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Water Supply and Sewage Disposal for Country Homes

by

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INTRODUCTION

This bulletin is compiled and published in the belief that it fulfills one of the primary objects which led to the establishment of the Engineering Experiment Station—namely, "to be of service to the people of the State of Missouri."

The isolated country home will never attain the modern standards of comfort and convenience until it is provided with an adequate supply of water under pressure. But water brought under pressure into a house is of itself merely a means to an end. Piping must be installed, and fixtures placed for use—laundry tubs, kitchen sinks, lavatories, bath tubs and water closets are all necessary accessories to insure the greatest possible benefits from the available water supply. Finally all the organic wastes from the household, washed away from these fixtures, must be collected in a sewer and carried to some point and treated so that neither nuisance nor danger may result.

Our problem then is fourfold:

a. To provide a copious supply of pure water;

b. To install fixtures making possible the most advantageous use of the water;

c. To provide a drainage line or sewer to carry away the water-borne wastes of living;

d. To dispose of these wastes so that there may be no offense or danger to anyone.

Much of the material in this bulletin is a revision of the substance of previous bulletins of the Station now out of print: viz., *Water Supply for Country Homes,* by Karl A. McVey, and *Sanitation and Sewage Disposal for Country Homes,* by William C. Davidson.

WATER SUPPLY

The sanitary surroundings of farmers' homes are showing many improvements which are the natural outgrowth of modern ideas of comfort, refinement, and convenience. The pleasures of country life are so often marred by the absence of comforts which in the city are accepted as a matter of course that there is growing conviction that the farm should be provided with at least some of the "modern conveniences." An abundant supply of pure water is a necessary prerequisite to most of these conveniences. The health of the household is largely dependent upon the quality of the water and its reaction upon the wholesomeness of the milk, butter, cream, and other products used on and sold from the farm.

A proper water supply is not necessarily expensive if its installation be kept within the bounds of utility. The chief source of expense aside from the piping for water is the plumbing fixtures and these may be of a very luxurious type and correspondingly expensive.

The methods of supply herein described have all been successfully used, and the costs as given are close approximations. There may be a wide variation from these costs due to the different character of fixtures that may be used.

SOURCES OF WATER SUPPLY.

Springs. Springs are the natural outlets of underground waters and in some parts of the country may yield pure supplies. As a rule, spring waters are palatable and reasonably free from organic impurities, owing to natural filtration processes going on in the soil; but such filtration will not take place in regions underlaid with limestone or where the subsoil is of a seamy rock. Springs coming from such strata may carry considerabe organic impurities. Springs located at an elevation considerably higher than the house or grounds to be supplied are to be desired, for the water may flow from these by gravity, thus avoiding the need of pumping machinery or power.

A water supply obtained by tapping a spring may have a wide variation in yield at the different seasons of the year. The guaging of a spring should be deferred until after the beginning of dry weather, and no spring should be selected for permanent supply unless it yields even under conditions of drought an excess of water over the maximum supply required.

All springs should be carefully protected against contamination by organic matter. This may be insured by constructing a small storage basin provided with a cover sufficiently tight to exclude small animals and surface impurities of any sort. A sunken barrel, receiving the flow from the spring and connected by a supply pipe leading to the house, serves as a reasonably satisfactory method of storage. The supply pipe should enter the barrel at least six inches above the bottom to permit space for the accumulation of solid matter which may settle out of the water. The outlet pipe should be provided with a screen to prevent the entrance of any foreign matter. A small concrete basin may take the place of the barrel at a very slightly increased cost.

Attention should again be directed to the fact that spring waters are not necessarily pure. The location of the spring with reference to surface drainage should be carefully noted, and if there are indications of contamination from animal sources such possibility should be removed or the spring water rejected.

Wells. In the country wells are used more generally than any other source of water supply. Most of them are shallow and collect water from the upper layers of the soil. Sometimes there is a purification of the water due to its percolation through the soil, but in many cases it is changed in character and made "hard" by reason of its ability to dissolve mineral constituents from the strata through which it flows. Wells may be considered as artificial springs, for they are sunk by digging, driving, or drilling down through the water-bearing stratum. But the water must be lifted to the surface by pumping, except in the case of true artesian, or flowing, wells few of which occur in this State.

It is usual to distinguish between shallow and deep wells, yet there is no sharp distinction between them; the terms "shallow" and "deep" have more reference to the nature of the underground strata which the well pierces. Wells from fifteen to thirty feet deep, intercepting water flowing in a layer of gravel or sand which rests upon an impervious stratum, are usually classed as shallow wells. These wells should always be looked upon with suspicion. It is very easy for them to become polluted in densely settled regions and also on the farm if located near out-buildings, cesspools, stables, or in close proximity to cultivated, manured fields.

These wells, if dug, are lined with brick, stone, or concrete, or they may be "driven" by making use of a pipe with a pointed, perforated shoe which is forced into the ground to the source of the underground supply. These driven pipes are usually either wrought iron or steel tubes one to three inches in diameter, and even these small pipes may furnish a comparatively large yield. The driven is superior to the dug well because there is less danger of pollution by surface inflow.

Deep wells sunk in gravel or sandy soil are driven or bored with tools similar to an auger. When wells are sunk through rocky strata, chisel drills are used, which are alternately raised and allowed to fall at the same time being rotated. The loosened material is removed by means of a sand pump. Deep wells usually draw their supplies from distant points, and these supplies are reached by cutting through successive layers of impervious rock.

In locating a shallow well, it is important to consider the sanitary aspects of surface surroundings. Wells located at a higher level than privy vaults and cesspools are not necessarily safe from pollution from these sources. The direction of flow of the water and the relative position of the water bearing strata are the controlling considerations. When a large quantity of water is pumped from a well, underground conditions of flow may be materially altered. The water in the well is lowered, but the surface of the underground stream for some distance around the well is also modified. The distance from the well that the flow is affected depends upon the amount of pumping, and while nearby cesspools might under ordinary conditions be outside the zone of contamination, the effect of pumping much water from the well may bring them within this zone. The fact of a connection between well and cesspool may be established by special tests; one of the simplest of these tests is to place a large quantity of saprol in the cesspool and note whether a strong naptha odor is perceptible in the well water. Another test is to use fluorescein which will give to the well water a bright yellowish-green color.

The Geological Survey of the United States examined farm water supplies in Minnesota and of seventy-nine examined, twenty were good and fifty-nine were polluted. In an examination of twenty eight dug wells, fifteen had poor surface drainage and for other reasons twenty out of twenty-eight had a poor sanitary aspect. The drilled and cased wells show the most favorable conditions. It is probable that like results would be shown by an examination in the rural districts of Missouri. The remedy in most cases is to provide an impervious covering, divert all surface water, and place a water-tight lining in the upper six or eight feet of the well. This lining should be of brick laid in cement mortar and the outside surface covered with a coating of cement at least three-fourths of an inch thick. The casing may also be made of concrete. The surface of the ground surrounding the well should be given a gradual slope in all directions away from the well curb.

There are certain fungus growths that may occur in pure water and become sufficiently rank to close the pipes. Green algae is a species of fungus which usually appears as a green scum. While not detrimental to health, it gives to the water a peculiar fishy flavor which makes it unpleasant for drinking. A good remedy for this condition is to use a solution of copper sulphate (blue vitriol) in the water affected. This may be done by immersing in the affected spring. pond, or tank a coarse cloth bag containing an amount of copper sulphate sufficient to make a solution of about one part in four millions—or one and one-half grains by weight of copper sulphate to every one hundred gallons of water. This remedy is harmless and effective.

Cisterns. In localities where underground water is hard to obtain or unfit for use, cisterns are frequently used to collect farm water supplies. They may be used for storage of water from any source, but are usually intended to collect rain water. They may be constructed of brick and mortar, concrete, stone masonry, or of galvanized iron, the latter being placed in any convenient locality. It is common practice to place iron tanks above ground, and during the summer season the comparatively high temperature of the water encourages the growth of organisms which are usually present in water collected from roofs. Some of the most common impurities collected from roofs include dust, dead insects, excreta of birds, and spores of plants.

