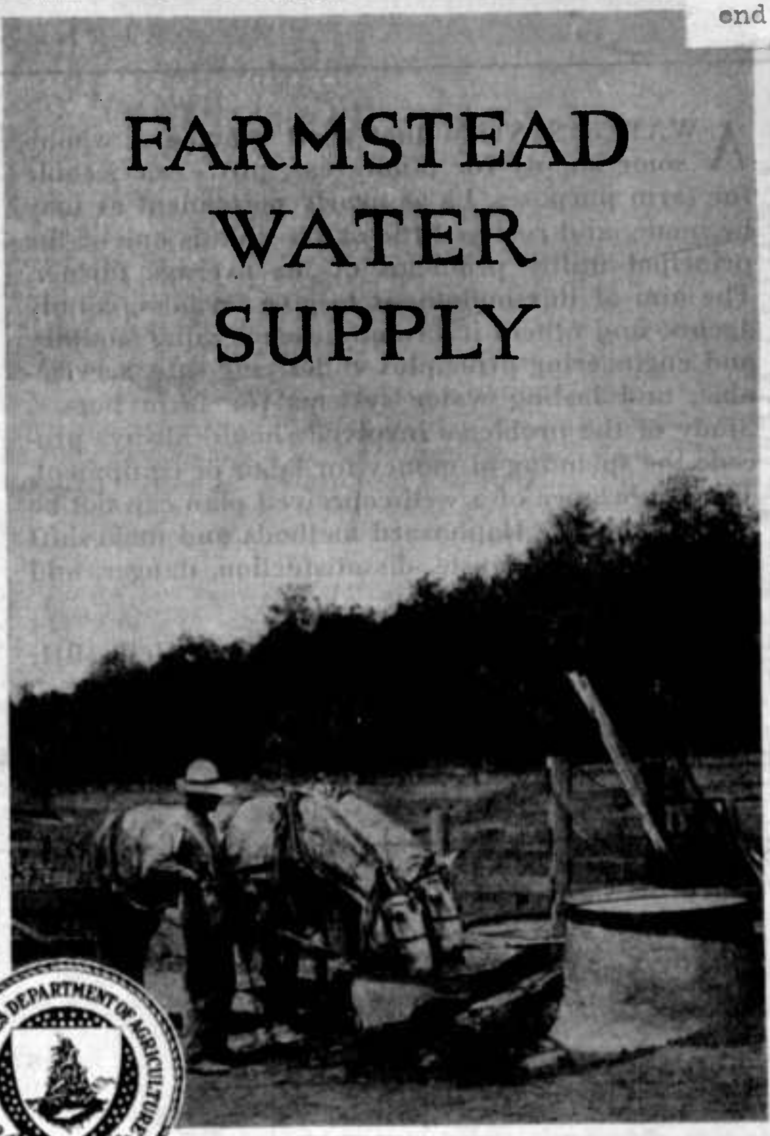
U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1448

FARMSTEAD WATER SUPPLY



A WATER SYSTEM that shall provide a wholesome supply for family use, prove serviceable for farm purposes, be as nearly permanent as may be made, and cost as little as possible is one of the principal utility problems of the average farmer. The aim of this bulletin is to give farmers, county agents, and others information concerning sanitary and engineering principles underlying safe, serviceable, and lasting water systems for farm homes. Study of the problems involved should always precede the spending of money for labor or equipment. The importance of a well-conceived plan can not be overestimated. Haphazard methods and makeshift devices result in waste, dissatisfaction, danger, and abandonment.

This bulletin supersedes Farmers' Bulletin 941, Water Systems for Farm Homes.

Washington, D. C. Issued August, 1925

FARMSTEAD WATER SUPPLY

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INTRODUCTION

FARM WOMEN say their greatest need is to have water piped into the house, especially to the kitchen sink. To draw water by turning a faucet does wonders to lighten the work and revive the spirits of the housewife. Farm men find running water no less convenient. No other utility is so often used. If the water is pure, no other utility does so much to promote the health of both man and stock.

The 1920 census reports 1 out of 10 farms in the United States as having water piped into the house. Vermont and California have the highest percentages, 62.9 and 56, respectively. Arkansas and Mississippi have the lowest percentages, 0.8 and 1.1, respectively. Illinois has a percentage of 11.2. In the latter State a recent canvass of about 1,200 rural and urban houses in 14 counties shows that at 546 homes water is carried to the house and at 206 it is carried to the barn; at 602 homes water is pumped to the house and at 106 it is pumped to the barn; 845 homes have sinks and 358 have none; 599 homes have a laundry on the first floor; 464 homes have a men's wash room outside the kitchen; 428 homes have bathtubs with running hot and cold water These statistics indicate how vast the undeveloped field is. Figures 1 and 2 show clearly how much it means to have running water in and about the farm buildings.

PURITY OF FARM WATERS

Purity of the water supply should be the first consideration of the farmer, though the fact is seldom realized until sickness or death visits some loved one. Disease germs can not be seen with the naked eye and thousands may lurk in a drop of water or in a particle of waste matter the size of a pinhead. From specific germs or parasites that may at any time exist in contaminated water there

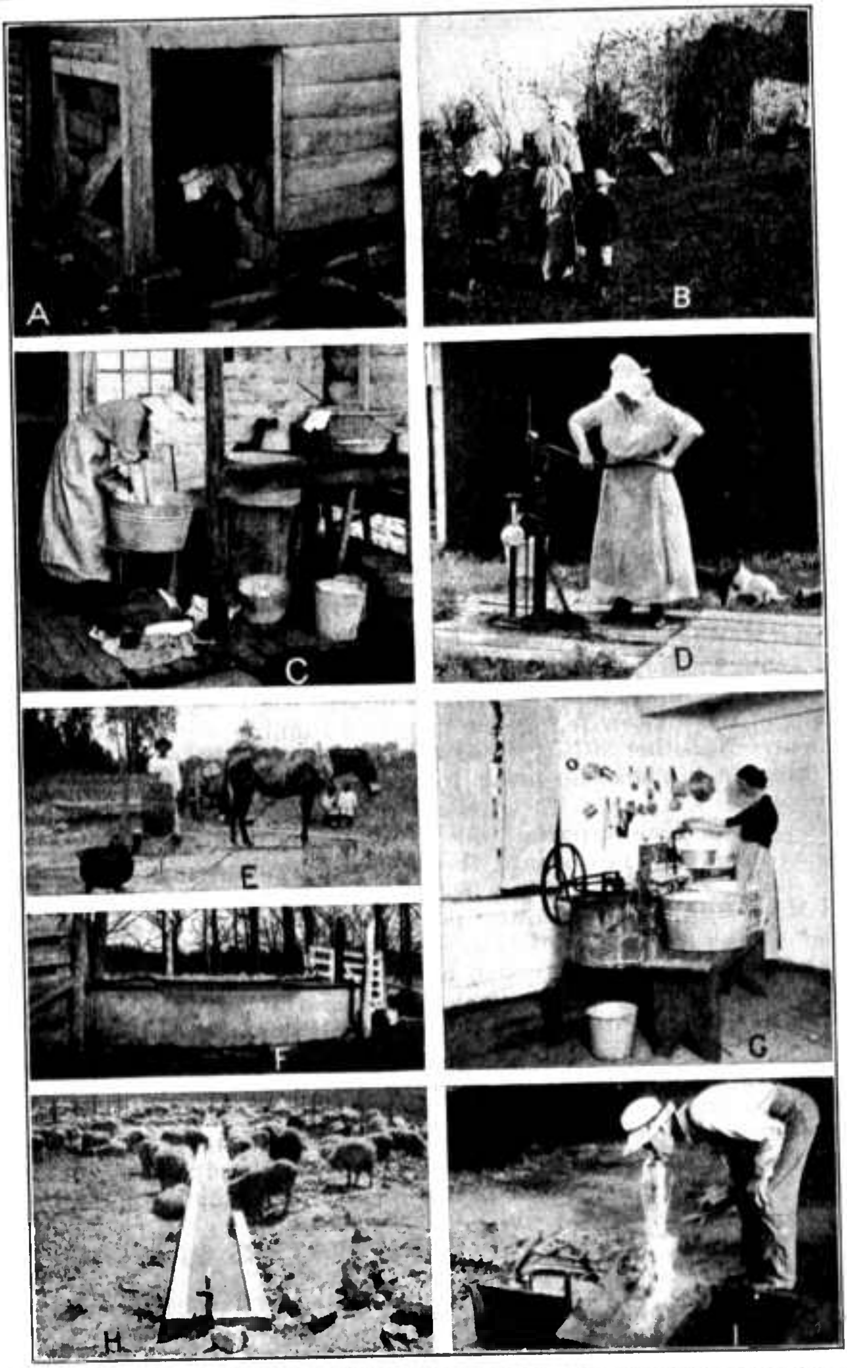

FIG. 1.—No water in the home makes steps and labor. Running water saves time and drudgery. *A*, Farm woman dipping water from a spring, Virginia; *B*, carrying water to the house; *C*, doing the family wash; *D*, farm woman pumping water, Wisconsin; *E*, farmhand hauling water, Alabama; *F*, concrete watering trough and heater, Maryland; *G*, corner of a kitchen supplied with running water in a log farmhouse, Virginia; *H*, watering trough on a sheep ranch, Idaho; *I*, plenty of drinking water for man and beast, Indiana

may result typhoid fever, dysentery, diarrhea, or intestinal worms, of which the hookworm, roundworm, whipworm, eelworm, tapeworm, and seatworm are the more common. Contaminated water may contain also the causative agents of numerous ailments common to livestock, such as tuberculosis, hog cholera, anthrax, glanders, and stomach and intestinal worms. Disease germs are carried by many agencies and are unsuspectingly received into the body. A few cases are cited herewith:

In 1911 the water of a nicely located and apparently tightly covered dug well in Virginia began to smell and taste foul and become the cause of intestinal disturbance. Examination disclosed 16 live frogs and 6 more or less decomposed. After the well had been cleaned and pumped out several times, the water was entirely satisfactory.

In 1914 90 cases of typhoid fever and 7 deaths in California were caused by a water supply contaminated by a septic-tank discharge which drained a long distance above ground and then through 141 feet of gravel.

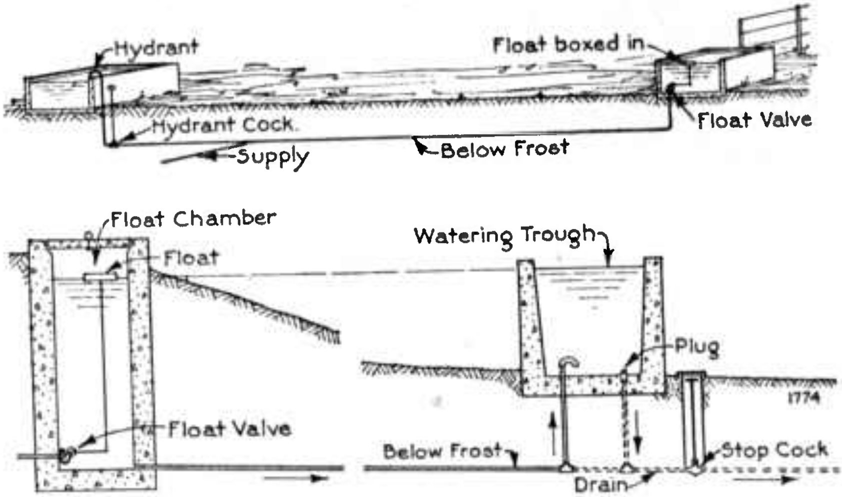

FIG. 2.—Methods of piping water to troughs. Upper left trough supplied from a simple anti-freezing field hydrant. Upper right trough automatically supplied by a float valve. Below, anti-freezing float chamber from which water may be automatically supplied to one or more troughs set to have the same water level; dotted pipes show how system may be drained

In 1915 a heavy rain gorged a house sewer in Virginia, whence some water escaped to the pit at the top of a drilled well and followed down the casing. Within 14 days five of the eight children in the family were stricken with typhoid fever and the eldest died.

Surveys indicate that three out of four farm water supplies are sufficiently polluted to be unsafe. Streams, ponds, irrigation ditches, and other surface supplies are sure to receive pollution, either directly or from surface wash. Wells and springs are polluted through the open or loose top and by foul drainage under ground. Figures 3 and 4 show some of the ways by which farm water supplies become polluted and dangerous.

SAFEGUARDING THE WATER SUPPLY

Tight well platforms and casings, clean grounds, and wide separation of the well from probable channels of impure drainage are the greatest safeguards. It is not enough that a well or spring is situated 50 or 150 feet from a source of filth or that it is on higher ground. Given porous ground, a seamy ledge, or long-continued pollution of one plat of land, the zone of pollution is likely to extend long distances, particularly in downhill directions. A well may draw pollution from lower ground, particularly when drought and heavy pumping depress the water table enough to re-

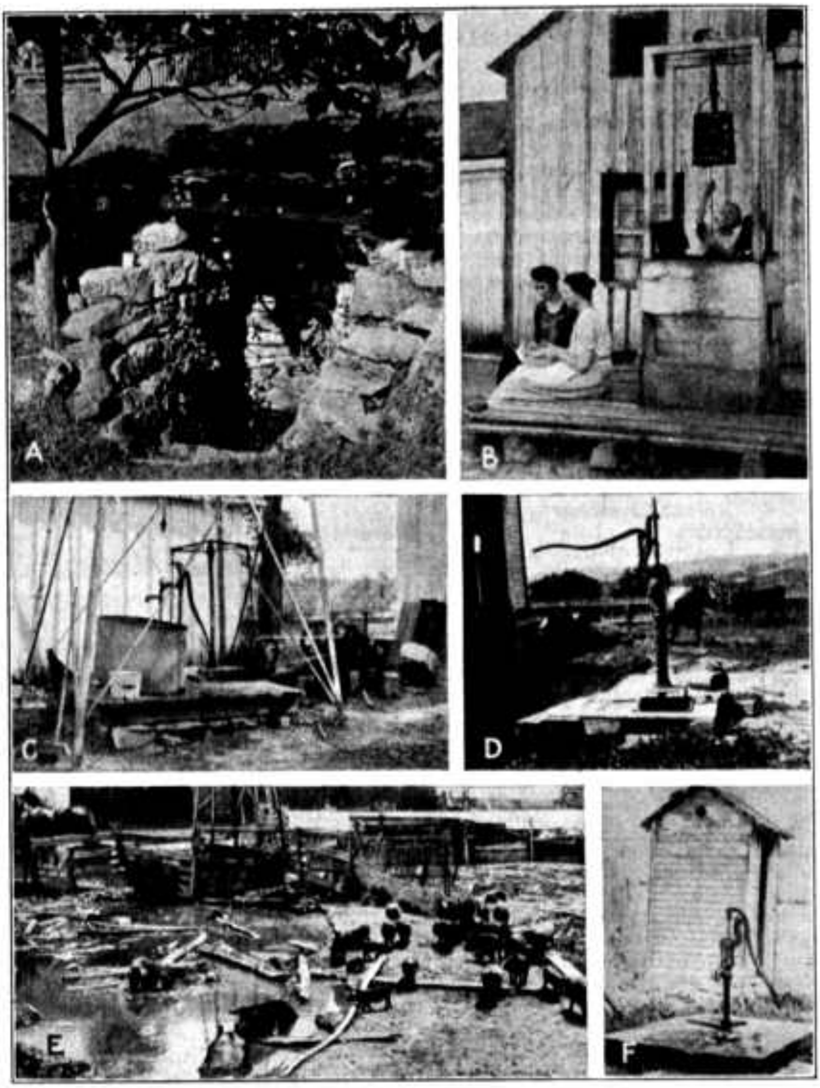

FIG. 3.—How springs and wells become polluted. *A*, Open spring: noxious substances are washed in by rain and carried by wind; vermin has free access; vegetable growths develop in the water; *B*, the favorite well of old is a menace; dust and bacterial life find lodgement; filth from the hands clings to the chain and bucket; *C* and *D* show wells having loose, unsafe platforms; pollution by surface wash, filth from shoes, droppings from poultry, worms, bugs, toads, mice, or other animal life; *E*, well between barn and hog wallow; *F*, well badly polluted by drainage from near-by privy

verse the direction of drainage movement. Only when the surface of the water in a well or spring is at a higher level at all times than any near-by sources of filth is there assurance of safety from impure seepage. Figures 5, *A*, *B*, and *C* and Figure 6 show well-protected water supplies; additional safeguards are shown in Figures 14 and 15. Figure 7 shows in striking manner what good water means to a community.

