2	2	4	118	3	2	10	448
2	2	5	150	3	2½	8	448
2	2	6	181	3	2½	10	565
2	2	7	210	3	3	10	673
2	2	8	240	4	2	8	478
2	2½	8	299	4	2	10	598
2½	2	8	299	4	2½	8	598
2½	2½	8	378	4	2½	10	748
3	2	8	360	4	3	8	718

Tanks 4, 5, and 6 feet long, 1 side and 1 top brace; 7 and 8 feet, 2 side, 1 top brace; 10 feet, 3 side, 2 top braces; longer and deeper tanks are extra well braced.

THE PNEUMATIC TANK SYSTEM.

The pneumatic tank system consists of a force pump, an air-tight steel tank, necessary pipe, valves, fittings, etc., and power for operating the pump. The system may be a small one operated by hand, windmill, or small engine, or it may consist of a large pump operated by a powerful engine with two or more tanks of large capacity. The tank may be placed in the basement or underground, thus keeping the water cool and preventing freezing. Figure 14 shows a pneumatic system with the tank in the basement and supplied by a hand force pump. This figure also well illustrates the water plumbing. Figure 15 shows the tank in the basement supplied by a windmill deep-well pumping outfit. The tank may be set in the ground below frost line close to the well or house foundation.

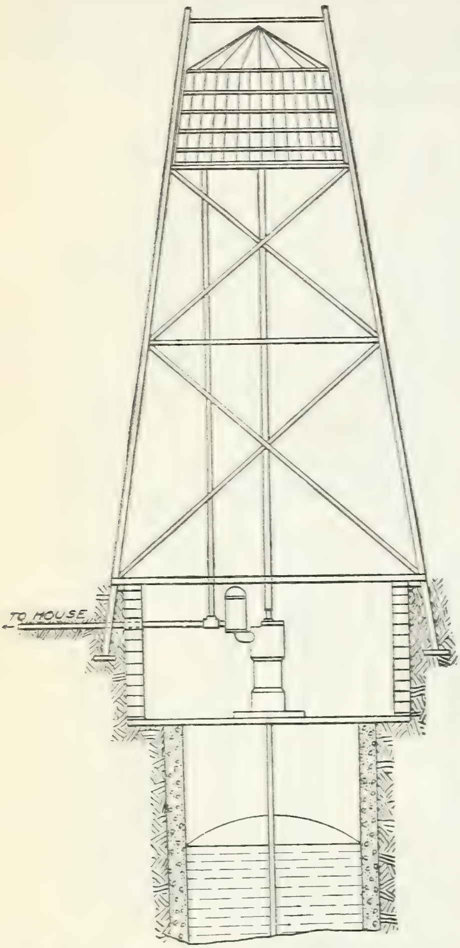

FIG. 13.—Gravity supply system with storage tank on windmill tower.

In the operation of the pneumatic system water is forced into the air-tight tank, thus compressing the air into a smaller space and creating an air pressure which forces the water to the discharge cocks. In determining the capacity of the tank, then, it is necessary that about one-third of the computed storage capacity be added to provide space for the compressed air. The following table gives commercial sizes of pneumatic tanks:

Commercial sizes of pneumatic tanks.

Diameter.	Length.	Weight.	Capacity.	Diameter.	Length.	Weight.	Capacity.
Inches.	*Feet.*	*Pounds.*	*Gallons.*	*Inches.*	*Feet.*	*Pounds.*	*Gallons.*
24	6	445	140	42	10	1,650	720
24	8	560	195	42	12	1,900	865
24	10	675	245	42	14	2,200	1,000
30	6	560	220	42	16	2,400	1,150
30	8	700	295	48	10	2,066	1,000
30	10	870	365	48	12	2,320	1,130
30	12	900	440	48	14	2,610	1,300
36	6	750	315	48	16	2,900	1,500
36	8	900	420	48	18	3,600	1,700
36	10	1,050	525	48	20	3,950	1,880
36	12	1,200	630	48	24	4,650	2,260
42	8	1,450	575	60	20	5,900	2,940

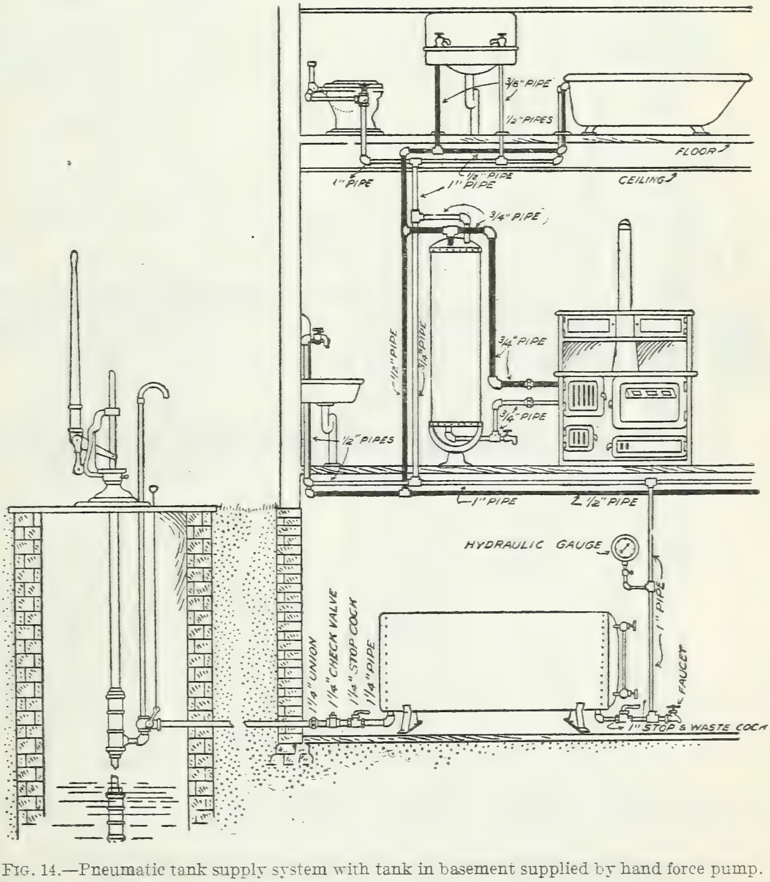

FIG. 14.—Pneumatic tank supply system with tank in basement supplied by hand force pump.

Each tank is equipped with a pressure gauge which will show the internal pressure at any time. If water is pumped into the tank until the pressure gauge registers 25 pounds, water can be forced about 60 feet above the tank. If a discharge cock 20 feet above the tank is opened, water is discharged until the pressure falls to 8.6

pounds, when it is insufficient to deliver the remaining water 20 feet high. It will also be found that when air is compressed in the same tank with water, the water gradually absorbs the air, thus making constant renewal of the air necessary. Both of the above troubles are overcome by compressing excess air in with the water until the pressure gauge again registers 25 pounds, if the tank is half full of water. Excess air pressure may be secured by an air intake valve in the suction pipe, controlled by hand, by a combination of air and water pump, or by use of an air compressor when power is used.

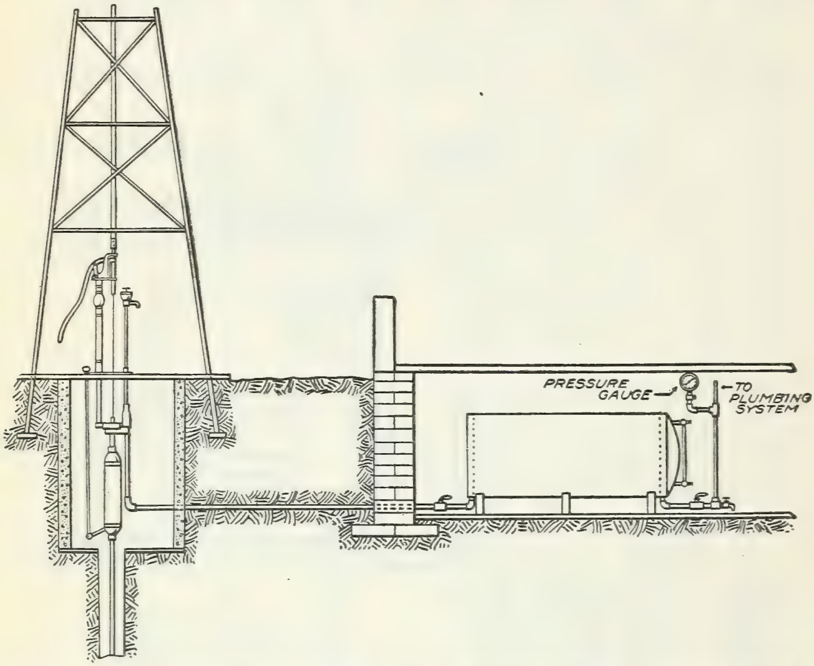

FIG. 15.—Pneumatic tank supply system with tank in basement supplied by windmill deep-well pumping outfit.

The following table gives the pressures in the tank necessary to force water to certain heights in the house:

Feet head of water and equivalent pressure in tank.

Elevation.	Pressure in tank.	Elevation.	Pressure in tank.	Elevation.	Pressure in tank.
Feet.	*Pounds.*	*Feet.*	*Pounds.*	*Feet.*	*Pounds.*
1	0.43	20	8.66	75	32.48
2	.87	25	10.83	80	34.65
3	1.30	30	12.99	85	36.81
4	1.73	35	15.16	90	38.98
5	2.17	40	17.32	95	41.14
6	2.60	45	19.49	100	43.31
7	3.03	50	21.55	110	47.64
8	3.40	55	23.82	120	51.97
9	3.90	60	25.99	130	56.30
10	4.33	65	28.15	140	60.63
15	6.50	70	30.32	150	64.96

Pipe friction should be included in computing the pumping height, as discussed under "Pumping."

THE AUTOPNEUMATIC SYSTEM.

In the autopneumatic system the water is delivered fresh from the well to the faucets. This system consists essentially of an air compressor driven by a small gas engine or electric motor, an air-tight steel air-pressure tank, and one or more autopneumatic pumps. No water tank is required, since nothing is stored but compressed air. The pump consists of two small metallic chambers submerged in the water, and when a faucet is opened they automatically fill and discharge, owing to the air pressure from the storage tank, thus giving a continuous flow of fresh water.

Figure 16 illustrates the principle of operation of the pump. Suppose a small air-tight tank *A* with inlet valve is submerged in water and allowed to fill. A discharge pipe *B* is connected at the bottom leading upward to faucet *K*. Compressed air is forced through pipe *C* into the top of the tank so that the water is forced out through the discharge pipe until the tank is emptied of water. A similar tank *D* is connected as shown. The pump has a device for automatically opening and closing the air valves and exhaust valves to the tanks alternately. While *A* is emptying of water *D* is filling, and they discharge alternately.