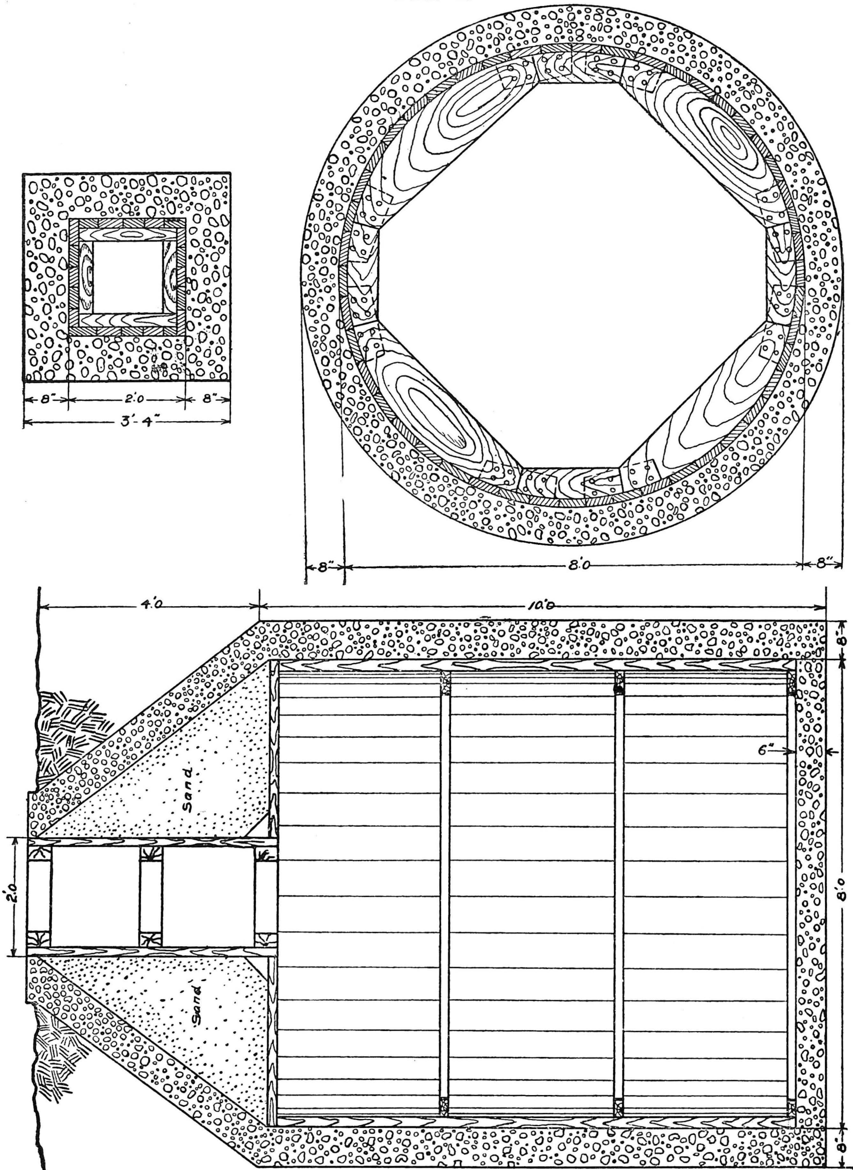
The opportunities for pollution after the water enters the cistern depend upon the construction and protection of the type of cistern used. Leaks offer the most common opportunity for pollution, if the cistern is placed below the surface of the ground so that ground water may find free entrance. Ground water around cisterns is frequently polluted from surface sources, and the cistern should be so constructed that no surface water can filter into it. The quality of the cistern water may be protected by installing a device such as a simple two-way valve at the bottom of the spout to prevent entrance to the cistern of the water falling during the early period of a storm.

While the absence of lime renders rain water desirable for cooking and its softness recommends it for use in the laundry, it is not to be considered as suitable as the pure ground water for domestic supplies.

A safe and durable underground cistern may be made of concrete or brick masonry. The designs for a concrete type together with an estimate of approximate cost follows:

Concrete cistern. Make a circular excavation in the ground with diameter 16 inches greater than the desired inside diameter of the cistern and about 12 to 14 feet deep. Construct a cylindrical form of ⅞ inch dressed pine lumber, the outside diameter of which will be equal to the diameter of the cistern. This form for a cistern 14 feet deep should be about 10 feet long. The form should be made in sections for convenience in handling. Lower these sections into the ex-

FIG. 1.



CONCRETE CISTERN SHOWING ARRANGEMENT OF FORMS.

cavation and unite them to form a nearly perfect cylinder and block it up about six inches above the bottom (see Fig. 1) of the excavation.

Mix a concrete using one part Portland cement, 2½ parts clean sand and 5 parts of gravel or broken stone, forming a so called 1:2½:5 mixture. Make up in small batches, using sufficient water to make it easy to pour. Fill in the space between the form and the earth with concrete, and ram or puddle with an ordinary 2 x 4 in order to compact the mix and keep the large pieces of stone from forming pockets. To construct the conical portion, build a floor across the top of the cylindrical form, leaving in the center a hole about 2 feet square. Brace this floor with uprights from the bottom of the excavation. Around the edges of the square hole and resting on the floor construct a vertical form with outside dimensions 2 feet square and reaching slightly above the surrounding ground. Build a cone-shaped core of earth or wet sand around this form, reaching from the outer edge of the flooring to the top of the form. Place a layer of concrete 4 or 5 inches thick over this cone of sand and flush with the outer edge of the wall. Alter allowing it to set for at least seven days, the inner forms may be removed, together with the sand and all the lumber that had been in use. The bottom of the cistern should be made of the same material as the walls and about 6 inches thick. The pipes from the house roof and the one leading to the kitchen pump should be placed through the forms before the concrete is put in so that they may be rigidly held in position. The following table may be of interest:

TABLE I. CISTERNS—COST OF MATERIAL

Fourteen feet deep (10 feet cylindrical and 4 feet conical) 8 feet in diameter, capacity 3,800 gallons.

	Parts	Quantity	Cost
Cement	1	43 bags	$34.40
Sand	2½	4½ cu. yds.	6.75
Gravel	5	9 cu. yds.	27.00

Lumber for forms 225 board feet.

Thirteen and one-half feet deep (10 feet cylindrical, 3½ feet conical) 6 feet in diameter, capacity 2,100 gallons.

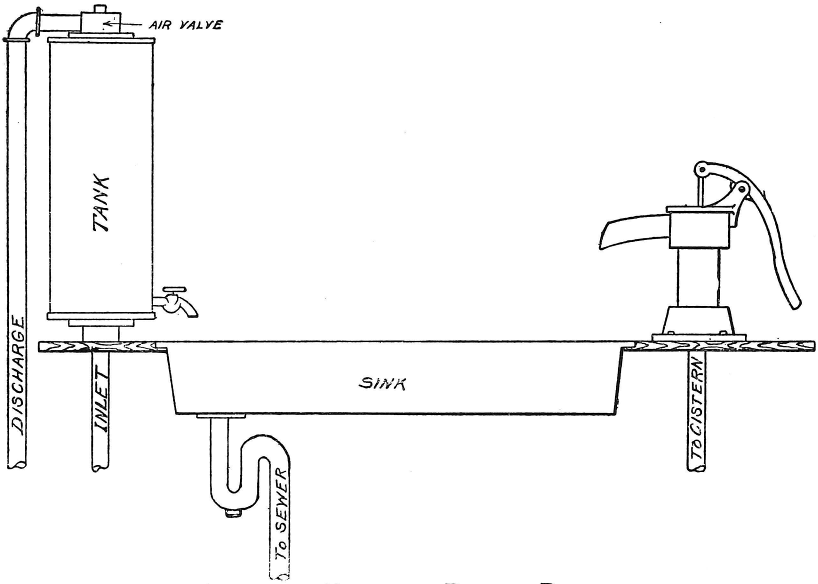
	Parts	Quantity	Cost
Cement	1	31 bags	$24.80
Sand	2½	3 cu. yds.	4.50
Gravel	5	6½ cu. yds.	19.50

Lumber for forms 200 board feet.

The total cost of a cistern may be made to approximate the above cost of materials if sand and gravel and the lumber for forms are easily obtained. Scraps of lumber may be used in the forms, or new lumber may be purchased and later used for other purposes. If sand or gravel is taken from streams, it must be carefully collected and possibly washed before being used in concrete. It may be possible that only the cement will have to be purchased on the market.

In central Missouri a concrete cistern 16 feet deep and 10 feet in diameter was built at a total cost $90, exclusive of lumber. Since

FIG. 2 (see page 12)



AUTOMATIC TANK AND PITCHER PUMP.

the system used may be duplicated on many farms throughout the state, a brief outline is here presented.

Advantage was taken of a hill which was higher than any of the barnyards. On this hill the concrete cistern was constructed, partly above ground and partly below. A 6-foot wind mill erected over a nearby spring operates the pump that fills the cistern. From the cistern, pipes are laid to three concrete watering troughs situated at convenient points in the barnyard, and to these the water flows by gravity. The water level in each trough is controlled by an automatic float valve. As the cistern is large, storage is provided to tide over the days during which there is not enough wind to operate the wind mill.

Use of Kitchen Pump. A small force or pitcher pump placed at one end of the kitchen sink, with the suction pipes reaching to the cistern, is a convenient means of utilizing a soft water supply, if it is not desired to invest in the more expensive methods of using a gravity tank or pneumatic tank, with piping to convey the water to wash basins, bath tubs, and other fixtures. Fig. 2 shows in outline an arrangement of pitcher pump supplemented by what is known as an automatic house tank. This tank is placed near the kitchen sink, and the wind mill pump forces well water through it on the way to stock tanks or barns. An air valve at the top of the tank lets out the trapped air as the tank fills with water. This arrangement allows the fresh and cool water to reach the house for drinking purposes. The capacity of this tank should be from 25 to 30 gallons. An estimate of the cost of an installation similar to that shown in Fig. 2 is as follows:

Cistern pump, 3 inch cylinder	$12.00
Kitchen sink, 18 x 30 inches	9.00
Tank complete, with air and relief valve	16.00
Piping to cistern and well and cost of installation, approximately	25.00
Total	$62.00

The amount of the last item depends upon the relative location of the cistern, well and kitchen, since such location determines the length of pipes needed.

WATER PRESSURE

Interior Tanks. Tanks, to hold a supply of water at sufficient height to insure pressure may be located in the attic of the house or in the upper story of the barn. These tanks may be of wood lined with copper or zinc or of galvanized iron or steel. The wooden tanks may be made in any suitable shape adapted to utilize available space under the house roof, but are usually of rectangular trough shape. The objection to inside tanks is the limit on their size on account of lack of space and also on account of the heavy weight of water. The latter factor is more readily appreciated if expressed in figures. A tank of 200-gallon capacity will weigh about 150 pounds; when full of water the total weight will be at least 1,800 pounds. To safely sustain this weight in an ordinary farmhouse will require the expenditure of considerable money. This objection is without force, however, if the tank be placed in the barn, where necessary supports can be easily erected.

