Dairy Div

WATER SYSTEMS FOR FARM HOMES

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A WATER SYSTEM that will provide a wholesome supply for family use, prove serviceable for farm uses, be as nearly permanent as may be made, and cost the least has been one of the four principal utility problems of the average farmer. The aim of this bulletin is to give to farmers, county agents, and others basic information concerning sanitary and engineering principles underlying safe, serviceable, and lasting water systems for farmhouses.

WATER SYSTEMS FOR FARM HOMES.

CONTENTS.

INTRODUCTION.

A GOOD WATER SUPPLY, a complete sewage-disposal plant, and effective heating and lighting systems constitute the four prime utilities of the farm home, the foundations of safe, comfortable living. To secure these ends in greatest measure, thought and planning are necessary. If the procedure is haphazard, if the parts are not correlated, there is neither economy in the construction nor satisfaction in the operation of the plant. To illustrate: When locating the well, the direction of surface and underground drainage should be considered, to the end that the water supply may not be contaminated by the sink drain, cesspool, or other sources of filth. The unused water from a spring or flowing well may be made valuable if brought to a watering trough, cooling tank, fish pond, or swimming pool, or harvested as ice. A saving may be effected by laying two lines of pipe in one trench. The engine which drives the pump may operate other useful appliances, such as a dynamo, saw, washing machine, cream separator, or churn. Figure 1 suggests a utility room built as an addition to a farmhouse having few improvements and no cellar. Attention is directed to the convenience of a laundry and a lavatory and a warm, dry room just off the main part of the house where farm hands can wash, and in stormy weather deposit their wet coats, boots, and shoes. A notable example of home-planned utilities is found upon a farm in northern Utah. By personal planning and hard work, the owner of this farm gradually has equipped his house with a pressure water system, a laundry containing a power washing machine, wringer, mangle, and drying machine, a heating plant, electric lights, electric range, electric heaters for emergency use in chambers, and a vacuum cleaning system.

SANITARY ASPECT OF FARM WATER SUPPLY.

Observation indicates that on the average three out of four farm wells are located within 75 feet of the back door of the house and in the direction of the barn. That convenience and first cost—not safety—have been the deciding factors in thousands of such locations is a fact made evident by the proximity of barnyards, pig pens, pastures, fertilized fields, sink drains, privies, cesspools, and house

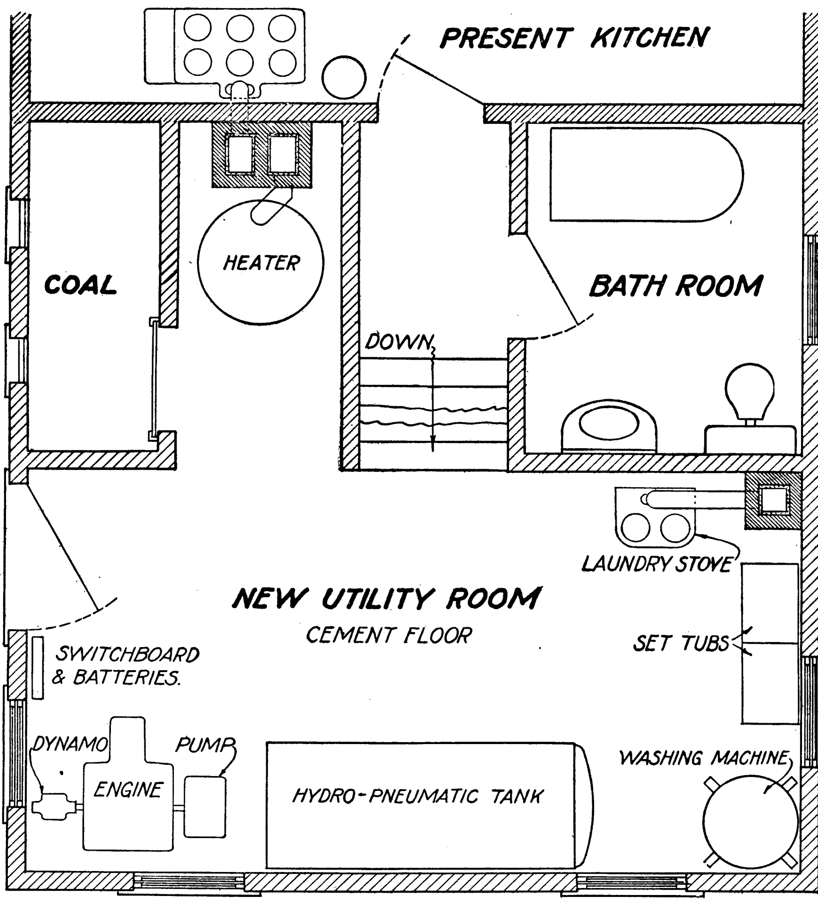

FIG. 1.—Suggested utility room for a farmhouse having few improvements and no cellar.

yards rendered insanitary by chickens, slops, garbage, and other filth. Too frequently the leach from these or other sources of filth, after joining the ground water, moves with greater or less directness to wells and springs, seriously impairing the water supply by organic impurity or grossly poisoning it with human sewage.

Among other ways by which surface waters and open or poorly covered wells and springs are contaminated or receive noxious substances are: Surface wash from roads, ranges, or the other sources of filth above mentioned; bodily entry of stock and poultry or their droppings; filth from the shoes of careless farm hands and children; drippings from the dipper or bucket handled by carriers of disease; dust and leaves from the air; and entry of worms, bugs, spiders, toads, frogs, mice, snakes, cats, or other animal life, which through death and decomposition may impart to the water disagreeable odor and taste and perhaps more serious characteristics.

Deterioration of water may be due to still other causes that make it unwholesome but not, so far as known, destructive of health. Among such are unusual dissolving of mineral salts from the earth, washings from clay that produce a milky appearance, discoloration from mineral or vegetable matter, admixture of mineral or vegetable oils, absorption of offensive gases, low forms of animal life, minute plant growths often productive of bright-colored, fibrous masses and scums, and, especially when water is of peaty or swampy origin, impregnation with iron. In short, investigations indicate that only a small minority of farm water supplies can be classed as unqualifiedly safe and desirable.

A few examples are cited herewith:

In September, 1900, water collected at a spring in Plymouth County, Mass., contained 2,650 bacteria per cubic centimeter (about 15 drops), including one species which normally infests the intestines of man and warm-blooded animals. The watershed contained cultivated fields and 10 houses with outbuildings, the nearest of which was within 300 feet of the spring. The spring was in a cemented reservoir 3 feet deep, resting on a ledge and covered with a platform, but not protected from surface water.[1]

In August, 1900, water as bottled for sale from a spring in Middlesex County, Mass., contained 483,000 bacteria per cubic centimeter, including one species normally of fecal origin. The watershed was chiefly cultivated and pasture land, and no house was within one-half mile of the spring, which was in a cemented reservoir 15 feet in diameter and 15 feet deep, resting on rock, and closed with an iron cover. From the spring the water flowed through 1,560 feet of tin-lined lead pipe to the bottling house.[1]

In July, 1911, the water of a nicely located and apparently tightly covered dug well at Highland Springs, Va., became foul smelling and tasting. Inspection disclosed 16 live frogs and 6 more or less decomposed.

In August, 1915, in Campbell County, Va., a quantity of dilute sewage trickled into a drilled well from the well pit above, the latter having become flooded from a house sewer choked with rain water. Within 14 days five of the eight children in the family were stricken with typhoid fever and the eldest died three weeks later.[2]

On February 5, 1916, a mountain spring supplying a farm used for educational purposes in Idaho and which was inclosed by a concrete box with tight plank cover was, upon inspection, found to have had the cover crushed in by cattle and the site thickly strewn with droppings. As the locality was covered with snow and the spring water comparatively warm (66° F.), it may be concluded that unusual effort had been made by stock to reach the water at its source.

Among the ailments caused or influenced by contaminated water are typhoid fever, tuberculosis, hookworm disease, cholera, dysen-

[1] Condensed from Annual Report, Mass. State Board of Health for 1900, pp. 561, 563, 580, and 583.
[2] Condensed from Annual Report of Health Commissioner, Va., 1915, p. 98.

tery and diarrhea, and certain obscure maladies that may be traced eventually to the poisonous effects of drainage from human wastes. Figure 2 shows in a striking manner how increased use of pure water in Massachusetts has been followed by decline in the typhoid-fever death rate. Frequently a home or village supplied with water from a mountain spring or canon is a center of goiter, although the possible relationship of such water to this disease has not been proved conclusively.

Among ailments of live stock, hog cholera, anthrax, and foot-and-mouth disease are spread by moving water. Hence sick animals should not have access to streams, and dead animals should not be left exposed in fields or buried where drainage may carry infection

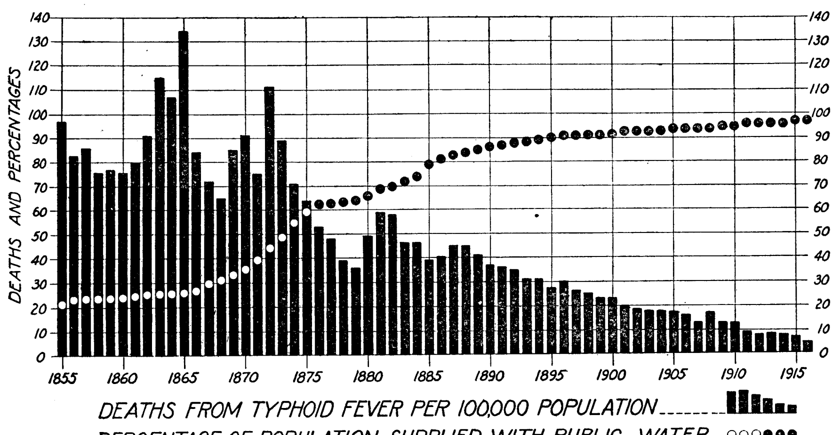

FIG. 2.—Typhoid-fever death rate and percentage of the population supplied with public water in the State of Massachusetts from 1855 to 1916. Notice the rise of the circles and the drop of the black bars. In 1916 fully 96 per cent of the people were supplied with public water and the typhoid-fever death rate declined to 4.6 per 100,000 population. Unquestionably pure water was the chief factor contributing to this notable decline.

to streams and water supplies. One's duty to himself and neighbors should obligate him to confine all sick animals and burn the carcasses of dead ones or bury them deeply in spots remote from streams, wells, and springs, and urge his neighbor to do the same.

DISPOSITION AND MOVEMENT OF WATER.

Rain is the source of water supply, and whether in the air or upon or within the ground, water is always acted upon by the earth's gravity. A part of the rainfall is reevaporated, a part is taken up by vegetation, and other portions run away over the surface of the ground or sink downward and percolate through the ground. Surface run-off and percolating water (ground water) both move in the lines of least resistance (lines of greatest slope and least obstruction) toward lower levels, dissolving more or less of the mineral and organic constituents of the earth over or through which they pass. Steep slopes and close soils increase the proportion of surface run-off, and flat slopes and open soils increase the porportion of ground water. In all cases increased slope means greater velocity. Close soils mean slower velocity of the ground water, the movement being not unlike that of ink in a piece of blotting paper. Ground water may move at rates of much less than a rod per day many miles through earth, or may enter the underlying rock and move freely through its crevices or very slowly through its pores. Due to peculiarities of the earth's slope and structure, it may appear at the surface as a seep or spring or enter a lake or a stream channel. The deeper and the longer either in distance or time the underground journey is, the greater the liability of mineral impregnation, but the less the chance of organic impurity.[1]

The vital things to remember are that ground water is not stagnant but moves usually, though not always, with the "lay" or slope of the land; that its character determines largely the character of wells and springs; that it is not an inexhaustible reservoir, but that a given well yields only as it receives; and that continued pumping will not improve the water in a well if the sources from which it is fed are permanently at fault. In short, ground water is natural drainage variously modified in its movement and character by subterranean conditions.

SAFE LOCATION OF WELLS.

Wells can not be located in all cases so that there may not be some pollution, but the great safeguards are clean ground and as wide separation as possible from the probable channels of any impure drainage. It is not enough that a well or spring is 50, 100, or 150 feet from a source of filth or that it is merely upon higher ground, although even moderate remoteness and elevation of the source of supply are of service. Given porous or gravelly ground, seamy ledge, or long-continued pollution of one plot of land, the zone of contamination is likely to extend long distances, particularly in down-hill directions and at such times as water supplies are lowered by drought or heavy pumping. Only when the surface of the water in a well or spring is actually at a higher level at all times than any near-by source of filth is there positive assurance of safety.

Upon any farm a wood lot, grove, or windbreak is highly desirable, not only to supply fuel and small timber, but for its beauty and

[1] 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, Urbana, Ill., p. 15.

the protection it affords. If kept clean and free from stock, such wooded area, an orchard even, may be made to serve another useful purpose, that of supplying water. Forest-covered lands conserve rainfall and soil moisture and in many instances afford ideal sources for farm water supplies. The farmer, therefore, who fences off his wood lot, or part of it, or forests an inclosed area and keeps it clean for water supply purposes, is following closely the wise policy of cities and towns which, to insure safe, ample water supplies, acquire elevated, sparsely-settled watersheds, and clean, forest, and patrol them.

Figure 3 illustrates a common, but unsafe, location for a farm well and a spring liable to contamination from both upland drainage and flooding in the stream. Beyond the probable channels of impure drainage is a wooded area which might afford an ideal and lasting source of good water supply.