CHARACTERISTICS OF GOOD WATER

Water for domestic use should be clear, colorless, odorless, soft, neither strongly acid nor alkaline, and its temperature for general farm purposes should be about 50° F. These characteristics, however, must never be deemed proof of purity, for a glass of water may possess them all and yet contain millions of disease-producing germs. Any suspicious water should be rejected or disinfected (see Disinfection of Drinking Water, page 10) until both the water and the surroundings where it is obtained are passed upon by competent sanitation authority, such as the town, city, county, or State board of health.

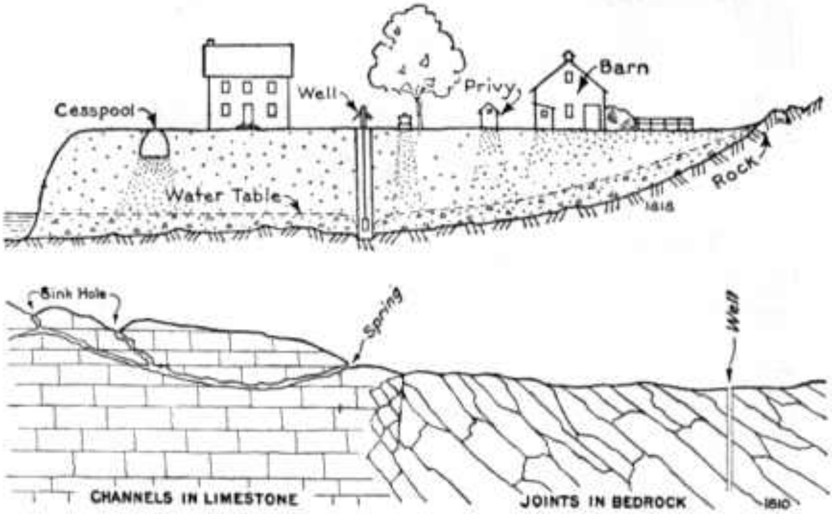

Fig. 4.—How foul drainage reaches wells and streams. Below: Characteristic openings in rock formations; sink holes and channels dissolved in limestone; jointed or broken condition in the upper portion of granite and other kinds of bedrock; the farm wastes should never be thrown or discharged in sink holes or other rock openings

CONSUMPTION OF WATER

Higher standards of living are everywhere creating new and increased demands for water. A bath requires 30 gallons, and each flush of a toilet takes 4 to 6 gallons. Heavily worked horses and mules and milk cows may consume 20 to 25 gallons per day in hot weather, and with all farm animals conditions of weather, food, and living may double or halve the ordinary requirements. Table 1 shows fair allowances.

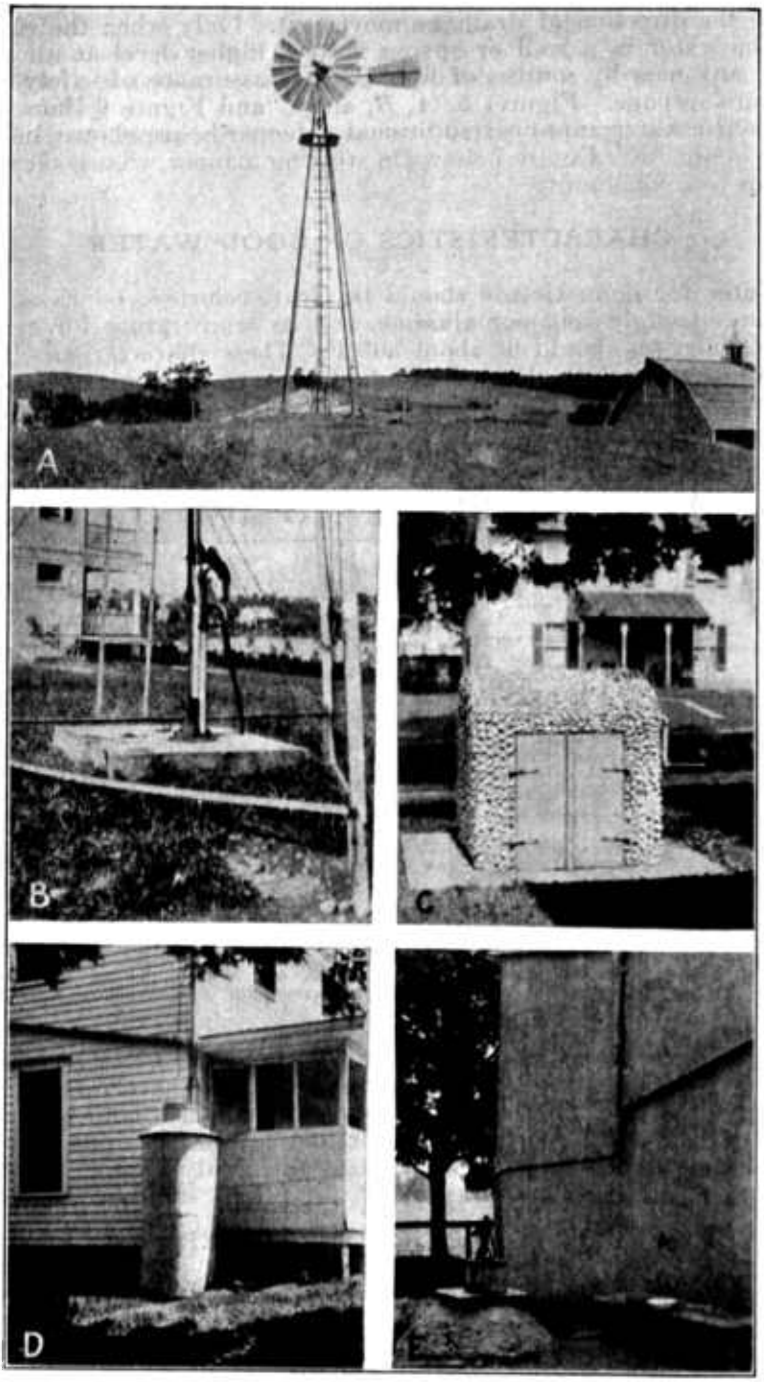

FIG. 5.—*A*, Favorable location for well; clean ground above or to one side of impure drainage from buildings; *B*, tight concrete platform with raised and sloping top and pump securely bolted to it; *C*, protection of an old well, Maryland; *D*, galvanized steel cistern objectionable because the water dissolves more or less zinc, is warm in summer and freezes in winter; *E*, loose rubble masonry cistern; water liable to pollution from surface wash and underground seepage.

TABLE 1.—*Water requirements of farms and schools*

[Gallons per person or animal for 24 hours]

Water use	Quantity
	Gallons
Domestic purposes, 1 pump at kitchen sink	4-8
Domestic purposes, 1 faucet at kitchen sink	7-15
Domestic purposes, running hot and cold water in kitchen, bathroom, and laundry	20-25
Sprinkling and cooling purposes, outdoor washing, leakage, etc	15
Average daily consumption, modern home	40
Maximum daily consumption, modern home	100
Schools, 3 to 15 gallons, average	7
Horse, mule, or cow	12
Sheep or hog	1

CISTERNS

Rain water is soft and comparatively pure, but when collected in cisterns often contains polluting matter. The evils of cistern water relate to the uncertainty of rainfall; to freezing in winter and unwholesomeness in summer; to entrance of dust, soot, bird droppings, and vermin from the roof; to objectionable taste from metal and concrete walls or from growth and decay of certain organisms in the water; to neglect in cleaning; and to poor construction resulting in loss of water or entrance of tree roots, or, what is frequent and more serious, foul seepage from a nearby source of filth. Figures 5, *D* and *E* show cisterns that should not be used for drinking water.

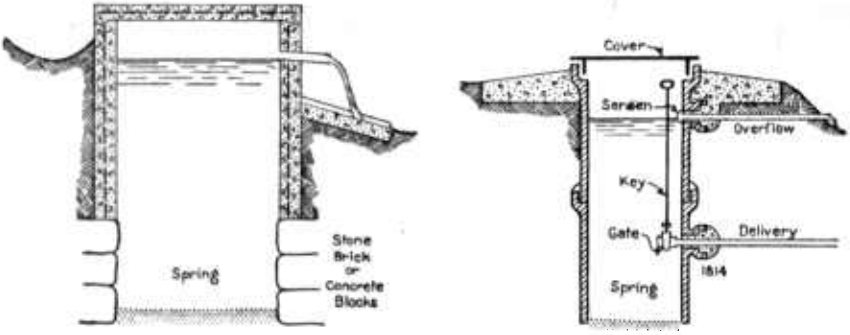

FIG. 6.—Protection of springs. Curbed and covered to keep out surface wash and to prevent dipping or bailing; water should be drawn only by natural flow through a pipe or by pumping; on the left, square concrete box having 4 or 5 inch walls and 3 inch top reinforced with heavy wire netting or stock fencing; on the right, curb composed of large-size clay or concrete pipe (T branches)

The vital features of a cistern for potable water are: (1) Absolute water-tightness, top, sides, and bottom, and close screening of inlet and waste pipes; (2) provision for excluding from the cistern the first portion of each rainfall until the roof or other collecting area has become rinsed thoroughly; (3) a first-class filter of clean, well-selected sand and thoroughly burned charcoal; (4) a waste pipe which removes surplus inflow from the bottom of the cistern where impurities tend naturally to settle; (5) periodic and thorough cleaning of the cistern and filter; (6) no connection between the waste pipe and a sewer or a drain which may carry impure drainage.

To determine the quantity of water falling on roofs: Measure horizontally in feet the ground plan of the roof and compute the area of the ground plan in square feet. Multiply this area by the rainfall in inches (for the wet-weather period[1] which must supply the desired storage) and divide the product by 1.6. The result is the number of gallons of water. The householder who would avoid the inconveniences of a shortage in his cistern supply is fully warranted in planning a large installation. Most localities experience long droughts or exceptionally dry years when rainfall drops to one-half or one-third of the normal. Moreover, many small rains may be impracticable of collection because of the dirty condition of the roof.

To find the capacity of square or rectangular cisterns and tanks: Multiply the inside length by the breadth and the product by the height, each dimension being in feet. Multiply the result (cubic feet) by 7½ to find the gallons. Gallons divided by 31½ give barrels. Table 2 shows the capacity of round cisterns of certain dimensions.

TABLE 2.—*Capacity of round cisterns and tanks*

Depth in feet	Diameter in feet								
	4	5	6	7	8	9	10	11	12
	Capacity in gallons								
4	376	588	846	1, 152	1, 504	1, 904	2, 350	2, 844	3, 384
5	470	735	1, 058	1, 439	1, 880	2, 380	2, 938	3, 555	4, 230
6	564	881	1, 269	1, 727	2, 256	2, 855	3, 525	4, 265	5, 076
7	658	1, 028	1, 481	2, 015	2, 632	3, 331	4, 113	4, 976	5, 922
8	752	1, 175	1, 692	2, 303	3, 008	3, 807	4, 700	5, 687	6, 768
9	846	1, 322	1, 904	2, 591	3, 384	4, 283	5, 288	6, 398	7, 614
10	940	1, 469	2, 115	2, 879	3, 760	4, 759	5, 875	7, 109	8, 460
11	1, 034	1, 616	2, 327	3, 167	4, 123	5, 235	6, 463	7, 820	9, 306
12	1, 128	1, 763	2, 537	3, 455	4, 512	5, 711	7, 050	8, 531	10, 152

Wood cisterns are objectionable because of their short life, probability of leaking, and tendency to promote bacterial growth; they cost about as much as steel or masonry. Brick cisterns are generally circular, with walls about 8 inches thick. The joints should be completely filled with cement mortar and both the inside and outside surfaces should be left rough to receive heavy plastering coats of rich Portland cement mortar. The inside should be troweled while green to produce a hard impervious surface. Concrete cisterns may be square or round, the latter, for a given capacity, requiring a little less material, but more labor in building the form. Information on mixing and placing concrete and plastering coats to secure watertightness is given in other bulletins[2] of the Department of Agriculture.

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[1] The amount and the seasonal distribution of rainfall at the principal cities throughout the country may be obtained from the U. S. Weather Bureau, Washington, D. C., from local forecasters in the several States, and from published reports of the Weather Bureau in many libraries.

[2] Yearbook Separate 824, Securing a Dry Cellar, Farmers' Bulletin 1279, Plain Concrete for Farm Use, and Department Bulletin 230, Oil-Mixed Portland Cement Concrete. The first two are mailed free on request by the U. S. Department of Agriculture and the last may be obtained for 10 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Before putting a masonry cistern to use the inside walls should be allowed to air and cure for a month or more and be occasionally sprinkled with water to convert the free lime in the cement to carbonate of lime, which is only slightly soluble in pure water. A new cistern should be pumped out two or three times prior to use of the water for drinking. With continued use of a cistern dissolved mineral matter ceases to be of importance.

FILTERS

Filters should operate slowly—like rainfall percolating into the ground. The rate of filtration should not exceed 50 gallons in 24 hours for each square foot of effective area in the filter bed; the rate is readily controlled by placing a valve in the pipe from the filter to the cistern, opening or closing the valve as necessary. The water level should be maintained above the filtering material, thus protecting the film of silt and mud on the surface of the filter. It is in this film and a thin layer just below it that most of the filtering is done.