Another objection to placing the tank within the house is on account of the "sweating" which occurs when the tank is filled with cold water, especially if the tank is made of iron. This "sweating" is due to the condensation of the air moisture on the outside of the tank when the difference in temperature between the tank water and the surrounding air is great; this condensation may develop in such quantities as to drip down the sides of the tank and endanger the plastering of the rooms below. This result may be avoided by using a metal-lined wood tank or by providing the iron tank with a covering of some sort—such as mineral wool or asbestos cement.

The Outdoor Tanks. Water can be raised into and stored in outdoor elevated tanks to serve the farm buildings. These tanks may be made of wood or sheet steel supported on a structure of wood, steel, or masonry. Combinations often occur, such as a wooden tank on a steel support or a steel tank on a wooden support. These structures should be proportioned so as not to disfigure the landscape. Since protection must be provided against frost a wood covering may be used well finished and painted, and the finished structure made pleasing to the sight. Tank towers or supports should be proportioned and constructed so as to be amply strong to carry their heaviest load. They must be placed on a firm foundation carried well below the frost line and designed to resist the strong wind pressure to which they are subjected. The height of tower is determined by the pressure desired at point of delivery of the water.

Wooden tanks to hold upward of 50 gallons are usually built cylindrical in form because this shape is the easiest to make watertight. Cypress lumber is frequently used for outside tanks, but white pine is also a satisfactory material. The strength of wooden tanks depends chiefly on the hoops, which may be made of flat bars or round bars of steel. The round hoops are more easily inspected and may be protected from rust by frequent painting. It is essential in erecting a wooden stave tank to support all of its weight on the bottom and none on the staves. This may be accomplished by placing the joists very near together under the bottom planking and cutting them off a few inches inside the tank circumference.

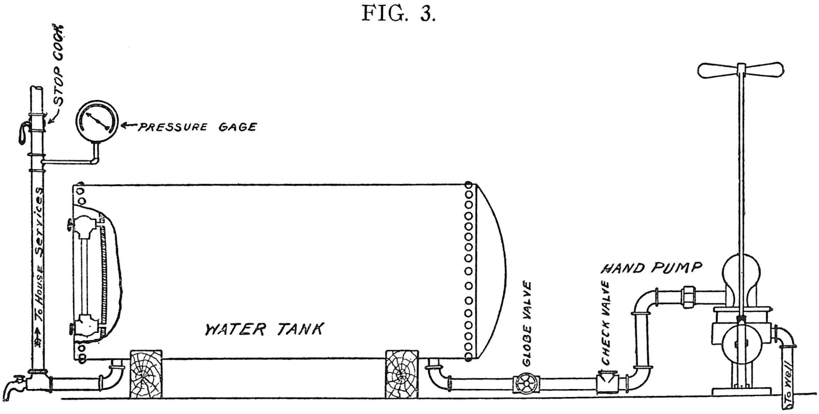
Wooden tanks are preferred to steel tanks, because the latter are more difficult to erect, give trouble by sweating, and must be painted frequently to prevent rusting. It is also more difficult to protect a steel tank from freezing. Of course, where large capacities are necessary, steel tanks are preferable, but for ordinary farm purposes the wooden ones are preferred. In practice it is found that good quality wooden tanks will last from fifteen to twenty years, and the cost is much less than that of steel tanks.

Pneumatic Tanks. The pneumatic water supply system has many advantages over the older methods of interior or outside tanks for gravity pressure. This system is of comparatively recent origin and depends upon compressed air for its operation. Its most important advantage is that the tank may be located either in the cellar underground, or any place where there is no danger of freezing.

The tank is of wrought iron or steel, air tight, and may be filled by power pump driven by wind mill, electric motor, or gasoline or by hand pumping. Either a horizontal or vertical tank may be used, as may suit convenience. Only one condition is necessary for its satisfactory operation, and that is a satisfactory source of water supply within reach of an ordinary force pump.

Water is pumped into the bottom of this air-tight tank, and as it rises the trapped air above it is compressed thus placing the water

FIG. 3.



OUTFIT FOR COUNTRY HOME.

under pressure. The expansion of this compressed air when a faucet is opened on a water line will force the water to points where it may be required. The pressure within the tank is increased by pumping water into it and decreased by drawing the water off. If, after some months of use, the tank becomes completely filled with water, it will be what is called "water-logged," and no stream will be forced through the supply pipes. In such case the tank should be drained until it contains only air, and the water pumped in until a suitable pressure is reached.

If the tank is supplied by wind mill power, an automatic pump should be used which will throw the wheel out of gear on attaining a certain pressure; when water is used, the reduction of pressure will again throw it in gear.

Fig. 3 shows a complete outfit for the average-sized country home. The tank represented is 30 inches in diameter and 8 feet long, with a total capacity of 295 gallons, and will ordinarily deliver about 200 gallons without refilling. As the space occupied by this tank is small, it may be located in the barn. In the sketch is represented a small hydro-pneumatic hand pump, which is quite satisfactory for pressures not exceeding 15 pounds per square inch. A hand air valve is provided on this type of pump, so that by opening it during operation the proper porportion of air and water can be maintained.

An outfit of this sort can be placed in a house ready to connect to service pipes for about $90.

The pneumatic system has many advantages. It avoids the use of an attic tank and allows the apparatus to be located conveniently to the pump; it is thus protected from freezing, which is a serious objection to the elevated tank placed outdoors, and it also eliminates the expense of erecting towers to support such outside tanks. An advantage also of placing the tank in the basement or underground is that the water delivered from it has nearly a constant temperature throughout the year. This system has a wide range of usefulness, since it may be planned to serve not only the house but also the stables, wash room, dairy, lawns and gardens.

If the water consumption is not too great, a single large tank may be used and pumping restricted to periods occuring two or three times per week. Any increase in consumption above the normal will require a corresponding frequency in the periods of pumping.

HOT WATER SUPPLY

A hot water supply may be furnished by an independent heater and boiler placed in the basement of the house, or by connecting the water system through a coil in the furnace, or, as is more usual in country houses where there is neither basement nor furnace, by a boiler and a water back placed in the fire box of the kitchen range.

When the house supply is derived from a tank in the attic, the hot water supply will be under the tank pressure, and an expansion pipe is provided as a safety device. In Fig. 4 is shown the arrangement of pipes for a successful water heating and circulating system.

The cold water should always enter the boiler at some distance below the return point for hot water from the water back in the range. The kitchen boiler is simply a storage tank to provide a supply that may be drawn upon as needed. Certain waters will rust a gal-

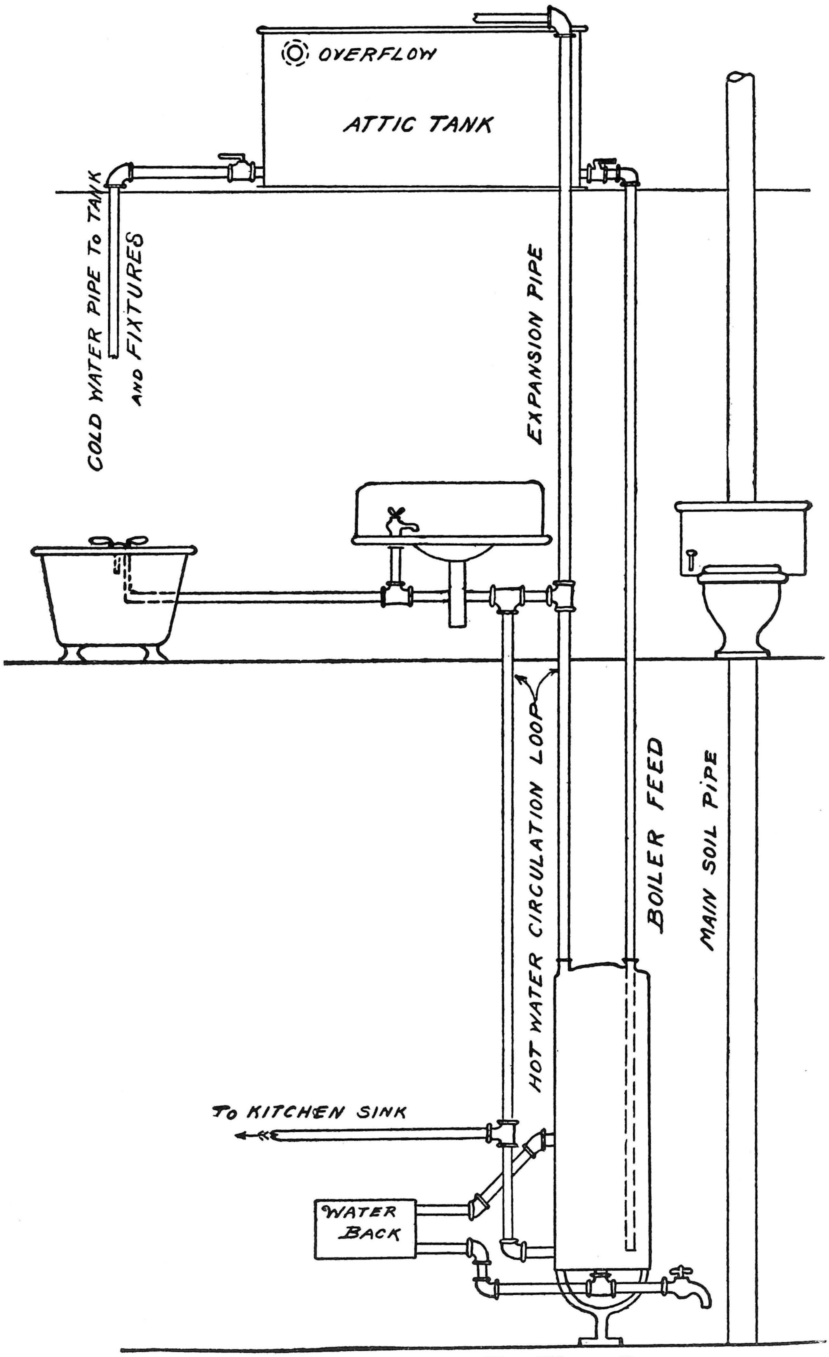


FIG. 4. ARRANGEMENT OF HOT WATER PIPING.

vanized iron boiler in a few years, but a copper boiler will last indefinately, although its original cost is great; in most cases kitchen boilers are made of galvanized iron with a capacity of from 30 to 40 gallons.