CHARACTERISTICS AND TESTS.

Water for domestic use should be clear, lustrous, odorless, colorless, wholesome, 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 until both the water and the surroundings where it is obtained are passed upon by competent sanitation authority, generally the State board of health.

There are few tests for contamination that the farmer can make. Peculiar odors, those of earthy, musty, vegetable, sulphurous, fishy, or fecal character, sometimes are developed by shaking or by heat. Water may be tinted green by vegetation or other shades by wash from clays. Brown and yellow tints are indicative of organic impurity and should be regarded with suspicion. Organic matter is indicated sometimes by the following simple test: Add a very little clean, white, granulated sugar to a half pint of the water in a clear, stoppered bottle, and allow it to stand in a warm room for a few days or a week. Gradually increasing turbidity, a smoky clouding, is evidence of impurity. Organic matter in water may be indicated also by heating any deposited sediment in a small porcelain dish over an alcohol flame and noting if the deposit chars and blackens.

The temperature of ground water varies with latitude, season, depth, and geological conditions. Ordinarily, at a depth of 40 to 60 feet, it is about 50° and is nearly uniform throughout the year. At lesser depth, seasonal and atmospheric changes are likely to affect it. Hence, if there is much fluctuation in the temperature, or if the water is made turbid by rains, a supply of shallow origin is indicated.

FIG. 3.—Illustrating common but unsafe location of the farm well and spring. A possible source of pure water is indicated also. *A*, Unsafe well; *B*, unsafe spring; *C*, privy; *D*, garden; *E*, chicken yard; *F*, hog yard; *G*, cultivated field; *H*, pasture; *J*, woodlot fenced off and kept clean; here, beyond the probable channels of impure drainage may be pure water.

Deep ground waters are generally progressively warmer, the deeper obtained, the increase running about 1° for each 50 to 60 feet increase in depth.

CONSUMPTION OF WATER.

The principal factors affecting water consumption are accessibility, pressure, quality and quantity of the supply, varying daily and seasonal needs, and personal differences of taste and habit. If carried by hand a long distance water will be used sparingly, perhaps one or two buckets drawn before mealtime sufficing for a family. If delivered under pressure and of good quality and ample quantity, it will be used liberally. Large quantities are used on wash days, during very hot weather, and, if water is wasted at the faucets to prevent freezing, during very cold weather. A bath requires 25 to 30 gallons, and each flush of a toilet takes from 3½ to 6 gallons. Fair requirements in rural homes are shown in the following table:

Water requirements in rural homes.

Purposes and conditions.	Consumption per person for 24 hours.
	Gallons.
Domestic purposes, 1 pump at kitchen sink	8
Domestic purposes, 1 faucet at kitchen sink	15
Domestic purposes, running hot and cold water in kitchen, bathroom, and laundry	25
Sprinkling and cooling purposes, outdoor washing, waste, leakage, etc	15
Average daily consumption, modern home	40
Maximum daily consumption, modern home	100
Average daytime consumption (7 a. m. to 7 p. m.)	28

As to the requirements of stock, animals prefer a living spring or a stream of pure cool water, and will go a long distance to obtain it. If supplied from artificial sources, fair allowances are 12 gallons per day for each horse, mule, or cow, and 2 gallons per day for each sheep or hog. Heavily worked horses and mules and milch 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.

WATER SUPPLIES CLASSIFIED.

Farm water supplies may be classified according to the source from which derived as follows:

(1) Rain and snow water (barrel and cistern storage).

(2) Surface water (streams, ponds, irrigation ditches, open reservoirs).

(3) Ground water (seeps, springs, dug and tubular wells, infiltration cribs and galleries, and collecting conduits).

RAIN WATER.

Rain water is soft and comparatively pure but contains ammonia, acids, dust, and other impurities washed from the atmosphere. On account of its softness and solvent powers it is used widely for laundry and general washing purposes, and in many sections where the ground-water supply is very deep, lacking in quantity, or strongly alkaline, rain water is the main reliance for all household uses.

CISTERNS.

Cisterns are wooden, metallic, plastered-on-earth, or masonry receptacles for the storage of rain water or melted snow. The evils of cistern water are many. They relate to the uncertainty of rainfall; to freezing in winter and unwholesomeness in summer; to impregnation with iron, zinc, or other metal in metal-lined cisterns; to direct entrance of organic matter in the form of dust, dirt, soot, insects, bird droppings, and even the bodies of birds and mice from roofs and conductors; to disagreeable tastes on account of the solubility of some roofing materials; to metallic taste acquired from the lime or cement in cistern walls; to the development of fungous growth and the organisms of decay as effects of long storage; to the entrance of roots of trees; to neglect in caring and cleaning; and, finally, to faulty construction or the development of leaks which permit either surface wash or underground leachings from sink drains, privies, cesspools, or other sources of filth to enter, harden, and contaminate the supply. A single example of cistern-water pollution is cited here:

In September, 1908, cistern water at a large farm in Kittson County, Minn., was found to be badly polluted, containing 80,000 bacteria per cubic centimeter (about 15 drops), including one species normally of fecal origin. The water was stored in two 100-gallon, uncovered, round, galvanized iron cisterns in the house cellar and was dipped out with pails for drinking and household purposes. A tin pipe leading from the roof to the cisterns was provided with a very small filter consisting of a tin box 12 inches by 5 inches by 5 inches filled with a clean bag of charcoal after each rain.[1]

The practice of throwing charcoal into cisterns to absorb the odors of decaying organic matter is of little advantage. Boiling cistern water, or "dosing" it with chemicals to sterilize it, although safe precautions, injure the wholesomeness of the water and should be regarded as emergency measures, never as suitable substitutes for the best possible construction and operation.

Notwithstanding the serious objections mentioned, thoroughly well-constructed, well-operated cistern installations are a boon, and their more extensive use is advised and urged. The vital features of a cistern installation are:

1. Absolute water tightness, top, sides, and bottom, and close screening of inlet and waste pipes.

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[1] U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 154, pp. 66, 79.

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. The flow should be downward, and the top area of the filter bed and the rate of flow to the bed must be so harmonized and regulated that slow, effective filtration (not rapid straining) is secured.

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. From time to time the clogged sand should be raked or renewed and the dirty charcoal replaced.

Other important features are:

1. Substantial construction of concrete plastered with rich Portland-cement mortar worked with trowels while green to produce a hard, impervious surface.[1] Lead-lined cisterns never should be used, and copper cisterns should be heavily tinned. Iron and steel cisterns should be well covered with pure asphalt paint; at greater cost they may be lined with tin or faced with slate, glass brick, porcelain brick, or tile. New cisterns should be pumped out two or three times prior to use of the water for drinking.

2. If water-tight, a cistern should be below ground, thus preventing freezing in winter and adding to the wholesomeness of the water in summer. The filter should be placed so the water in it can be drained away. This may require it to be above or partially above the ground.

3. If rain water is filtered effectively, the keeping qualities will be improved greatly and large-sized cisterns may be used. When a cistern is full, deflect and waste any flow from the roof, thus avoiding unnecessary work on the filter.

4. Never connect the waste pipe with a sewer or a drain which may carry sewage. The practice is dangerous. (See example 4, p. 5.)

The proper size of a cistern depends on the requirements for water, the area of roof or roofs, and the amount and frequency of rainfall. A liberal margin (perhaps one-third of the rainfall) should be allowed for the rinsings wasted, the water blown from the roof by wind, leakage in conductors and connections, and evaporation. Data (past records) of the amount and the seasonal distribution of rainfall at the principal cities throughout the country may be obtained from the United States Weather Bureau, Washington, D. C., from local forecasters in the several States, and from published reports of the Weather Bureau in many libraries.

To determine the amount 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 which must supply the desired storage) and divide the product by 1.6. The result will be the number of gallons which may be expected from past rainfall records. The table on page 14 shows the capacities, both in gallons and barrels, of cylindrical cisterns and tanks of certain dimensions.

To find the capacity of square or rectangular cisterns and tanks: Multiply the inside length by the breadth and the product by the

[1] For methods of mixing and placing concrete and mortar to promote imperviousness and resistance to the action of alkaline water, see Department of Agriculture Bulletin 230, "Oil-Mixed Portland Cement Concrete."

height, each dimension being in feet. Multiply the result (cubic feet) by 7½ to find the gallons. Gallons divided by 31½ give barrels.

An example is given to show how, under fixed conditions, the dimensions of a cistern may be determined roughly:

A farm in Texas has a mean annual rainfall of 15.15 inches, of which 11.95 inches fall May to October, inclusive, and only 3.20 inches November to April, inclusive. Each person in a family of 5 requires 5 gallons of water daily, the roof plan measures 30 feet by 50 feet, and one-third of each rain is wasted because of dust and dirt on the roof. Obviously, the surplus May to October, inclusive, must be stored to meet the deficiency from November to April, inclusive. The area of the roof plan is $30 \times 50 = 1,500$ square feet. Applying the rule given, $\frac{1,500 \times 11.95}{1.6} = 11,200$ gallons falling on the roof during the six wet months. Deduct from this one-third wasted, and there is found to have entered the cistern 7,470 gallons. During the period, May to October, 184 days, the amount of water drawn out of the cistern would be 4,600 gallons ($5 \times 5 \times 184$), and deducting this from the collected amount (7,470 gallons) leaves 2,870 gallons in storage at the end of October. The latter amount would be the minimum needed capacity of the cistern. Inspection of the table shows that although several selections to hold about 2,870 gallons could be made, perhaps the most suitable size would be 8 feet in diameter and approximately 8 feet in depth. Continuing the calculation for the 6 dry months, $\frac{1,500 \times 3.2}{1.6} = 3,000$ gallons, and deducting one-third for waste, it is seen that 2,000 gallons more would enter the cistern and there would be drawn out 4,525 gallons ($5 \times 5 \times 181$). Hence there would be left in the cistern on April 30 a small surplus, 345 gallons ($2,870 + 2,000 - 4,525 = 345$.)

The reader is cautioned that in the foregoing example only mean or average distribution is taken. In nearly every locality there comes at intervals the long drought, the extraordinarily dry year, 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. Therefore the householder who would avoid the inconveniences of a shortage in his cistern supply is fully warranted in planning his installation upon very liberal lines.

Capacity in gallons and barrels ($31\frac{1}{2}$ gallons) of plain cylindrical cisterns and tanks.

Depth of cistern in feet.	Diameter of cistern in feet.																	
	4		5		6		7		8		9		10		11		12	
	Capacity of cistern in gallons and barrels.																	
	Galls.	*Bbls.*	*Galls.*	*Bbls.*	*Galls.*	*Bbls.*	*Galls.*	*Bbls.*	*Galls.*	*Bbls.*	*Galls.*	*Bbls.*	*Galls.*	*Bbls.*	*Galls.*	*Bbls.*	*Galls.*	*Bbls.*
4	376	12	588	19	846	27	1,152	37	1,504	48	1,904	60	2,350	75	2,844	90	3,384	107
5	470	15	735	23	1,058	34	1,439	46	1,880	60	2,380	76	2,938	93	3,555	113	4,230	134
6	564	18	881	28	1,269	40	1,727	55	2,256	72	2,855	91	3,525	112	4,265	135	5,076	161
7	658	21	1,028	33	1,481	47	2,015	64	2,632	84	3,331	106	4,113	131	4,976	158	5,922	188
8	752	24	1,175	37	1,692	54	2,303	73	3,008	96	3,807	121	4,700	149	5,687	181	6,768	215
9	846	27	1,322	42	1,904	60	2,591	82	3,384	107	4,283	136	5,288	168	6,398	203	7,614	242
10	940	30	1,469	47	2,115	67	2,879	91	3,760	119	4,759	151	5,875	187	7,109	226	8,460	269
11	1,034	33	1,616	51	2,327	74	3,167	101	4,132	131	5,235	166	6,463	205	7,820	248	9,306	295
12	1,128	36	1,763	56	2,537	81	3,455	110	4,512	143	5,711	181	7,050	224	8,531	271	10,152	322

CISTERN FILTERS.