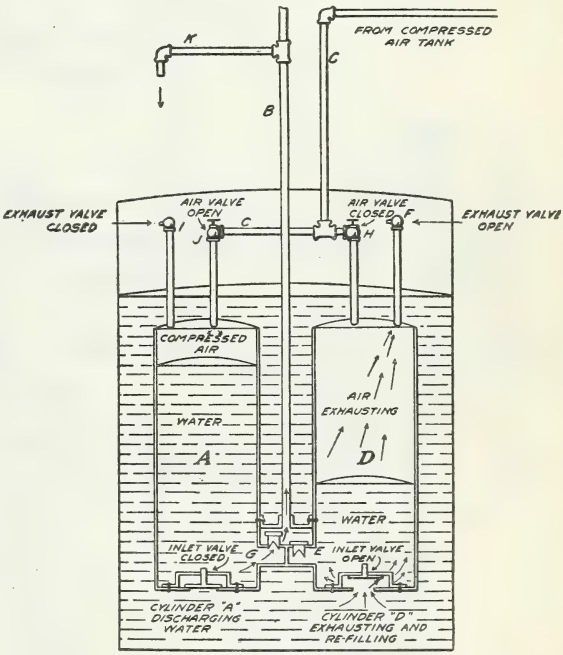

FIG. 16.—Principle of operation of an autopneumatic pump.

Figure 17*A* gives a front and side view of an autopneumatic pump and figure 17*B* shows the entire working parts of a system and also how the pump may be used in bored and cased wells.

Each pump requires an air-pressure reducer, shut-off and release cocks, pressure gauge, etc. The air-pressure reducer is necessary to reduce the high pressure carried in the tank to the uniform low pressure required to operate the pump. It is placed in the air-pipe line between the air tank and the pneumatic pump. It can be adjusted to the proper pressure with an ordinary wrench. The proper working pressure required to operate the pump and raise water to the

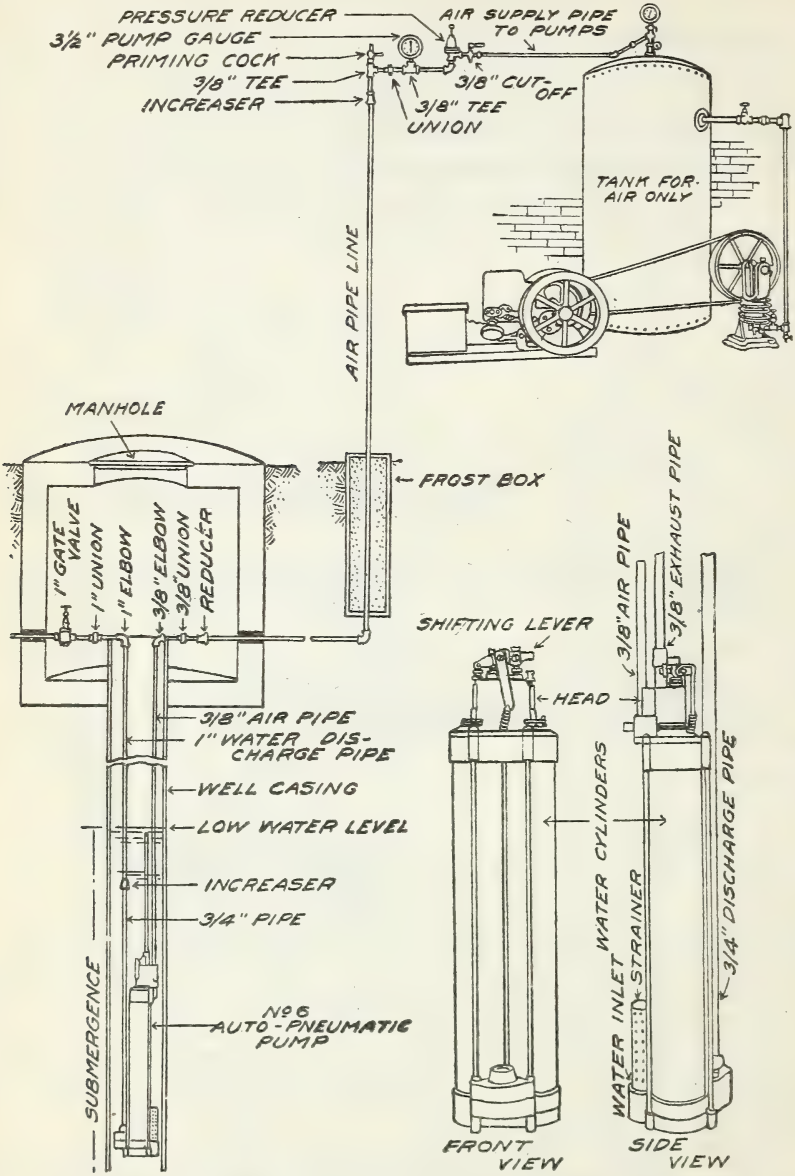

FIG. 17.—Working parts of an autopneumatic pumping system: *A*, Front and side view; *B*, entire working system as used in bored or cased wells.

required height in the building is recorded on the pump gauge placed on the air-pipe line between the reducer and the pump. The following table shows the number of gallons of water that can be drawn from faucets with the pump under working pressures varying from 25 to 35 pounds and total starting pressures in a 1,000-gallon air tank varying from 40 to 100 pounds:

Pumping capacity of a 1,000-gallon air tank, in gallons, under varying internal pressures.

Work pressure on pump guage.	Total pressure in air tank at start.						
	40 pounds.	50 pounds.	60 pounds.	70 pounds.	80 pounds.	90 pounds.	100 pounds.
Pounds.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
25	375	259	833	1,075	1,310	1,548	1,786
30	221	442	663	884	1,105	1,326	1,548
35	102	306	510	714	924	1,123	1,327
40	....	187	374	561	748	936	1,123
45	....	85	255	425	596	765	936
50	....	....	153	306	460	612	765
55	....	....	68	204	330	476	612
60	....	....	....	119	237	375	476
65	....	....	....	51	153	255	357

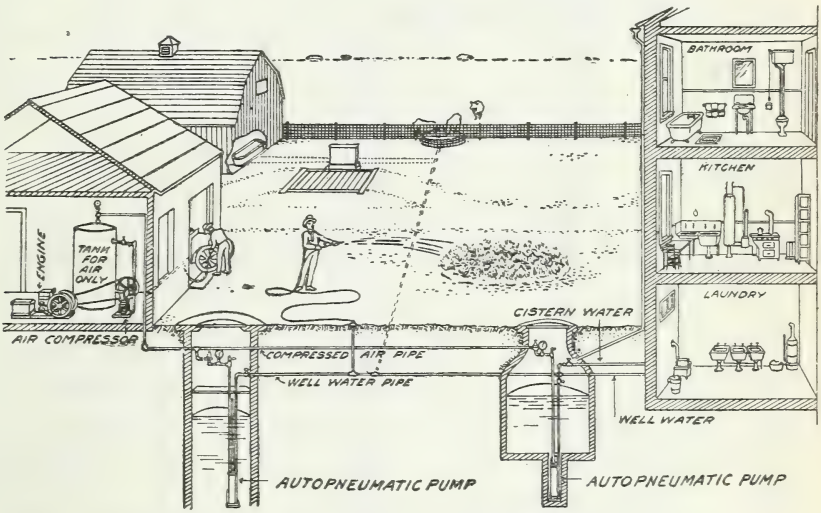

FIG. 18.—Application of autopneumatic system to a farm home.

For air tanks of other than 1,000-gallon capacity divide the figures in the table by 1,000, move the decimal point three places to the left, and multiply the result by the capacity of the tank in gallons.

Assume, for example, that the height to which the water is to be raised and the pressure required to operate the pump, including friction, make necessary a working pressure of 40 pounds on the pump. Then if the initial pressure in the air tank is 50 pounds, 187 gallons of water can be delivered at the faucets before the pressure in the air tank becomes too low to operate the pump.

The autopneumatic pump can be used in wells, springs, or lakes where the water is free from sand and mud and does not have to be lifted more than 100 feet, or where the working pressure on the pump does not exceed 65 pounds.

Figure 18 illustrates the application of this system to a farm home.

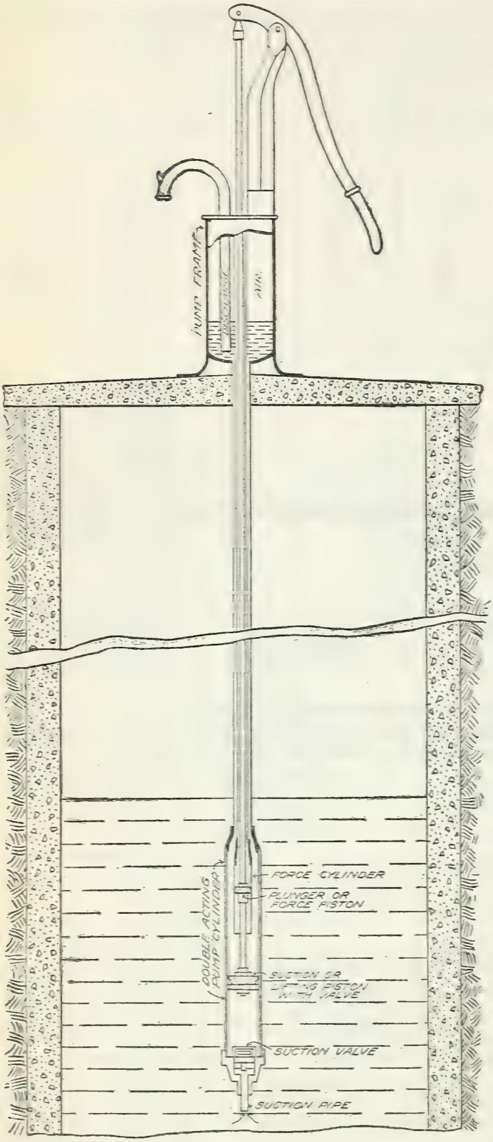

FIG. 19.—Force pump with cylinder submerged in shallow well.

PUMPING.

The water level in shallow wells is usually near enough to the surface to be within the limits of suction. The limiting practical suction lift for a pump is about 20 feet, although it will vary with the elevation above sea level. This means that the pump cylinder which raises the water by suction in lift pumps and which raises by suction and also forces the water in force pumps should not be more than 20 feet above the water level in the well. To practically eliminate suction lift the cylinder may be submerged as shown in figure 19, thus making the cylinder and pump frame separate and connected only by a section of pipe. This prevents the valves from drying out and makes the pump self-priming. Force pumps often have two cylinders, and in deep wells it is necessary that the lower or suction cylinder be either submerged or within at least 15 feet of the water level. In the figure shown the forcing cylinder is within the suction cylinder. The suction of any type of pump must be air-tight.

To find the approximate discharge at each stroke of a pump in gallons use the following table:

Table of capacity of pumps.