The hot water return pipe connecting the water back and boiler should have a continuous rise from range to boiler and should enter the boiler at as high a point as practicable; it should be slightly larger than the supply pipe in order to promote circulation and insure rapid heat of the water in the boiler. An expansion pipe is provided to allow steam and air to escape, thus preventing the noise of pounding in the boiler. Any sediment accumulating in the boiler may be drawn off at the faucet, which should in all cases be provided at the base of the boiler.

When using an attic tank, the available water is limited, and it is desirable that hot water should discharge from the faucets very shortly after the instant of opening without the necessity of emptying long lines of pipe with the consequent waste of water. The use of circulating pipes, properly installed, is therefore a matter of importance. As shown in the figure, the hot water pipe is started from the top of the boiler, where the water is hottest, carried up to the highest fixture, and returned to the base of boiler. Since it is desirable to use the least length of pipe possible, the bathroom should be located above the kitchen if convenient, as this will not only simplify piping but will secure a safer installation.

If the house has a basement, the heating arrangement can be supplemented by a small water heater placed in the basement and used when it is not convenient to have a fire in the kitchen range.

AVAILABLE POWER

The local situation in each case will determine the most economical and convenient means of forcing water into a storage tank. The source of supply, the amount required, the available fuel, and prevailing labor cost must all be taken into account. The hydraulic ram and the wind mill operate without fuel, but the ram can be used only in case there is considerable available head and excess of water, and the wind mill is not to be depended upon to furnish a regular daily yield. Gasoline and kerosene engines require fuel and attention, but the supply may be easily regulated to suit varying demands.

Wind Mills. A simple means of securing power for a supply of water is to make use of a wind mill. Where the machine is properly constructed, it will pump large quantities of water at a very small cost, for the wind is free and the expense for repairs small. To be most efficient and to take advantage of the wind from any direction, the tower should be tall enough to elevate the wheel at least ten feet above the tallest nearby structure. Galvanized steel towers have proved satisfactory and durable and are fast displacing wooden towers.

Combination towers carrying both wheel and tank are being sold under the name of "suburban outfits." Like all outside tanks, these must be protected against frost. Pipes leading to them are protected by enclosing them in two or more wooden cases, with air spaces between. There are also on the market, at an additional cost, combination pumping and power mills that will pump water, grind feed, shell corn, and saw wood, but for the heavier work a strong breeze is required. For pumping water in the central part of Missouri, where the average wind velocity is about nine miles per hour, 8-foot wheels on 35-foot towers are most commonly in present use. A mill of this sort erected would cost from $120 to $130.

A pump used in connection with a wind mill should be of smaller size than if intended to be operated by hand, for in hand pumping a pump is needed which will elevate the maximum amount of water in the shortest time. A wind mill, however, must frequently operate under a light breeze, and therefore the pump capacity must be limited. Generally the wind mill need not run more than three or four hours a day to supply the tank with the necessary amount of water. During certain seasons of the year in this State, there are many days in which the wind is very light, particularly during July and August. At these times the wind mill should be under as light a load as possible, in order that it may be certain to perform at least some work. Therefore a small pump, even though of but half the capacity that could be operated by hand, will prove most satisfactory. This small pump will allow the wind mill to work a longer time during the prevalence of light breezes, and it will be found that more water will be pumped during the 24-hour period than would have been the case had a larger pump been used.

The depth of the well should be known and whether it is driven, drilled, or dug; if drilled, the inside diameter of the casing should be known and the height to which the water must be raised and the distance through which it is to be moved. The distance is measured from the water level in the well to the base of the elevated tank. The amount of water entering the well during dry seasons should be estimated, also the capacity of the tank and the height of tower necessary to raise the wind mill free from obstructions. All this information should be given to the manufacturer when purchase is contemplated, as it is necessary to enable an intelligent estimate to be made of the cost.

Gasoline Engines. Small gasoline and kerosene engines are now manufactured to operate pumps and the other machinery about the farm. These engines have a distinct advantage over other types of prime movers in their ability to pump water in the amount and at the time needed, so that the size of the storage tank can be very closely estimated. An engine can be selected to burn natural gas, gasoline, kerosene, or alcohol. These engines are simple and do not require much skill to operate them. They require little fuel and may be used for driving any light machinery when not needed for pumping. Since they have a wide range of usefulness, it is well to select one of the portable types, particularly if gasoline or kerosene is to be used for fuel. They are mounted on skids or trucks and may be used to drive churns, feed mills, corn shellers, grain fans, or other machinery. It is best to choose an engine of four to six horsepower, except when only pumping is required; for this purpose a two or three horsepower engine is large enough. With a further improvement in the manufacture of denatured alcohol, there is a possibility of having a more economical fuel. A good two or three horsepower engine can now be purchased at a cost of $90 to $110.

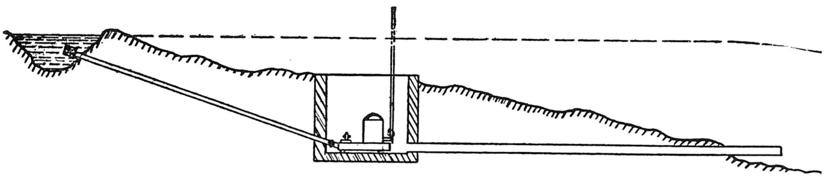
With a good type of stationary gasoline engine operating under favorable conditions, a fuel consumption as low as one pint of gasoline per horsepower hour may be reasonably expected. Any gasoline engine of the ordinary type may be run with alcohol as a fuel without material change in the construction of the engine. Some difficulty may be encountered in starting and in supplying the correct amount of alcohol fuel, which is about 40 per cent more than the amount of gasoline for the same power. The fuel consumption which governs the cost of operation depends chiefly upon the load which the engine is carrying and upon the adjustment of the valve controlling the fuel supply. It is easily possible to double the fuel consumption by either running the engine on a load below its full capacity or by ill adjustment of the fuel supply valve.

Hydraulic Rams. Where water has to be lifted and conditions will permit, the installation of a hydraulic ram may be advisable. It may be used to fill a storage tank if the supply is much in excess of needs and the source is at sufficient height above the tank to supply the necessary power to lift the quantity needed. In a proposed installation, the quantity of supply and the available fall should be determined. A ram may be used with a flow of as low as two gallons per minute and a fall of eighteen inches. These are the lower limits of operation and any increase in quantity and fall will improve conditions by increasing the amount pumped as well as the distance and height through which it can be elevated. The relation between the height of supply above the ram and the elevation to which the water is to be delivered determines the proportion of water raised to that which runs to waste.

Water falling from a higher to a lower level can furnish energy directly proportional to the distance it falls and the weight of the quantity falling. In the hydraulic ram, part of this energy is used to elevate some of the water to a height greater than the original source, thus utilizing for power that which otherwise would run to waste. The energy which operates the ram is created by the sudden arrest of the velocity of the moving water supplied to it under somewhat the same conditions that exist in the operation of a small water wheel.

The ram is a combined water motor and pump. It works in pulsations by a sort of water hammer caused by the abrupt stopping of the flow in the drive pipe. The energy acquired by the moving water is partly used in forcing a portion of the flow through the delivery pipe up into the tank or reservoir.

FIG. 5.



LOCATION OF HYDRAULIC RAM.

The best location for a ram is at a hillside spring, where the natural fall of the land furnishes a working head, or near a natural fall in a stream, where the supply may be taken from the stream above the falls and conducted to the ram; the excess is then allowed to run back into the stream below the falls. If a spring is the source of the water, the fall may be increased by walling it in with brick or concrete, provided this method does not materially decrease the flow. Fig. 5 shows how the natural fall is increased by placing the ram in a pit and conducting the waste water away through an ordinary drain tile.