That method of filtration which copies most nearly the slow percolation of rainfall into the ground will give the greatest degree of purification. The rate may be kept down to advantage to 1 pint in four minutes (45 gallons in 24 hours) for each square foot of effective area in the filter bed. Sand is one of the best and most available filtering materials, and well-burned charcoal is most useful in removing color, taste, and odor. Fine sand removes minute particles to a greater extent than does coarse sand, but on the other hand it clogs

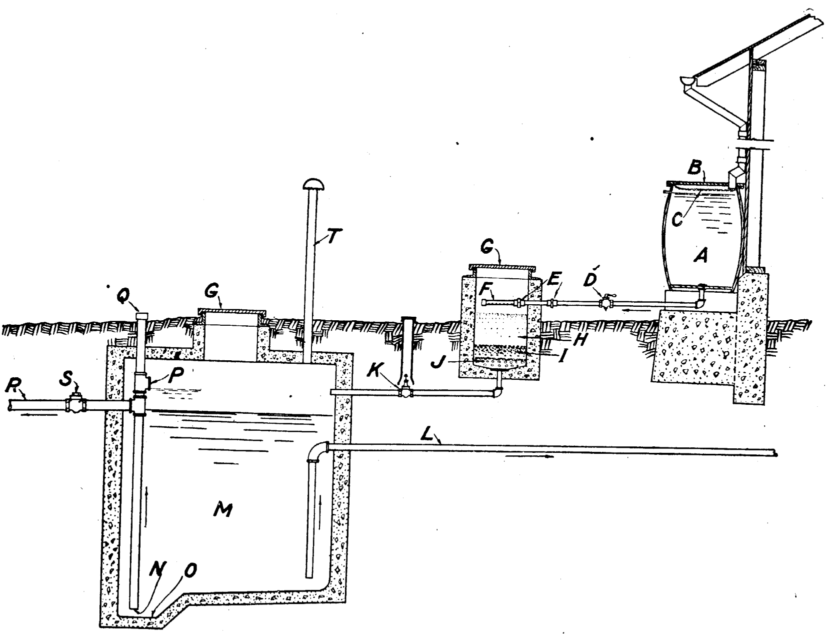

FIG. 4.—Cistern and filter installation. Approximate cost, $150. *A*, Hogshead or large tank; *B*, tight cover; *C*, wire screen; *D*, ¾-inch 2-way rain cock; *E*, ¾-inch union; *F*, ¾-inch brass or galvanized pipe, perforated; *G*, tight overhanging cover; filter box may be wood, iron, brick, concrete, or 4 feet of large-size vitrified pipe; *H*, 24-inch layer fine sand; *I*, 6-inch layer well-burned wood charcoal size of wheat grains; *J*, 2-inch layer of gravel size of a small pea to give support and drainage; *K*, ¾-inch 2-way rain cock with 1 branch piped to waste; *L*, suction pipe; *M*, cistern, side walls 6 to 10 inches thick; *N*, 1-inch overflow; *O*, sump or catch basin; *P*, emergency overflow; *Q*, screw cap (remove cap and attach hand pump when cleaning cistern); *R*, waste pipe; *S*, swing check valve; *T*, screened ventilator. When starting operation, waste the first water filtered; throttle cocks *D* and *K* to give the desired low rate of filtration; maintain water level above sand layer, thus protecting the surface film of mud.

more quickly. Crushed quartz and thoroughly clean pit or beach sand, such as is used in mixing mortar, are employed extensively. The size of the grains should be quite uniform and should be such that all could be sifted through holes made in a sheet of paper by a medium-sized awl or knitting needle. A depth of 2 feet of carefully selected sand free from clay, loam, and vegetable matter, is preferable to a greater depth of sand of indifferent quality. As the thin surface layer becomes clogged with continued use, it may be scratched or furrowed or a half inch or so may be scraped off with a trowel, until eventually the bed is reduced to 12 or 15 inches in thickness. The sand removed either should be washed and returned, or be replaced with new sand. It is advantageous to place about 6 inches of well-burned charcoal under the 2-foot bed of sand. Triple-burned, triple-ground wood charcoal, the pieces averaging the size of wheat grains, has given excellent results and costs normally about 60 cents a bushel, in sacks, at kilns in eastern States.

FIG. 5.—Galvanized-iron charcoal filter and rain-water switch. Water passes into a dug well. Not a desirable installation.

A cistern and filter embodying the foregoing principles is shown in figure 4. The construction may be inexpensive, and if the filter is well handled, good results will ensue. As the filter is above ground, it is inspected, cleaned, and aerated readily, but should be drained at the rain cocks or the connections should be protected in cold weather.

Figure 5 shows a galvanized-iron charcoal filter connected with a rain conductor. Above the filter is a switch for diverting and wasting the dirty rinsings from the roof. Within the filter is a piece of cheesecloth supported by galvanized-iron netting beneath which are lumps of charcoal. The filtered water passes to a dug well 25 feet deep. Objections to this installation are: Rapid and mere mechanical straining (not filtering) through a coarse medium and loss of water in the well. If the well were free yielding, as in sand or gravel, the result would be comparable to pouring water into a basket.

SURFACE-WATER SUPPLIES.

Streams, ponds, irrigation ditches, and small open reservoirs are very unsatisfactory, 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. Often the carcasses of farm animals are found therein. In thousands of cases the domestic supply is taken directly from irrigation ditches. In other instances a cistern, often without a filter, is filled at such times as the ditch water runs clearest. Often open reservoirs [1] are necessary to collect and store rainfall for the use of stock, and occasionally they are used as sources of domestic water and ice supplies.

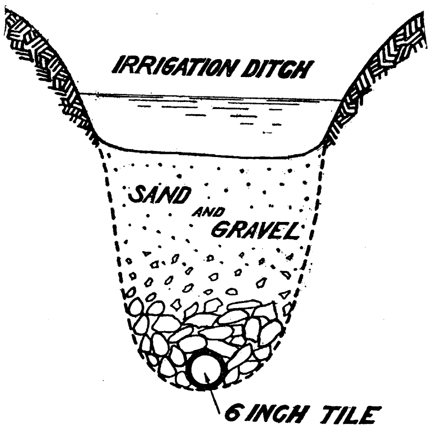

FIG. 6.—Drain tile collector beneath an irrigation ditch, Sevier County, Utah.

Under favorable conditions, where the basin is large and deep (10 feet or more), the bottom free of mud, muck, or other organic matter, the surroundings clean, and the circulation good, the quality of surface water may improve by long storage. However, these conditions are seldom realized on the farm, and the amount of improvement or purification is never certain.

The only safe course is to avoid drinking water from any surface source unless such water has been purified by filtration or sterilized by boiling or by chemicals.[2] Prudence dictates, also, that ice gathered from shallow, unclean sources should not be brought in contact with food and drinking water. It is particularly important to reject snow ice and the first inch or so of clear ice formed.

[1] For information on reservoir construction, see U. S. Department of Agriculture Farmers' Bulletin No. 592, "Stock-watering Places on Western Grazing Lands;" Office of Experiment Stations Bulletin No. 179, "Small Reservoirs in Wyoming, Montana, and South Dakota;" Office of Experiment Stations Bulletin No. 249, Part I, "Earth-filled Dams and Hydraulic-filled Dams;" Office of Experiment Stations Bulletin No. 249, Part II, "Timber Dams and Rock-fill Dams."

[2] The United States Public Health Service recommends: (1) Boiling 20 minutes. (2) Disinfection with chloride of lime. The disinfecting solution is prepared by dissolving 1 teaspoonful of fresh chloride of lime (bleaching powder) in 1 quart of water. Keep the solution in a tightly stoppered bottle away from light. To disinfect water, add 1 teaspoonful of the solution to each 2 gallons of water, stir thoroughly, and allow to stand 15 minutes before drinking the water. See Public Health Bulletin No. 70, "Good Water for Farm Homes."

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Figure 6 shows the method of obtaining water from an irrigation ditch in Sevier County, Utah. A short stretch of the ditch was excavated to an additional depth of about 5 feet, 6-inch drain tile was laid therein and surrounded with coarse gravel, and the refilling was completed with sand. This simple infiltration gallery clarifies the

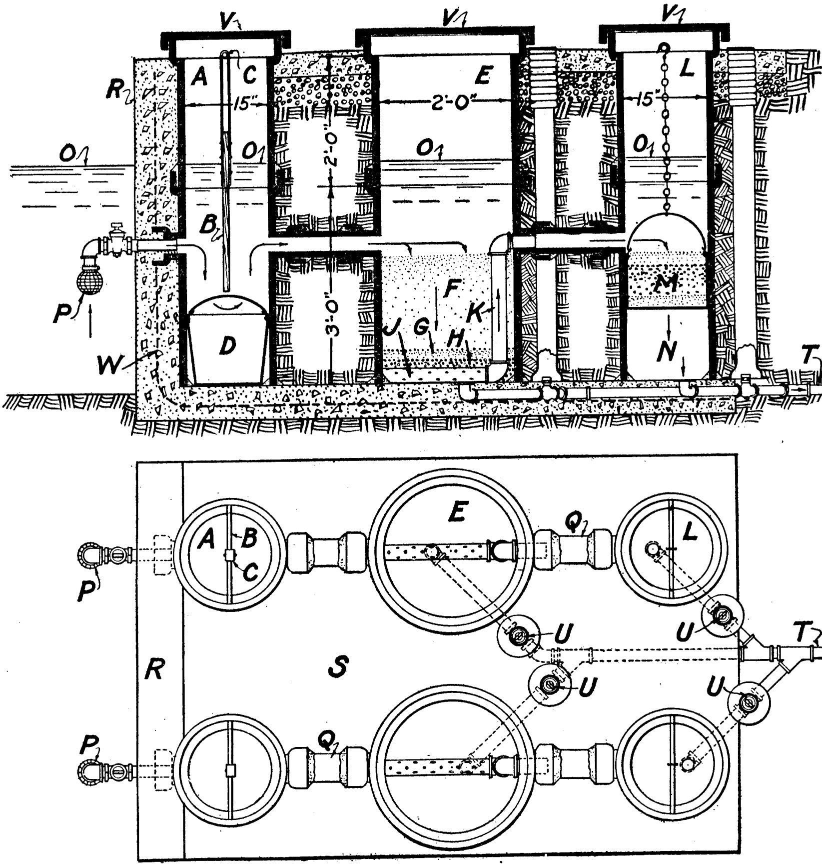

FIG. 7.—Slow sand and charcoal filter in two units. Estimated cost, $125. Chambers are large-size vitrified pipe. All pipe joints made water-tight. Arrows show direction of flow. *A*, Settling chamber; *B*, baffle board suspended by strap iron from rod *C*; *D*, galvanized pail to catch sediment; *E*, sand chamber; *F*, fine sand; *G*, 1-inch layer coarse sand; *H*, 1-inch layer fine gravel; *J*, brass or galvanized, perforated pipe; *K*, riser; *L*, charcoal and filtered water chamber; *M*, galvanized basket or perforated pail held by a chain and crossbar; 6-inch layer of charcoal between restraining layers of fine gravel; *N*, filtered water; *O*, low water level; *P*, inlet pipe with strainer and valve; *Q*, 3-inch vitrified pipe; *R*, retaining wall; *S*, base; *T*, delivery pipe; *U*, valve with extension box to surface; *V*, tight overhanging cover; *W*, steel rods. When the filter is in operation, valve *U* in pipe from chamber *E* is closed; opening this valve and closing inlet valve *P* permits drainage and aeration of the sand; throttle valve *U* on pipe from chamber *L* to give the desired low rate of filtration; waste first water filtered and maintain water level *O* above sand and charcoal.

water quite well but is little protection if the supply constantly carries disease germs. Where mud and silt settle so as to clog the sand, relief may be obtained by raking the bottom of the ditch at such times as the flow is strongest.

Figure 7 shows a sand and charcoal filter of simple design to improve the water from irrigation ditches. The filter is arranged in two units. By closing either inlet valve that unit or side may be pumped out, the chambers cleaned, the sand furrowed, scraped, or renewed, and the dirty charcoal replaced with new. If this filter and the one shown in figure 4 are kept clean and are operated at a slow rate, as already suggested, they may be expected to remove nearly all the sediment, to oxidize a portion of the dissolved organic matter, and to eliminate a high percentage of the bacteria (these may include both harmless and harmful varieties as well as organisms causing unpleasant taste and odor). In order to provide a reserve of filtered water that would supply a pump properly or fill a gravity pipe line, it would be necessary to enlarge chamber *N* greatly or lay pipe *T* to a cistern similar to the one shown in figure 4. The rate of filtration then may be unaffected by the rate of pumping, and by trial the opening in valve *U* can be reduced so that the normal daily consumption of water will require the full 24 hours to pass through the filter.

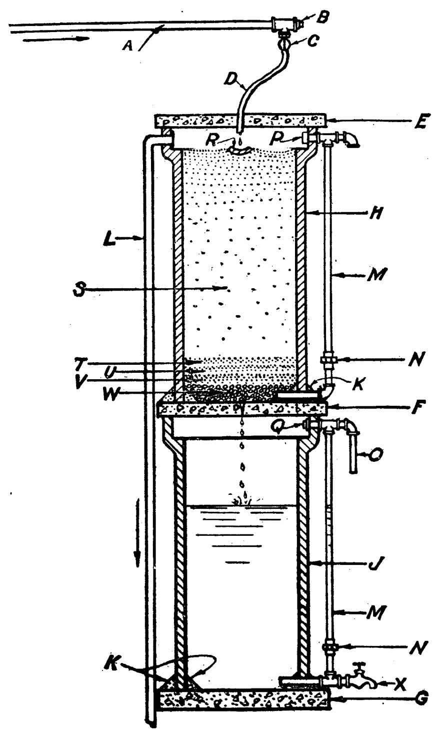

FIG. 8.—Homemade slow sand filter. Capacity, 25 to 30 gallons per 24 hours and costs about $10. *A*, Supply pipe; *B*, brass tee, plugged; *C*, brass pet cock; *D*, rubber tube; *E*, concrete cover; *F*, concrete slab with cone-shaped hole $\frac{1}{32}$ inch in diameter at the bottom of the slab in the center; *G*, concrete base slab; *H*, *J*, 10-inch vitrified pipe, each 2 feet long; *K*, water-tight cement fillet; *L*, overflow, $\frac{1}{2}$-inch lead pipe; *M*, $\frac{1}{2}$-inch glass tube; *N*, $\frac{1}{2}$-inch union; *O*, $\frac{1}{2}$-inch vent and overflow; *P*, tight cap; *Q*, nut, pipe open; *R*, piece of slate, brick, or tile; *S*, clean fine sand; *T*, 1-inch layer of coarse sand; *U*, $\frac{1}{2}$-inch layer of gravel size of shot; *V*, $\frac{3}{4}$-inch layer of gravel size of a pea; *W*, $1\frac{1}{4}$-inch layer of gravel about $\frac{1}{2}$-inch size; *X*, $\frac{1}{2}$-inch brass faucet for drawing filtered water.