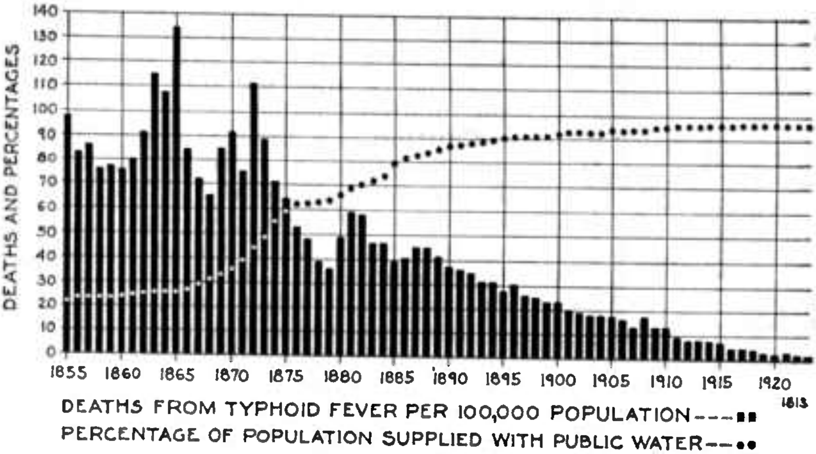

FIG. 7.—Typhoid-fever death rate and percentage of the population supplied with public water (good water) in Massachusetts from 1855 to 1923; notice the rise of the dots and the drop of the vertical bars; in 1923 fully 96 per cent of the people were supplied with public water, and the typhoid-fever death rate had declined to 1.8 per 100,000 population; though many agencies contributed to this notable decline, unquestionably good water is a leading one

Sand is one of the best and most available filtering materials, and well-burned wood charcoal, the pieces averaging the size of wheat grains, is useful in removing color, taste, and odor. Clean pit or beach sand or crushed quartz is much used. Where the water to be filtered is relatively clear (like rainwater) the sand should be very fine. For surface waters carrying sediment, slightly coarser sand, such as is used in plastering work, is generally used. A depth of 2 feet of carefully selected, uniform size sand, washed to remove all clay, silt, loam, and vegetable matter, is preferable to a greater depth of poor sand. As the thin surface layer becomes clogged with continued use it may be scratched or furrowed or a half inch may be scraped off with a trowel, until eventually the bed is reduced to 12 or 15 inches in thickness. The sand removed should be washed and returned, or be replaced with new sand.

Figure 8 shows a simple home-made slow sand filter having a capacity of 25 to 30 gallons per 24 hours. It can be made by any handy person for about $10. Figure 9 shows the important features of a filter and cistern to care for roof water. Figure 10 shows an arrangement to clarify water from an irrigation ditch.

The foregoing filters are of the gravity or open type. They operate by natural flow at slow rates and under low heads. Pressure or closed filters are on the market. They may be placed conveniently in the home and be connected with the discharge pipe from a pump or other pressure supply. The filtering material may be a natural product such as tripoli stone or sand and charcoal. If the water is discolored and contains matter too fine to settle on standing, the filter may be provided with a device which automatically feeds a small quantity of alum or other coagulant into the unfiltered water.

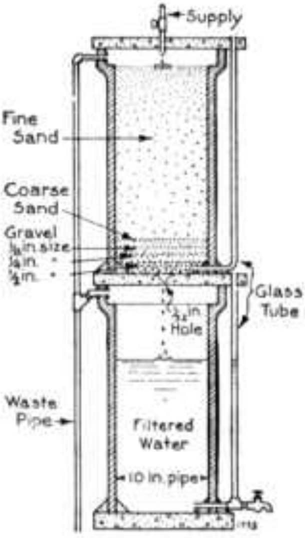

FIG. 8.—Homemade slow sand filter

Caution.—A filter is a device for removing dirt or sediment from water. It promotes purity and safety but never is a guaranty. It does not excuse the use of water taken from sources known to be contaminated. Filtration alone does not materially affect such dissolved minerals as the water may contain. For instance, if brine be filtered, the resultant will still be salt water. A filter should be easily accessible for cleaning. The frequency of cleaning depends on the dirtiness of the water and the use of the filter. Dirty sand can be washed, but dirty charcoal should be replaced with new charcoal. Charcoal filters, if neglected, may become a detriment rather than a benefit, due to the storage and overloading of organic matter within the pores and upon the surface of the charcoal.

DISINFECTION OF DRINKING WATER

Disinfection (destruction of disease germs) of drinking water by home methods should be considered an emergency measure. The purity of a cistern, spring, well, or surface water is often suspected before the existence of disease becomes definitely known. Suspicion may be created by minor intestinal ailments or by odor or taste of the water. Pending examination of the water supply by competent sanitation authority, the householder should stop using the water for drinking and cooking or employ some method of disinfection. Where chemical disinfection is employed, great care should be used in preparing the chemical, keeping it on hand, and adding it to the water. Directions should be followed explicitly. Stock solutions should be kept where children can not get them and bottles should be plainly labeled "Stock Solution for Disinfecting Water—Poison".

It is very important to understand that, even though printed directions are closely followed, disinfection processes are not always complete. Waters of varying physical and chemical composition react differently with equal quantities of a given chemical, similarly as two individuals may be differently affected by like doses of medicine. Clear water is usually more readily disinfected than muddy or cloudy water. Well or spring waters may, however, be clear and sparkling and yet contain so much ferrous iron, nitrite nitrogen, or other oxidizable matter as to be little affected by an ordinary dose of the chemical disinfectant. The sediment in a muddy water or the oxidizable constituents, if such be present, in a clear water uses up the chemical before germicidal action takes place.

Chemists and bacteriologists by laboratory experiments determine the exact amount of disinfectant for each particular water and its action on the germs therein. These matters are guesswork with the average individual. He may guess wrong, and his efforts to disinfect drinking water may lead to a false sense of safety. For these reasons absolute reliance can not be placed upon home methods of sterilizing water with chemicals. As a temporary precaution against disease, such methods may serve a very great service. Two methods of disinfecting drinking water recommended by the Bureau of Chemistry are as follows:

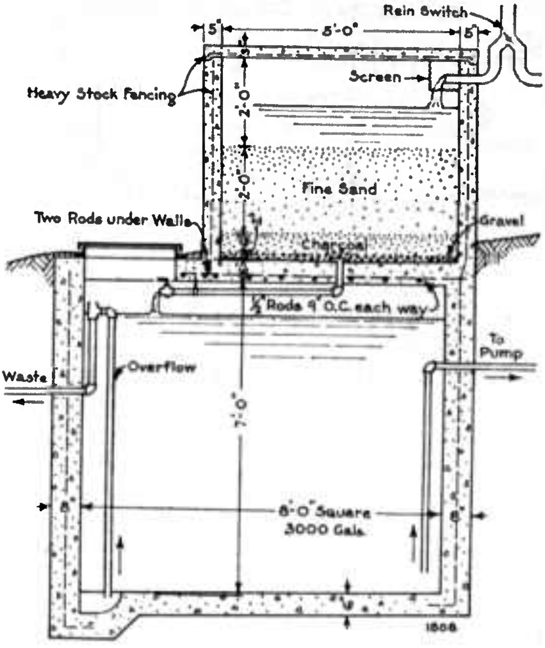

FIG. 9.—Working drawing for a square filter and cistern to hold about 3,000 gallons; estimated cost $150 to $250

(1) *Disinfection with chloride of lime.*—Prepare a chloride of lime solution by dissolving 1 teaspoonful of fresh chloride of lime (bleaching powder) in 1 quart of water. Place this stock solution in a stoppered bottle. Such a solution gradually loses its strength, and fresh solutions should be made up occasionally. For disinfecting water, mix thoroughly 1 teaspoonful of this solution with 2 gallons of water. After 30 minutes the water will usually be fit to drink.

(2) *Disinfection with tincture of iodine.*—This drug is an excellent disinfectant for drinking water, can be obtained at any drug store, and is found in the medicine chests of most households. Ordinary tincture of iodine contains approximately 7 per cent of iodine. Mix 1 drop of this tincture thoroughly with 1 quart of water. The

water so treated will usually be safe for drinking purposes after 30 minutes have elapsed. Proportional mixtures for other quantities of water are as follows: 11 drops of tincture in 2¾ gallons of water (an ordinary pail full), 1 tablespoonful or 3 teaspoonfuls of tincture in 52 gallons of water (a large barrel, approximate inside middle diameter 24 inches, end diameters 20 inches, depth 30¾ inches).[3]

SURFACE-WATER SUPPLIES

Streams, ponds, irrigation ditches, and small open reservoirs are unsafe sources of farm water supply. The temperature of such water seldom is satisfactory, and the presence of more or less polluting matter is certain. The only safe course is to avoid drinking water from any surface source unless such water has been disinfected.

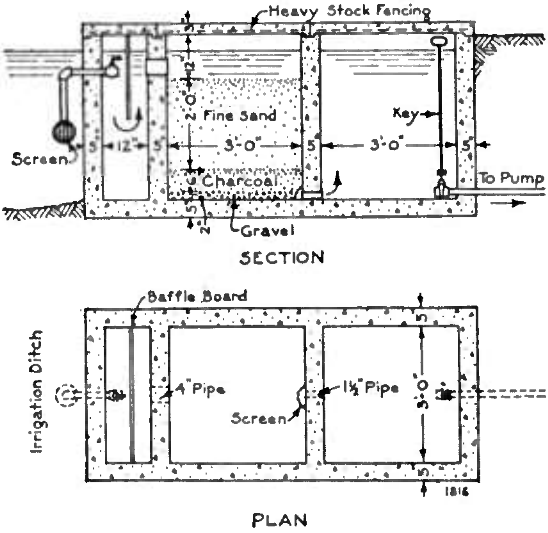

FIG. 10.—Working drawing for a cistern and filter to clarify water from an irrigation ditch; cistern holds 225 gallons; capacity of filter about 450 gallons per 24 hours; estimated cost $75 to $125

GROUND-WATER SUPPLIES

Good ground water is the ideal supply for the farm. If uncertain of the depth, quantity, or quality of the water likely to be encountered, one should describe fully the location and conditions to the United States Geological Survey or to State geological authorities and ask for advice. Many wells have been sunk to great depths in the belief that a plentiful supply would be reached, only to find no water, or that it was unfit for use, or that a mere hole had been created which served only to drain water from relatively near the surface. Information as to the kind, thickness, porosity, and dip of the strata of the region, the results obtained in neighboring wells, and examination of the land slopes, vegetation, and evidences of seeps and springs serve as good guides in locating water supplies. There is little to recommend certain patented electrical water finders or the use of a forked willow, hazel, or peach stick, although so-called forked-stick artists, from their experience and observation of surface conditions, usually are better able to judge of the probabilities of ground water than is the average person.

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[3] Two other methods often used to disinfect drinking water are as follows:

(1) Boiling water 20 minutes. This is a very safe method but is inconvenient for large quantities of water or where the method must be employed for a considerable period of time.

(2) Disinfection with tablets containing a compound of chlorine. This method is simple and convenient, as suitable tablets with directions for using may be purchased at many drug stores.

The most likely appearance of seeps and springs is near the base or toe of slopes. Shallow wells thus located usually are stronger than those higher up the slope or farther out on the flats. Wells upon the crown of a hill or close to rock outcrops are not likely to yield plentifully. The stronger artesian flows usually come from the lower strata.

Sands, gravels, porous sandstone (consolidated sand), and conglomerates (consolidated gravel) are the most promising water-bearing materials. Quicksand, clay, marl, and hardpan usually contain considerable water, but yield it too slowly to afford satisfactory supplies. Shale and slate (consolidated silt and clay) are not good water bearers, but water sometimes is obtained at considerable depths from the joints and cleavage planes. Granite, gneiss, and schist (rocks formed or modified by heat) are likely to be hard and impervious, but due to broken or jointed condition (generally within 300 feet of the surface and seldom below 500 feet) may yield moderate quantities of very good water. Lava rock often yields abundantly, but generally the supply is essentially of surface origin, frequently seepage from irrigation ditches. Limestone usually carries an abundance of water within the passageways and cavernous channels which characterize this rock, but the water usually is hard and may be contaminated easily from surface sources. (See Fig. 4.)

SEEPS AND SPRINGS

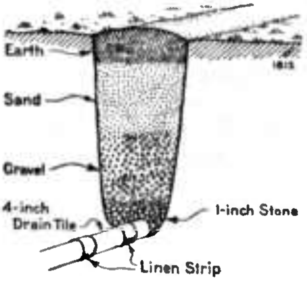


FIG. 11.—Drain tile laid to capture seeps and small springs

Seeps and springs are the natural emergence of ground water upon the surface. Anything that reduces resistance to the flow, such as open-joint pipes or conduits for the collection of seeps or excavating and encasing a spring, tends to increase the yield. Increase of resistance through choking the flow or building up the curb to a moderate height above the natural surface tends to decrease the yield, and may cause its complete loss by deflecting it to other channels. Figure 11 shows drain tile laid to collect seeps or small springs. To prevent silt entering the tile a 6 to 8 inch wide strip of linen or burlap should be fastened around each joint. If any part of the line is in quicksand, mud, or clay, where little or objectionable water would be collected, sewer pipe should be used in that portion and the joints should be tightly made with jute and cement mortar or bituminous jointing compound to keep out fine material.

Horizontal pipes, cribs, or chambers are sometimes located beneath irrigation ditches or where water is to be taken from the margin of a pond or stream. In the latter instances it is better to locate the collector 50 or more feet from the body of water, because it is better to intercept ground water moving toward a surface supply than to draw water from it direct. Collectors may be of tile, wood, stone, brick, or concrete, and there should be ample space, particularly at the bottom, for water to enter. They should be placed below all low-water levels, lengthening them as necessary to increase the yield.

In many instances an elevated spring may be piped to the buildings, forming a gravity system, as shown in Figure 12. Where feasible, such a system is superior to any other kind because the water is generally good, the construction is simple, the operation is certain and the expense and bother of pumping are saved. Figure 6 shows two simple curbs to inclose and protect springs.

WELLS

Wells are artificial openings in the ground to or below the water table. They should be sunk sufficiently into the water-bearing material in order that neither drought nor maximum pumping operations of the farm shall so lower the ground water that the pump must be stopped to avoid taking air. No new well should be regarded as complete until a pumping test of proper continuous duration has been made to determine its sufficiency for the purpose of the farm and to make sure that a mere pocket of water has not been tapped. Unscrupulous contractors resort to numerous tricks when testing wells, and these matters should have the personal attention of the farmer who pays the bill. In making the final pumping test the discharge should be taken by pipes or troughs a considerable distance from the well and to lower ground if possible.