For the average farm house using 150 gallons per day, a ram which will operate on 4 gallons per minute will furnish sufficient supply. It may be safely assumed that if water is conveyed from 50 to 60 rods, at least 1/10 of the amount supplied can be raised and discharged at a height equal to 10 times the fall. A rule given by one of the ram manufacturers is as follows: "To find the quantity of water which a ram will deliver, multiply the fall in feet from the spring to the ram by the number of gallons per minute supplied to it. Divide this product by twice the height to which the water is to be forced, and the result will be the quantity of water in gallons per minute delivered by the ram at point of discharge." The following table gives sizes of rams and the approximate cost of the same:

SIZES AND COST OF HYDRAULIC RAMS

Gallons per minute to operate	Diameter of supply pipes in inches	Diameter of discharge pipes in in.	Prices
1½ to 4	1	½	$12
6 to 14	2	1	27
10 to 25	2½	1¼	35
20 to 60	4	2	65
30 to 120	6	2½	110

INSTALLING PLUMBING IN HOUSES

Plumbing can be put into a house most conveniently at the time the house is being built; but if this has not been done, it is not particularly difficult to install it afterward. While the installation may conflict with household routine for a few days, little inconvenience is experienced in putting the fixtures and pipes in place, since most pipes should for sanitary reasons be exposed. A water back can be easily placed in almost any kitchen range and attachment made to a hot water boiler.

As illustrating the cost of introducing such conveniences, two actual cases are cited. In an 8-room, 2-story house having a lavatory, bath tub, and water closet in the bathroom, a lavatory in one bedroom, a 30-gallon boiler and a sink in the kitchen and one cold water faucet in the laundry, all fixtures were installed, with complete supply and waste pipe connections, for $225.

In a 6-room cottage using an attic tank, water is supplied to bathroom fixtures consisting of lavatory, bath tub, and water closet and kitchen sink, with hot water heating tank all provided, at a total cost of $145.

Electric Pumping. Many suburban residences on the outskirts of towns and villages may easily be reached by the extension of electric light wires. If wires are so extended to light the house, electric power may be used to pump water. The installation of an electric motor for this purpose should be provided with an automatic arrangement to control the water supply. If an elevated tank be used, the raising or lowering of the water in the tank to predetermined points will stop or start the motor. The same results may be attained in the use of the pneumatic system by fixing the range of pressure.

These pumps with attached motors are attractive in appearance and take up but little space, so that they may be easily placed in the basement. The size of a motor depends upon the capacity of the pump, and the type of motor depends upon the character of current used.

A one-half horsepower motor direct connected to a 2x4 inch cylinder pump has a capacity for ordinary house lifts of nearly 300 gallons per hour.

The first cost of an installation of this sort is comparatively large, but the power cost and maintenance charges are likely to be much smaller than for any other type of power mechanism.

CONCLUSION

Many modifications of the systems described are possible which will allow the use of both hard and soft water but which will result in a more or less complicated piping system. As an example of one type, hard water may be raised from a deep well by wind mill power and forced into a pneumatic tank, from which it is drawn for use in laundry and kitchen and for watering stock and other purposes. A supplementary soft water tank may be placed in the barn. Water from the pneumatic tank is then used to operate a water lift, which pumps from a cistern into the soft water tank. This water lift is so constructed that, when the pressure in the soft water tank equals the pressure in the hard water tank, the lift will stop working and will not again start until the pressure has been reduced by drawing off water. Any system of this kind can be worked out by a competent plumber.

The requirements of no two families or homes are alike, but the foregoing suggestions may be modified in any way to meet special conditions, and it is hoped that they may help in the solution of the problem of water supply for country homes. The importance of purity of supply cannot be too strongly emphasized. The labor saved by installing a water supply for the house as well as for the barn and garden will very soon pay for the installation, while the value of such supply from the standpoint of healthfulness cannot be estimated in money.

SEWAGE DISPOSAL

It is not sufficient from the standpoint of comfort, convenience, or decency to install a water supply in a home and carry the wastes away through a sewer pipe and give the matter no further consideration. The water-borne wastes from a dwelling house equipped with plumbing fixtures are to a great extent organic matters easily putrescible and highly offensive in any stage of decay. Sewage includes all wastes that are carried away in the sewer pipes and includes kitchen slops, laundry wastes, and lavatory, bathtub and water closet discharges.

Sewage may be "disposed of" by allowing it to flow out upon the soil, by discharging it into a flowing stream, or by depositing it in a cesspool. By the first method, unless the soil is very porous, there is danger of "water logging," with consequent decay of organic matter, forming a highly offensive situation. By discharging into a flowing stream or body of water, there is danger of offense and also danger of spreading disease if the water is used by any one as a source of supply. By making use of a cesspool, there is likely to be a production of offensive gases, which may find their way back through the sewer and plumbing fixtures into the house. Also the liquid part of the sewage will leak away into the soil, carrying with it organic matter and inducing a highly undesirable state of soil pollution.

None of the foregoing methods of disposal are satisfactory from the standpoint either of safety or of freedom from offense. More specific "treatment" of the sewage is necessary, and the following pages are the result of an attempt to outline a simple statement of the character, purpose, and results of treatment of water-borne household wastes by means of a preliminary use of the septic tank and a secondary treatment by some form of oxidation or nitrification.

In what follows, the term "treatment" will be used instead of "disposal" in order to indicate either a reduction in the amount of organic matter in the sewage or its transformation to an inorganic form. In any problem of sewage treatment there are two distinct phases presented for solution, and the fundamental purposes should not be confused. One problem has to do with treating the sewage so as to prevent it from creating a nuisance by the deposit and subsequent putrefaction of organic matter, while the other requires a treatment that not only will completely mineralize the dead organic matter but will also either destroy or remove living germs and thus prevent the transmission of disease.

For conditions in the country the problem is to a great extent of the first type, and one of the most common and satisfactory methods of preliminary treatment is by the use of the septic tank; but it must be understood at the outset that this process is for the purpose of mechanically removing organic matter rather than transforming it.

Definition. A septic tank may be defined as a reservoir or basin receiving sewage and so proportioned in its capacity as to retard the sewage flow and allow a large percentage of the solid organic matter to settle to the bottom and be retained in the tank. Bacterial action is promptly begun in this organic matter, resulting in a partial liquefaction and gasification of the solids. The extent to which this liquefaction is carried will depend somewhat upon the character of the sewage and may range from 20 to as high as 60 per cent. If no liquefaction takes place, the tank simply acts as a settling basin from which all the settled organic matter must be removed by hand. If the tank is operating satisfactorily, the settled organic matter, or sludge, becomes somewhat digested, or stabilized, and the amount to be handled is made correspondingly less than that to be handled from a settling basin.

The septic tank therefore accomplishes two distinct purposes: it removes solid matter from the sewage, the same as an ordinary sedimentation basin, and through bacterial action it transforms a portion of these solids into liquids and gases, the amount of such transformation varying widely as noted above.

Character and Final Disposition of Septic Tank Effluent. Where the effluent or the flow from the septic tank is to be discharged into a large body of water none of which is used for drinking purposes, the presence or absence of disease germs in the sewage may be of no particular importance. Where it is impossible to dispose of the effluent in this manner on account of the use of the water for domestic purposes, the flow from the tank may be spread over areas of land or carried in open drain tiling under the surface of the earth, where percolation through the soil may render it both inoffensive and harmless.

When small quantities of sewage are dealt with in septic tanks, the effluent may easily be disposed of by some method of land treatment. Larger quantities may be discharged into flowing streams, if these are of sufficient volume to oxidize the remaining organic matter in the sewage. The required ratio of dilution is variously estimated at from twenty to forty times the quantity of the tank effluent.

If fresh sewage is applied to the surface of land or discharged into open drains under the surface, the soil is likely to become clogged by the solid matter unless extensive areas are provided.

Likewise, if discharge takes place in a flowing stream, a nuisance may be produced by the accumulation of these solids in shoals or banks and their later putrefaction. Therefore the first purpose to be fulfilled by a septic tank is to remove solid matter from the sewage and thus simplify the final disposition whether on land, in the soil, or by dilution in a stream.

The second purpose of the septic tank is that from which the process takes its name. This process will be described in detail later; it results in the transformation of a portion of the retained solid matter into liquids and gases.

Sedimentation. Returning to a consideration of the first action taking place in the septic tank, it is found that it is essentially a process of sedimentation. This sedimentation, should secure the removal of about 50 per cent of the total suspended matter or about 70 per cent of the total solids. The actual time allowed for this sedimentation will be more fully discussed later, since the size of tanks necessary for any particular installation is dependent upon the time allowed.

After the precipitation of the solids has taken place, the effluent discharging from the tank may be disposed of upon a much smaller area of land than would be needed if the solid matter were allowed to remain in the liquid; also, the discharge of such treated effluent into a flowing stream will be much less likely to produce nuisance by the stranding of solid matter along the shores and in shallows. Entirely apart from the unsightliness of such stranded matter, there is danger of forming sludge banks of organic material which will decay and produce offensive odors.

It should be clear from the foregoing statements that a certain degree of purification may be attained by the use of this tank from the simple process of sedimentation, and even if nothing further is accomplished in the process, the effluent will be much improved either for land treatment or for discharge into lakes or flowing streams. It may be pointed out that other means may be used to secure the removal of a portion of the organic solids from sewage. Screens may be interposed to accomplish this purpose, or sedimentation basins may be used with no reliance placed on septic action. The objection to these methods lies in the fact that the total solids abstracted from the sewage flow must be removed from the screens or basin and disposed of by a special process, no reduction taking place in the amount of solids to be handled as in the case of septic action to be discussed in the next paragraph.

Septic Action, or Septicization. A further problem demands consideration at this point. What shall be the final disposition of the solid matter accumulated in the tank? The action which gives this septic process its name here comes into play and offers a partial solution. By a peculiar bacterial action, much of the solid matter retained in the tank becomes transformed into liquid and gaseous forms, so that the total quantity of solids necessary to be removed from the tank is materially reduced. If the process is proceeding properly, the portion of the solids not liquefied is converted into a humus-like, non-odorous and fairly stable organic substance which may be disposed of cheaply and satisfactorily by spreading over and plowing into ordinary soil.