Figure 8 shows the essentials of a homemade slow sand filter [1] used with much satisfaction for many years by Dr. Robert Fletcher, president New Hampshire State Board of Health, and director Thayer School of Civil Engineering, Hanover, N. H. This filter need not cost more than $10. The materials are procurable everywhere, and it can be made and installed by any handy farm laborer.

Figure 9 shows a tripoli stone (consolidated siliceous ash) pressure filter. It may be placed conveniently in the home and connected

[1] New Hampshire Sanitary Bulletin, July, 1906, and Engineering News, New York, Aug. 9, 1906.

with the discharge pipe from a pump or with a gravity pipe line. Pressure forces the water through the pores of the stone in the direction of the arrows, and the filtered water is drawn as required from the faucet *L*. This filter costs about $25 but may be had in different styles and sizes at lesser or greater cost. Pressure filters may be purchased in which the filtering material is sand or sand and charcoal, and their purifying efficiency is greatly increased if they contain a device which automatically feeds a small quantity of alum or other coagulant into the unfiltered water.

Caution.—A filter is a device for removing dirt from water. It promotes purity and safety but never is a guarantee. It does not

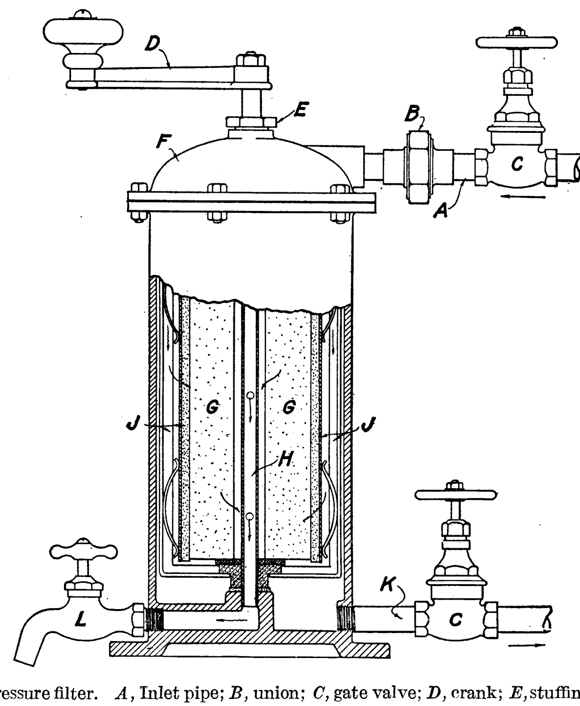

FIG. 9.—Stone pressure filter. *A*, Inlet pipe; *B*, union; *C*, gate valve; *D*, crank; *E*, stuffing box: *F*, removable top; *G*, filtering stone; *H*, center pipe; *J*, cleaning stone and holder; *K*, drain, used when cleaning the filter and flushing out; *L*, filtered water faucet.

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. If, for instance, brine be filtered, the resultant still will be salt water. Not only must the accumulated dirt be removed from filters according to their use and the dirtiness of the water filtered, but the filtering material must be cleaned, aerated, or sterilized from time to time. Dirty sand can be washed, but dirty charcoal should be replaced with new charcoal four or five times a year. 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.

GROUND-WATER SUPPLIES.

Good ground water is the ideal supply for the farm. The subject has been so well covered in publications of the United States Geological Survey [1] that this bulletin will record merely some general conclusions and personal experiences. Any farmer about to put down a deep or expensive well, and who is uncertain of the depth and the quantity or quality of the water likely to be encountered, should describe fully the location and conditions of his project to national or State geological authorities and ask for advice. Times without number, wells have been sunk to great depths in the belief that eventually a plentiful supply would be reached, only to find that water was not there, or that it was unfit for use, or that a mere hole or sump had been created which served but to drain water from relatively near the surface. There is no short cut and no better guide in this matter than information as to the kind, thickness, porosity, and dip of the strata of the region and of the results obtained in neighboring wells, study of the land slopes and character of the vegetation,[2] and examination for evidences of seeps and springs.

Regarding the use of a forked willow, hazel, or peach stick for locating underground water, it can be said safely the method is without merit, 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 not thus trained. So, also, there is little to recommend certain patented automatic water finders which are based upon the possible, but largely conjectural, proposition that electrical exchanges between the earth and atmosphere are stronger in the vicinity of subterranean waters.

The most likely appearance of seeps and springs is near the base or toe of slopes, and shallow wells similarly located usually are stronger than those higher up the slope or farther out on the flats. Often vegetation is the only visible evidence of the presence of water which, if it reaches the surface, suggests prospects for flowing wells, and even for artesian wells. Wells upon the crown of a hill or close to rock out-crops, are not likely to yield plentifully. The stronger artesian flows usually come from the lower strata.

Sands, gravels, and mixtures of them, porous sandstone (consolidated sand), and conglomerates (consolidated gravel) are the most promising waterbearing materials. Quicksand, clay, and hardpan

[1] See Water Supply Papers Nos. 255 "Underground Waters for Farm Use" and 257 "Well Drilling Methods," and many others treating of conditions in different States, issued by the Geological Survey, U. S. Department of the Interior.

[2] Due to differences of soil and climate, the criteria developed in one region can not be relied upon with certainty in another locality. In Big Smoky Valley, Nevada, vegetation indicative of shallow-water areas, or, at least, of more than the ordinary supply of moisture were as follows: Salt grass, samphire, buffaloberry bush, giant reed grass, rabbit brush (broom sage), big greasewood, wild roses, and birch, willow, and cottonwood trees. U. S. Geological Survey, Water Supply Paper No. 423, p. 95.

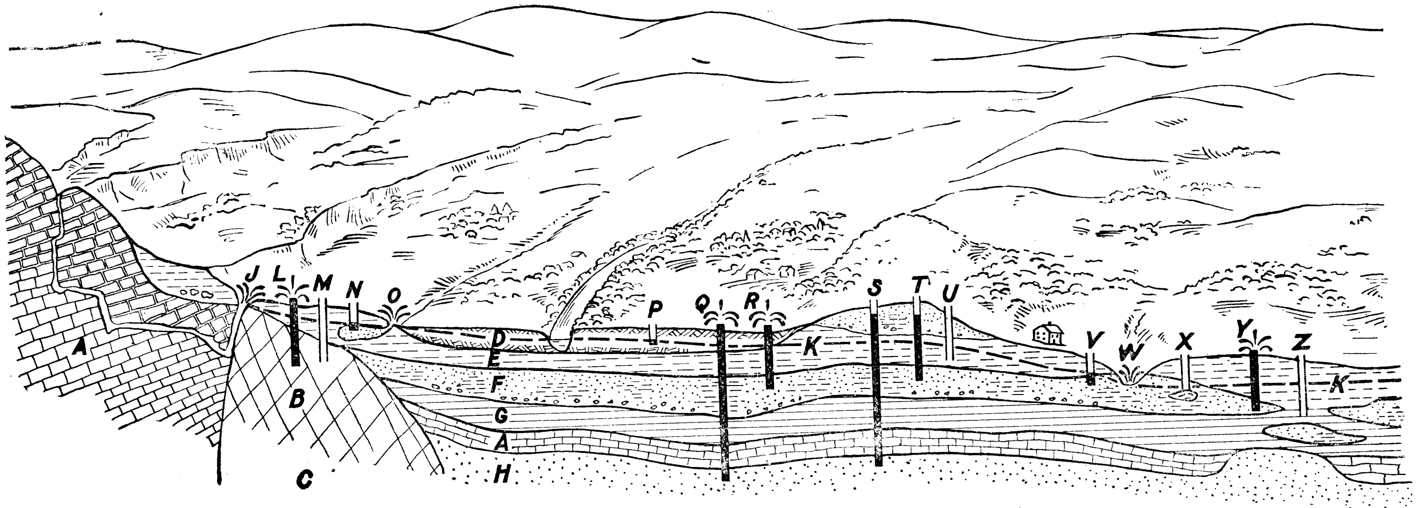

FIG. 10.—Diagram showing how wells and springs may be affected by geologic conditions, surface elevation, and by differences in location and depth. *A*, Limestone showing both small and large passageways; *B*, jointed crystalline rock; *C*, solid crystalline rock; *D*, alluvial soil; *E*, comparatively impervious stratum, as clay; *F*, stratum composed of sand, gravel, bowlders, clay, and mixtures of them; *G*, comparatively impervious stratum, as clay or hardpan; *H*, porous sandstone; *J*, fissure spring (may be contaminated easily by campers or others); *K*, water table or line below which ground is saturated; *L*, flowing well (strikes joints carrying water); *M*, nonflowing well (strikes no joints); *N*, shallow well (strikes a pocket of sand); *O*, seepage spring (yield small and perhaps during wet weather only); *P*, shallow and poor well; *Q*, artesian well (strong flow); *R*, artesian well (bottom in sand, flow moderate); *S*, *T*, nonflowing artesian wells (head insufficient to force water to the surface of the high ground); *U*, well in clay (no yield); *V*, shallow well in sand; *W*, hillside spring (both *V* and *W* are liable to contamination from the house wastes above); *X*, shallow and dry well (bottom in clay and against a bowlder); *Y*, flowing well (bottom in sand); *Z*, dry well (same depth as well *Y* but sunk where the water-bearing bed thins out).

usually contain an abundance of water, but yield it too slowly to afford satisfactory supplies. Among rock formations, 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 and marble carry an abundance of water within the passageways and cavernous channels which characterize these rocks, but the water usually is hard and may be contaminated easily from surface sources. Figure 10 illustrates how differences in slope and underground conditions may give rise to seeps and springs and may cause success or failure in wells of varying location and depth.

SEEPS AND SPRINGS.

Seeps and springs are the natural emergence of ground water upon the surface. If the emergence is slight and diffused over a considerable area, it is spoken of as a seep or ooze; if concentrated, it is spoken of as a spring. In either case, it is water under head and moving where the resistance is least. Hence, anything that reduces resistance, such as open-joint pipes or conduits for the collection of seepage, or excavating within and encasing a spring, tends to increase the yield. On the other hand, increase of resistance, as by accidentally choking the flow, or by building up the curb to a considerable height above the natural surface, tends to decrease the yield, and may cause its loss altogether by deflecting the flow to other channels.

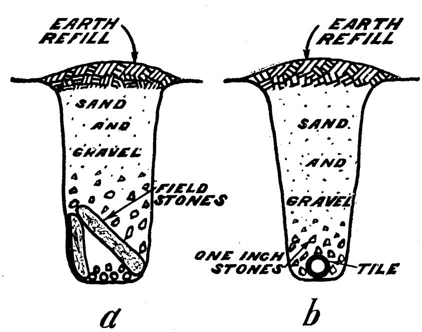

FIG. 11.—Collecting conduits.

Figure 11 (*a* and *b*) show two simple collecting conduits for the capture of seeps. A system very similar to figure 11 (*b*), aggregating 1,758 linear feet of 3, 4, and 6 inch vitrified socket pipe, was laid in Norfolk County, Mass., to collect seepage and the water from several small springs. The pipe was laid to line and grade, strips of burlap 6 to 8 inches wide were placed around the joints and tied with strings, and 4 inches of screened gravel, 1-inch size, was deposited around the pipe for a length of about 10 inches at each joint. Seventyfive joints in muck, quicksand, or clay were closed with jute and cement mortar. Not including the cost of the pipe itself, the cost of labor and materials on this work was $234.72. The result has been a daily yield of 100,000 to 200,000 gallons of good water for about 15 years and the creation of an artificial pond having an area of 4 acres and an average depth of about 8 feet.

Figure 12 shows the method of collecting water upon a farm in California.[1] Trenches 2 feet wide, 4 feet deep, and 1 rod apart were dug across the slope of the hillside and refilled with 3 feet of broken stone over which was a layer of straw and then about 1 foot of earth. These trenches were connected by 4-inch tile drains laid about 18 inches below the surface and running in parallel lines about 2 rods apart down the slope. An outlet to the surface was provided from the lower trench, and an air inlet or vent was inserted at the high end of the upper trench. The soil was of retentive character, and where the stone-filled trenches encountered sand and gravel the sides were sealed with concrete up to the height of the drains to prevent seepage. The two lower trenches were installed first and the others added to increase the yield. Virtually this is an artificial spring.

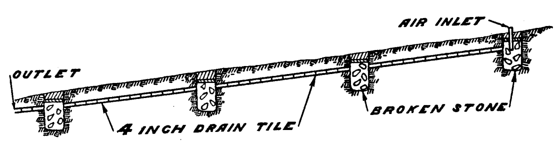

FIG. 12.—Collecting system on a farm in California.

In many instances the water from elevated springs may be piped to the buildings, thus forming a gravity system, a type of installation superior to all others. Figure 13 illustrates such a system. In 1904 the flow of three small springs in Berkshire County, Mass., was collected by a few hundred feet of 2 and 3 inch vitrified pipe laid similarly to figure 11 (*b*). The flow of these springs was 2.6, 3.7, and 7.9 gallons per minute, respectively, and was taken in 2-inch wrought-iron pipe about 1 mile to the point of delivery. Because of a large amount of rock, and to reduce the cost, a considerable portion of the delivery pipe was laid very shallow, and to avoid trouble from freezing the delivery end was so arranged that the flow could not be shut off, except by design. The lowest winter temperatures of the locality run from 15 to 20 degrees below zero, but the owners report never having had trouble from frost and the installation as entirely satisfactory. It is better, however, for the farmer to lay all pipes well below the frost line. Failure to do so often results disastrously.