FIG. 12.—Water delivered by gravity (natural flow). Note protection of the spring: a shallow trench on the upper side to divert surface water, and the site inclosed by a fence to keep out stock

DUG WELLS

Dug wells are open excavations, the diameter varying with the freedom with which water enters, the rates of pumping, and the requirements for water. Excavations showing the slightest indication of caving should be carefully braced to guard against accident. The usual method of digging wells is to have one or two men at the bottom to loosen the material and shovel it into a bucket which is hoisted to the surface with the aid of a windlass or tackle blocks as shown in Figure 13, *A* and *B*. Sometimes a small orange-peel bucket operated by hand with the aid of a tripod derrick is used. In loose sand yielding an abundance of water the excavation sometimes is made entirely by the use of a centrifugal pump. The lining

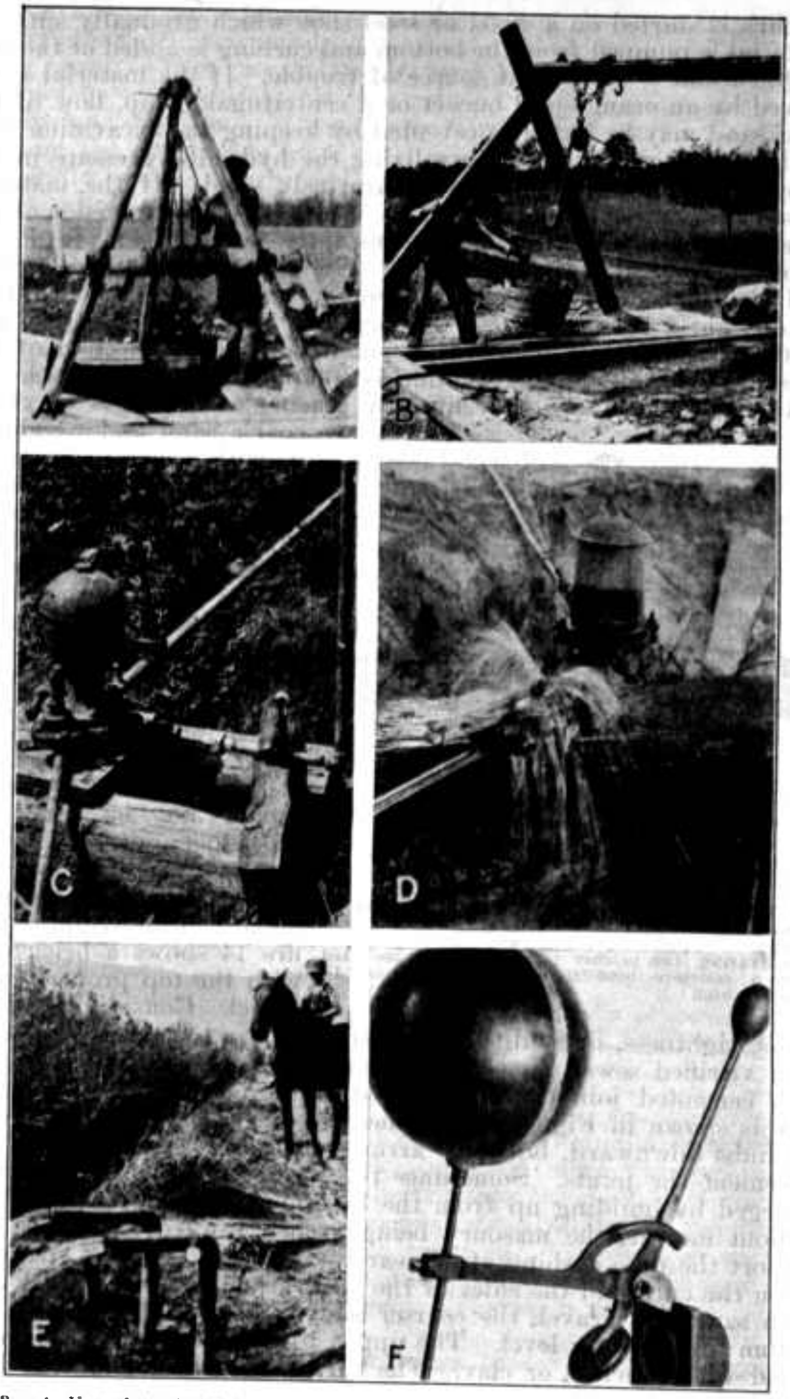


FIG. 13.—*A*, Use of a windlass in digging a well, Maryland; *B*, raising the loaded bucket by horse power, New Hampshire; *C*, hydraulic ram, Virginia; *D*, hydraulic ram in operation; the water which does the work is gushing from the escape valve; *E*, flowing wells, Utah; *F*, float-controlled valve for use where the flow of a spring is too small to operate a ram continuously; a 2-inch valve costs about $10

or curb is started on a wood or steel shoe which gradually sinks as material is pumped from the bottom and curbing is added at the top.

Quicksand is a frequent source of trouble. If the material is removed by an orange-peel bucket or a centrifugal pump, flow of the quicksand may be largely prevented by keeping the excavation partially full of water, thus neutralizing the hydraulic pressure in the quicksand and rendering it comparatively solid. If the material must be excavated by hand methods, the lower or cutting edge of the sheeting or curbing should be constantly kept from 1 to 4 feet below the bottom of the excavation. Wood may be used for sheeting and steel or concrete for permanent curbing; its sides should be water-tight. Hay, straw, or fine brush is very useful to give men footing and to close temporarily small boils in the bottom of the excavation. After the excavation is completed, entry of quicksand at the bottom may be prevented by placing a thin layer of clean, coarse sand and weighting it with several layers of sand or gravel of increasing coarseness. There is thus created a graded sand filter, each layer of which is held in position by the slightly coarser material above it.

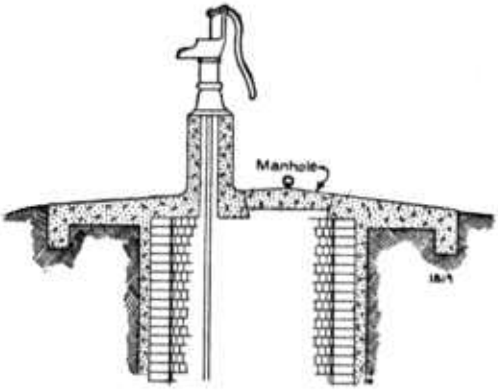


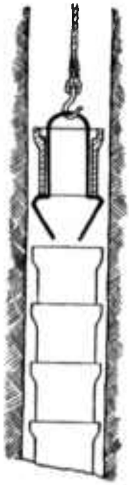
FIG. 14.—Dug well, curbed with 4-inch course of brick laid dry. One like this in Maryland, 4 feet in diameter and 23 feet deep in clay soil cost $53.18 in 1915; manhole and cover shaped by using a large dish pan; cost includes 1,900 brick, the pail, rope, pick and shovel used in excavating, the pitcher pump which is mounted on a concrete base 9 inches square and 18 inches high

Curbs may be of stone, brick, concrete block, or of concrete, vitrified, corrugated, or cast-iron pipe. Wood soon decays and should not be used. At least the upper 10 feet of masonry curbs should be laid in cement mortar to make it water-tight. Figure 14 shows a brick curb with the top properly protected. Considering cleanliness, tightness, durability, and cost, perhaps no curbing is better than vitrified sewer pipe or hard-burned drain tile. Such a curb with cemented joints and a method of lowering and placing the pipe is shown in Figure 15. Sometimes the pipes are placed with the hubs downward, but such arrangement makes it impracticable to cement the joints. Sometimes the lower portion of the curb is enlarged by building up from the bottom with stone or brick laid without mortar, the masonry being arched inwardly to meet and support the pipe curbing at or near the water level. The space between the curb and the sides of the excavation should be filled with clean sand and gravel, the coarser material being placed from the bottom to the water level. The upper 10 feet may to advantage be sealed with concrete or clay. The curb should be brought at least 1 foot above the ground and be surmounted by a concrete platform in which is placed a tight-fitting iron or concrete manhole cover.

The platform should slope from the center and the earth be graded to shed pump drippings and surface water quickly.

If a pump is to set upon the platform, a block of wood or a tin can may be embedded in the concrete to provide an opening for the pipe and cylinder. A firm, water-tight joint between the pump base and the concrete is made by using expansion bolts or anchor bolts and a gasket. Expansion bolts are screwed through the pump base into holes in the concrete. Anchor bolts to fit the holes in the base are embedded in the concrete when it is placed. Ordinary bolts with the thread end up and a large flat washer on the head in the concrete answer every purpose.

If properly located, built, and protected, dug wells are more likely to be satisfactory than tubular wells. The advantages relate to longer life, softer water, and larger volume, permitting more rapid pumping, lower lifts, easier inspection and cleaning, and less trouble from quicksand and air leaks.


METHOD OF LOWERING PIPES

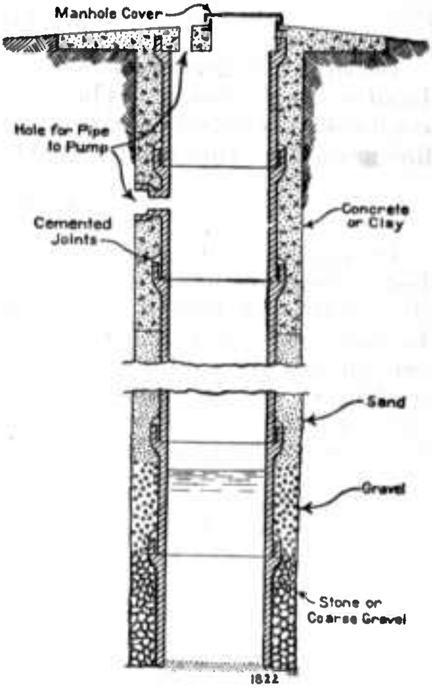


FIG. 15.—Dug well curbed with vitrified or concrete socket pipe such as is used for sewers. Wells of this kind 24 inches in diameter and 35 feet deep in sand have cost about $200, Massachusetts.

CLEANING DUG WELLS

Most dug wells require cleaning occasionally, due to the entrance of dust or other foreign matter at the top and to the washing in of clay and silt with the ground water. The first step should be an inspection of the curb, which if weak or defective would make entrance dangerous. This examination may be made more thoroughly by the aid of a beam of sunlight reflected into the well by a mirror. To determine the presence of harmful gases, a lighted candle or small bird should be lowered into the well. Complete or partial failure of the candle to burn, or death or exhaustion of the bird, indicates dangerous conditions for man. Thorough ventilation of the well is the best remedy.

If it is found safe to enter the well a ladder should be lowered and the curb from the top down scrubbed with wire or other stiff brushes and rinsed thoroughly. The well should then be pumped as low as possible, and any mud, moss, or other debris should be scraped into pails and removed. After thorough cleaning the well should be allowed to fill and should then be pumped out rapidly. This operation may be repeated to advantage two or three times. The disinfection of wells with chemicals is not recommended unless the work is done under technical direction. (See Disinfection of Drinking Water, page 10.) The volume of water must not only be estimated with reasonable exactness, but the character of the water and the proper amount of chemical should always be determined by an expert chemist. The effects of disinfection gradually disappear as water flows into a well to replace that drawn out.

BORED WELLS

Bored wells are made with earth augers turned and lifted by hand or horse power. The method is not extensively used and is confined to relatively small diameters and depths and to clay, sand, fine gravel, or other comparatively soft materials free from bowlders.

DRIVEN WELLS

Driven wells are iron or steel pipes forced into a water-bearing bed. They are more likely to yield hard water than are shallower dug wells, but they are less likely to receive organic impurities.[4] In simplest form, 1 to 3-inch extra strong wrought pipe is cut in convenient lengths and provided with a well point driven as shown in Figure 16, *A*. The pipe joints should be coated with red lead or graphite and oil and should be tightly screwed with pipe wrenches or tongs. Otherwise, if used as suction pipe, it will leak air, or when the pipe is being driven the threads may be stripped or the couplings split. The top must have a heavy cap or steel drivehead to prevent battering the pipe. A 1½-inch well need not cost over 50 cents per foot, including extra strong pipe. The method is very useful in prospecting for water within 20 or 30 feet of the surface and for temporary supplies. Where there is no rock it is the quickest and cheapest method of obtaining ground water. The principal fault of such wells lies in the strainer becoming corroded and choked. Often a well must be abandoned in a few years or the pipe pulled and redriven.

Open-end, driven wells are less easily choked, and if properly cleared of clay and silt, are frequently used in very fine sands. The material which enters the drive pipe is removed with a sand pump or is washed up with the aid of a force pump and a smaller pipe known as the drill or wash pipe inside the drive pipe. A steel jetting drill is screwed into the end of the wash pipe and is very useful to loosen the earth and split small stones at the bottom of the drive pipe, which should be protected by a steel coupling or shoe. Use of a saw-tooth shoe and turning the entire string of pipe at each blow increases the progress. To facilitate water entering the well the first piece of pipe usually has numerous one-fourth-inch holes drilled through the shell. Figures 16, *B*, *C*, and *D*, show hand outfits and

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[4] Out of 1,943 wells less than 25 feet deep in Illinois, 74 per cent were condemned; out of 2,707 wells 25 to 50 feet deep, 63 per cent were condemned; out of 1,333 wells 50 to 100 feet deep, 32 per cent were condemned; out of 3,228 wells more than 100 feet deep, only 13 per cent were condemned. See Water Survey Series, No. 13, Edward Bartow, director, State Water Survey, Urbana, Ill., p. 15.

methods for driving open-end wells. Figure 16, *D* shows the jetting process; the method is equally useful with the driving outfits shown in Figure 16, *B* and *C*. Wells always should be tested for yield when the wash water fails to rise to the surface of the ground. Where the material is coarse enough to "lose" the wash water, it is of suitable character to yield freely.