If a tank is working properly, this conversion of the solids into liquids and gases will take place quietly and without bubbling. If it is not working properly, the disturbance produced by the evolution of large quantities of gas may stir up a sediment before it has become stable and allow it to pass away in the effluent. This result is seriously objectionable, but it should not occur if the tank has been properly proportioned and if the sewage flow remains reasonably uniform both as to quantity and quality. A newer form of tank, known as the Imhoff or Essen tank, is provided with a trap to bypass the gases and prevent them from interfering with either sedimentation or septic action. In some cases the tank may be constructed too large for the amount of sewage to be treated, in which case there is brought about an action known as "over-septicization," or offensive putrefaction, and this results in objectionable odors. This putrefaction is especially serious in case the sewage is to be further treated by some form of filter to secure a more perfect purification, but in all cases it should be carefully guarded against by a proper proportioning of size of tank to flow of sewage.

Removal of Bacteria. The removal of bacteria from sewage by the action of a septic tank and particularly the removal of such germs as produce disease is a matter upon which information is not definite. The septic tank will show, when working at its best, a removal of total bacterial content to an amount roughly corresponding to the percentage reduction of total suspended matter. There are, however, frequent exceptions to this rule on account of the fact that special bacterial growths take place within the tank. The very process of septicization involves a decomposition induced and sustained by bacterial action. This necessitates the cultivation of extensive growths within the tank, and it is impossible to determine whether or not such growths will be retained in the sludge or pass away in the effluent.

So far as disease germs are concerned, it is not believed that they are at all likely to multiply under the conditions which exist in the ordinary septic tank. Indeed it is known that many of them cannot live in such environment but quickly die out. Others, however, are more resistant and are known to pass through the tank into the effluent, although it is probable there is no marked multiplication in numbers in the body of the tank. It must be positively stated, nevertheless, that the septic tank can in no sense be considered as a final process of purification for a suspected sewage or a sewage known to contain the germs of disease. If bacteria are removed at all, such removal is purely an incidental and not a contemplated result.

Size of Tanks. The septic tank is an apparatus which will not admit of standardization. It must be designed and adapted to each special case. Many tests have been made to determine the efficiency of septic tanks operating with periods of sedimentation varying from eight to twenty-four hours. The investigations at Columbus, Ohio, appear to indicate that there is not much difference in the character of the effluent from tanks which have a range in the sedimentation period as great as that noted above. It follows, therefore, that from the standpoint of cost the shorter period of sedimentation will be more economical. For the estimates which are later included in this bulletin a ten-hour period for sedimentation is taken as a basis. In many cases the amount of sewage to be treated is intended to serve additional population. Where this increase may be foreseen it is wise to install tanks with compartments or so-called multiple units so that the period of sedimentation may be controlled within practicable limits.

Design of Tanks. Three points are to be considered in designing the capacity and form of a septic tank: (1) The quantity of sewage to be dealt with; (2) the time allowed for sedimentation; (3) the space necessary to accommodate the accumulation of sludge.

The quantity of sewage to be treated must be determined in most cases by a consideration of the population to be served, and as close an estimate as may be made of the amount of water used by each person each day. No roof water or flow from the streets should be allowed to pass into a septic tank. Members of the ordinary American family are free users of water, and our domestic sewage is at best sufficiently dilute without allowing it to be made even more so by the introduction of clean water. Only the flow from the ordinary house fixtures should be considered in this connection, and this will enable a reasonably close estimate to be made of the quantity of flow that may be expected. Very extensive statistics are available regarding the quantity of water used per capita per day in various American cities, and the range is found to be from 30 to 250 gallons. It is probable that in the smaller towns the per capita consumption is less than in the larger cities, where the plumbing installations in homes may be more elaborate. In small towns, where the water supply is freely used and the people not inclined to wastefulness, and where most families celebrate wash day at home, a fair allowance for water used for domestic purposes is from twenty to forty gallons per person per day. Fortunately, as noted above, the septic tank will work satisfactorily under conditions of rather a wide variation in flow, so that it is not necessary to estimate the amount of sewage with any great degree of accuracy. Probably forty gallons per person per day would be an extreme allowance in any case not of sufficient importance to justify a careful investigation for a more accurate determination of quantity of sewage.

The time to be allowed for sedimentation, as indicated in a previous section, may range from eight to twenty-four hours. If it is believed that the quantity of sewage has been generously estimated, it will be well to approximate the lower limit of time allowed for sedimentation. There will thus be a tendency to balance conditions, since once the size of the tank is fixed, if the quantity actually dealt with is less than the amount estimated, the time of sedimentation will automatically be increased.

In the matter of space allowed for the accumulation of sludge, the records of numerous plants working satisfactorily indicate that we may expect anywhere from 1 to 2½ cubic yards of liquid sludge from each million gallons of sewage treated. It is suggested that in making an estimate of capacity, provision be made for cleaning the tank once a year. It has happened in many cases that tanks have operated satisfactorily for two and even four years without cleaning. But, on the whole, it is best that the tanks receive some attention at not infrequent intervals, and this attention may be secured by a definite arrangement that will require it to be cleaned annually.

The depth of flow in a septic tank should not be less than four feet and should not exceed eight feet except in the largest installations.

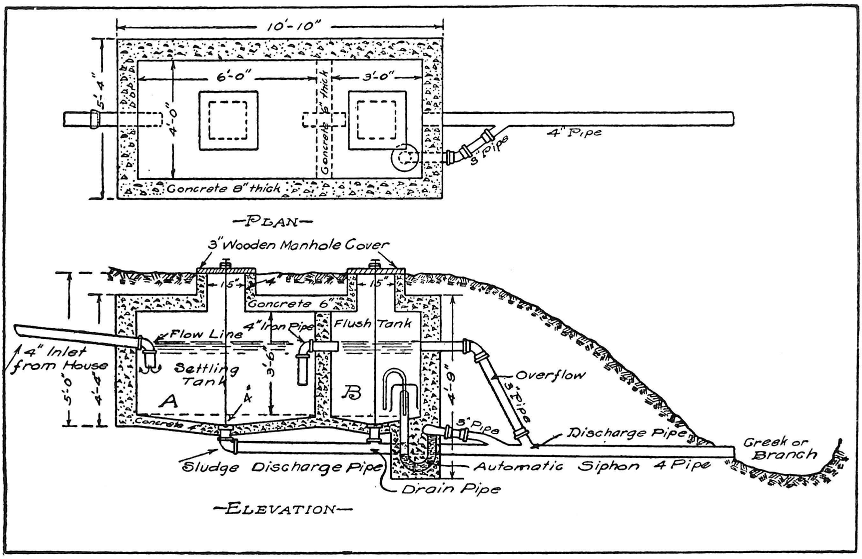
The surface area should vary from one-fourth to one square foot for each person served.

The relation of width to length varies from about one-fourth in large tanks to three-fourths in very small ones.

Capacity of Septic Tanks. The capacity of a septic tank should be designed to equal approximately three-fourths of the daily volume of sewage. If the tank is much smaller than this, it is likely to act as a sedimentation basin, and no digestion or liquefaction of the sludge will take place. If, on the other hand, the tank is too large, offensive putrefaction is likely to begin. With a water consumption of about 75 gallons each day for each person and assuming a family of eight, the capacity of tank should be about 450 gallons, or 60 cubic feet. Fig. 6 shows a sketch of a concrete tank which is designed to provide for the treatment of sewage to this amount.

The tank operates as follows: Sewage enters the tank (A) thru a 4-inch inlet pipe from the house and overflows into the tank (B) thru a 4-inch iron pipe as shown. After a short time of operation, a heavy scum will form over the surface of the liquid, and beneath this covering the solid matter which settles to the bottom is partly liquefied by the action of the bacteria, which develop and thrive in the ab-

FIG. 6.



SMALL CONCRETE SEPTIC TANK.

sence of light and air. For the successful growth of these bacteria, the scum should not be broken or disturbed, and for this reason the inlet pipe is designed to discharge as shown below the surface of the liquid. For like reason the overflow pipe from the tank is extended below the surface to a point where the scum will not be disturbed.

By means of the sludge discharge pipe, provision is made for cleaning out the sediment from the settling tank without interrupting its service, and furthermore provision is made for the discharge of the contents of the tank during such time as it may be found necessary to repair the siphon in the flush tank.

After passing through the flush tank (B) the sewage may be discharged directly into a creek or running stream if the flow is sufficient to dilute it at least forty times.

When the effluent is discharged directly into a running stream, the flush tank (B) may be omitted, but if the waste is treated by subsurface irrigation, then this tank should be used in order to have the sewage delivered intermittently. If the flow is continuous upon the ground, sufficient time will not be given to allow the air to enter the soil with the sewage, and it soon becomes water-logged and offensive.

A 6-inch partition should separate the settling tank (A) from the flush tank (B). The settled sewage flows into the tank (B), from which it is removed by means of an automatic siphon so designed as to discharge when the sewage reaches a certain height. This siphon should be so arranged that it will discharge the liquid at least twice every twenty-four hours.

To provide for the entrance of air into the flush tank necessary for the successful operation of the siphon and also to provide for an overflow of the sewage in case the siphon becomes clogged, an overflow pipe is connected to the main discharge pipe. (Fig. 6.)