Diameter of cylinder in inches.	Length of stroke in inches.									
	5	6	7	8	9	10	12	14	15	16
	Capacity per stroke in gallons.									
1	0.017	0.020	0.024	0.027	0.031	0.034	0.041	0.048	0.051	0.054
1⅛	.022	.026	.030	.034	.039	.043	.052	.060	.065	.069
1¼	.027	.032	.037	.043	.048	.053	.064	.074	.079	.085
1⅜	.032	.039	.044	.051	.058	.064	.077	.089	.096	.103
1½	.038	.046	.054	.061	.069	.077	.092	.107	.115	.122
1¾	.052	.063	.073	.083	.094	.104	.125	.146	.156	.170
2	.068	.082	.095	.109	.122	.136	.163	.190	.204	.218
2¼	.086	.103	.121	.138	.155	.172	.206	.241	.258	.275
2½	.106	.128	.149	.170	.191	.213	.255	.298	.319	.340
2¾	.129	.154	.180	.206	.231	.257	.309	.360	.386	.411
3	.153	.184	.214	.245	.275	.306	.367	.428	.459	.489
3¼	.179	.215	.251	.287	.323	.359	.431	.503	.539	.575
3½	.208	.249	.292	.333	.375	.417	.499	.583	.625	.666
3¾	.239	.287	.335	.382	.430	.478	.574	.669	.717	.765
4	.272	.326	.381	.435	.490	.544	.653	.762	.816	.870
4¼	.307	.368	.429	.491	.553	.614	.737	.860	.921	.982
4½	.344	.413	.482	.551	.619	.689	.826	.964	1.033	1.102
4¾	.384	.460	.537	.614	.690	.767	.920	1.073	1.150	1.227
5	.425	.510	.595	.680	.765	.850	1.020	1.190	1.275	1.360
5¼	.469	.562	.656	.750	.843	.937	1.124	1.311	1.405	1.499
5½	.514	.617	.720	.823	.926	1.029	1.234	1.440	1.543	1.646
5¾	.562	.674	.787	.899	1.011	1.124	1.348	1.573	1.686	1.798
6	.612	.734	.857	.979	1.102	1.224	1.469	1.714	1.836	1.958

The discharge per stroke as shown by the above table may be multiplied by the number of strokes per minute to find the discharge in gallons per minute.

The power required for pumping will depend on the number of gallons per minute one wishes to pump and the total lift.

The total lift is the vertical distance from the surface of the water in the well to the highest faucet or to the storage tank plus the friction loss in the pipes. If the length of distribution pipe is over 100 feet the loss by frictional resistance in feet of lift should be determined and included in the total lift. The following table gives the frictional loss in feet of lift per 100 feet in pipes from ¾ to 4 inches in diameter, discharging from 5 to 40 gallons per minute.

Fractional loss in feet for 100 feet clean iron pipes.[1]

Gallons per minute.	¾ inch.	1 inch.	1¼ inches.	1½ inches.	2 inches.	2½ inches.	3 inches.	3½ inches.	4 inches.
5	7.6	1.9	0.71	0.27	0.09	0.05	0.01	....	....
10	29.9	7.3	1.4	1.0	.28	.09	.05	0.01	....
15	66.0	16.1	5.5	2.2	.57	.18	.09	.05	0.02
20	115.0	28.0	9.5	4.8	.96	.32	.13	.07	.03
25	179.0	43.7	14.7	6.0	1.7	.48	.23	.09	.05
30	264.0	63.2	21.0	8.6	2.1	.69	.30	.14	.07
35	372.0	85.1	28.9	11.6	2.7	.92	.39	.20	.11
40	461.0	110.0	37.0	14.9	3.7	1.2	.53	.25	.14

[1] Ellis and Howland's experiments.

Water weighs 62.5 pounds per cubic foot and there are 7.48 gallons in a cubic foot. Divide the number of gallons pumped per minute by 7.48 to get the cubic feet pumped per minute. Multiply the cubic feet by 62.5 pounds to get the weight of water pumped per minute. Multiply the weight by the total lift, which will give the foot-pounds of work per minute; 33,000 foot-pounds per minute equal 1 horsepower. Divide the foot-pounds per minute by 33,000 and the result will be horsepower. The horsepower as computed from the quantity pumped per minute and the total lift should be doubled, as a pumping outfit usually has an efficiency of about 50 per cent. In general, from 1 to 3 horsepower is all that is required for ordinary farm pumping. In cases where water for the house only is wanted, $\frac{1}{2}$ to $\frac{3}{4}$ of a horsepower is sufficient.

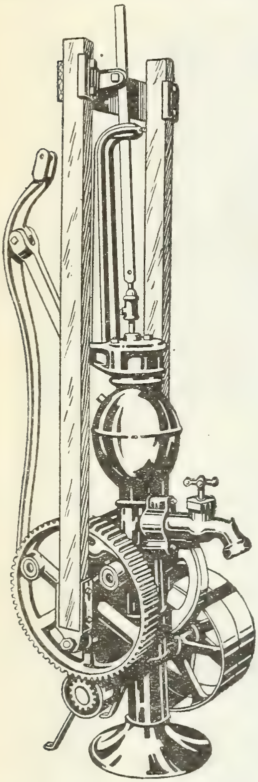

FIG. 20.—Pumping jack for either deep or shallow well pumping.

TYPES OF PUMPS.

There are several types of pumps which may be used in farm pumping. The most common are the ordinary lift pumps which simply raise the water to the ground surface from a shallow well. For elevated tank systems and pneumatic tank systems the combination lift and force pump is necessary. If a special air pump or compressor is not employed it is necessary that a combination air and water pump be used for pneumatic tanks, especially in pumping from deep wells.

There are many types of hand force pumps for shallow and deep well pumping which may be applied to either elevated tank or pneumatic tank systems.

Figure 15, page 18, shows a deep-well windmill pumping outfit applied to a pneumatic tank system, and figure 13, page 16, shows a shallow well windmill pumping outfit supplying water to a tank on the windmill tower. Figure 20 is a pumping jack which may be connected with a deep or shallow well pumping outfit applied to either system. This jack may be operated by gas engine or electric motor. Figure 21 shows two other types of windmill force pumps, *A* for shallow wells, and *B* for deep wells.

In obtaining information from the manufacturers of pumping equipment as to the particular equipment which will suit certain needs, the power required, etc., it is well to send data on the following: The source of water supply, whether a well, spring, or surface supply; inside diameter and total depth of the well; the distance from the ground surface to the water level in the well; the flow of the well; the number of gallons to be pumped per hour; the relative positions of the water supply and the point to which the water is to be forced; the position in which the pump is to be placed; one's preference as to pneumatic tank, elevated tank, or autopneumatic system; the kind of power to be used, and whether or not power is already available, such as electric motors, windmills, or gasoline engines, with a complete description of the power, its revolutions per minute, voltage, cycles, phase, direct or alternating current, etc.

Where a supply of pure water may be obtained in the immediate neighborhood, which is so situated that a considerable fall may be obtained within a reasonable distance, a hydraulic ram may be used for pumping.

THE HYDRAULIC RAM—HINTS ON INSTALLATION AND OPERATION.

The hydraulic ram is a simple though wasteful machine, which utilizes the momentum of a stream of water falling a small height to elevate a portion of that water to a greater height. A complete installation consists of a drive pipe, ram, and delivery pipe, and the ram itself consists of an air chamber, dash valve, delivery valve, and body pipe.

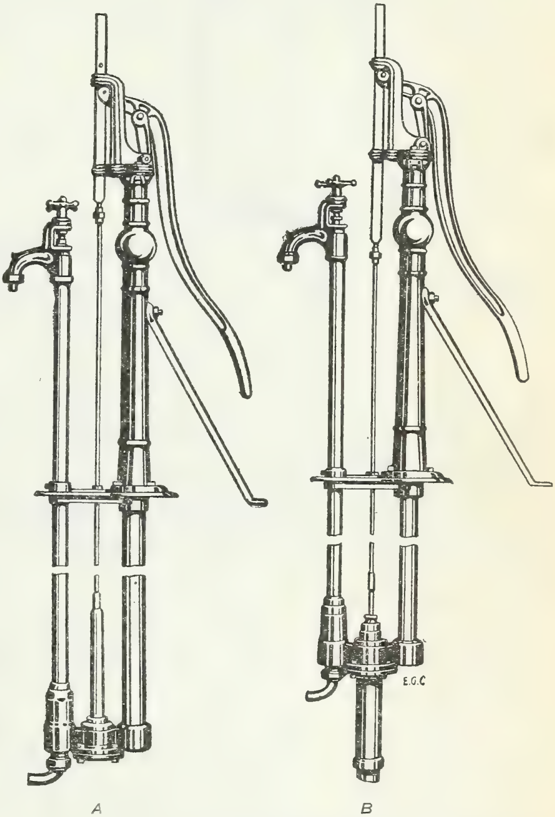

FIG. 21.—Two types of windmill force pump: *A*, For shallow wells; *B*, for deep wells.

The hydraulic ram is usually used to elevate water from a pure spring. Water may be elevated from streams to stock tanks, but this water should not be used for household purposes. The flow of the spring should not be less than one-half gallon per minute. It is necessary that there be considerable difference in elevation between the level of the supply and a convenient location for the ram within a reasonable distance. Figure 22 shows a cross section of a simple type of hydraulic ram. Figure 23 shows the usual relative positions of spring, ram, and storage tank.

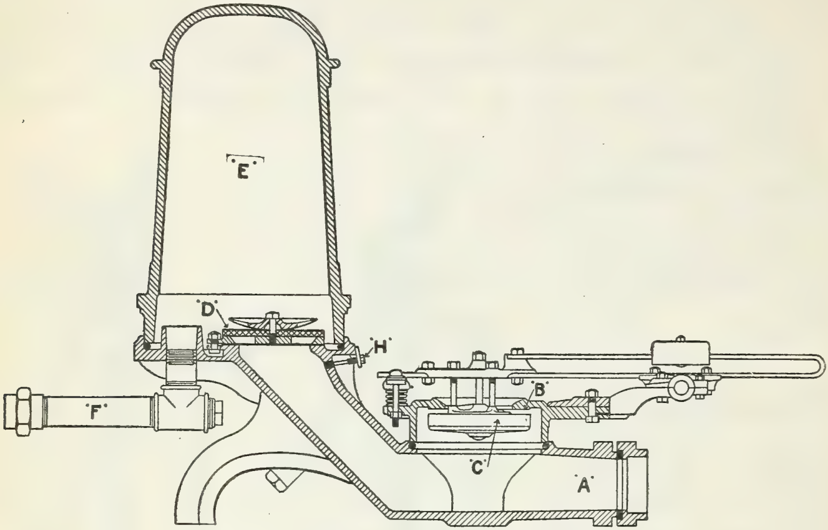

FIG. 22.—Cross section of simple type of hydraulic ram.