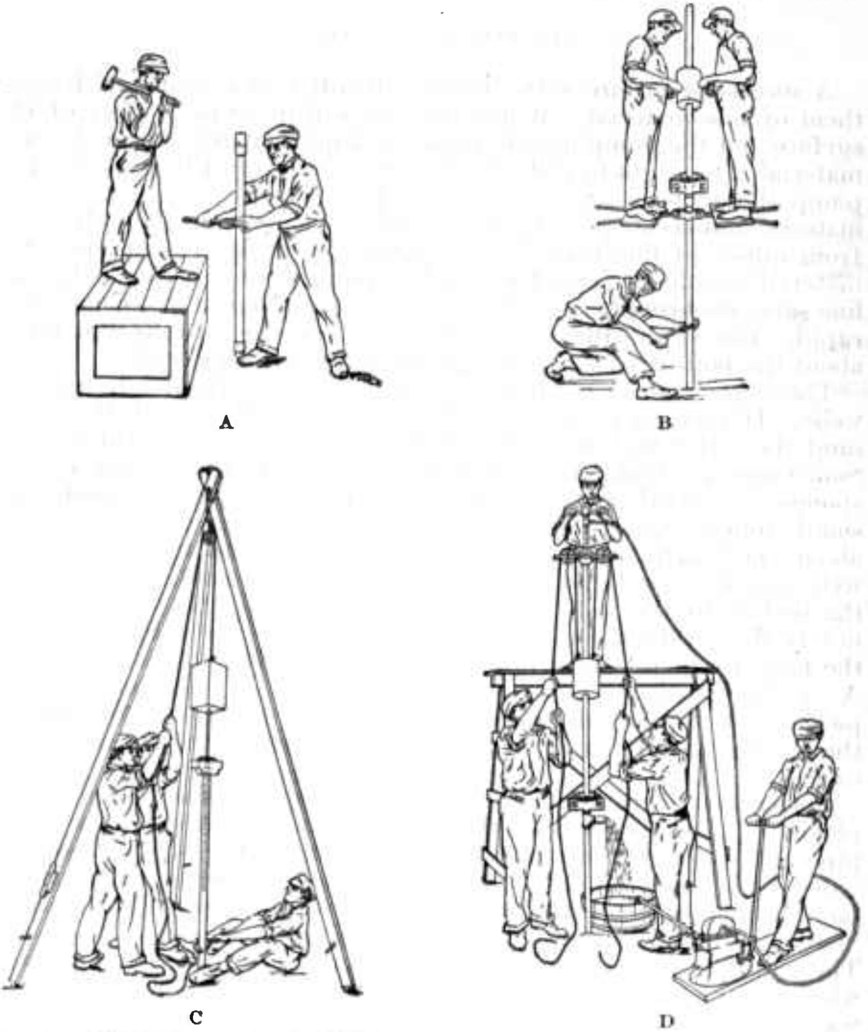

FIG. 16.—Hand methods of driving wells. *A*, use of a heavy striking hammer, sledge, or maul; *B*, drive block with hole through center and raised by direct lift; laborers prefer this method, and their weight assists the driving; *C*, drive block raised with the aid of a pulley, and its fall guided by a spindle which goes inside the pipe; *D*, jetting process

Driving and jetting outfits can often be made from odds and ends about the farm. They are readily operated by three or four men to depths of 100 or more feet in clays, sands, and gravels. Frequently an outfit with one experienced well-driver may be hired for

$8 or $10 a day, and with the aid of farm hands, after everything is assembled, a well may be sunk 50 feet in a day. Fair prices for 2 and 2½-inch wells are $1 to $2 per foot, including extra strong pipe. Where the water is very deep, driven wells are usually 4 to 8 inches in diameter and are sunk by parties experienced in the work.

CLEARING DRIVEN WELLS

A success or failure with driven wells often is a matter of freeing them of fine material. Water may be within 20 or 30 feet of the surface, but the pump handle yanks back quickly, indicating that the material is too tight to yield freely. Such wells must be coaxed. The pump should be worked slowly and patiently to draw out the fine material and create percolation into the well. Should the well choke from inflow of fine material the pump should be detached and the material should be bailed or washed out. As more clay, silt, and fine sand are brought out of the well the pumping may become more rapid. The result often is the creation of a pocket of coarse material about the bottom of the pipe, giving a free-yielding well.

There are several methods of coping with quicksand in tubular wells. If there is probability of coarse material beneath the quick sand the latter may be kept out by driving the casing through it. Sometimes quicksand is restrained by forcing to the bottom a large sponge or several small sponges wired together and weighted with small stones. Sometimes a brass strainer, closed at the bottom and about one-fourth of an inch less in diameter than the bore of the well and of a length to extend through the fine sand, is lowered to the bottom of the well. The casing is pulled up till its bottom is nearly flush with the top of the strainer. A tapered brass tube to the top of which is attached a lead packer is inserted at the joint. A swedge block or expander is lowered till it rests on the lead packer. A few blows suffice to expand the lead outward against the casing making a sand-proof joint between the strainer and casing.

Sometimes a strainer 4 to 6 inches smaller than the casing is employed. It is lowered from the surface by means of ordinary screw pipe cut in lengths convenient for handling. The strainer is provided with guides to center it in the bottom of the well, and coarse sand or fine gravel a little larger than the strainer openings is poured in at the top to fill the annular space between the strainer and casing. The sand filling may be brought to the surface of the ground and the whole outer casing drawn, leaving the pipe with which the strainer was lowered as the permanent casing. If it is desired to retain the original casing, the sand filling may end above the quicksand. The casing is drawn up until its bottom is above the quicksand. The pipe used to lower the strainer is unscrewed from the strainer and is removed from the well. Such portion of the casing as is above ground is cut off.

DRILLED WELLS

A drilling outfit is necessary where there is rock. A gasoline or steam drilling machine is generally used, and wells are put down by contract with persons equipped for the business. Recent contract prices for 6 to 8 inch cased wells vary from $3 to $5 per foot. The yield of drilled wells is sometimes increased by shattering the rock with dynamite. This is called "shooting" or "torpedoing" a well and may create openings to adjacent passageways carrying water. The method is less used than formerly, and in all instances, because of uncertain results and liability of damage to the well or loss of the existing supply, it should be employed only as a last resort.

FLOWING WELLS

Figure 13, *E* shows three flowing wells side by side on a Utah farm. Shallow flowing wells are usually short-lived. Artesian flows derived from strata outcropping in distant elevated localities frequently remain strong for many years. In general, however, there is a marked tendency toward exhaustion because of reduced pressure and the sinking of other wells tapping the same stratum. By using sound, heavy casing and valves to regulate the flow as needed, and by capping or plugging abandoned wells, farmers can aid greatly in conserving artesian supplies.

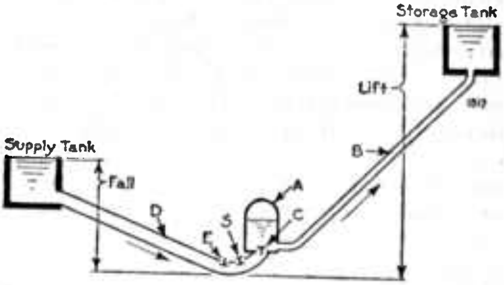

Fig. 17.—General layout of a hydraulic ram installation. *D*. Drive or supply pipe; *E*, escape valve; *C*, check valve; *A*, air chamber; *B*, delivery or discharge pipe; *S*, sniff or air valve

HYDRAULIC RAMS

Hydraulic rams are not mechanical toys. They are the most economical pumps known and have been used to raise large quantities of water. Two farm rams are shown in Figures 13, *C* and *D*. Hydraulic rams utilize the principle of water hammer. Their operation will be understood from Figure 17 and the following description: Water flows from the source of supply through a straight iron pipe *D*, wasting through escape valve *E* until the velocity is sufficient to force the valve outward to its seat. This creates a "kick" or water hammer in pipe *D* and opens check valve *C*, through which some of the flow is forced into air chamber *A* and delivery pipe *B*. The greater pressure in pipe *B* quickly overcomes the movement and causes a reaction or backward pulsation closing valve *C* and unseating valve *E*, whereupon the water in pipe *D* flows again and the whole operation is repeated. On the recoil, a little air is sucked through the sniff valve *S* to maintain the supply in chamber *A*.

The approximate quantity of water raised by a good ram, properly installed, may be estimated from Table 3.

Table 3.—*Quantity of water raised by a hydraulic ram*

Lift (feet) divided by fall (feet)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18	20
Gallons raised in 24 hours for each gallon per minute to the ram	605	370	280	195	150	120	100	85	70	60	50	45	40	35	22	16

Example: What quantity of water will be raised in 24 hours to a height of 48 feet above a ram receiving 3 gallons per minute from a spring 12 feet above the ram? Solution: Lift (48) divided by fall (12) equals 4; under 4 in Table 3, 1 gallon per minute to the ram raises 260 gallons in 24 hours; therefore 260 multiplied by 3 equals 780 gallons, the quantity of water that will be raised by the ram. If the delivery pipe is very long, the friction loss therein should be determined from Table 4 on page 23 and should be added to the lift (48 feet in the above example) to find the true pumping head.

Manufacturers of rams require the following information to determine the size needed for a particular installation: (1) Quantity of water in gallons per minute available at ram; (2) quantity of water in gallons per day desired at buildings; (3) available fall in feet; (4) horizontal distance in feet in which fall occurs; (5) length of delivery pipe in feet; (6) lift in feet. Manufacturer's instructions for installing should be closely followed, thereby fixing responsibility for results.

The minimum or the average flow should govern the size of the ram, as otherwise the one selected may be too large to be actuated by the dry-weather flow. Sometimes the flow of a spring is too small to operate a ram continuously. In such cases a float-controlled regulating valve shown in Figure 13, *F* may be used to stop and start the ram automatically. The valve is screwed on the upper end of the drivepipe, and opens quickly when the supply tank fills and closes quickly when the water falls to a permissible level. Sometimes a small spring is sufficient for actual home needs, but the power head must be obtained from a near-by brook. In such instances a double-acting ram is employed, utilizing the recoil to admit the spring water which is pumped by the brook water. Where the power supply is far from the ram, it is usual to pipe the flow to an open tank or standpipe located so as to secure the desired length and fall of drivepipe.

A hydraulic ram should be fastened to a suitable foundation and housed properly. The waste pipe from the ram pit should be of good size and not subject to backwater or other obstruction. Four-inch drain tile is often used. The drivepipe must be air-tight. Bends are a detriment, but if unavoidable should be of gentle curvature, leaving the bore unrestricted. For small installations, lead pipe is much better than iron. Full-way gate valves should be used to lessen friction. The upper end of the drivepipe, which may be made bell-shaped to facilitate entry of water, should be submerged at least a foot to prevent sucking air, and should have a strainer with openings totaling three to five times the cross-sectional area of the pipe. Rubber valves are less noisy than metal, but where the pounding is objectionable, as it may be in a dwelling, a piece of lead pipe or rubber hose inserted in the delivery pipe lessens or ends the trouble.

Every newly installed ram requires adjustment. Action may be induced by intermittently pressing down on the waste valve and allowing it to rise with the escape of water. The travel of the escape valve and the rapidity of its strokes should be regulated by experiment (by sight, sound, and inference). To illustrate: A ram running 37 strokes a minute used 13.1 gallons, of which 10.1 gallons were wasted and 3 gallons were pumped. When speeded to 72 strokes a minute the ram used only 4 gallons, of which 2.9 gallons were wasted and 1.1 gallons were pumped. If the escape valve remains up, excessive pressure or leakage in the ram is indicated. If the escape valve remains down, lack of fall or water is indicated. This difficulty can often be overcome partially by plugging two (one on each side) or more of the small holes in the plunger. Should the ram operate and discharge no water, lack of air in the air chamber or a leak in the delivery pipe is probable.

FRICTION LOSS AND PUMPING HEAD

Movement of water in a pipe produces friction, a form of resistance that increases with the length and roughness of the pipe and the rapidity with which the water moves. Wherever much water is to be delivered through a long pipe, the power or head necessary to overcome friction should be determined. This is called friction loss or friction head. Its effect is to increase the vertical height against which a pump operates. Bends, especially sharp turns, in a pipe line also increase the friction, but ordinarily the farmer may neglect this loss in discharge pipes. Excessive loss due to friction may be avoided by increasing the size of the pipe. Table 4[5] shows the friction head (number of feet to be added to the vertical height) for each 100 feet of iron pipe (not new) to overcome friction when discharging given quantities of water. The comparative discharging power of pipes of the several sizes also is shown.

TABLE 4.—*Friction head or loss and comparative discharging power of pipes*

Discharge in gallons per minute	Diameter of pipe in inches												
	¼	⅜	½	¾	1	1¼	1½	2	2½	3	4	5	6
	Friction loss in feet for each 100 feet length of pipe												
0.5	7.8												
1	28.0	6.4	2.1										
2	103.0	23.3	7.4	1.9									
3		49.0	15.8	4.1	1.26								
4			27.0	7.0	2.14	0.57	0.26						
5			41.0	10.5	8.25	.84	.40						
6				14.7	4.55	1.20	.56	0.20					
8				25.0	7.8	2.03	.95	.33	0.11				
10				38.0	11.7	3.05	1.43	.50	.17				
12					16.4	4.3	2.01	.70	.24				
14					22.0	5.7	2.68	.94	.32				
16					28.0	7.3	3.41	1.20	.41				
18						9.1	4.24	1.49	.50				
20						11.1	5.2	1.82	.61	0.25			
25						16.6	7.8	2.73	.92	.38	0.09		
30						23.5	11.0	3.84	1.29	.54	.13		
35							14.7	5.1	1.72	.71	.17		
40							18.8	6.6	2.20	.91	.22		
45							23.2	8.2	2.76	1.15	.28		
50								9.9	3.32	1.38	.34	0.11	
60								13.9	4.65	1.92	.47	.16	
70								18.4	6.2	2.57	.63	.21	
80								23.7	7.9	3.28	.81	.27	
90									9.8	4.08	1.00	.34	
100									12.0	4.96	1.22	.41	
120									16.8	7.0	1.71	.58	0.24
140									22.3	9.2	2.28	.76	.32
160										11.8	2.91	.98	.40
180										14.8	3.61	1.22	.50
200										17.8	4.4	1.48	.61
240										25.1	6.2	2.08	.86
Comparative discharging power of pipes[1]	.03	.08	.16	.47	1.0	1.8	2.9	6.2	11.1	18.0	38.3	68.9	111.3

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[1] Based on diameters raised to the 2.63 power. Discharge depends not only upon size of pipe but upon velocity of flow, a factor that changes with the relation of head of water to length of pipe. Inspection shows that doubling the diameter of a pipe increases the discharging power about 6 times, assuming like heads of water and like lengths of pipe. Assuming like velocities, doubling the diameter increases the capacity 4 times, because the areas of circles are proportional to the squares of their diameters. This table should not be used for pipes shorter than 500 times the interior diameter.

[5] Hydraulic Tables, Williams and Hazen, N. Y. 1909. Coefficient here used is 100, a fair value where the interior of iron pipe is roughened by 10 to 15 years' rust formation.

A column of water 1 foot high and having a base equal in area to 1 square inch weighs 0.43 pound. The pressure on the base is equal to the weight of the column. Double the height, and the weight and the pressure are doubled. Hence it may be taken for granted that the pressure of water at rest (static pressure or head) is in direct proportion to the vertical height or depth of the water. From the above Table 5 is computed.