Springs lower than the farm buildings frequently operate hydraulic rams and force a part of the flow to suitable storage about the premises. Such installations are shown later.

[1] Described by Messrs. Charles Kellogg and P. C. McNulty, jr.

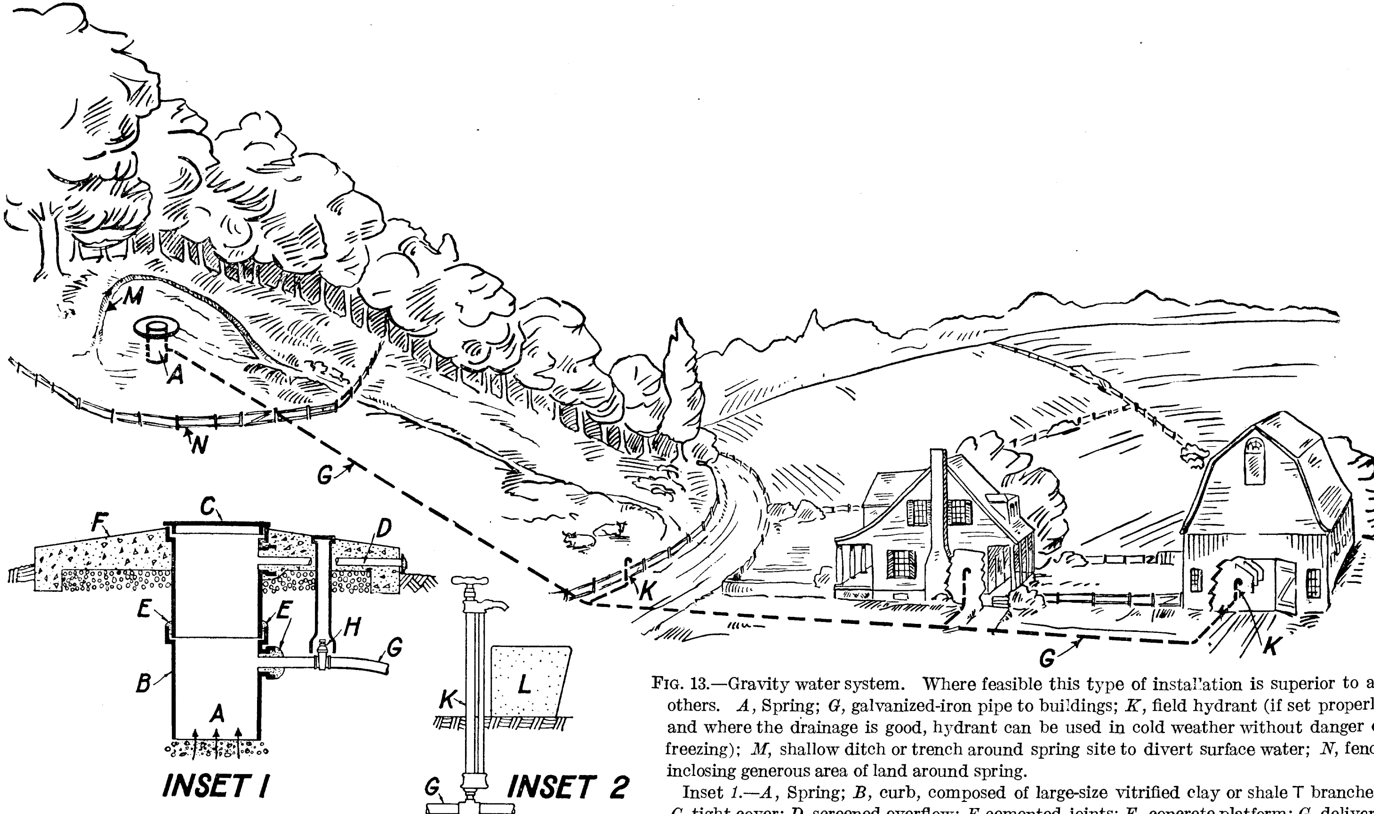

FIG. 13.—Gravity water system. Where feasible this type of installation is superior to all others. *A*, Spring; *G*, galvanized-iron pipe to buildings; *K*, field hydrant (if set properly and where the drainage is good, hydrant can be used in cold weather without danger of freezing); *M*, shallow ditch or trench around spring site to divert surface water; *N*, fence inclosing generous area of land around spring.

Inset *1*.—*A*, Spring; *B*, curb, composed of large-size vitrified clay or shale T branches; *C*, tight cover; *D*, screened overflow; *E*, cemented joints; *F*, concrete platform; *G*, delivery pipe; *H*, gate valve and box.

Inset *2*.—*G*, Delivery pipe; *K*, field hydrant; *L*, watering trough.

WELLS.

Wells are artificial openings in the ground to or below the water table. They should be sunk sufficiently into the water-bearing material so that neither drouth nor the maximum pumping operations of the farm shall so lower the ground water that the pump must be stopped to avoid taking air. Hence no new well should be regarded complete until a pumping test of proper continuous duration has been made to determine its sufficiency for the purposes of the farm and that a mere pocket of water has not been tapped. In shallow wells this can be done usually at slight cost with hand pumps, and in deep wells it is a recognized part of the well business, but should have the personal attention of the person who pays the bill, the farmer. In making the final pumping test the discharge should be taken by pipes or troughs a considerable distance from the well and, if possible, to lower ground.

Wells are spoken of rather loosely as shallow or deep, as dug, bored, driven, or drilled, according to the method of sinking, and in the case of tubular wells, as nonflowing, flowing, or artesian.

DUG WELLS.

Dug wells may be small, as when made with a post-hole digger, or may be very large, the size varying with the freedom with which water enters, the rate of withdrawal or pumping, and the requirements for water. They usually are less than 50 feet deep, although depths of 100 or more feet are not unknown. Often in arid regions wells are not curbed, but in humid sections linings are necessary and are made variously of wood, corrugated iron, stone, brick, vitrified pipe, and concrete. Durability of the curb and water-tightness in its upper portion are highly desirable. Wood never should be used. Stone and brick laid in cement mortar are much to be preferred to curbs laid dry. Data upon corrugated iron and concrete curbs are meager. Bracing a deep excavation, building forms, placing reinforcement and depositing concrete to secure a good job are likely to be costly, especially if much water is encountered. In the arid regions a factor to be considered is the disintegrating action of alkaline water on concrete.[1] Undoubtedly precast, oil-mixed, cement-concrete pipe in 2 to 5 foot lengths with the joints well cemented makes splendid lining, especially if the concrete be reinforced.

Considering cleanliness, tightness, durability, and cost, perhaps no lining is better than heavy, vitrified well tubing, drain tile, or sewer pipe. Either socket or ring pipe may be used. Socket pipe leaves smoother joints inside than does ring pipe, and the joints are more easily made tight. Ring pipe may, however, be made to hold alignment and not separate by means of a series of wooden or iron splices

[1] See footnote page 12.

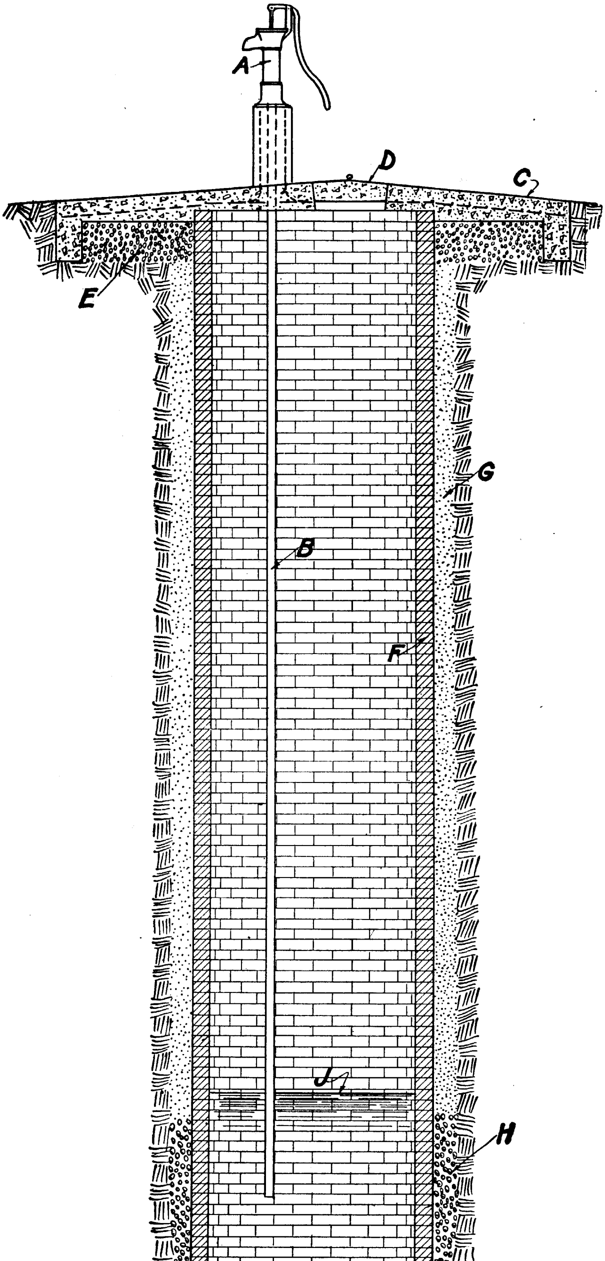

FIG. 14.—Well 23 feet deep in clay soil dug in 1915, Prince Georges County, Md. Manhole and cover shaped by using a large dish pan. Total cost $53.18, and includes pump, 1,800 brick, and purchase of the pail, rope, pick and shovel used in excavating. *A*, Pitcher pump on concrete base 9 inches square and 18 inches high; *B*, 1¼-inch suction pipe; *C*, platform; *D*, manhole; *E*, gravel foundation; *F*, brick curb; *G*, clean sand; *H*, clean gravel; *J*, water level.

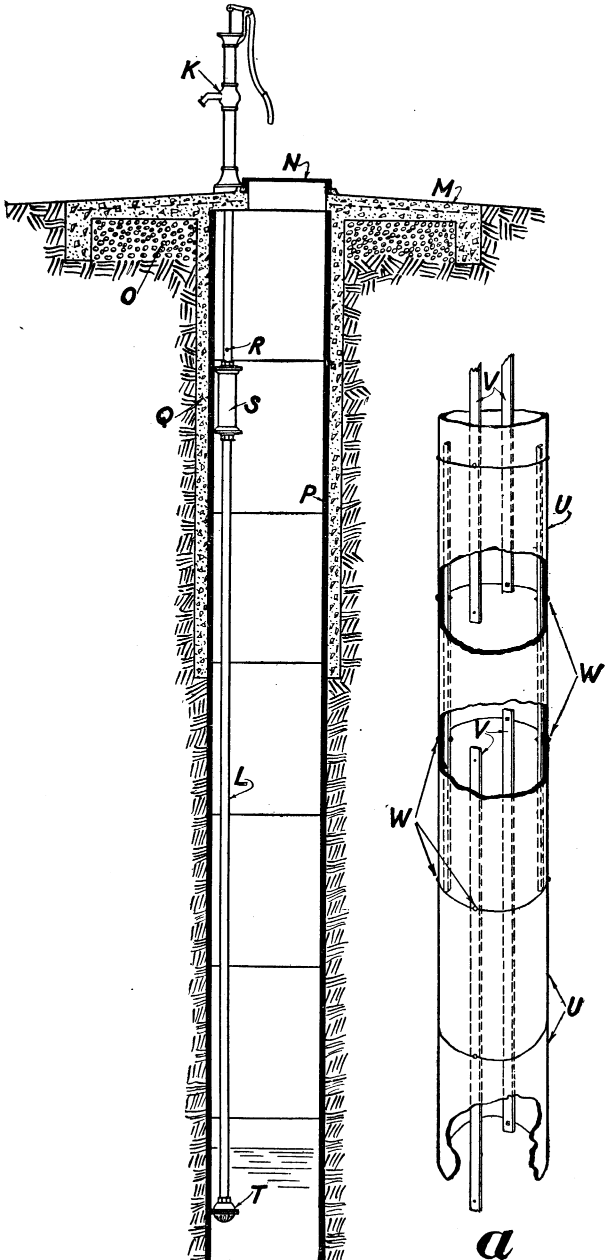

FIG. 15.—Dug well curbed with vitrified ring pipe. Wells of this type 24 inches in diameter and 35 feet deep in fine sand have cost about $200 in Massachusetts (Engineering News, Sept. 7, 1916). *K*, Set-length pump; *L*, suction pipe; *M*, platform; *N*, iron manhole frame and overhanging cover: *O*, gravel foundation; *P*, vitrified ring pipe; *Q*, concrete protection; *R*, drip hole; *S*, cylinder; *T*, foot valve and strainer. (*a*) Shows one method of splicing the pipes for construction purposes; *U*, ring pipe; *V*, 1-inch by 2-inch oak splices; *W*, ½-inch carriage bolts with washers.

bolted to the pipes, and is particularly useful when a well is to be sunk and lined at one operation in relatively soft materials. Long lengths of pipe mean fewer joints.