The operation of a ram may be briefly explained as follows: The water flowing down the drive pipe acquires a certain energy due to its weight and velocity and upon entering the body pipe of the ram strikes

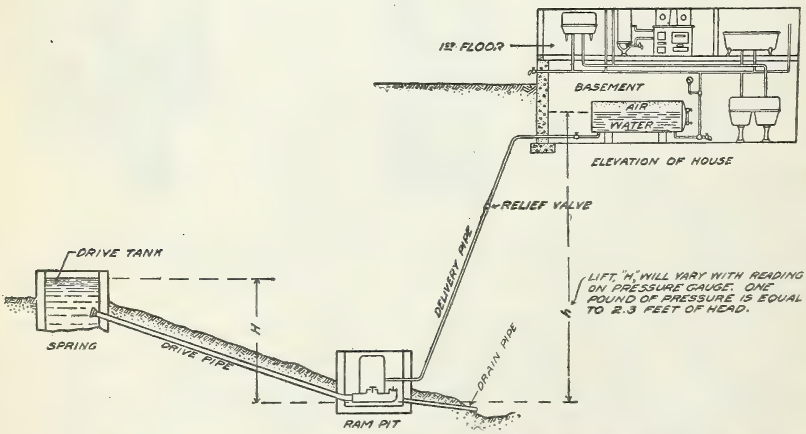

FIG. 23.—Hydraulic ram pumping to a pneumatic tank supply system, showing usual relative position of spring, ram, and storage tank.

the open dash valve with considerable force, which is sufficient to close it. The result is that the water piles up and exerts an interior pressure, which causes the delivery valve to open, admitting water into the air chamber. (See fig. 22.) The water then rebounds back up the drive pipe until forced down again by the weight of the water in the drive pipe, and the operation is repeated. During each momentary reflow a small quantity of water is forced into the air chamber, compressing the air. The resulting air pressure forces water up the delivery pipe to the point of delivery. The operation of a ram is continuous, once started, until the valves become worn. The ordinary small ram completes its cycle about 60 times a minute, the length of stroke of the dash valve governing the number of pulsations per minute.

The length of drive pipe is most important and is governed by the ratio of the fall to the elevation. If too long or too short the automatic supply of air is interfered with and the efficiency impaired. The length of drive pipe is usually about 7 times the height of fall, although this may vary between 5 and 10, depending on the height and distance to which water is to be delivered. The diameter of the drive pipe is usually twice that of the discharge pipe.

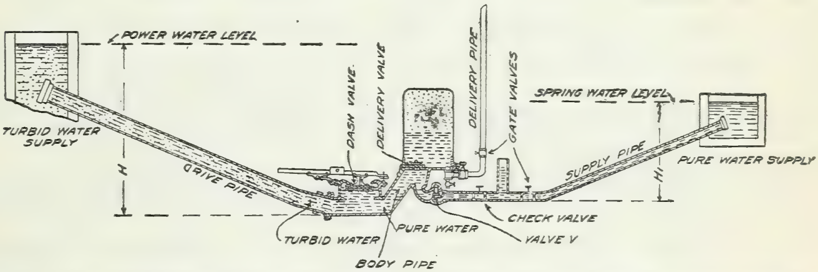

FIG. 24.—Double acting hydraulic ram, showing method of using a turbid creek supply to pump clear spring water.

The proper size of ram to suit certain conditions depends on the following: (1) The flow of water from the source of supply, determined by the time necessary to fill a vessel of known capacity or by weir measurement; (2) the difference between the level of the supply and the lowest point within a reasonable distance for the location of the ram; (3) the distance between the source of supply and the proposed location of the ram; (4) the difference in level between the ram location and the highest point to which water is to be delivered; (5) length of pipe necessary to conduct the water to the point of delivery. In purchasing a ram this information should be sent to manufacturers.

Sometimes a double-acting ram is installed where there is a spring too small to operate a single-acting ram but located near a brook from which an ample supply and fall can be obtained to operate the ram. These are so constructed that if properly installed under a fall of at least 2 feet below the spring and 3 feet below the brook it is impossible to deliver anything but the spring water. Figure 24 illustrates this method. If this method is preferred, it should be so stated in purchasing. The following table gives approximate sizes of hydraulic rams to suit certain conditions.

Sizes of hydraulic rams.

Number.	Dimensions.			Size of drive pipe.	Size of delivery pipe.	Quantity per minute required to operate engine.	Least fall recommended.
	Height.	Length.	Width.				
	Ft. ins.	*Ft. ins.*	*Ft. ins.*	*Ins.*	*Ins.*	*Gallons.*	*Feet.*
10	2 2	2 10	0 12	$1\frac{1}{4}$	$\frac{3}{4}$	2–6	2
15	2 2	3 0	0 12	$1\frac{1}{2}$	$\frac{3}{4}$	6–12	2
20	2 5	3 3	1 2	2	1	8–18	2
25	2 5	3 4	1 3	$2\frac{1}{2}$	1	12–28	2
30	2 7	3 7	1 3	3	$1\frac{1}{4}$	20–40	2
40	3 7	4 9	1 8	4	2	30–75	2

There are four separate problems connected with the hydraulic ram. These, with practical examples, are described by W. C. Davidson[1] as follows: (1) Given the fall, lift, and quantity of water desired, find the necessary supply at spring. (2) Given the lift, quantity of drive water, and quantity of water desired, find the fall required. (3) Given the fall, lift, and quantity of drive water, find the quantity of water supplied to the storage tank. (4) Given the fall, quantity of drive water, and quantity of water desired, find how high this water can be pumped.

The computations which follow are based upon an approximate rule, which is stated as follows: Multiply the fall in feet by the quantity of water supplied to the ram in gallons per minute, divide the product by the height the water is to be raised, and the result will be in gallons per minute. This may be expressed in an equation as follows: $q=\frac{Q\times H}{h}$, in which Q=supply of spring in gallons per minute. H=fall in feet from spring to ram. h=height of storage tank above the ram in feet. q=quantity of water pumped in gallons per minute. The result should be reduced by about one-third to allow for friction.

Example 1. It is desired to find the quantity of drive water in the spring necessary to raise 8 gallons per minute to a height of 60 feet, when the head of drive water on the ram is 8 feet. Substituting in the equation $Q=\frac{h\times q}{H}=\frac{8\times 60}{8}=60$ gallons per minute. In this case about one-third of the result should be added to allow for friction in pipes, valves, etc., making the necessary drive water supply 80 gallons.

[1] Missouri Bd. Agr. Mo. Bul., 10 (1912), No. 2.

Example 2. It is desired to find the necessary fall from the spring to the ram in order to supply the storage tank with 2 gallons per minute, when the drive water supply in the spring is 10 gallons per minute and the height to which the water is to be pumped is 40 feet. Substituting in the equation $H=\frac{h\times q}{Q}=\frac{2\times 40}{10}=8$ feet. Add one-third to allow for friction, making the total fall necessary 10.66 feet.

Example 3. It is desired to find how much water will be delivered into the storage tank if the drive water supply is 6 gallons per minute, the fall is 10 feet, and the height to which the water is to be pumped is 40 feet. Substituting in the equation $q=\frac{Q\times H}{h}=\frac{6\times 10}{40}=1.5$ gallons per minute. Deduct one-third of this result to allow for friction, making the quantity delivered per minute 1 gallon.

Example 4. It is desired to find how high 1 gallon per minute can be pumped if the drive water supply is 4 gallons per minute and the fall is 15 feet. Substituting in the equation $h=\frac{Q\times H}{q}=\frac{4\times 15}{1}=60$ feet. Deduct one-third to allow for friction, making the result 40 feet.

The above computations are only approximate, but should give a good general idea of the operation of a ram.

The following table gives commercial estimates of the quantities of water delivered in 24 hours under certain conditions:

Capacity of hydraulic rams.

Power head in feet.	Pumping head in feet—																
	4	10	15	20	30	[1] 40	50	60	70	80	90	100	120	140	160	180	200
2	540	192	128	96	64	43	29	24	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	301	192	144	96	72	58	43	37	27	24	.....	.....	.....	.....	.....	.....
4	.....	432	256	192	128	96	77	64	55	43	38	29	24	.....	.....	.....	.....
5	.....	540	345	240	160	120	96	80	69	60	53	43	30	26	.....	.....	.....
6	.....	.....	432	302	192	144	115	96	82	72	64	57	43	31	27	24	.....
7	.....	.....	505	378	235	168	134	112	96	84	75	67	50	36	31	28	25
8	.....	.....	.....	432	270	192	154	128	110	96	86	77	64	55	43	38	29
9	.....	.....	.....	485	300	216	173	144	124	108	96	86	72	62	54	43	39
10	.....	.....	.....	540	360	[1] 252	192	160	137	120	107	96	80	68	60	53	43
12	.....	.....	.....	.....	430	301	230	192	165	144	128	115	96	82	72	64	57
14	.....	.....	.....	.....	505	353	270	224	192	168	150	135	112	96	84	75	67
16	.....	.....	.....	.....	.....	432	323	257	220	192	171	154	128	110	96	85	77
18	.....	.....	.....	.....	.....	486	390	303	247	216	192	173	144	124	108	96	86
20	.....	.....	.....	.....	.....	540	430	336	288	240	214	192	160	137	120	107	96
22	.....	.....	.....	.....	.....	.....	475	370	303	264	235	212	176	151	132	118	105
24	.....	.....	.....	.....	.....	.....	520	405	346	288	256	230	192	164	144	128	115
26	.....	.....	.....	.....	.....	.....	.....	470	375	328	278	250	208	178	156	139	125
28	.....	.....	.....	.....	.....	.....	.....	505	430	354	300	269	224	192	168	149	134
30	.....	.....	.....	.....	.....	.....	.....	540	465	405	336	288	240	206	180	160	144

[1] Multiply factor opposite "power head" and under "pumping head" by the number of gallons per minute used by the engine and the result will be the number of gallons delivered per day. Example: With a supply of 6 gallons per minute, 10 feet fall, 40 feet elevation, No. 10 or 15 engine will deliver 1,512 gallons per day; 6×252=1,512.

This table will give only approximate quantities since the results will vary with the length of delivery pipe. Due consideration of pipe friction will give more correct results.

The efficiency developed is governed by the ratio of fall to pumping head, being greatest for a ratio of 1 to 2½ or 1 to 3, and the ram will not usually work well when the ratio is over 1 to 25, friction in the delivery pipe being duly considered.

The spring should be walled in to form a reservoir as shown in the discussion of springs, page 12. If a stream is used it should be dammed back until a sufficient flow and fall is obtained.

Rams may be obtained to supply water for both elevated tank and pneumatic tank systems. In purchasing a ram this should also be specified.

In order to obtain the desired fall it is often necessary to convey the water a greater distance than the length of drive pipe used. Figure 25 illustrates two methods of securing the necessary fall.