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

Height	Pressure	Height	Pressure	Height	Pressure
Feet	*Pounds*	*Feet*	*Pounds*	*Feet*	*Pounds*
1	0.43	20	8.67	75	32.51
2	.87	25	10.84	80	34.68
3	1.30	30	13.00	85	36.85
4	1.73	35	15.17	90	39.01
5	2.17	40	17.34	95	41.18
6	2.60	45	19.51	100	43.35
7	3.03	50	21.67	110	47.68
8	3.47	55	23.84	120	52.02
9	3.90	60	26.01	130	56.36
10	4.33	65	28.18	140	60.69
15	6.50	70	30.35	150	65.03

Two examples are given to show the use of Tables 4 and 5. Example 1: How much water will be delivered by 500 feet of 1½-inch pipe from a spring 26 feet above the outlet? Solution: Multiply the head (26) by 100 and divide the product (2,600) by the length (500), giving 5.2. In Table 4 under 1½-inch pipe find 5.2 and follow to the extreme left to find the answer—20 gallons per minute. It is assumed that all the head is used to overcome friction and that the water emerges full bore of the pipe. Example 2: What is the pumping head where a pump is delivering 3 gallons a minute through 1,000 feet of 1-inch pipe to a hydropneumatic tank carrying 39 pounds per square inch situated 20 feet higher than the pump? Solution: To the vertical height water is raised (20 feet) must be added friction loss which is 1.26 feet for each 100 feet of length, or 12.6 feet; there must be added the equivalent height of the 39-pound tank pressure which from Table 5 is seen to be 90 feet; 20 plus 12.6 plus 90 equals 122.6 feet, the true pumping head.

PUMPS

If a perfect vacuum could be created in a pump cylinder at sea level, water would follow the plunger to a vertical height of 33.9 feet. This is called suction or suction lift. With elevation above sea level, air becomes lighter and suction becomes weaker. It will be helpful to see how the discharge of a pump diminishes as the suction lift increases. Figure 18 shows the results of a test close to sea level with an ordinary 1¼-inch pitcher pump. The diagram shows the discharge decreasing from 10.3 gallons per minute when the suction lift is low, to no discharge at 30 feet 2 inches, the extreme height to which the pump would draw. It is important to have a low suction lift but approximately three-fourths as much water was drawn when the lift was 22 feet as when it was 1 foot. On this basis Table 6 gives the limiting suction lift for the satisfactory operation of pumps at stated elevations up to 8,000 above sea level.

TABLE 6.—*Limiting suction lift of pumps (vertical distance from water level to top of cylinder)*

Elevation above sea level	Atmospheric pressure reduced to equivalent head of water	Limiting suction lift [1]	Elevation above sea level	Atmospheric pressure reduced to equivalent head of water	Limiting suction lift [1]
	Feet	*Feet*		*Feet*	*Feet*
Sea level	33.9	22.0	5,000 feet	28.0	18.2
1,000 feet	32.6	21.2	6,000 feet	27.0	17.5
2,000 feet	31.4	20.4	7,000 feet	26.0	16.9
3,000 feet	30.2	19.6	8,000 feet	25.0	16.2
4,000 feet	29.1	18.9			

[1] Taken as 65 per cent of the heads shown in the second column.

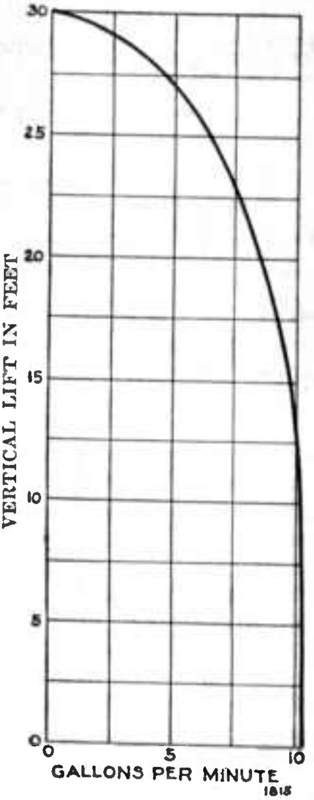

FIG. 18.—Diagram showing how the discharge of a pump varies with the suction lift

Suction pipes may be long provided the friction loss (see Table 4) plus the vertical height from water level to pump valve does not exceed the limiting suction lifts shown in Table 6. Lengths of 100 to 1,000 feet are frequent. An ordinary pitcher pump raised 5 gallons per minute through 320 feet of 1¼-inch pipe having two elbows, a foot valve, and a vertical height approximating 19 feet. Suction pipes should be straight, air-tight, slope uniformly upward from well to pump, and never be smaller than the pump suction connection. Long suctions should be larger than such connection and should have a foot valve and strainer on the end in the well.

Pumps may be divided into two classes—suction and force, or a combination of these types. A suction pump has the cylinder above the water; it does not raise water above the pump nor discharge it against pressure. A force pump can raise water above itself and against pressure. The general arrangement of valves in these two types of pump and in a deep-well pump is shown in Figure 19.

Where a pump is more than 22 feet above the water it is necessary to lower the cylinder. Where the water is 22 to 30 feet below the surface, a set-length pump may be used. This pump has the pipe and rod lengthened to permit placing the cylinder several feet below the well platform. A drip hole may be drilled in the pipe just above the cylinder, thus allowing the water above to escape and, provided the platform is tight, preventing freezing. By lengthening the pipe and rod and by using a small cylinder lowered into or near the water, this type of pump may be used in wells 75 or more feet in depth.

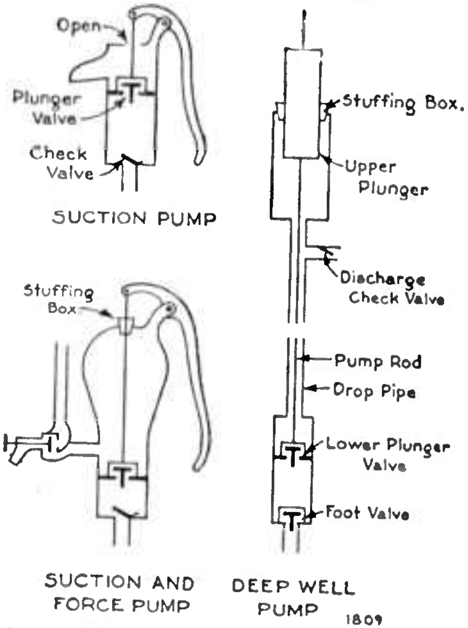

FIG. 19.—General arrangement of valves and plungers in suction, force, and deep-well pumps

Where the water is far below suction lift, a deep-well pump driven by power is generally used. The working head is placed over the well, and pump rod and drop pipe are lengthened to permit setting the lower cylinder in or close to the water. Submergence is best because it keeps the cylinder primed and the pump leathers pliable. Deep-well pumps are usually single acting; that is, water is lifted on the up stroke. This brings a heavy, variable load on the working parts, and an upper or differential cylinder in or just below the working head is employed to divide the work between the up and down strokes. In this way the water that is lifted to the surface by the up stroke of the lower plunger is forced to the discharge pipe by the down stroke of the upper plunger.

It is a great convenience, especially in wells 75 or more feet in depth, to use an open-type cylinder fitted for drop pipe one size larger, to facilitate pulling up the lower plunger for renewal of leathers or other parts. A closed-type cylinder with smaller drop pipe requires drawing cylinder, pump rod, and drop pipe. The two types of cylinder are shown in Figure 20. The size of the cylinder should always be determined from the size, depth, and yielding power of the well, the hours within which the daily requirements are to be pumped, and the available power. Ordinarily the day's pumping is done in one to three hours. Deep wells and hand and windmill outfits take the smaller cylinders; the advice of a reliable dealer or manufacturer whose product is to be used should always be obtained. Table 7 shows the capacity of pumps per stroke for one single-acting cylinder.

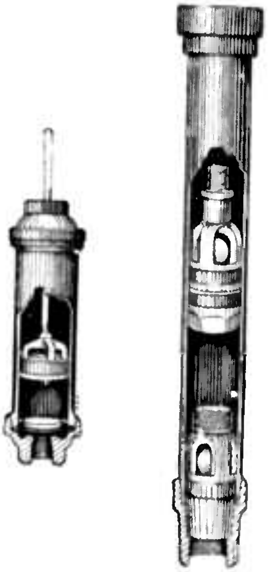

FIG. 20.—Closed and open cylinders

TABLE 7.—*Capacity of pumps*[1]

Diameter of cylinder in inches	Length of stroke in inches								
	2	3	4	5	6	7	8	10	12
	Capacity per stroke in gallons								
1	0.007	0.010	0.014	0.017	0.020	0.024	0.027	0.034	0.041
1¼	.011	.016	.021	.027	.032	.037	.042	.053	.064
1½	.015	.023	.031	.038	.046	.054	.061	.077	.092
1¾	.021	.031	.042	.052	.062	.073	.083	.104	.125
2	.027	.041	.054	.068	.082	.095	.109	.136	.163
2¼	.034	.052	.069	.086	.103	.120	.138	.172	.207
2½	.042	.064	.085	.106	.127	.149	.170	.212	.255
2¾	.051	.077	.103	.128	.154	.180	.206	.257	.308
3	.061	.092	.122	.153	.184	.214	.245	.306	.367
3¼	.072	.108	.144	.179	.216	.251	.287	.359	.431
3½	.083	.125	.167	.208	.250	.291	.333	.416	.500
3¾	.096	.143	.191	.239	.287	.335	.383	.478	.574
4	.109	.163	.218	.272	.326	.381	.435	.544	.653
4½	.138	.206	.275	.344	.413	.482	.551	.688	.826
5	.170	.255	.340	.425	.510	.595	.680	.850	1.020
5½	.206	.308	.411	.514	.617	.720	.823	1.028	1.234
6	.245	.367	.490	.612	.734	.857	.979	1.224	1.469

[1] Plunger displacement. No allowance for slip of water past valves. For double-acting cylinders multiply by two. For a longer stroke than shown in the table add the capacities of two shorter strokes to make the required length of stroke.

Figure 21 shows pumps of the kinds described. In selecting a pump the following information should be known: (1) The kind of well, inside diameter, depth to bottom, depth cased, depth to water level both at rest and when pumping, and the sustained yield, as found by test, in gallons per minute (see "Ground Water Supplies," page 12, and "Wells," page 14); (2) the maximum quantity of water required at buildings, gallons per hour or day; (3) distance from well to proposed location of pump and the vertical height between these points; (4) distance from pump to reservoir or tank, and the vertical height between these points; (5) kind of power.

If electricity is to be used the following information should be obtained from the local light or power company: The voltage, if the current is direct, the voltage, cycles, and phase, if the current is alternating. With the above information a reliable manufacturer or dealer will be able to select suitable equipment and the farmer can check the suitability of the selection.

PUMPING WITH COMPRESSED AIR

AIR LIFTS

Air lifts are useful in raising large quantities of water from deep wells. Compressed air is led through a small pipe deep into a well, and is there released in an upward direction through numerous small holes in the side of a nozzle-shaped foot piece to which is screwed a vertical pipe for the delivery of water to the surface. The air, as small jets or bubbles in contact with water, rises and expands within the delivery pipe, carrying with it and ejecting some of the water. To secure the best results, the submergence and the size and arrangement of air and water pipes for each installation should be determined by the manufacturer or others experienced in the work. Air lifts have no moving parts in the well. The main advantages are simplicity, durability, large capacity, noninterference by cold,

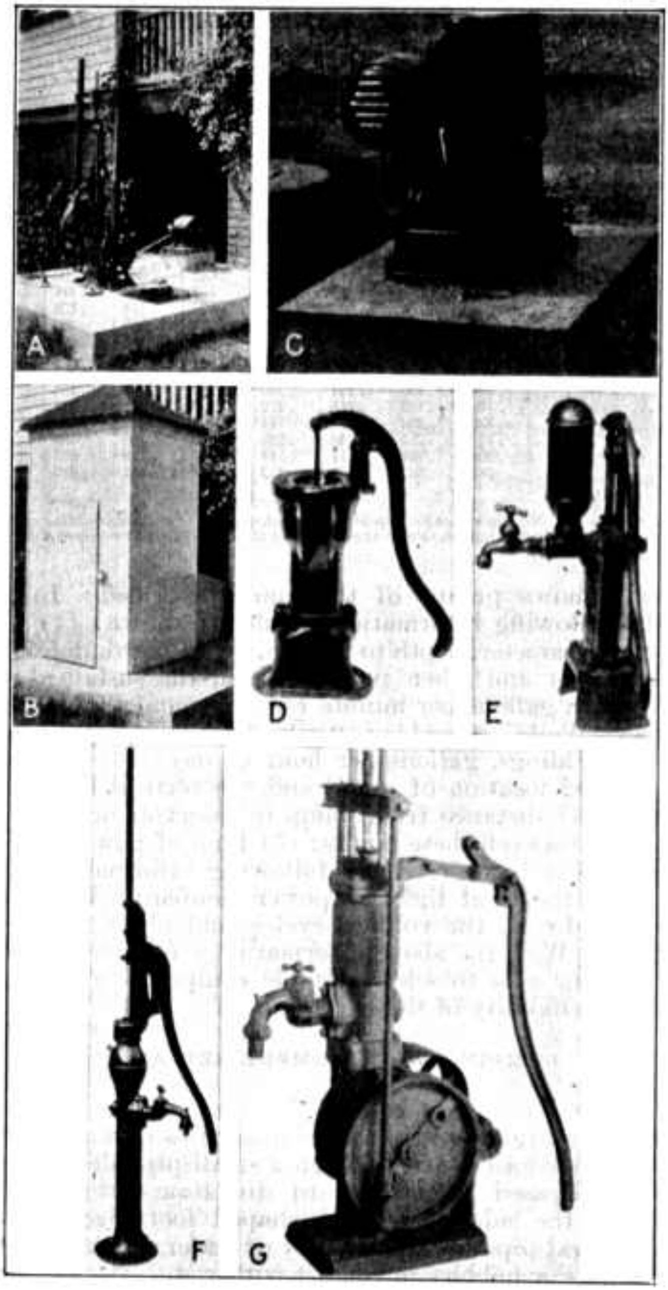

FIG. 21.—Pumps. *A*, Pumping jack and force pump with underground and spout discharge controlled by hand wheel; *B*, after completion of improvements; *C*, pumping unit consisting of deep-well pump, underground discharge, electric motor with a worm-gear drive inclosed in a weatherproof housing; *D*, pitcher spout pump; *E*, house force pump; *F*, hand and windmill force pump with front and back outlets; *G*, power working head for shallow or deep wells, front and back outlets, belt drive adjustable stroke

grit or sand, and adaptability to drawing from a crooked well or from several widely-separated wells with one power outfit. Disadvantages are cost, low efficiency unless correctly designed and installed, and tendency of the air to slip over the water where the horizontal discharge distance is great. An air lift is often used to raise water to the surface, after which it is pumped by other means.

AIR-DISPLACEMENT PUMPS

An air-displacement pump consists of a submerged cylinder or cylinders from which water is automatically displaced by compressed air, the operation of the pump being wholly controlled by opening and closing any faucet on the water-delivery pipe. No water is stored, and the pump is at rest when faucets are closed. The chief advantage of the system is that water may be taken from one or several sources with one power outfit and delivered direct from well to faucet. The system is not cheap and is not as simple as some other methods of raising water. Pipes and pumps must be tight and remain tight in service and the working parts be maintained in good order.