The excavation for wells 24 inches or less in diameter is made sometimes with a small orange-peel bucket operated by hand with the aid of a tripod derrick. In larger wells a man can work inside the pipe. The material is loosened and placed in a bucket, and another man on the surface raises it with a tag rope or with the aid of a small derrick. The pipe sinks into the excavation thus made, and lengths are added at the surface until the required depth is reached. In loose sand yielding an abundance of water the excavation sometimes is made entirely by the use of a diaphragm or a centrifugal pump. Wells have been sunk in this manner to depths of 30 to 40 feet. By the use of a wooden or steel shoe upon which the curb is started, brick-lined wells 10 to 20 feet in diameter have been thus built, the masons laying the brick at the surface of the ground as the curb sank slowly. Wells sunk in the manner described need not be sheeted and braced, as the curb itself protects. Otherwise, excavations always should be braced carefully to guard against caving and possible loss of life.

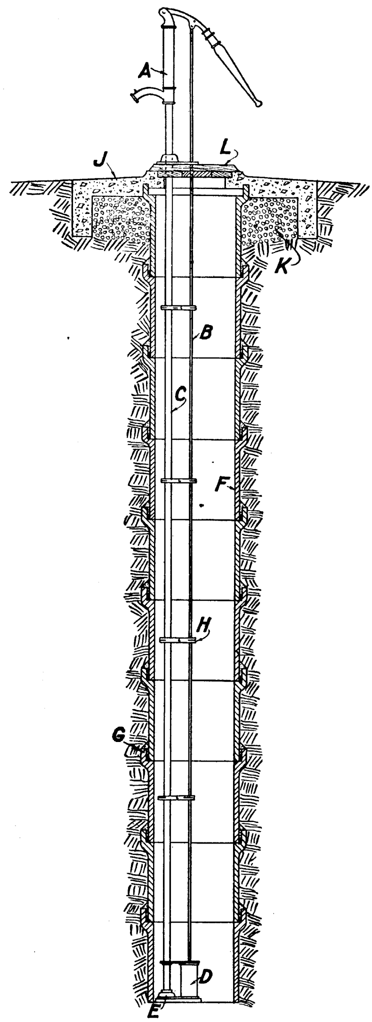

FIG. 16.—Dug well curbed with vitrified socket pipe. *A*, Pump stand; *B*, pump rod; *C*, riser pipe; *D*, cylinder; *E*, check valve; *F*, vitrified socket pipe; *G*, joints packed with a strand of oakum dipped in grout and filled with cement mortar; *H*, pump rod guides; *J*, platform; *K*, gravel foundation; *L*, cross-planked cover.

Below the water table the space between the curb and the sides of the excavation should be filled with clean sand and gravel, the coarser material being placed at the bottom. The upper 8 or 10 feet of this space should be sealed with concrete or clay. The curb should be brought at least 1 foot above the ground and surmounted by a concrete platform in which is a tight-fitting iron or concrete cover and manhole frame. The platform should slope and the earth be graded away from the curb so as to shed pump drippings and surface water quickly. Four types of dug well are shown in figures 14, 15, 16, and 17. If properly located, built, and protected, dug wells are more likely to be permanently satisfactory than any other kind. The advantages relate to the larger volume of water immediately available, whereby the pumping may be rapid and the average lift low, and to less liability of trouble with air and sand in suction pipes and pumps.

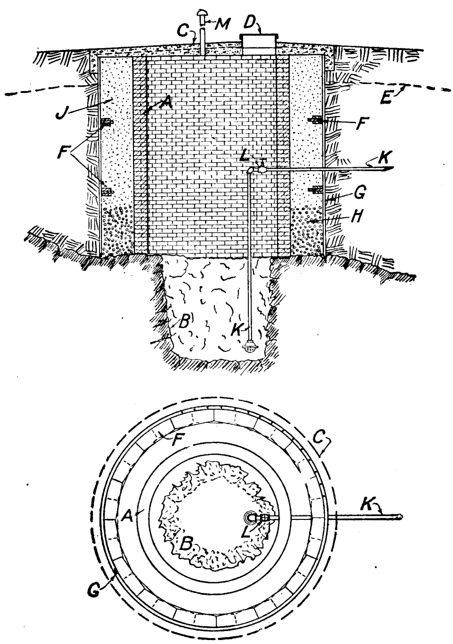

FIG. 17.—Large dug well in rock and caving earth. *A*, Masonry curb; *B*, rock excavation; *C*, platform; *D*, iron manhole frame and overhanging cover; *E*, original surface of ground; *F*, heavy wooden segmental ribs; *G*, heavy grooved sheet piling with hard pine splines or tongues greased before driving; *H*, clean gravel or stone filling; *J*, clean sand filling; *K*, suction pipe; *L*, gate valve; *M*, screened ventilator.

CLEANING DUG WELLS.

Most dug wells require cleaning occasionally. This is 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 inspection of the curb, which, if weak or defective, may make entrance dangerous. This examination may be made more thoroughly, and even the bottom of the well may be observed by the aid of a beam of sunlight reflected into the well by a looking glass. Next, lower a lighted candle to determine if carbonic-acid gas has accumulated in the bottom of the well. Complete or partial failure of the candle to burn indicates that it is dangerous to enter the well. If found safe to enter, a ladder should be lowered and the curb from top down scrubbed with wire or other stiff brushes and rinsed thoroughly. The well then should be pumped as low as possible, and any mud, moss, or other débris should be scraped up into pails and removed. After thorough cleaning, the well should be allowed to fill and then be pumped out rapidly. This operation may be repeated to advantage two or three times, and often the whole work results in a freer, larger-yielding well. Many wells can be drained by hand pumping, but in other cases a power pump is necessary.

Unless there are special reasons for so doing, there is little use in attempting to disinfect wells with chemicals. The volume of water receiving the chemical solution can not be known definitely, and the results are neither certain nor permanent.

TUBULAR WELLS.

"Tubular" is used broadly to include wells variously sunk by boring, driving, or drilling and lined in whole or in part with a tight casing, usually wrought-iron or steel pipe. Such wells may or may not flow, depending upon hydrostatic conditions in the ground. If they go through one or more relatively impervious strata to a more or less confined and porous stratum whose water is under hydrostatic pressure, they properly are called artesian wells, although the head may or may not be sufficient to cause flow at the surface of the ground. (See fig. 10.)

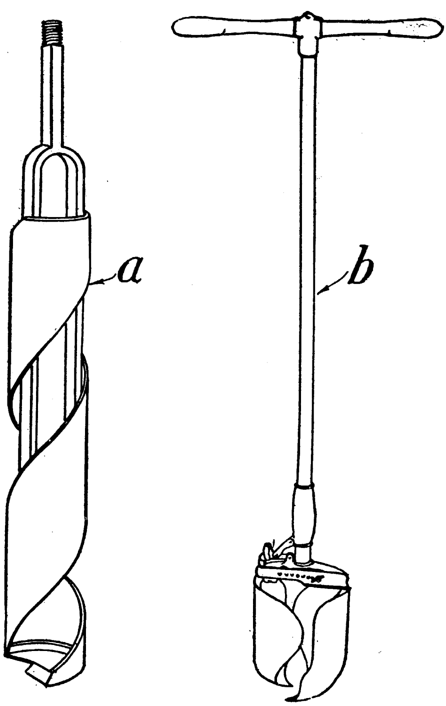

FIG. 18.—Earth augers.

BORED WELLS.

Bored wells are made with earth augers turned and lifted by hand or horse power. The method is adapted to relatively small diameters and depths and to clay, sand, fine gravel, or other comparatively soft material free from bowlders. Two types of earth auger are shown in figure 18 (*a* and *b*). In the type shown in figure 18 (*b*) there is an expansion blade which may be set to cut holes of varying sizes, and there is a movable blade easily opened to release dirt. A small derrick with windlass and block and fall facilitates raising a loaded auger, and a tool resembling a corkscrew is useful in loosening and lifting out small stones. An auger to cut holes from 8 to 16 inches in diameter and including 40 feet of connecting stem (pipe), expansion blades, and tile grapple costs $12 to $13. A mounted well auger, moved and operated by horse power and capable of boring holes 24 inches in diameter and 150 feet deep, is available. Bored wells are lined frequently with hard-burned or vitrified drain tile.

DRIVEN WELLS.

Driven wells are iron or steel pipes forced into a water-bearing bed. Distinction should be made between drive pipe and well casing. Both may be black, galvanized, or asphalted, but drive pipe is heavier and able to stand much pounding. Casing is thinner and is used most frequently to line holes sunk by a water jet, by drilling, or other means. Drive pipe may be had in thicknesses known as standard, extra strong, and double extra strong; also in random lengths (usually between 12 and 22 feet), or, if desired, cut in specified lengths, reamed, threaded, and fitted with couplings. Heavy drive pipe and heavy casing are advisable, as they resist longer

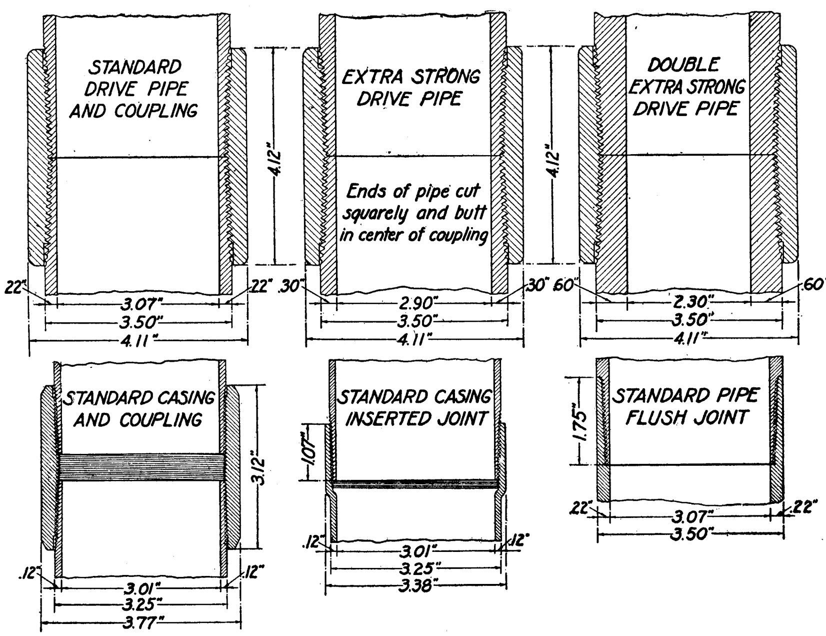

FIG. 19.—Sections of typical joints, 3-inch drive pipe and 3-inch well casing.

corrosion and rough treatment incident to all well-sinking operations. Figure 19 shows the thickness of metal and the common types of joint in 3-inch drive pipe of the several strengths, and of ordinary 3-inch casing.

In the simplest form 1 to 3 inch pipe cut in 5-foot lengths is driven with a heavy striking hammer, sledge, or maul, as shown in figure 20. Other methods of driving whereby heavier weights are used and deeper wells sunk are shown in figures 21, 22, 23, 24, and 25. In figure 24 the weight of the men greatly assists the driving, and the men seem to prefer this direct method of raising the drive block. The first piece of pipe carries a malleable-iron point, either fitting loosely in the end or attached to it. Usually the point is secured to a strainer piece (perforated pipe) 1½ to 3 feet in length, and generally, where the material is silt and fine sand, the perforations are covered with brass gauze protected by an open brass jacket or a wrapping of wire. The threads of every joint should be well coated with a mixture of graphite and cylinder oil. Every joint must be made up tight with pipe wrench or tongs, otherwise, if used as suction, the pipe will leak air, or in driving, the threads may be stripped and the couplings split. The top must have a heavy cap or steel drive head to prevent battering the pipe. In relatively soft material free of bowlders driven wells, as above described, are the quickest and cheapest method of obtaining water. The method is particularly useful in prospecting for water and for temporary supplies. The greatest drawback to such wells lies in the gradual incrustation of the strainer and packing of fine material around it. Very frequently the well must be abandoned in a few years or the pipe pulled and redriven.

FIG. 20.—Driven well.

Figures 26 and 27 show applications of drive-well points and driven wells. The simple installation shown in figure 27 was long used with complete success both winter and summer on a dairy farm at Westboro, Mass. The sawdust-filled walls were frost proof. In summer the milk-cooling tub was emptied and pumped up two to four times daily, the tempered water passing through a lead pipe into a watering trough. Eventually, the strainer in this well choked, and it became necessary to lay a suction pipe to a distant dug well.

Driven wells of the open-end type are much less subject to obstruction than are those having fine screens, and, with proper development of the well, open-end pipe is used frequently where the sand is extremely fine. The material ahead of the drive pipe is removed with a sand bucket or washed up with the aid of a force pump and a smaller pipe known as the drill or wash pipe dropped inside the drive pipe.

Into the end of the wash pipe is screwed a steel jetting drill which loosens the earth, makes the water jet more effective, and is useful in splitting small stones at the end of the drive pipe. The end of the drive pipe should be protected by an extra heavy coupling or a steel shoe. Using a saw-tooth shoe and turning the entire string of drive pipe at each blow, as shown in figures 20, 21, 22, 23, and 24, materially increases the progress. To facilitate the entry of water the first piece of pipe usually has numerous $\frac{1}{4}$ or $\frac{3}{8}$ inch holes drilled through the shell. The holes should be reamed, preferably on the inside.