It is necessary to provide a shelter for the hydraulic ram to prevent freezing in cold weather. The pipes should also be placed below the frost line. In setting a ram the foundation should be firm and level. The drive pipe should be laid on a perfectly straight incline without

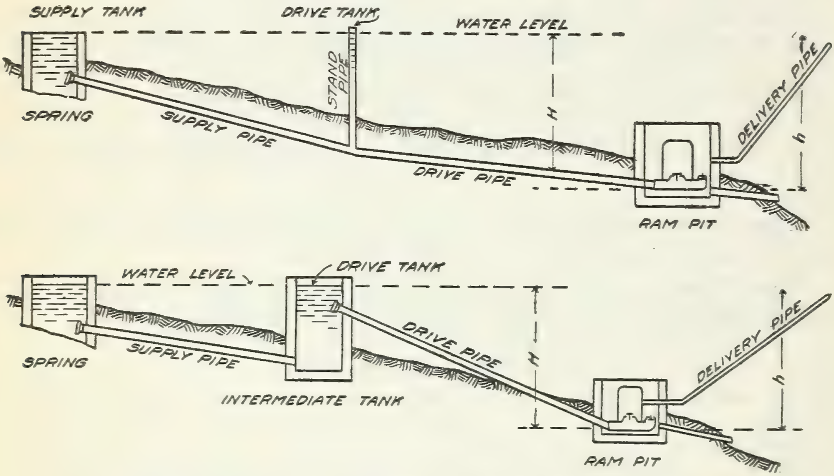

FIG. 25.—Two methods of securing the necessary fall in drive pipe.

bends or curves, except where the pipe enters the ram, and this should be made by bending the pipe. Fittings should not be used. The upper end of the drive pipe should be sufficiently below the surface of the water to prevent air suction—at least a foot. A good open strainer should be provided at the upper end also. Above all things the drive pipe should be air-tight.

The delivery pipe may be laid with the necessary bends, according to the usual practice in laying water pipes, but all pipes should be connected before starting the engine and they should be left uncovered until all leaks are stopped. However, there should be as few bends and elbows in the delivery pipe as possible in order to reduce friction.

Manufacturers of hydraulic rams should supply directions for the proper installation, operation, and care of their particular rams, and these directions should be carefully followed.

PLUMBING.

IMPORTANT POINTS TO BE CONSIDERED.

The important points to be considered in the arrangement of a plumbing system are (1) durability of material and construction, and (2) simplicity. Avoid any complication of pipes and arrange the water pipes so as to carry the water to the point of discharge in as nearly a straight line as possible. The use of lead pipe or lead-lined receptacles for drinking water should be avoided in small private systems.

WATER PLUMBING.

The main pipe from the supply tank should be about $1\frac{1}{4}$ inches in diameter and never less than 1 inch. It leads to the kitchen range and then branches. One branch conveys cold water to the fixtures and the other conveys water through the heater, through the hot-water tank, and thence to the hot-water fixtures. The hot-water pipe should parallel the cold-water pipe but should not be so close to it that the temperature of either will affect that of the other. The arrangement of water pipes, hot-water tank, etc., is shown in figure 14. The hot-water pipes are shown in black. All water pipes should be put in with red lead and all fittings should be screwed tight. The natural direction of travel of hot water is upward, and this should be aided, in arranging the hot-water pipes, as much as possible.

The sizes of pipes generally used for supplying water to the various fixtures are given in the following table:

Size of water pipes in building.

Supply branches.	Low pressure.	High pressure.	Supply branches.	Low pressure.	High pressure.
	Inches.	*Inches.*		*Inches.*	*Inches.*
To bath cocks	$\frac{3}{4}$–1	$\frac{1}{2}$–$\frac{3}{4}$	To water-closet flush pipes	$1\frac{1}{4}$–$1\frac{1}{2}$	....
To basin cocks	$\frac{1}{2}$	$\frac{3}{8}$–$\frac{1}{2}$	To kitchen sinks	$\frac{5}{8}$–$\frac{3}{4}$	$\frac{1}{2}$–$\frac{5}{8}$
To water-closet flush tank	$\frac{1}{2}$	$\frac{1}{2}$	To pantry sinks	$\frac{1}{2}$	$\frac{3}{8}$–$\frac{1}{2}$
To water-closet flush valve	1–$1\frac{1}{4}$	$\frac{3}{4}$–1	To slop sinks	$\frac{5}{8}$–$\frac{3}{4}$	$\frac{1}{2}$–$\frac{5}{8}$

All water pipes should have sufficient slant to drain them back into the tank or drainage system, and a drain pipe and cock should be provided at the low point in the system, so that in extremely cold weather the system may be drained into the sewer or drainage system to prevent freezing. This necessitates a stop cock on the pressure-tank outlet to prevent draining the tank.

Pipes should be kept from the outer walls to prevent freezing, and pipes located where they are in any danger whatever of freezing should be boxed in sawdust or some other nonconducting material.

Since a plentiful supply of hot water is convenient and a large quantity retains heat for some time, it is well to provide a fairly large hot-water tank. However, the size of boiler depends on the existing conditions, such as the water supply and the size of building. A safe rule is to allow a 35 or 40 gallon boiler to a building having one bathroom and to add 30 gallons additional capacity for every extra bathroom. One hundred square inches of water-back heating surface is sufficient for a 40-gallon boiler.

Boilers should be galvanized inside and out, particularly inside. Copper boilers are preferable if properly coated inside with block tin. These are classed as light, heavy, and extra heavy, the latter being tested to 150 pounds water pressure. Ordinary steel or iron boilers are tested to 150 pounds water pressure and extra heavy ones to 250 pounds pressure. The latter should be used when the gauge pressure is more than 40 pounds per square inch. The following table gives standard sizes of galvanized boilers:

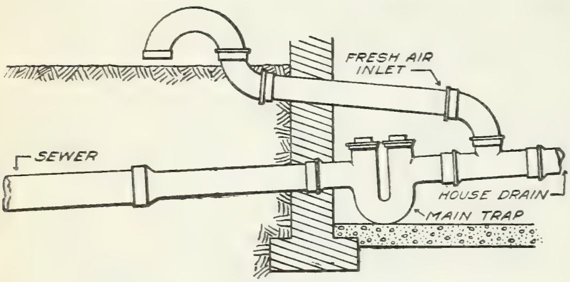

FIG. 26.—Sewer trap at house foundation, showing ventilator.

Standard sizes of galvanized boilers.

Capacity.	Length.	Diameter.	Capacity.	Length.	Diameter.
Gallons.	*Feet.*	*Inches.*	*Gallons.*	*Feet.*	*Inches.*
18	3	12	48	6	14
21	3½	12	52	5	16
24	4	12	53	4	18
24	3	14	63	6	16
27	4½	12	66	5	18
28	3½	14	79	6	18
30	5	12	82	5	20
32	4	14	98	6	20
35	5	13	100	5	22
36	6	12	120	6	22
36	4½	14	120	5	24
40	5	14	144	6	24
42	4	16	168	7	24
47	4½	16	182	8	24

SEWER PLUMBING.

The sewer plumbing serves as a drain for the water plumbing. The drainage system should be so constructed as to carry away completely everything emptied into it, and it should be constantly vented, frequently and thoroughly flushed, and have each of its openings into the house securely guarded. All drains, soil pipe, and waste pipe should be water-tight and air-tight. The soil pipe or house-drainage main begins at the sewer opening and passes up through the house as nearly vertical as possible and out through the roof for free ventilation. It should be at least 4 inches in diameter, of extra heavy cast iron, and all joints should be tightly calked with lead and oakum. All discharge from the wash basins, sinks, and toilets empties into the soil pipe, and connections should be tightly made. The sewer inside the cellar wall should always be soil pipe; tile should never be used except outside of the wall. A soil-pipe trap should be provided at the house foundation, as shown in figure 26. Every fixture should have a trap to prevent foul air from coming back through the waste pipe. Vent pipes should be provided on all waste pipes to prevent siphonage and the consequent destroying of the traps. Figure 27 (p. 34) shows a good arrangement of sewer plumbing.[1] Note the traps and vent pipes on each waste pipe. The least sizes of waste and vent pipes are given in the table below.

Sizes of waste and vent pipes.

Name of pipe.	Diameter.	Name of pipe.	Diameter.
	Inches.		*Inches.*
Main and branch soil pipe	4	Wash tubs, 1½-inch waste pipe to 2-inch trap for 2 tubs	1½–2
Main waste pipe	2	Waste pipe for 3 or 4 tubs	2
Branch waste pipes for kitchen sinks	2	Main vents and long branches	2
Bath or sink waste pipe	1½–2	Branch vents for traps over 2 inches	2
Basin waste pipe	1¼–1½	Branch vents for traps less than 2 inches	1½
Pantry sink waste pipe	1½		
Water-closet trap	3½–4		

All plumbing should be tested by filling with water or smoke to detect leaks.

SEWAGE PURIFICATION AND DISPOSAL.

The problem of the purification and disposal of farm sewage by small private systems differs somewhat from that of city sewage disposal, owing principally to the extreme fluctuations in flow, small size of the system, fresh character, and variation in the quality of the sewage.

The process of sewage disposal is partly mechanical and partly bacterial, consisting of (1) preliminary or tank treatment and of (2) final treatment, which is application to a natural soil by surface or subsurface distribution or to a specially prepared filter.

PRELIMINARY OR SEPTIC-TANK TREATMENT.

The exact nature of the action which takes place in a septic tank is a subject of dispute among sanitary experts and bacteriologists. Several theories have been advanced, but it is apparent that no definite conclusion has been reached. Some authorities advocate the use of open ventilated tanks, others advocate the use of air-tight tanks.

Experience has shown that, in a small sewage disposal system, a dark, air-tight tank of sufficient capacity and so constructed that sewage may remain in it entirely at rest for a period of from 18 to 24

[1] Univ. Mo. Engin. Expt. Sta. Bul. 3.

hours gives the best results and the least annoyance. The solid matter settles out in such a tank and, according to the theory at present accepted, it is partially liquefied, deodorized, and destroyed by countless numbers of bacteria, which thrive in filth and live without air. Some authorities assert that these bacteria also slightly affect the dissolved organic matter in raw liquid sewage.

In such a tank a thick scum forms on the surface of the sewage, which protects the bacteria from the incoming air and is evidence of good bacterial action. The breaking up or disturbance of this scum will destroy the bacterial action for the time being and is likely to cause considerable annoyance by bad odors.