Air lifts and air-displacement pumps require some method of compressing and storing air. Figure 22, *E*, shows these parts in a typical air-displacement pump installation; they consist of a gasoline engine, air compressor, air tank, and air pipe to the well in the foreground, and water pipe from the well. The air-displacement pump is submerged in the well; if desired, an air-lift foot piece could be employed.

POWER

The theoretical horsepower necessary to raise water is found by multiplying the gallons pumped in one minute by the total lift in feet, including friction in both suction and discharge pipes, and dividing the product by 4,000. To overcome losses in the machinery the theoretical horsepower is generally multiplied by 3 to 4 for electric-driven pumps and by 4 to 6 for pumps driven by gasoline engine. Ordinarily half-horsepower motors and 1-horsepower engines are sufficient for farm pumping, but it is safest to compute the amount of power needed and to get the advice of a reliable pump concern. Table 8 shows the actual horsepower required to pump water, assuming an overall efficiency of 25 per cent (actual four times the theoretical).

TABLE 8.—*Horsepower required to pump water (based on overall efficiency of 25 per cent)*

Gallons per minute	Lift in feet									
	50	60	70	80	90	100	125	150	175	200
	Horsepower required									
2	0.10	0.12	0.14	0.16	0.18	0.20	0.25	0.30	0.35	0.40
3	.15	.18	.21	.24	.27	.30	.38	.45	.53	.60
4	.20	.24	.28	.32	.36	.40	.50	.60	.70	.80
5	.25	.30	.35	.40	.45	.50	.63	.75	.88	1.00
6	.30	.36	.42	.48	.54	.60	.75	.90	1.05	1.20
7	.35	.42	.49	.56	.63	.70	.88	1.05	1.23	1.40
8	.40	.48	.56	.64	.72	.80	1.00	1.20	1.40	1.60
9	.45	.54	.63	.72	.81	.90	1.13	1.35	1.58	1.80
10	.50	.60	.70	.80	.90	1.00	1.25	1.50	1.75	2.00

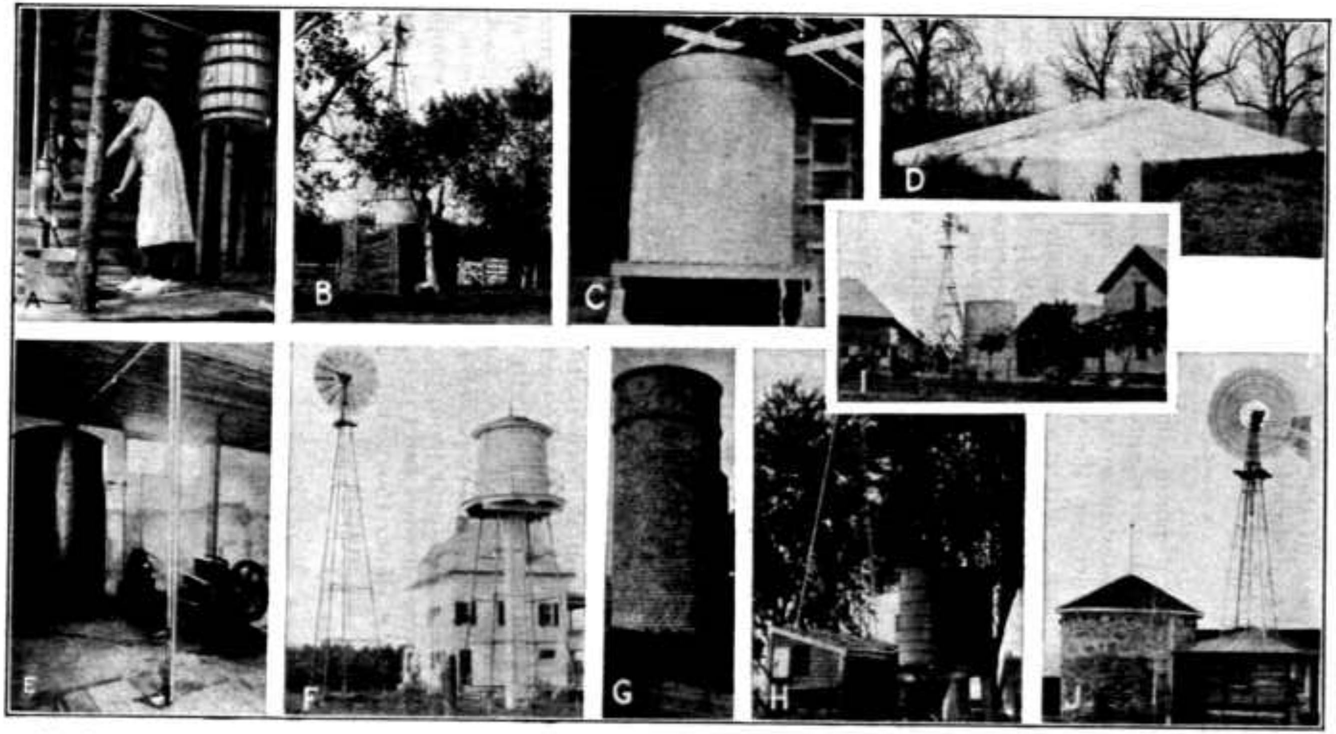

FIG. 22.—Pumping and storing water. *A*, Pumping to a wood barrel, faucet in the kitchen; *B*, galvanized steel tank protected by straw; *C*, galvanized tank in barn loft; note the bulge caused by ice near the top; *D*, square concrete, underground tank; *E*, pumping with compressed air; *F*, a serviceable installation; *G*, water tank on top of a clay tile silo; *H*, wood tank 8 by 8 feet; supply pipe wrapped with burlap and enclosed in a wood box packed with cinders; *I*, concrete standpipe; *J*, attractive rubble masonary tank

Hand power is unsuited to large supplies or high lifts. Windmills are more extensively used for pumping water than any other source of power, and if well installed and maintained give good low-cost service. In selecting an outfit, the prevailing wind velocity, the size of the wheel, the diameter of the cylinder, and the lift should be considered to avoid overloading. Windmills are generally loaded in the Middle West to operate in 15-mile winds, starting to pump in a 6 to 8-mile wind, doing excellent work in a 15-mile wind, and reaching the maximum in a 25 to 30-mile wind. In mountainous regions windmills are generally loaded for a 10-mile wind. With the exception of Kansas and a few other states the most desirable wind velocities for pumping rarely prevail as much as one-third of the time.[6] The most common cause of overloading comes from using a cylinder excessively large in diameter. The longer periods of operation by small cylinders as compared to large cylinders, enables the former, in the course of a season or year, to pump more water. Cylinders and mills which have long, slow strokes are recommended. Recommendations and claims as interpolated from the catalogues of different manufacturers of back-geared windmills are given in Table 9.

TABLE 9.—*Approximate capacity of windmills (from manufacturers' ratings)*

Lift	Velocity of wind per hour	Diameter of wheel							
		6 feet		8 feet		10 feet		12 feet	
		Diameter of cylinder	Capacity per hour	Diameter of cylinder	Capacity per hour	Diameter of cylinder	Capacity per hour	Diameter of cylinder	Capacity per hour
Feet	*Miles*	*Inches*	*Gallons*	*Inches*	*Gallons*	*Inches*	*Gallons*	*Inches*	*Gallons*
25	10	2½	140	3½	320	4¼	420	5½	1, 010
35	10	2	120	3	270	4	360	5	675
50	10	1¾	110	2¾	180	3½	305	4	520
75	10	------	------	2½	135	3	235	3	365
100	10	------	------	2	105	2½	160	2¾	265
125	10	------	------	1¾	90	2	125	2½	200
25	15	3½	250	5	560	7	1, 190	9	2, 190
35	15	3	175	4	400	6	880	7	1, 595
50	15	2½	125	3½	280	5	610	6	1, 165
75	15	2	85	2¾	190	4	375	5	760
100	15	1⅞	60	2½	140	3½	305	4½	565
125	15	------	------	2¼	115	3¼	250	3¾	450

Gasoline and oil engines are well adapted to farm pumping and may be equipped to stop at any desired pressure in the tank supply. Hot-air engines have had considerable use. The use of electricity for pumping is increasing rapidly. The method is clean, quiet, and convenient, and stopping and starting a distant pump by throwing a switch may be a reality wherever transmission lines are so near as to make this power available. Electric motors may be had in small sizes and low powers and may be arranged to start and stop automatically with changes in the tank pressure; two installations are shown in Figures 21 *C* and 25 *C*.

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[6] Information on the velocity and prevalence of wind may be obtained from the U. S. Weather Bureau, Washington, D. C.

STORAGE OF WATER

ELEVATED TANKS

Water may be stored in wood, steel, or masonry tanks, and to secure gravity delivery the tank must be elevated above all faucets. Tanks placed in attics, barn lofts, and upon light trestles are unsatisfactory. The objections relate to insecurity and leakage, lack of pressure, and unwholesomeness in summer and freezing in winter. Masonry tanks may be placed on a hill, silo, or masonry tower. Where possible, an underground concrete tank on a hill is very desirable, avoiding trouble with frost and giving a tempered and sure supply. Tanks should hold more than one day's supply. For windmill supplies the requirements of a week or more may be needed at times. Tanks should be provided with a waste pipe and valve to facilitate emptying and cleaning, and without fail should be covered tightly for protection against heat, cold, dust, vermin, and sunlight. Where exposed to light, ground and filtered waters are liable to develop growths which impart objectionable odor, taste, or appearance. Figures 22, 23, and 24 show a number of poor and good tanks.

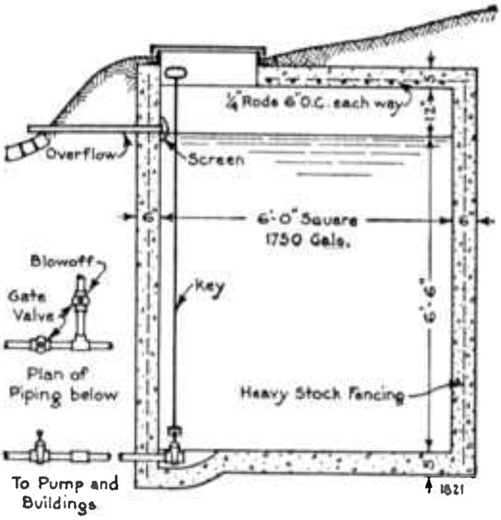

FIG. 23.—Working drawing for a square, reinforced concrete, underground tank. Very convenient when emptying and cleaning a tank, to have a valve on the supply pipe and a valve on a branch pipe or blow-off ending above ground and graded to drain the higher situated pipe and tank; closing the main valve and opening the branch valve empties the tank

HYDROPNEUMATIC TANKS

Water may be stored and delivered to the faucet by the use of a hydropneumatic (water-air) tank. The tank need not be elevated and usually is conveniently located in a utility room, basement, or cellar. Hydropneumatic tanks must be absolutely air-tight. Air being lighter than water occupies the upper portion of the tank, and it presses with increasing force against the water as either more water or more air is pumped into the tank. When air and water are under pressure the latter gradually absorbs the former, and this absorption is the more rapid the higher the pressure. From time to time, therefore, the air supply must be replenished, or the tank becomes water-logged. Maintenance of the air supply is a vital factor. Inlet and outlet pipes must enter at the bottom of the tank. Hydropneumatic tanks are made of three-sixteenths inch or thicker steel with riveted and welded or calked joints. A range boiler or other thin-walled tank should not be used for this purpose. The smaller tanks generally are galvanized and may set vertically or horizontally; the larger tanks are set horizontally. Figures 25 *A* and *C* show typical installations.

To obtain the best service from a hydropneumatic tank it is necessary to carry an initial or excess air pressure; that is, enough air to give pressure when no water is in the tank. Table 10 shows what percentage or fractional part of any tank, either vertically or horizontally set, contains water under varying conditions of gage pressure and initial air pressure.

TABLE 10.—*Quantity of water in fractional part of total capacity of any hydropneumatic tank (based on atmospheric pressure of 14.7 pounds per square inch)*

Gage pressure (lbs.)	Initial air pressure in pounds						Gage pressure (lbs.)	Initial air pressure in pounds					
	0	5	10	15	20	25		0	5	10	15	20	25
5	0.25	------	------	------	------	------	45	0.75	0.67	0.59	0.50	0.42	0.34
10	.40	0.20	------	------	------	------	50	.77	.70	.62	.54	.46	.39
15	.51	.34	0.17	------	------	------	55	.79	.72	.65	.57	.50	.43
20	.58	.43	.29	0.14	------	------	60	.80	.74	.67	.60	.54	.47
25	.63	.50	.38	.25	0.13	------	65	.82	.75	.69	.63	.56	.50
30	.67	.56	.45	.34	.22	0.11	70	.83	.77	.71	.65	.59	.53
35	.70	.60	.50	.40	.30	.20	75	.84	.78	.72	.67	.61	.56
40	.73	.64	.55	.46	.37	.27	80	.85	.79	.74	.69	.63	.58

Table 10 has many uses. It shows that if water is pumped into a tank having no pressure above that of the atmosphere until the gage shows 5 pounds, the tank will be one-fourth (0.25) filled with water; at 15 pounds it will be about one-half (0.51) full; at 30 pounds it will be two-thirds (0.67) full; at 45 pounds it will be three-fourths (0.75) full; at 60 pounds it will be four-fifths (0.80) full. An example will be helpful: Suppose a 220-gallon tank is half full of water under a gage pressure of 45 pounds and it is desired to know what quantity can be drawn before the pressure reaches 25 pounds. Inspection of Table 10 shows that if half (0.50) full at 45 pounds the initial air pressure must be 15 pounds, and under that excess a tank is one-fourth (0.25) full at 25 pounds gage pressure. Therefore, 0.50 minus 0.25 equals 0.25, which, multiplied by 220, equals 55 gallons, the available quantity. In general, the working capacity of a tank is from one-fourth to one-third of its total capacity.

PLANNING A SYSTEM

Sufficient information has been given to enable the farmer to outline his plans. An example will be helpful. Suppose a plant is desired to meet the needs of 5 persons, 25 cattle (including horses or mules), 50 sheep, and 50 hogs. The average daily requirements (see Table 1) would be as follows:

	Gallons
5 persons at 40 gallons each	200
25 cattle at 12 gallons each	300
50 sheep at 1 gallon each	50
50 hogs at 1 gallon each	50
Total	600

A suction pump would be used with a shallow supply (see Table 6); a deep-well pump or set-length pump would be used with a deep supply. A suction pump probably would be located in a dry, frost-proof basement, pump house, pit, or underground concrete chamber opening into the house cellar. A deep-well pump probably would be outside of main buildings: if in a pit or chamber, there should be a manhole over the center of the well to permit pulling up the pump rod and drop pipe.