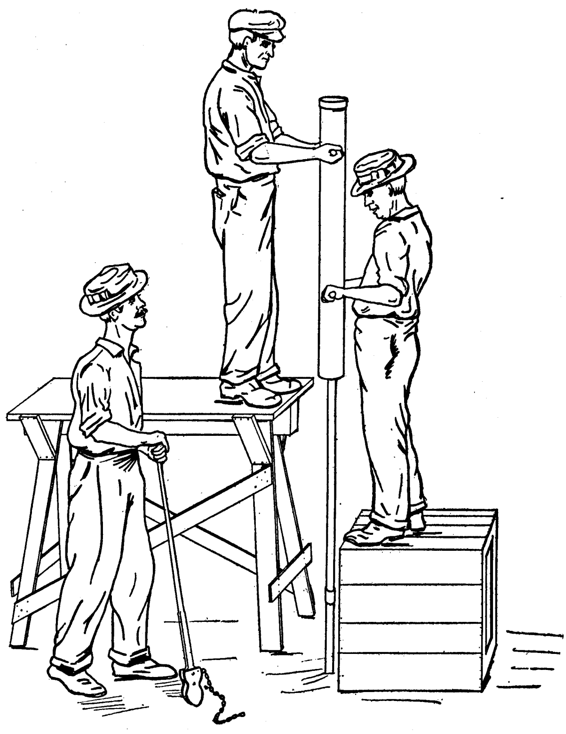

FIG. 21.—Driven well.

Figure 25 shows the application of the jetting process, but it may be used with other methods of driving, as in figures 22, 23, and 24. Simple hand-power outfits are operated readily by three men. 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 2 or $2\frac{1}{2}$ inch well may be sunk 50 to 75 feet in a day. 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. Figure 28 shows an open-end driven well.

DEVELOPMENT OF DRIVEN WELLS.

Success or failure with driven wells often is a matter of development. Comparatively few wells yield freely at first, and often the pump handle yanks back quickly, indicating little or no water available. Such wells must be coaxed, and with proper development good yields, sometimes 40 to 50 gallons a minute, may be drawn from them with an ordinary pitcher pump. To develop a well, screw a hand pump to the top of the casing and work the handle slowly and easily. This is to avoid a sudden rush of fine material and consequent choking of the well. Should the well choke, the pump must be detached and the sand removed with a sand bucket or with a jet of water. Gradually, as more and more clay, silt, and fine sand are brought out of the well, the pumping may become more rapid until eventually the pump is worked to utmost capacity. The result often is the creation of a pocket of coarse material about the bottom of the pipe and a yield as free as from a dug well. In the above manner and in material nearly as fine as quicksand several days have been spent upon a single well with gratifying results. A similar effect sometimes is produced by dropping small stones into the well and forcing them out into the adjacent material with a drill.

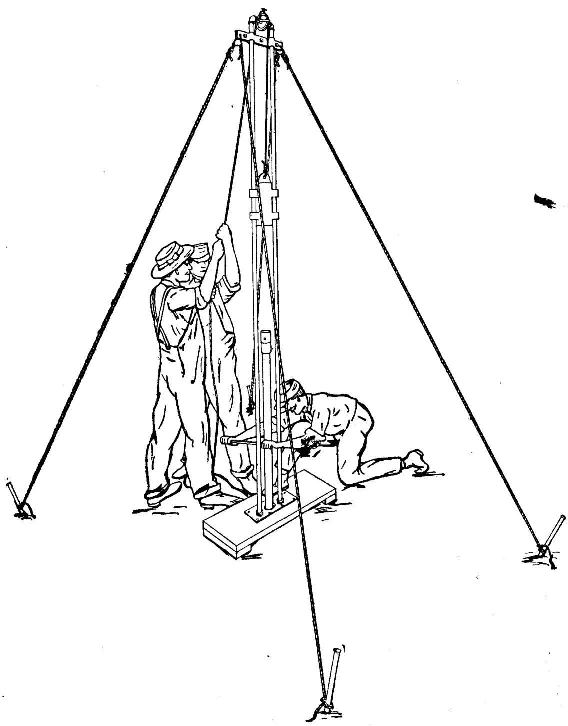

FIG. 22.—Driven well.

DRILLED WELLS.

A drilling outfit is necessary where there is ledge or large bowlders. Generally, a gasoline traction drilling machine is used, and wells are put down by contract or rental by persons equipped for the business. For example, in the vicinity of Twin Falls, Idaho, farm wells are drilled 50 to 150 feet into lava rock at a contract cost of $1 per foot. This cost covers 16 feet of casing, mainly $5\frac{5}{8}$ or $6\frac{1}{4}$ inches inside diameter, through the soil and subsoil. Additional casing, if needed because of loose rock or other material, is paid for by the farmer. It is of value to note that formerly it was necessary to drill about 350 feet to water-bearing sandstone beneath the lava rock, but due to seepage from irrigation ditches, the water table has risen gradually to within 100 feet of the surface of the ground. In the vicinity of Washington, D. C., in September, 1917, $1.38 per foot was bid for drilling and casing (ordinary black 5⅝ inches inside diameter) a well 100 feet or less in depth in clay, sand, gravel, and bowlders.

The yield of drilled wells frequently is increased by shattering the rock with dynamite. This is called "shooting" or "torpedoing" a well and often creates new connections to adjacent passageways carrying water. The method is of little use in unconsolidated materials, and in all instances, because of liability of damage to well or casing or loss of the existing supply, it should be employed only as a last resort. In all well operations a complete record of the kind, depth, and water prospects of each bed or formation should be kept. Frequently it is necessary to pull back a string of pipe, drive it deeper, or perhaps slit it at some water-bearing stratum.

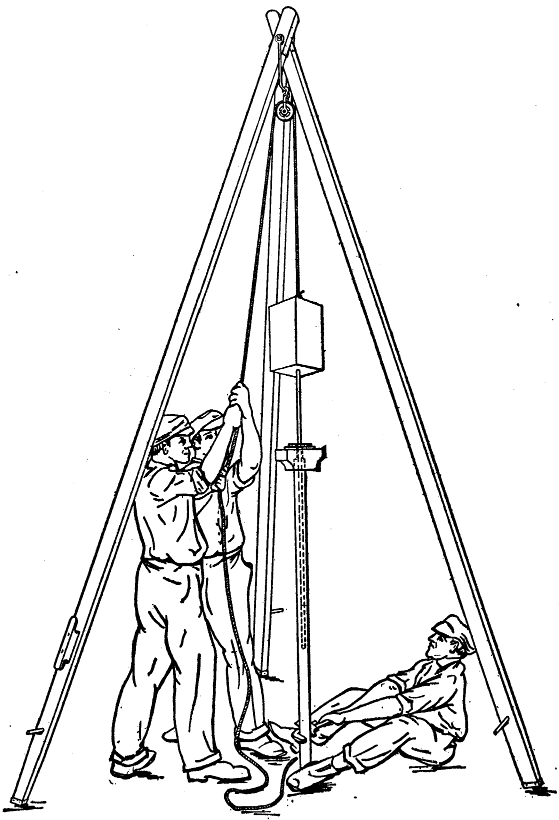

FIG. 23.—Driven well.

INFILTRATION GALLERIES.

Cribs, galleries, and collecting conduits may be defined as horizontal wells. Two examples of galleries are shown in figure 29. Figure 11 (*a* and *b*) shows simple collecting conduits. The construction may be of wood, drain tile, sewer pipe, stone, brick, or concrete, and there should be ample chance, particularly at the bottom, for water to enter. The method is adapted to locations where water is in sheets or thin beds relatively near the surface, or where water is to be taken from the margin of a pond or stream. In the latter case, however, the galleries should be located well back from the stream's edge, at least 50 feet where possible, the idea being to intercept ground water in its movement toward the pond or stream rather than to draw water from them. Galleries should be well below water tables and low-water marks, as otherwise there may be shortage of water during drought. Galleries may be lengthened to increase yields.

METHODS OF RAISING WATER.

Water may be raised by natural flow, hydraulic rams, pumps, air lifts, and air-displacement pumps.

FLOWING WELLS.

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 marked tendency toward exhaustion because of reduced pressure and the addition 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.

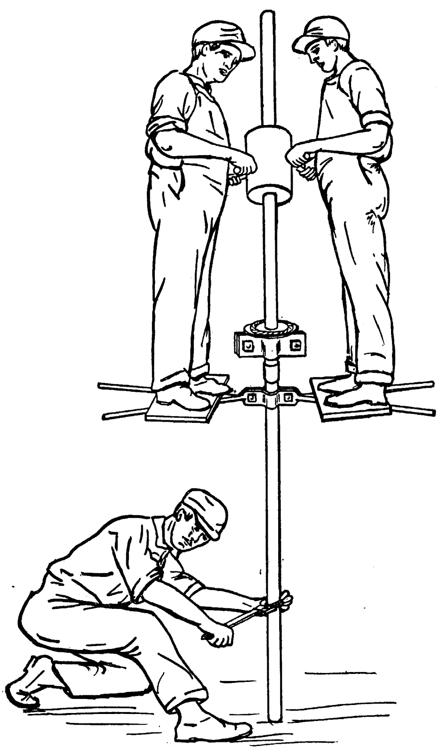

FIG. 24.—Driven well.

HYDRAULIC RAMS.

Although hydraulic rams are an old invention, many people regard them more or less as mechanical toys. They are, however, the most economical pumps known and have been used to raise large quantities of water, as, for instance, the railroad supply at Fort Pierce, Fla., where a battery of four rams is pumping 125,000 to 175,000 gallons daily through more than 2 miles of 6-inch force main.

Hydraulic rams utilize the principle of water hammer. Their operation is as follows: Referring to figure 30, water flows from the source of supply through a straight iron pipe[1] *D* until the velocity

[1] The drive pipe need not slope but may be horizontal or even vertical. A ram screwed to the top of a 4-inch flowing artesian well was long used to supply an Illinois village. "Some Small Water Pumping Installations," 1902, by Daniel W. Mead, professor of hydraulic engineering, University of Wisconsin.

is sufficient to force escape valve *E* outward to its seat. Under rest conditions valve *E* is held open by its own weight or a steel spring. Immediately valve *E* seats, the "kick" of the water (water hammer) in pipe *D* opens check valve *C*, through which some of the flow is forced into air chamber *A* and from thence into delivery pipe *B*. Air chamber *A* promotes constancy of pressure and discharge, and pipe *B* may convey water to a higher-situated watering trough, cistern, reservoir, or to an air-pressure tank. As the kick, or hammer, transmitted through the ram is overcome by the greater pressure in

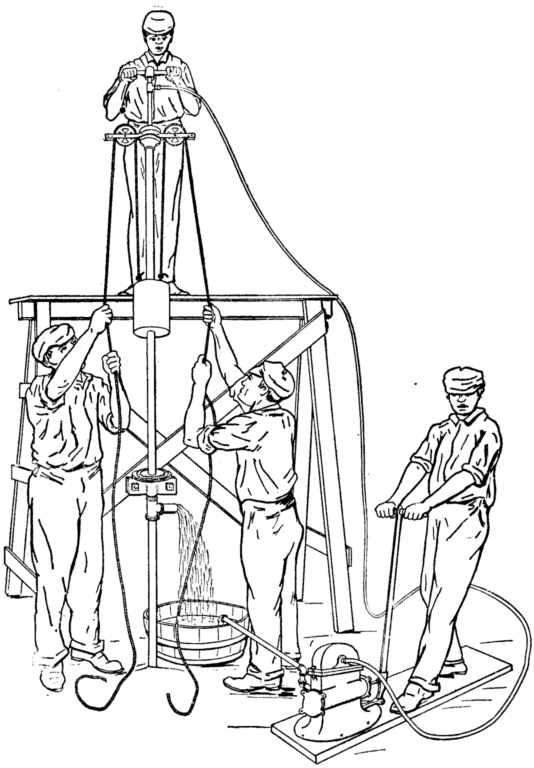

FIG. 25.—Driven well and application of the jetting process.

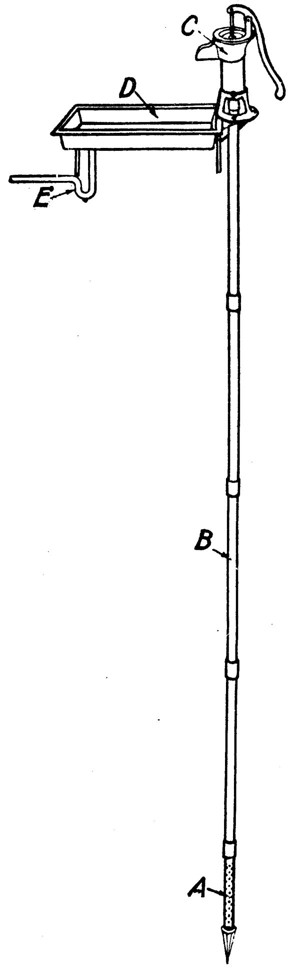

FIG. 26.—Driven well in the home. Where conditions are favorable, this is the quickest and cheapest method of getting ground water to the kitchen sink. *A*, Well point; *B*, drive pipe; *C*, pitcher or kitchen pump; *D*, sink; *E*, lead trap and waste pipe to connect with an absolutely water-tight carrier extending not less than 100 feet in a downhill direction from the well. The cost of a pump, sink, and $1\frac{1}{4}$-inch well 20 feet deep installed as shown should not be more than $20.

pipe *B*, a reaction or backward pulsation is set up which closes valve *C* and unseats valve *E*, whereupon the water in pipe *D* flows again and the whole operation is repeated continuously. The backward pulsation or recoil is utilized to suck air through sniff valve S and so maintain the supply in chamber A. Thus a hydraulic ram automatically pumps water at small cost for power and with little attention. An installation in use nearly 40 years is shown in figure 31.