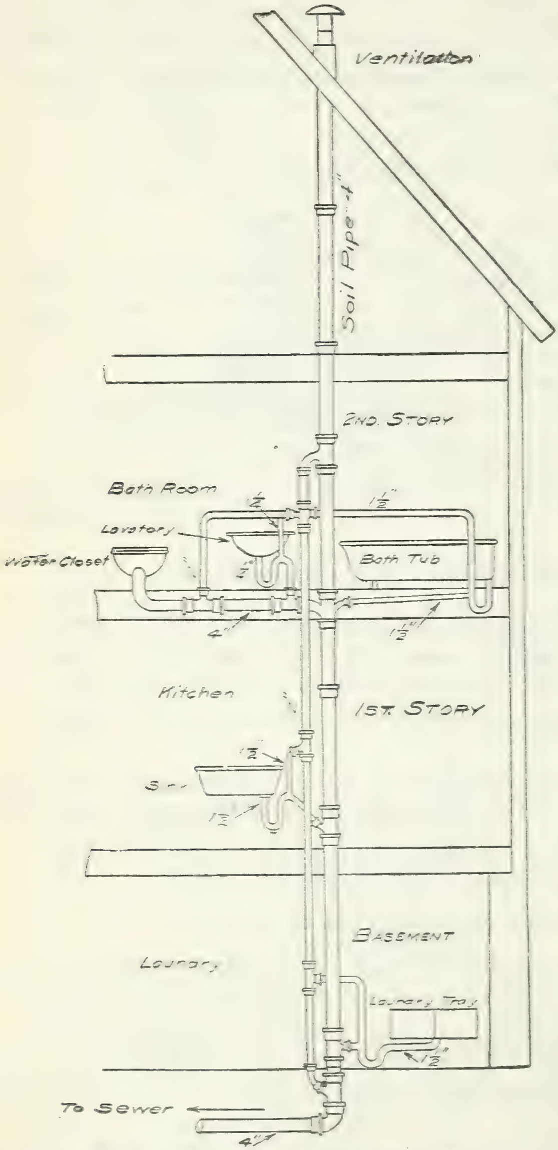

FIG. 17.—Plumbing system for sewage disposal.

FINAL TREATMENT.

It is found that the septic tank effects only about 40 per cent purification. The liquefying action in the tank, however, makes it possible to subject the sewage to a final treatment by filtration or distribution in a natural soil. This final purification is effected by means of bacteria which work in the air. Therefore it is necessary that the sewage be applied to the final disposal system in intermittent doses so that the system may have a chance to air out.

If the sewage is applied continuously and in such quantities that the system is kept saturated, the filter or disposal area becomes water-logged and "sewage sick" and ceases to be effective. It is therefore necessary that the final treatment system be of sufficient capacity to dispose of each dose of sewage quickly.

DOUBLE-CHAMBER SEPTIC-TANK SYSTEMS.

The septic tank for a small sewage-disposal system should ordinarily consist of two chambers. In this type of tank the sewage is received, settled, and partially purified in one chamber and collected and discharged from a second chamber. This type of tank if properly designed should give satisfactory operation, since the sewage in the settling chamber suffers little disturbance, and the discharge to the final disposal system may be made intermittent by means of an automatic siphon placed in the discharge chamber.

DESIGN.

Practice indicates that the settling chamber of a small septic tank should have a capacity of from 5 to 15 cubic feet or from 40 to 80 gallons per person in the family. Some allow an average of 10 or 11 cubic feet per person. The best results are obtained when the capacity approaches the larger limit, so that 18 to 36 hours' sewage from the house may be held at one time, thus causing the sewage to remain in the tank and undergo sedimentation and bacterial action for this length of time. But care should be taken not to make the tank so large that liquefied sewage will remain in it more than 36 hours, for in that event putrefaction is likely to set in. For this reason one should make an accurate estimate of the daily sewage flow, which will be practically equal to the daily water consumption. Although a depth of 3 feet may be sufficient for some classes of sewage, it is better to have the depth from 4 to 8 feet, according to the number of people, in order to give the sludge a good chance to settle and liquefy. The width of the chamber may ordinarily be about one-third or one-half the length, although this may vary for economy and convenience. The width should not be less than 3 feet, however.

The inlet from the house should be provided with an elbow, so that the discharge will be at least a foot below the contained sewage, thus preventing disturbance of the surface scum. The outlet from the settling chamber should be equipped in the same way. Where the entrance and discharge velocities are very strong, baffle walls of wood or concrete should be placed before these openings to break the current. These precautions are especially beneficial in the smaller-sized tanks.

The discharge chamber should be of such capacity and depth as to discharge about every 10 to 12 hours. It may be desirable to discharge at more or less frequent intervals, according to the nature of the soil in the disposal area, and this may be controlled by the arrangement of discharge chamber and siphon. Where little outlet fall is available it is possible to so construct the discharge chamber that its floor will be considerably above that of the settling chamber.

The capacity and depth of discharge chamber and the size of siphon will depend on the number of persons served and the means of disposal. If a sand filter is used or a distribution system in heavy loam, the discharge chamber must be larger and deeper, in order that the discharge interval may be lengthened and the distribution system be given ample time to aerate. If the distribution is in sandy or very porous soil the discharge may be more frequent.

The following table of dimensions of septic tanks suggests sizes of settling and discharge chambers and the corresponding siphon sizes to apply to various average conditions. The depths of siphon chamber given are the minimum allowable.

Dimensions of septic tanks.

Number persons.	Settling chamber.			Siphon chamber.						Siphon diameter.
				Sand filter or heavy loam distribution.			Sandy or porous soil distribution.			
	Width inside.	Length inside.	Depth.	Width inside.	Length inside.	Minimum depth.	Width inside.	Length inside.	Minimum depth.	
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Ft. in.*	*Feet.*	*Feet.*	*Ft. in.*	*Inches.*
6	4	6	3½	4	3	2 4	3	2	2 4	3
8	4	6½	4	4	4	2 4	3	2½	2 4	3
12	4	7	5	4	5	2 5	3	4	2 5	4
15	4	8	5	4	6	2 5	3	4	2 5	4
25	4	10	5	4	6½	3 2	3½	4	3 2	5
35	4½	12	5	4	6½	3 2	3⅔	4½	3 2	5

The above table is computed on the basis that the inlet and outlet of the settling chamber should be placed with their inverts 12 inches below the roof of the tank, thus making the depth of sewage in both settling and discharge chamber 12 inches less than the mean inside depth.

The tank dimensions given in the above table, it should be remembered, are for average cases only and are not standard for all such cases. They are subject to such variations to suit local conditions as the farmer's judgment indicates; yet care should be taken not to vary any of the esssential dimensions and not to go below the given minimum depth of siphon chamber.

Figure 28 shows a type of double chamber septic tank for a family of six people, designed by W. C. Davidson.[1] Figure 29 is another

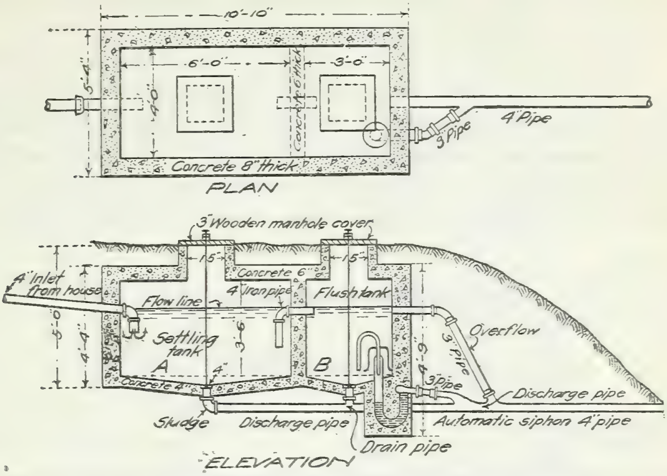

FIG. 28.—Double chamber septic tank for six people, suited to conditions where plenty of outlet fall is available.

type of septic tank for a family of eight people. These tanks are suited to conditions where plenty of outlet fall is available. Figure

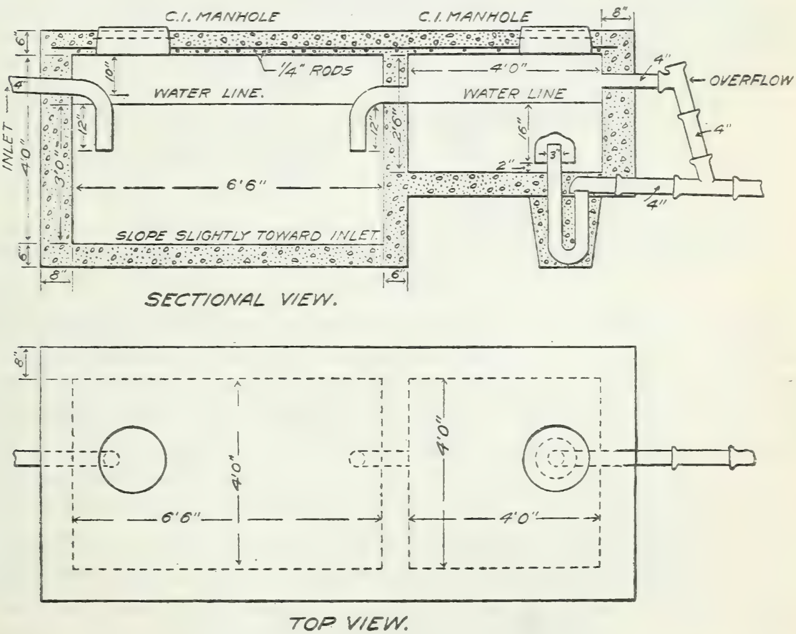

FIG. 29.—Double chamber septic tank for eight people.

30 is a double-chamber tank for a family of six persons, designed by C. A. Ocock of the Wisconsin Agricultural Experiment Station.[2]

[1] Univ. Mo. Engin. Expt. Sta. Bul. 3. [2] Wisconsin Sta. Circ. Inform. 34.

This tank is suited to flat ground where outlet fall is difficult to obtain, as will be noted by the difference in elevation between the floors of the two chambers. For satisfactory operation a small septic tank should not be built of smaller size than for six persons.

LOCATION AND CONSTRUCTION.

The septic tank, although air-tight and supposedly water-tight, should be located as far from the house and the well or spring as convenience and local surroundings will permit, thus reducing the danger of pollution or nuisance in case of leakage or improper operation of the system.

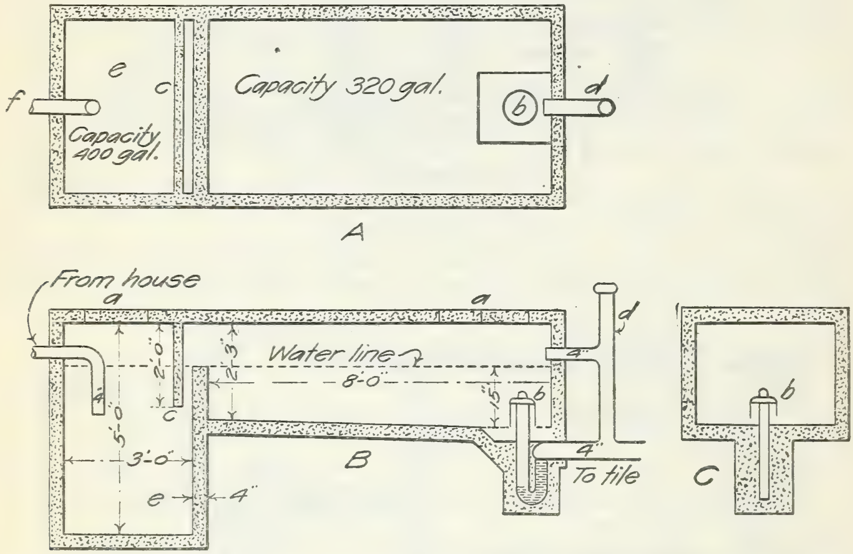

FIG. 30.—Double chamber septic tank for family of six people, suitable to conditions where outlet fall is difficult to obtain.