A valve is placed in the bottom of the flush tank to provide for the removal of sediment which may collect there. A tank of the type indicated will cost complete about $100. The following tabulation is given that may be helpful in considering the installation of septic tanks of large capacity. The table is based upon an estimated maximum flow of sewage of fifty gallons for each person each day, a maximum period of twelve hours for sedimentation, and allowing space for the accumulation of sludge amounting to not more than two cubic yards (85 per cent water) for each million gallons of sewage.

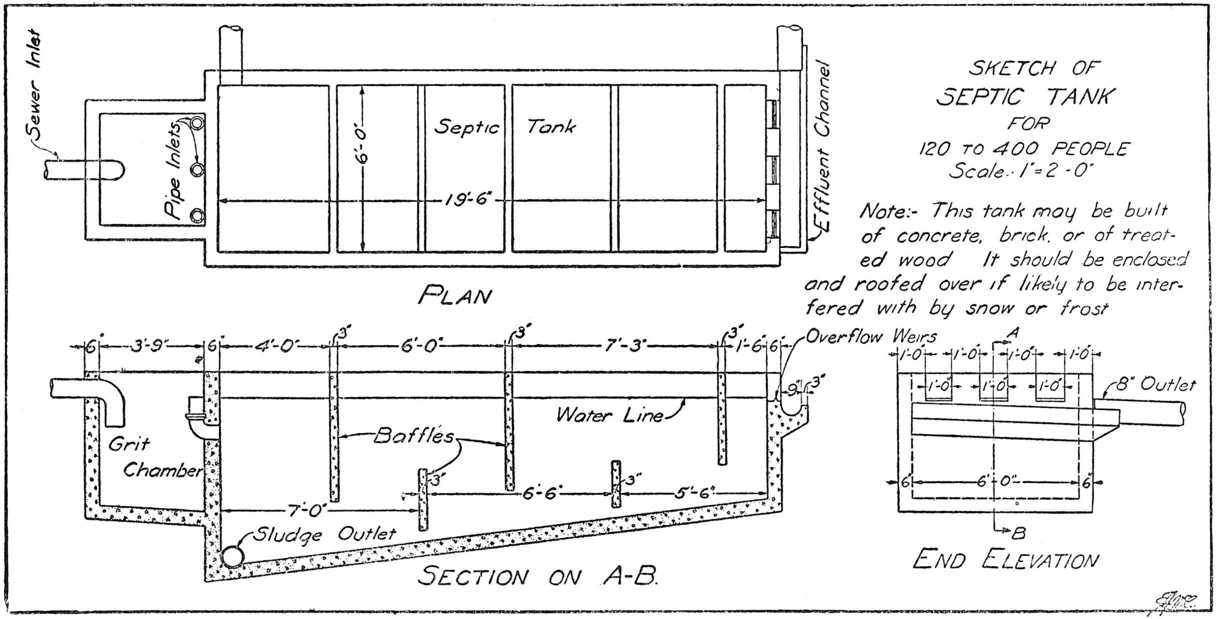
SIZES OF SEPTIC TANKS

Persons Served	Capacity Cu. Ft.	Width Feet	Length Feet	Depth of Sewage Ft.
From 8 to 16	48	3	4	4
From 10 to 40	70	3½	5	4
From 20 to 60	128	4	8	4
From 35 to 80	180	4	10	4½
From 50 to 100	240	4	12	5
From 70 to 150	315	4½	14	5
From 90 to 250	450	5	18	5
From 120 to 400	600	6	20	5
From 200 to 700	840	7	24	5

The total depth of the tank should exceed the depth of liquid by from twelve to eighteen inches.

Fig. 7 is inserted to give an idea of the method of construction of septic tank of larger capacity than the one described.

FIG. 7.

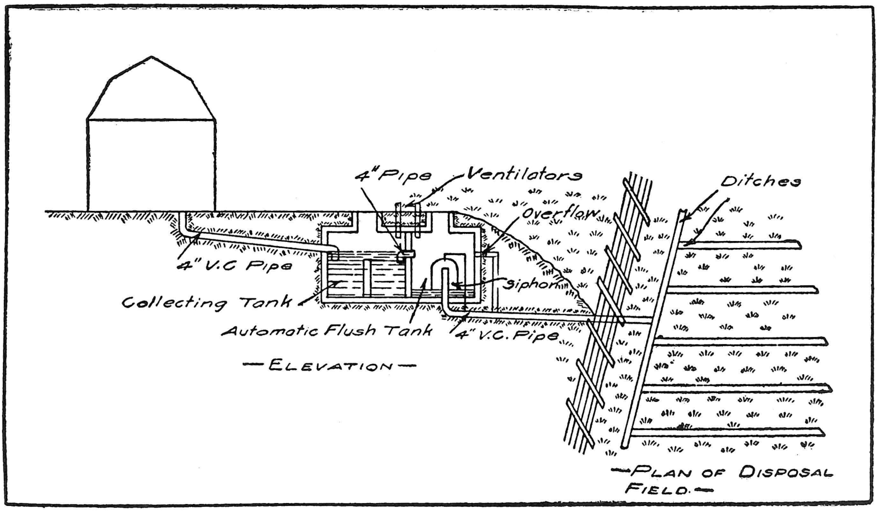


SKETCH OF SEPTIC TANK.

Disposal of Effluent from a Septic Tank. The effluent from the septic tank may be disposed of by discharging it into a flowing stream. If this stream is not to be used as a source of water supply, a volume of from twenty to forty times that of the flow from the septic tank will be sufficient to oxidize the organic matter contained in the effluent and thus prevent a possible nuisance. If the stream is to be used as a source of water supply, the effluent from the septic tank should not be allowed to flow into it without some further treatment, such as sterilization by the use of chlorid of lime.

In case a stream or a large body of water is not convenient, the effluent may be disposed of by distributing it over the surface of

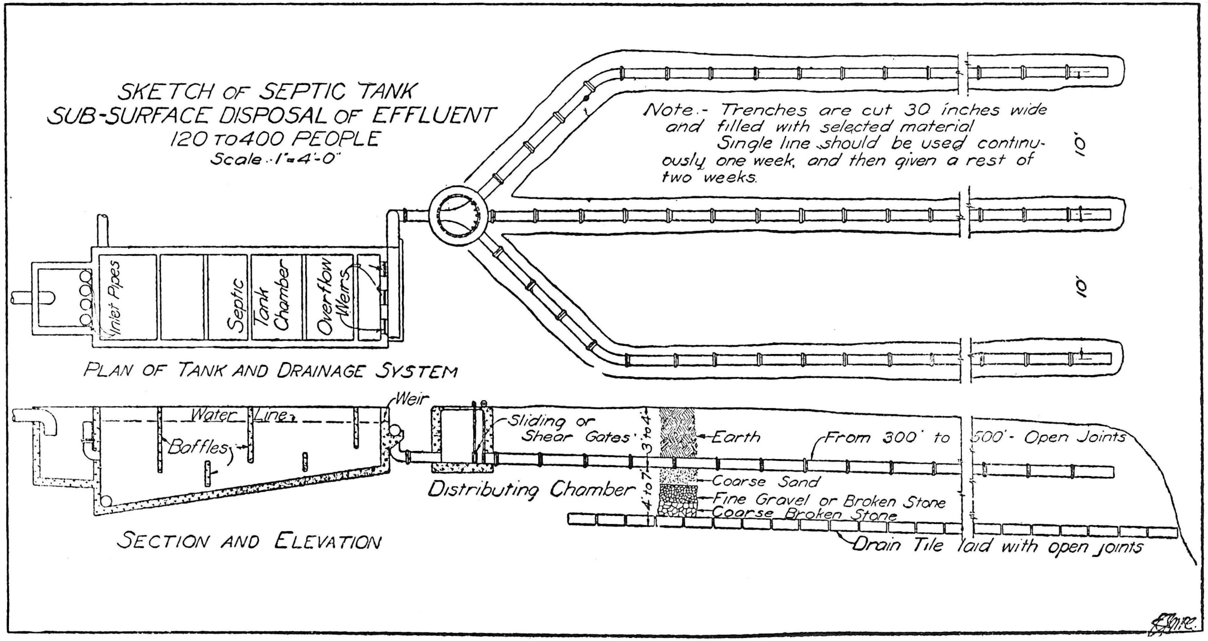
FIG. 8.



SURFACE DISPOSAL PLANT.

suitable land areas. This method will require rather extensive areas, depending upon the character of the soil. Light, porous soils can absorb and purify much more frequent and copious discharges than can be taken care of by heavy clay soils. In any case the discharges should be intermittent and not continuous, otherwise the soil becomes clogged with organic matter and all purifying action ceases. Experience with clarified sewage irrigation indicates that at least three acres will be required for the disposal of the sewage of a thousand people. Fig. 8 shows a rough sketch of a surface disposal plant. The disposal plot of ground may be a small patch of culti-

FIG. 9 (see page 34).



SUB-SURFACE DISPOSAL.

vated land with a growing crop, or it may be meadow or pasture land. A plot of ground 50 by 60 feet in dimensions will be needed to take care of the sewage from a family of eight provided the soil is open and kept well stirred up. A plot should be at least two hundred feet from the house or from any well or other source of water supply. The sewage is distributed over the field by ditches about a foot wide and four inches deep as shown in the sketch. They should be from four to six feet apart, and their arrangement should depend somewhat upon the character and location of the land.