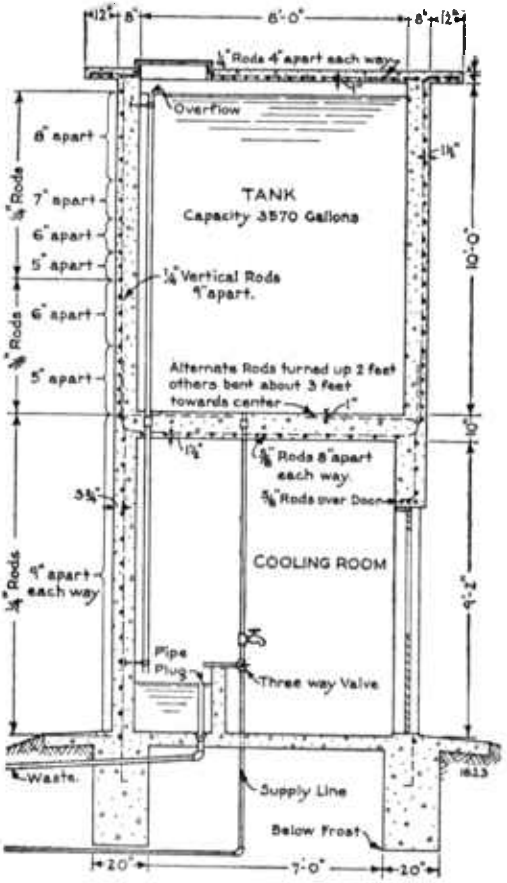

Fig. 24.—Working drawing for a combined cooling room and round reinforced concrete tank. Suggested mixtures for concrete: Tank walls and tank bottom 1 : 2 : 3 (1 volume cement, 2 volumes sand, 3 volumes stone, none larger than ¾ inch); cooling room walls 1 : 2 : 4; foundation 1 : 2½ : 5

To do the day's pumping in two hours would require a pump having a capacity of 300 gallons per hour or 5 gallons per minute. The more constant the power, the more reliable the equipment, and the more accessible the repair parts the less is the need of large water storage. An automatic electric-driven pump (see fig. 25 *C*) may have a pressure tank varying in capacity from 10 gallons upward. It would be arranged to start pumping when the pressure falls to 25 or 30 pounds per square inch and to stop when the pressure reaches 45 or 50 pounds. With very small tanks any considerable use of water starts the pump and delivers water by direct pump pressure. The smaller pumps and tanks are especially useful for cistern and other household supplies, but the pump capacity (5-gallons per minute) figured in the example, would give fair discharge from one garden hose nozzle or two ordinary spray nozzles or two house faucets. Faster use of water would require a larger tank; a tank 30 inches in diameter by 6 feet long, 220 gallons capacity (water and air) should be sufficient for short heavy drafts, having a working capacity of approximately 50 gallons (oil barrel capacity) between the usual stopping and starting pressures noted above. If electric current cost 15 cents per kilowatt-hour the cost of pumping 600 gallons would approximate 14 cents per day.

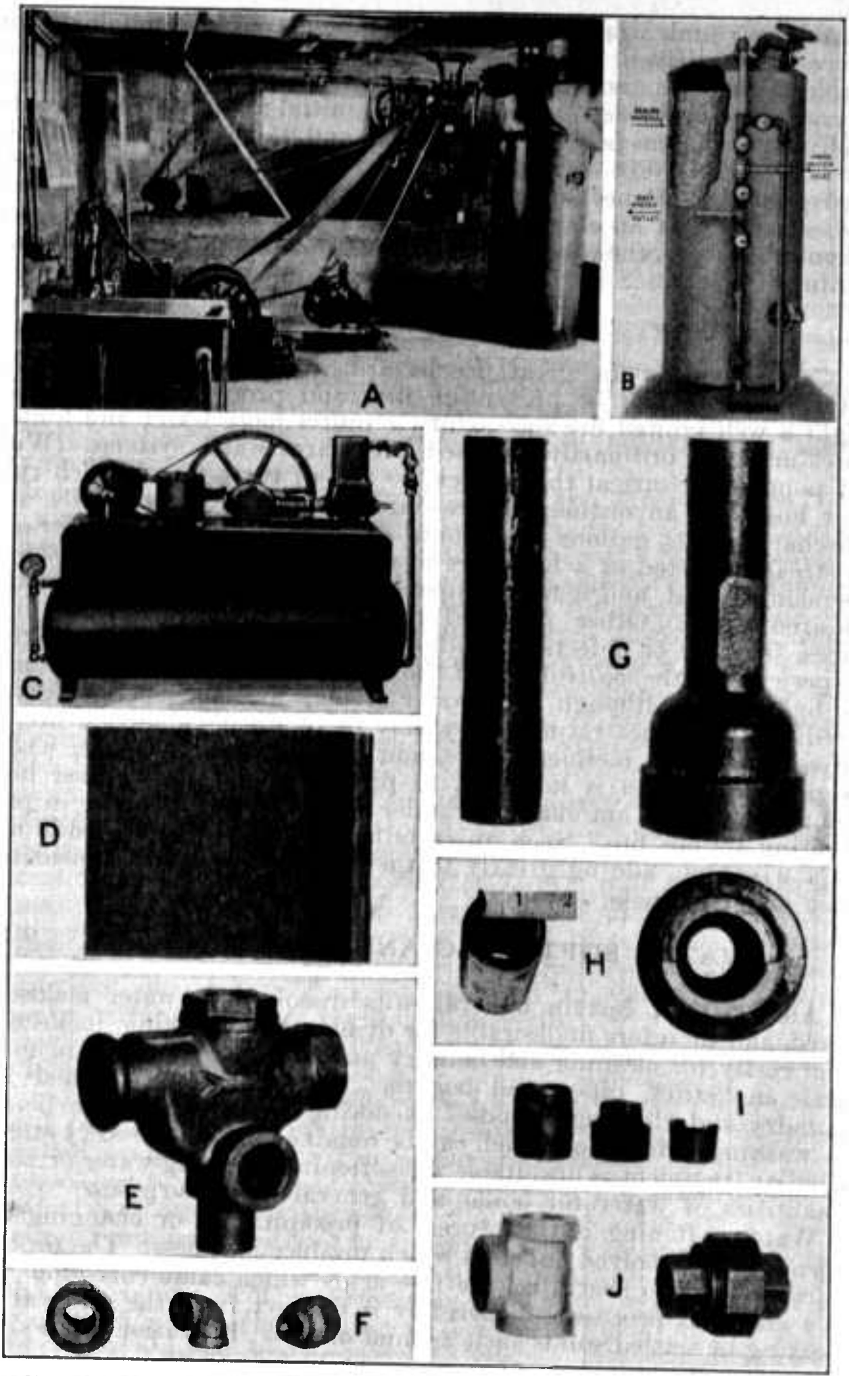

FIG. 25.—*A*, Hydropneumatic tank in basement; *B*, water softener—zeolites in a steel tank; *C*, automatic hydropneumatic tank system; *D*, bore of small, cast-iron water pipe after 35 years' use; *E*, a cold water valve for use on automatic systems; *F*, one-inch black wrought pipe lined with cement to a ¾-inch bore; bore clear after 40 years in the ground; elbow; reducer; *G*, side view of short pieces of 1¼-inch, hub and spigot, cast-iron pipe with foundry prepared lead joint ready for calking: *H*, end view of pipes shown in *G*; *I*, close nipple; plug; face bushing; *J*, tee; union

A larger tank would be used if the pump were not automatic or were engine-driven. Under those circumstances a hydropneumatic tank 42 inches in diameter and 14 feet long, 1,000 gallons total capacity would be suitable. With 20 pounds initial air pressure, it would deliver 290 gallons between pressures 45 and 25 pounds. (See Table 10: 0.42 minus 0.13 equals 0.29, which, multiplied by 1,000, equals 290 gallons.) Hence it would be necessary to operate the pump twice a day. If an elevated tank were to be employed its capacity should be larger, the equivalent of the tank shown in Figure 23 being suitable.

FIRE PREVENTION

Carelessness is the great fire hazard, and the watchword upon every farm should be prevention first and protection second. To fight a well-ignited fire successfully requires more water and higher pressure than ordinarily obtained with farm water systems. With 57 pounds pressure at the sillcock, 50 feet of three-fourths-inch rubber hose and an ordinary three-sixteenths-inch 75-cent nozzle, the discharge is 7½ gallons per minute—less than three pailfuls. Such a stream directed at a large fire avails little, on account of its dispersion by heat, and it may happen easily that no water reaches the desired point. Other practical difficulties relate to frozen pipe lines, shortage or defects in the hose, misplaced nozzles, and lack of experience in the skillful use of the equipment when the time comes to fight fire. Although farm water systems are not generally given credit in insurance ratings, they may be of great value if a fire be discovered in its incipient stage, and it undoubtedly is wise, where a pressure system is installed, to provide a few well-placed hose connections. An automatic sprinkler system is very effective in preventing serious fire. Such an installation in costly farm buildings is a wise step, adding greatly to the value of the plant considered as a going business.

WATER SOFTENING AND IRON REMOVAL

An excess of certain mineral salts dissolved in water makes it hard, and therefore undesirable for drinking and cooking, ineffective and costly for cleaning and laundry purposes, and causes it to form scale in kettles, pipes, and boilers. Water may be softened for laundry and cleaning purposes by dosing it with ammonia, borax, or washing soda, all of which can be obtained at most grocery stores. Similar treatment is unsuitable for softening drinking water or large quantities of water for boiler and general farm purposes.

Water softening is the process of precipitating or changing the form of the dissolved minerals which produce hardness. The process further seeks to neutralize the free acids which cause corrosion. It is a chemical process and therefore is distinct from the removal of floating or settled solids such as mud or silt. Filtration alone does not soften water.

The principal hardening constituents are the carbonates, sulphates, and chlorides of lime and magnesia. The principal scale forming constituents are the carbonates and sulphates of lime and magnesia, and usually more or less solid matter such as mud or silt.

Hardness caused by lime and magnesia carbonates held in solution by carbonic acid may be partly removed by boiling the water which drives off the acid or by adding lime water or caustic lime which neutralizes the acid. Hardness caused by the sulphates of lime and magnesia is not removed by boiling but may be partly removed by adding soda-ash. Such water may be treated chemically to form a more or less insoluble precipitate which may be removed by sedimentation followed by filtration.

A group of impurities found in alkaline waters are sodium chloride (common salt), sodium sulphate (Glauber's salt), and sodium carbonate (soda ash). The first two constitute what is known as white alkali, and the third constitutes black alkali. These compounds are nonscale forming, but their presence in more than normal amounts makes water unfit for domestic consumption. The sodium salts are very soluble in water. They are not precipitated by heat or chemicals nor are they removed by filtration, but they may be removed by distillation.

Household water softeners are on the market. In every instance the water should be analyzed by a trained chemist to determine the proper treatment. The United States Department of Agriculture is unable to undertake the analysis or other examination of samples of water submitted by individuals, since its authority for work of this kind is restricted to official samples collected by the department. No doubt many of the states are similarly restricted with respect to analyses for individuals. However, those knowing of no private chemist who makes water analyses and who desire to employ one can usually obtain information regarding competent chemists who would be in a position to make these analyses by addressing the State health officer, the State chemist, the director of the agricultural experiment station, or the professor of chemistry in the State or other university. Many manufacturers of water softeners have laboratory facilities and do analytical work without charge to prospective customers. Not less than one-half gallon of water is required for an analysis. The water should be carefully collected in a clean bottle. The sample should be representative of the whole supply and should be packed with sawdust or similar material in a box or carton to prevent breakage or freezing.

Figure 25 *B* shows a water softener of the zeolite type suitable for home use and costing from $175 upward, according to the size and make. The names and addresses of manufacturers can be obtained from trade and equipment directories, which can often be consulted in public libraries or commercial houses. Operation of this softener is not difficult or costly, common salt being the only chemical the householder uses to maintain it. Zeolites are hydrous aluminum sodium silicates, a hard granular mineral product insoluble in water and having the power to exchange its sodium for an equivalent amount of the calcium and magnesium in the hard water passing through it. The quantity of dissolved mineral matter in the water is not reduced, but its form is changed. The life of the zeolite material is maintained by adding at the top from time to time a 10 per cent solution of common table salt. The amount of salt and the frequency of applying it vary with the hardness of the water and the quantity of water used in the home. A report on one installation states that 300 gallons of water are softened by one charging of 8 pounds of salt; another states that 600 pounds of salt a year softens 37,500 gallons of water.

Many waters, clear when drawn, contain dissolved iron which upon release of pressure and exposure to air settles out as a rusty-looking sediment. Such water is likely to cause rust spots on laundry work and is undesirable for other household purposes. Water of this kind can usually be improved by thorough aeration, followed by a period of rest to settle the precipitate, and filtering the uppermost water through muslin, linen, cotton duck, or sand. The precipitation of the iron is hastened by adding a little (determine the quantity by trial) limewater, a simple and safe solution obtainable at drug stores or easily and cheaply made at home. Limewater is prepared as follows: Put a small lump of fresh quicklime (caustic lime) in a wood pail and slake the lime by gradually adding about 30 times its weight of water. Stir or shake frequently during one-half hour, allow time to settle, and reject the liquid. Add to the lime residue about 300 times its weight of water, stir frequently during the next 24 hours, and allow the lime to settle. The clear water above the undissolved lime is limewater, and should be kept for use in large well-corked bottles or carboys. There is some saving if the undissolved lime is bottled with the limewater, every time some of the limewater is used adding a like quantity of fresh water.

Water containing iron can frequently be improved for laundry purposes by adding a little limewater or washing soda to the water in a tank or vat, stirring thoroughly, allowing the iron to settle to the bottom, and drawing off the uppermost (clearest) water for use. The water drawn off should be filtered through cloth or other material, but this is not always done because of the inconvenience. Long boiling of water is an aid to the precipitation of iron, but the method is generally impractical. Apparatus for the removal of iron is upon the market, and the names and addresses of manufacturers can be obtained from trade directories on file in many public libraries.

Iron removal and water softening are subjects not easily understood by the ordinary individual. Examination of the water is always necessary to determine the proper treatment. (See page 37.) The apparatus and piping should be adapted to the work to be done, and should be suitably housed to protect from frost. The apparatus is costly, and its operation can not be neglected. Individuals who can afford such plants or groups of farmers combining to install them can obtain very good results, provided proper attention is given to the operation of the plant.

PIPES AND FITTINGS

Galvanized wrought-iron or steel pipe screwed into galvanized, beaded, malleable-iron fittings is generally used for farm water piping. At greater cost, more lasting, cleaner-bore pipe, such as cast iron, brass, tin-lined lead, or cement-lined wrought, is available. Some of these pipes and the more common screw fittings are shown in Figures 25, *F*, *G*, *H*, *I*, and *J*. Further information on pipe materials and sizes and methods of jointing, laying, and protecting pipes is given in Farmers' Bulletin 1426, "Farm Plumbing."

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1925