The sewer from the house should be of vitrified sewer pipe, usually of 4 inches size, with tightly cemented joints, and should be laid to a grade not less than 9 inches per 100 feet. Where the fall from the house to the tank is excessive, it is a good idea to lay the last 100 feet of tile to the minimum grade to break up entrance velocity.

It is assumed that the farmer has a working knowledge of small concrete structures.[1] The septic tank should be constructed as nearly water-tight as possible, preferably of concrete. The walls should be 6 or 8 inches thick, the floor 4 to 6 inches thick, and the roof about 6 inches thick and reenforced. Some means should be provided at the bottom to facilitate the cleaning out of settled sludge. Either the floor may be sloped toward the inlet end for this purpose or a pipe

[1] U. S. Dept. Agr., Farmers' Bul. 461.

with a valve may be installed below the tank, as shown respectively in figures 29 and 28. The discharge chamber should be fitted with an outlet set above the siphon which will allow the sewage to escape in case the siphon becomes clogged.

A concrete mixture of 1 part cement to 2 or 2½ parts sand to 4 or 5 parts of broken stone or gravel should be used in the construction of the tank, and it is a good idea to use the oil-mixed method previously noted (p. 4) to help to waterproof the concrete.

THE AUTOMATIC SIPHON.

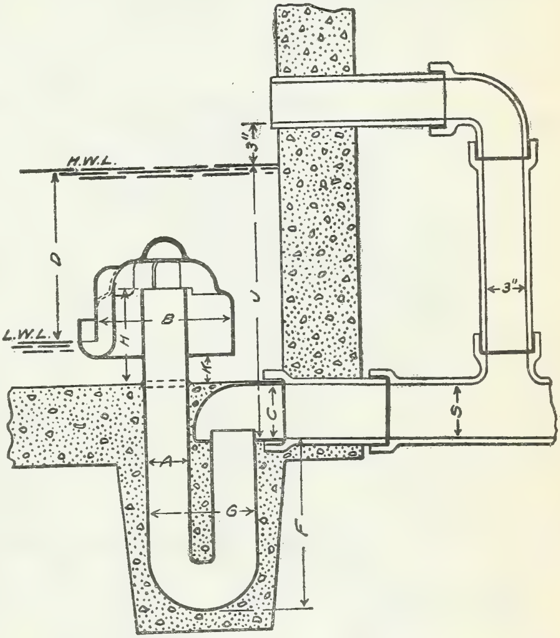

FIG. 31.—Three-inch or four-inch automatic siphon installed.

The automatic siphon may be installed to operate as frequently as may seem desirable. Figure 31 shows a 3 or 4 inch automatic siphon installed. The siphon operates as follows: As the liquid enters the discharge chamber its weight increases with increasing depth, and the air between the water surface in the bell and the water inside the "siphon leg" is compressed. As the water outside increases in depth the compression inside becomes greater until the water outside reaches the drawing or discharge depth for the siphon. Then the inside pressure is sufficient to force the water in the siphon leg around the bend, instantly relieving the compression. The water from the tank then rushes in to fill up the space which was occupied by the air and starts the siphon, which continues until the outside and inside pressures are again equalized.

The following table gives working data and dimensions, as shown in figure 31, to be used in installing 3, 4, and 5 inch siphons. Sizes of 5 inches and over are constructed a little differently from the 3 and 4 inch sizes, although the working principles are the same.

Dimensions for automatic siphons.

Dimension.	Reference letter.	Inches. (1)	Inches. (2)	Inches. (3)
Diameter of siphon	A	3	4	5
Diameter of bell	B	10	12	15
Diameter of discharge head	C	4	4	6
Drawing depth	D	13	14	23
Depth of trap	F	12	13	22
Width of trap	G	10	12	14
Height above floor	H	7¼	8¾	9½
Clearance under bell	K	2	2	3
Diameter of carrier	S	4	4–6	6–8
Invert to discharge line	J	20½	22¾	33½
Average discharge per second ... cubic feet		0.16	0.35	0.73

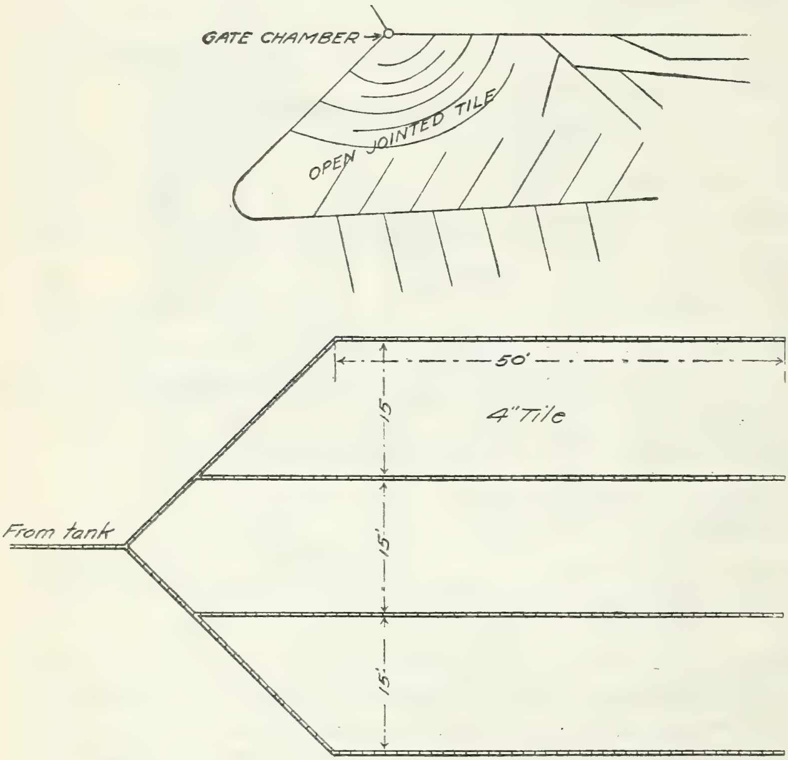

FIG. 32.—Ground plans of tile sewage disposal systems.

THE FINAL DISPOSAL SYSTEM.

DISPOSAL BY SURFACE OR SUBSURFACE DISTRIBUTION.

Where the soil is porous or sandy and there is plenty of area available which is used for no other purpose, the sewage from the septic tank may be discharged through 4-inch distribution tile laid on the surface of the ground in gridiron or herringbone fashion. Four hundred and fifty to 500 square feet of area are necessary for each person served if the soil is very porous and sandy, and the soil should either be tile-drained or have natural underdrainage.

A better method of disposal is by subsurface distribution. In this method the tile are placed in the ground in herringbone or gridiron fashion, not deeper than 14 or 16 inches from the surface of the soil to the top of the tile. Figure 32 shows ground plans of such systems. In very porous or sandy soils 1 foot of 4-inch tile per gallon of discharge per day is sufficient. In the heavier loam soils 2 feet of 4-inch tile are necessary and sometimes more for every gallon. A rough estimate should be made of the number of gallons of sewage in each discharge from the tank and the number of discharges per day. Not less than 35 feet of 4-inch tile per person should be used in sandy or porous soil and not less than 60 feet per person in very heavy loams. In average loams 300 to 400 feet of tile are sufficient for a family of six or eight.

Aeration of heavy soils can be brought about by the use of coarse cinders or gravel laid in 12-inch to 16-inch layers in the bottom of the tile ditch with the top about 12 inches below the surface. The tile are laid in these at the usual depth. Figure 33 shows such an arrangement.

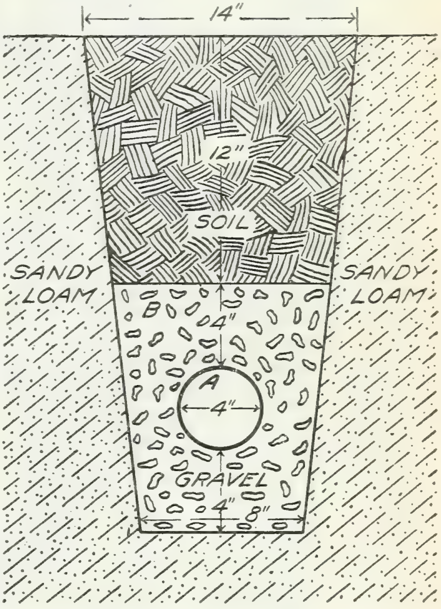

Fig. 33.—Cross section of single tile sewage disposal system, showing method of aerating heavy soils.

The disposal tile should have a fall not to exceed 1 inch in 50 feet, else the water will rush to the lower end and water-log the soil there. The tile are usually laid about $\frac{1}{4}$ inch apart and in rows about 15 feet apart. The latter distance, however, will vary with the porosity of the soil. Where there is no subsurface drainage, artificial drainage should be provided by means of tile drains laid below the sewage tile as shown in figure 34. In some cases an impervious stratum underlying the filter earth is underlain by a stratum of sand. Cases have been noted in which this impervious stratum has been broken by dynamite at 15-foot to 20-foot intervals along the tile line, thus providing natural drainage.

DISPOSAL BY INTERMITTENT SAND FILTRATION.

If subsurface disposal is not feasible, for instance when the soil is compact and nearly impervious or is swampy and underdrainage is difficult to obtain, disposal by intermittent sand filtration is necessary.

The sand filter usually is a bed of sand 3 to 4 feet thick which is fine on top and gradually increases in size to coarse gravel at the bottom. The sewage from the tank is distributed over the filter by means of tile laid loose-jointed over the surface in much the same manner as in the ground-surface distribution system. The filter should be sufficiently porous and there should be sufficient natural or artificial underdrainage to allow every dose of sewage to sink away rapidly. Sewage should not stand on the surface of the filter for any length of time, as this will soon destroy its purifying properties. About 45 square feet of filter should be provided for each person served by the sewer. The area should be divided into from three to five beds so that each bed may be allowed to rest occasionally. Figure 35 shows a plan and partial section of a sand filter for a family of eight persons.