Subsurface Disposal. Another method of taking care of the effluent from a septic tank which is quite suitable for small installations is to convey the liquid in pipes with open joints placed a short distance below the surface of the soil. The open joints will allow the effluent to percolate out into the open layers of the soil, and if provision is made for proper drainage the land will take care of a comparatively large amount of flow without danger of clogging. If, however, the soil is compact and not easily drained, an arrangement such as indicated in Fig. 9 should be provided; that is, deep trenches should be dug, with open drain tile laid at the bottom and connected with some proper outlet. The trench should then be filled, beginning with coarse, broken stone over the drain tile, followed by a finer, broken stone or gravel, and then coarse sand, on which should be laid the tiling to receive the sewage flow from the septic tank. This tiling should be laid with open joints, as shown in the figure. The effluent will then filter down through the coarse sand and fine and coarse stone into the drain tile, with a satisfactory degree of purification.

The open joints in the tile should be from one-fourth to one-half inch and covered with some material like paper or muslin to prevent the loose earth from falling into the pipe during the back filling of the ditch. The length of drain will depend upon the amount of sewage and character of the soil, but in loose soils from 200 to 250 feet will be necessary, while in the compact clays from 400 to 500 feet will be required to take care of the sewage from a family of eight.

Fig. 9 (see page 33) shows the method of subsurface irrigation applied to disposal coming from a single outlet, such as a septic tank. A distributing chamber is interposed, and the gates are arranged to be operated by hand, so that the flow may be diverted successively to different lines of open tile. If desired, the hand-operated gates may be replaced by a set of siphons which will rotate the flow to the different lines automatically.

Plumbing. Fig. 10 is intended to give a diagrammatic representation of the plumbing in a modern house where provision is made for

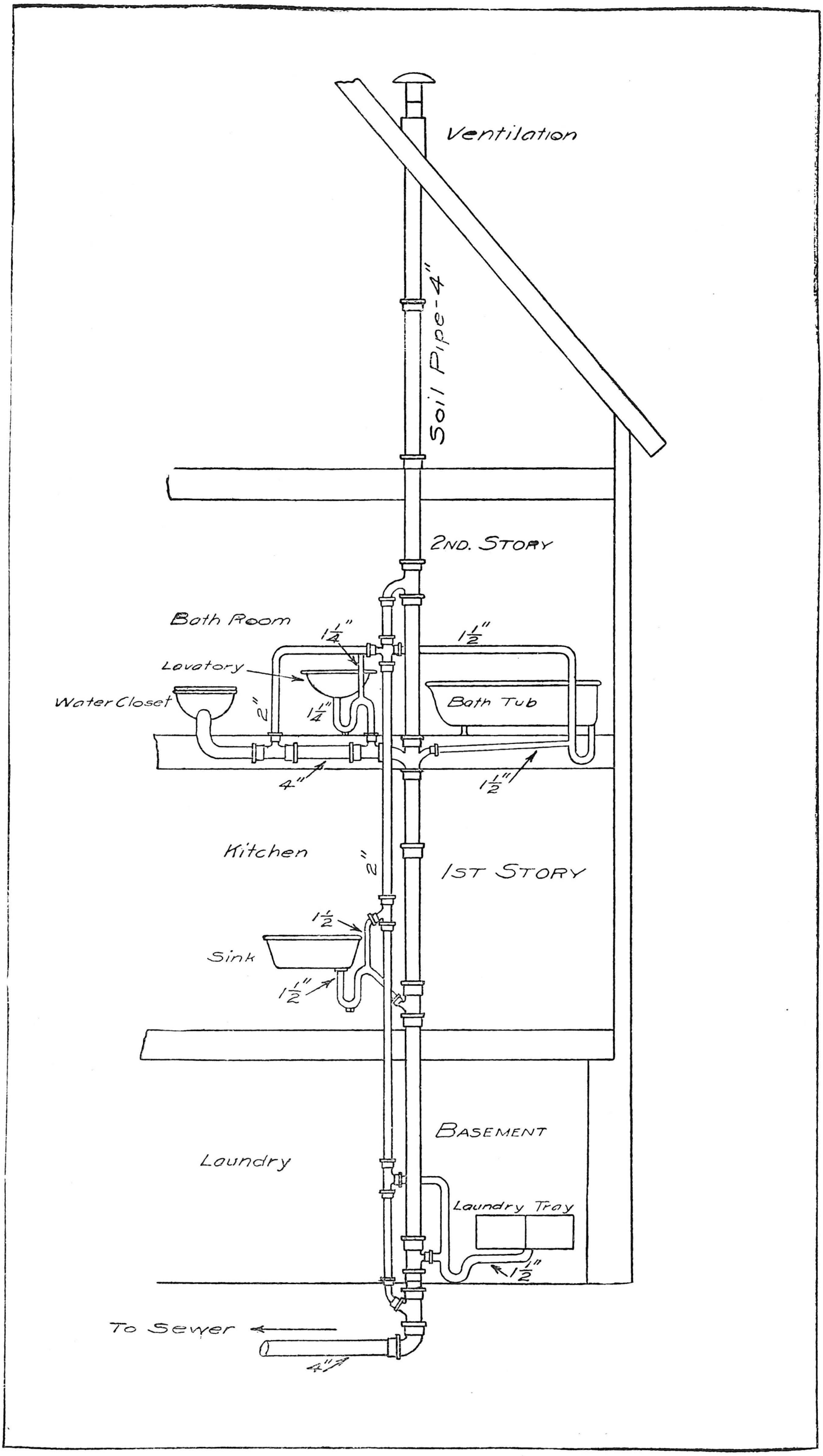
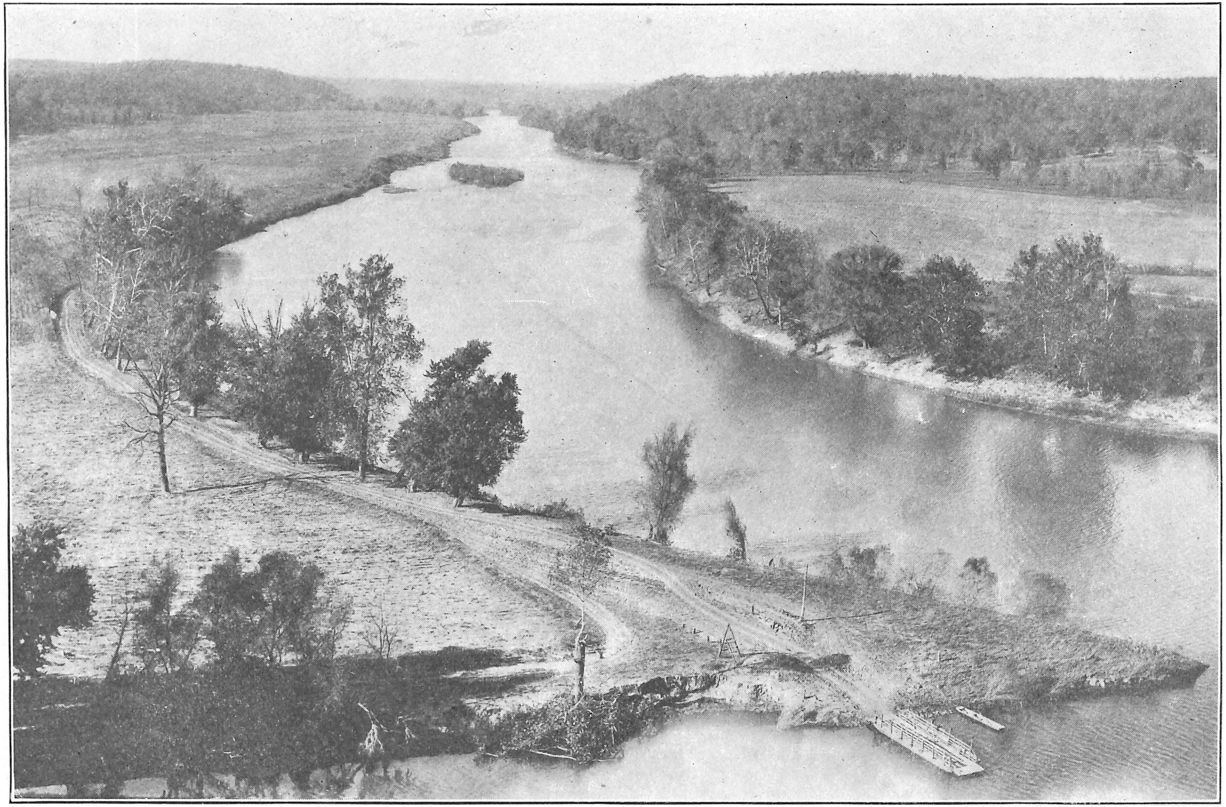


FIG. 10. PLUMBING SYSTEM FOR SEWAGE DISPOSAL.

bathroom, kitchen, and laundry. The 4-inch connection for carrying the sewage to the main sewer outside of the house is also indicated. Attention is called to the pipes which provide for air venting, so that the traps may not lose their water seal due to the rush of the stream in the main pipes and thus allow an escape of sewer gas into the house.

Only simple fixtures are shown such as would be used in the moderate priced house.

The main ventilation, or "soil pipe," should pass up through the roof into the open air in order to give free vent to the air in the pipes and avoid the unsealing of the traps. The top of the soil pipe should be covered, as shown, with a cap which will prevent the entrance of rain or snow while at the same time offering no serious obstruction to the movement of the air.



Where the Niangua and Osage Rivers Meet. Typical Topography of the Ozark Streams.
[Photo by J. K. Wright]