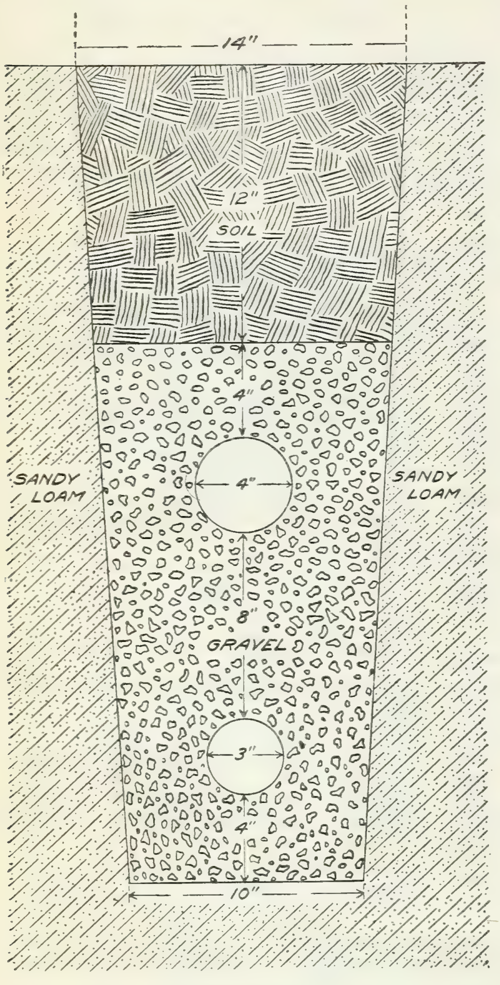

FIG. 34.—Cross section of single tile sewage disposal system, showing second tile below for underdrainage.

In constructing a filter a sufficient area should be leveled off and small earth embankments be made 18 inches to 2 feet high to inclose the beds. The depth of the filtering material will depend largely on the porosity of the subsurface and the means of underdrainage, but it is well to have it not less than 2½ feet; 3 to 5 feet is better, but the depth should not exceed 6 feet. A good plan is to allow a minimum of 1 cubic yard of filtering material for every 50 gallons of sewage flow.

SINGLE-CHAMBER TANK SYSTEMS.

Single-chamber septic-tank systems may be made to give fair satisfaction if properly designed and operated. In such a system the sewage is received, settled, partially purified, and discharged by one chamber.

There is necessarily considerable disturbance of the sewage in the tank, and, in addition, the discharge is continuous. This makes necessary two disposal systems, with a diverting gate to allow an occasional breathing spell for each system. If such an arrangement is not used the disposal system must be of much larger capacity than for the double-chamber tank system, in order to prevent the continuous discharge from waterlogging the system.

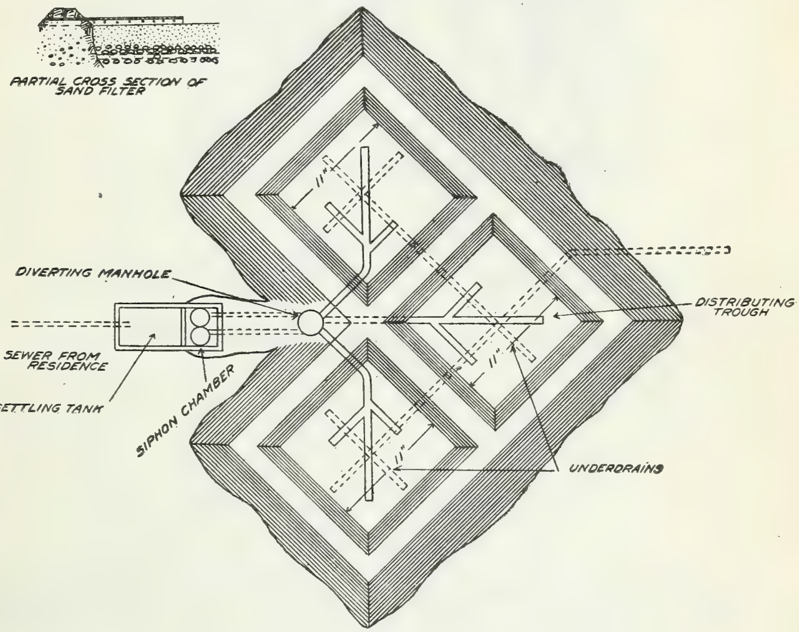

FIG. 35.—Sand filter for eight people.

If a single-chamber tank is used it should be designed and constructed on the same basis as the settling chamber of a double-chamber tank, with the elbows at inlet and outlet and baffle boards before these openings to break up the current.

Figure 36 shows a single-chamber tank for a family of six. This tank has a continuous discharge, and it is necessary to use a switch or diverting gate, as shown in figure 37, so that the liquid sewage may be intermittently diverted from one part of the disposal system to another.

The disposal system should be divided into at least two divisions for intermittent application, and the capacity of the system should be 10 to 15 per cent larger than for a double-chamber tank system.

The single-chamber septic tank system requires considerable attention, since there is no provision for automatic discharge. Figures taken from the work of the Wisconsin Agricultural Experiment Station show that in the long run there is little difference in the cost of the single and double chamber tank system.[1]

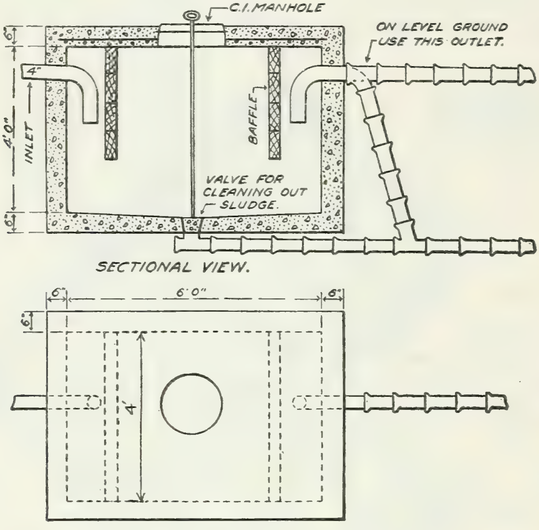

FIG. 36.—Single-chamber septic tank for six people.

THE GREASE TRAP.

The grease trap acts as a separator of the grease and sewage from the kitchen sink or dairy room. If grease is allowed to enter the sewer it accumulates and eventually clogs the system.

Figure 38 shows a grease trap.[1] Two large, glazed sewer tiles are placed in the ground. The inlet is usually a 2-inch iron pipe. The outlet must be so arranged that the mouth of it is at all times below the surface of the sewage. The grease, being lighter, naturally floats upon the water, and is thus prevented from entering the outlet. The outlet is made of 4-inch glazed sewer tile and is connected with the sewer inlet of the septic tank. A concrete cover is provided, and grease and dirt which may accumulate are removed when necessary.

[1] Wisconsin Sta. Circ. Inform. 34.

SUGGESTION ON OPERATION.

Contrary to the usual opinion, small sewage systems require some watching and care. It is well to study the system and watch the action in the entire plant for any signs of clogging or waterlogging. In this way one will soon become acquainted with the conditions of location and soil best suited to his needs and will be able to operate his plant on a satisfactory basis.

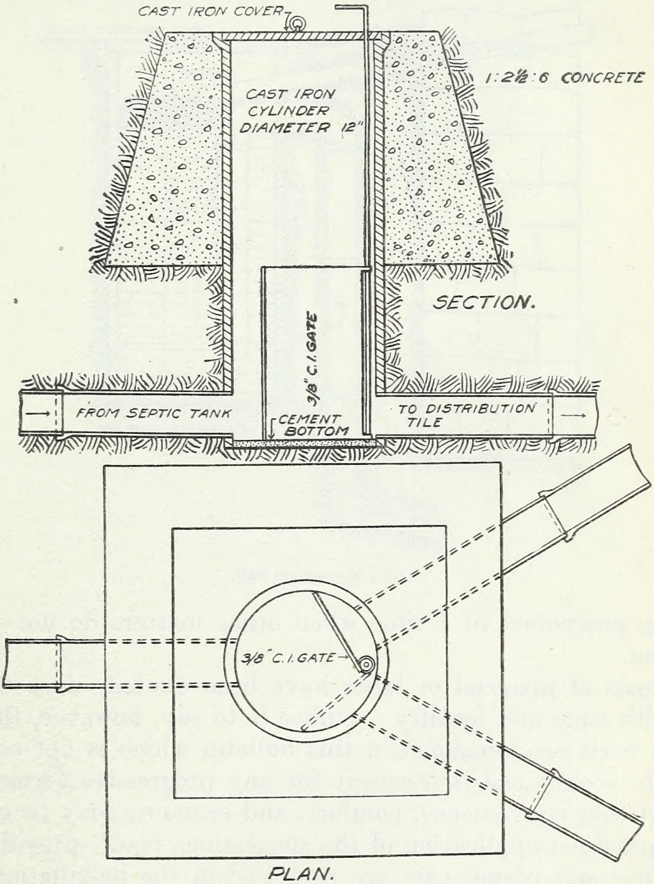

FIG. 37.—Plan and section of sewage diverting gate.

CONCLUSION.

It is hoped that the foregoing discussion has presented information of a nature practical enough at least to indicate the general requirements to be met in planning sanitary systems adapted to the average farm home. Nevertheless, should the farmer feel that, though desirable, such an installation is beyond his own skill, the matter is still of such importance as to make it advisable to employ a reliable pump expert, plumber, or sanitary engineer, local prices of labor and materials and other conditions permitting. Enormous expenditures are being made by progressive cities in the installation of sanitary systems to protect the health of their people, and similar protection is surely due the country resident. It is urged, therefore, that the questions discussed in this bulletin be considered of prime importance in planning or improving the farm home, instead

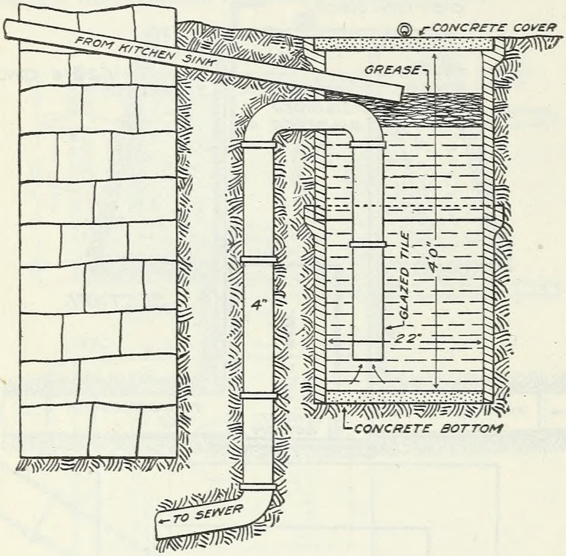

FIG. 38.—Grease trap.

of being postponed to a time when other matters do not press for attention.

No costs of material or labor have been quoted, since these will vary with time and locality. Suffice it to say, however, that nothing has been recommended in this bulletin which is not considered to be an economical investment for any progressive farmer. It is believed that convenience, comfort, and economy may be combined in the practical application of the suggestions made, providing common sense and proper care are exercised in the installation, operation, and maintenance of the conveniences.

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