Rams of different size and make perform differently. Generally, it is necessary to accept the mechanical details determined by the particular manufacturer whose ram is to be used. His instructions should be followed closely, thereby fixing responsibility for results. Manufacturers require the following information: (1) Quantity of water available at ram, gallons per minute.[1] (2) Quantity of water desired at buildings, gallons per day. (3) Available fall, feet (F in fig. 30). (4) Horizontal distance in which fall occurs, feet. (5) Lift to reservoir or tank, feet (L in fig. 30). (6) Length of delivery pipe, feet. It often is recommended that no ram be installed under a fall (F, fig. 30) of less than 3 feet, increasing to 5 or 6 feet with the larger rams; also that no drive pipe shorter than 30 feet be used. Commonly, the diameter of the delivery pipe is about half that of the drive pipe, but it should be increased in size where the discharge is very long, as will be explained in the succeeding caption.

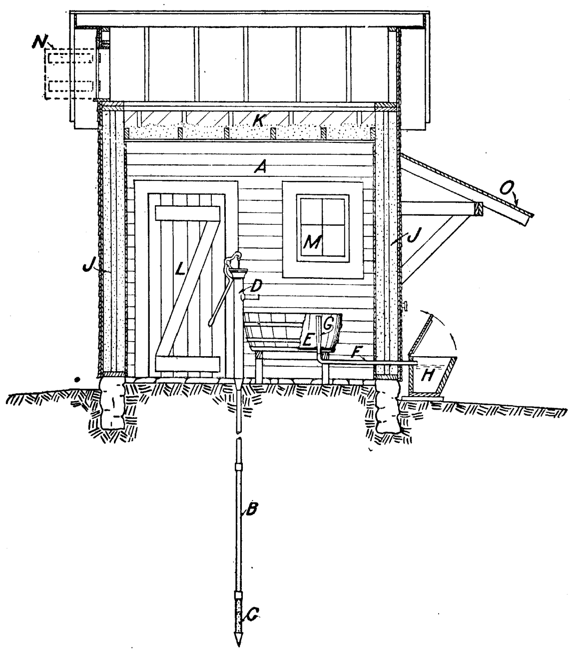

FIG. 27.—Driven well in a milk house. A, Milk house, sectional view, showing interior; B, drive pipe; C, well point; D, copper pump; E, cooling tub; F, lead waste pipe; G, wooden plug; H, watering trough; J, hollow walls, 10-inch space filled with dry sawdust; L–M, double doors and windows on north side; N, door in gable to facilitate placing sawdust; O, shed.

The minimum, never more than the average flow of a spring, should determine the size of the ram. Otherwise a ram may be selected which is too large to be actuated by the dry-weather flow. Under average conditions, say where a fall of 3 to 20 feet can be obtained

[1] Small flows may be determined by noting the time required to fill a vessel of known capacity. Larger flows may be determined from weir measurements. See U. S. Department of Agriculture, Farmers' Bulletin 813, "Construction and Use of Farm Weirs."

within a distance of 30 to 200 feet of a spring or flowing well, from 3 to 25 per cent of the water entering the drive pipe can be raised to ordinary heights or distances. Obviously, with increase of lift (*L*, fig. 30) less water will be raised, and the fall (*F*) must be greater when operating against high lifts. In exceptional cases, where the lift (*L*) is very small, the amount of the water pumped may exceed the quantity wasted. The approximate quantity of water raised by a good hydraulic ram properly installed may be computed by the following rule:[1] Multiply the number of gallons a minute available for supplying the ram by the fall in feet (*F*, fig. 30). Multiply this product by 40 and then divide by the sum of the fall and lift (*F*+*L*, fig. 30). The result is the number of gallons discharged in one hour, and if multiplied by 24 gives the daily discharge.

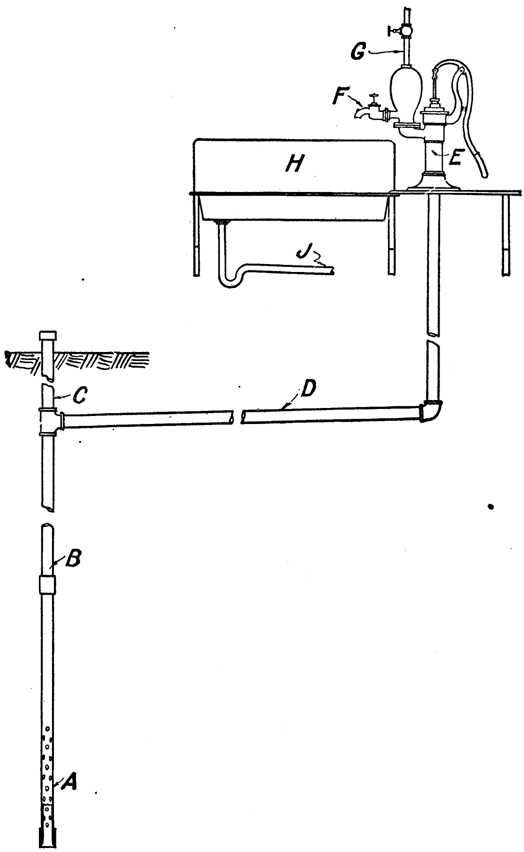

FIG. 28.—Open-end driven well and force pump. *A*, Open-end strainer piece with steel shoe; *B*, drive pipe; *C*, screw cap above ground surface, thus facilitating examination and cleaning of well; *D*, suction pipe laid below frost and on a smooth, upward slope to pump; *E*, force pump; *F*, spout and shut-off; *G*, delivery pipe and valve; *H*, sink; *J*, lead trap and waste pipe to connect with an absolutely water-tight carrier extending not less than 100 feet in a downhill direction from the well.

Where the supply is far from the ram site it is usual to pipe the flow to an open tank, reservoir, or standpipe located so as to secure the desired length and fall of drive pipe. Experience has proved, however, that long drive pipes and high power heads may be used successfully where ample waterway area in the check valve and ample air-chamber capacity are provided. The tank, reservoir, or stand pipe inserted at the upper end of the drive pipe should be protected from frost, and its top must be above the water level of the source of

[1] Based on a mechanical efficiency of 66⅔ per cent (D'Aubuisson formula). Many farm rams operate at 20 to 40 per cent efficiency, but under favorable conditions the best rams may develop from 70 to 90 per cent.

supply as shown in figure 32. Sometimes the flow of a spring is too small to actuate a ram but is sufficient for domestic requirements. In such instances and where a near-by brook can be dammed so as to obtain the necessary power head, the backward pulsation or recoil in a ram may be employed to admit the spring water which is pumped by the fall of the brook water in the drive pipe. Figure 32 shows this method.

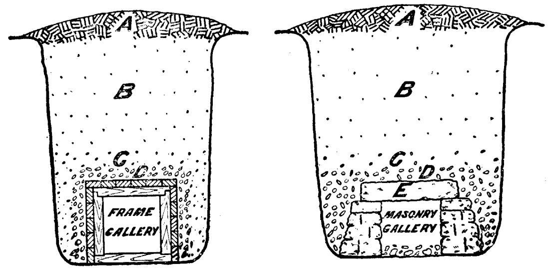

FIG. 29.—Infiltration galleries. *A*, Earth refill; *B*, sand and gravel; *C*, 6-inch layer of screened gravel $\frac{1}{8}$ to $\frac{1}{2}$ inch in size; *D*, 6-inch layer of screened gravel, $\frac{1}{2}$ to $1\frac{1}{4}$ inch size; *E*, covering stone. The frame gallery has been used constantly 27 years. Always submerged, the wood is preserved fairly well, but silt and quicksand gradually are filling up the gallery.

A hydraulic ram should be fastened to a suitable foundation and be housed properly. The waste pipe from the ram pit should be of good size and not subject to backwater or other obstruction. All joints in the drive and discharge pipes should be tight. (See methods of making tight joints, p. 33.)

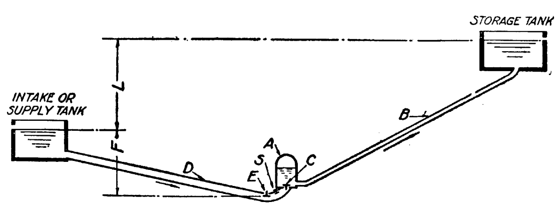

FIG. 30.—General layout of a hydraulic ram installation. *D*, Drive, feed, or supply pipe; *E*, escape, waste, impetus, dash, or clack valve; *C*, check, delivery, or discharge valve; *A*, air chamber; *B*, delivery or discharge pipe; *S*, sniff or air valve; *F*, fall, supply head, or power head; *L*, lift, discharge head, or pumping head.

Bends in the drive pipe are a detriment, but if unavoidable should be of gentle curvature, leaving the bore unrestricted. Full-way gate valves should be used to lessen friction. The upper end of the drive pipe may be made bell-shaped to facilitate entry of water, and 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

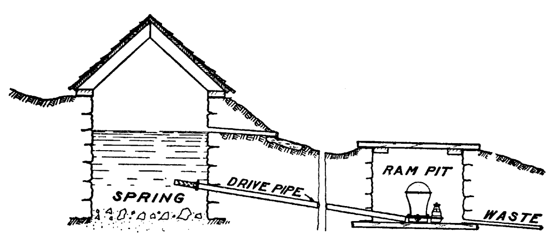

FIG. 31.—Hydraulic ram installed in 1878 and in use nearly 40 years, Worcester County, Mass. Ram pit and spring curbed roughly with field stones. Delivery pipe about one-third of a mile long and supplies two watering troughs in a dairy barn holding about 30 head of stock. Total cost of installation, not including delivery pipe, was $75. Labor was paid $1.75 per day.

valves are less noisy than metal, but where the pounding is objectionable, as it may be in a dwelling, an air chamber and a piece of rubber hose inserted in the delivery pipe ends the trouble.

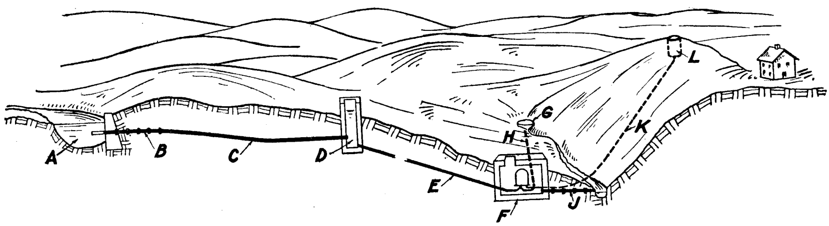

FIG. 32.—Method of using a distant surface supply to raise clear spring water. *A*, Surface supply; *B*, supply pipe (may be vitrified pipe for a portion of the way, where the pressure is small); *C*, iron supply pipe; *D*, standpipe; *E*, drive pipe; *F*, ram; *G*, spring; *H*, spring-water supply pipe; *J*, waste pipe; *K*, delivery pipe; *L*, elevated reservoir.

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) until its movements have been brought into unison with the natural "beat" or pulsations in the drive pipe.[1] If the escape valve remains up, excessive pressure or

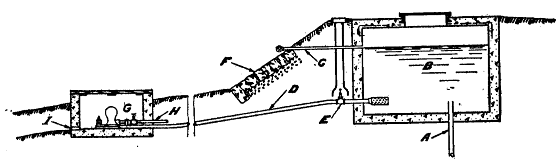

FIG. 33.—Hydraulic ram installation, St. Marys County, Md. *A*, $1\frac{1}{2}$-inch well flowing 4 gallons a minute; *B*, concrete supply tank; *C*, screened overflow; *D*, $1\frac{1}{4}$-inch drive pipe; *E*, gate valve; *F*, paved slope; *G*, ram; *H*, $\frac{3}{4}$-inch delivery pipe to storage tank; *I*, wasteway.

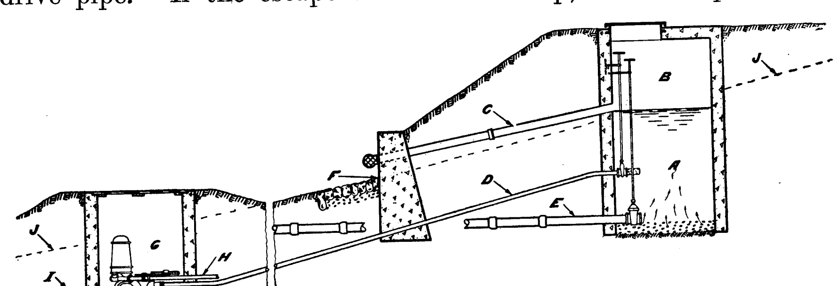

FIG. 34.—Hydraulic ram installation, Pennsylvania. *A*, Springs, yield about 5 gallons aminut e; *B*, spring chamber; *C*, 4-inch screened overflow; *D*, $1\frac{1}{4}$-inch drive pipe, 170 feet long, with gate, gate key, and screen; *E*, 4-inch drain pipe, with gate and key; *F*, retaining wall and pavement; *G*, ram; *H*, 1-inch delivery pipe; *I*, waste pipe; *J*, original surface of ground.

leakage in the ram is indicated. If the escape valve remains down, lack of fall or water is indicated. This difficulty can often be over-

[1] Distinction should be made between maximum discharge and point of greatest mechanical efficiency (useful work taken out divided by whole work put in). For example, a ram running 37 strokes a minute used in that time 13.1 gallons of which 10.1 gallons were wasted and 3 gallons were pumped, the mechanical efficiency being 41 per cent. When speeded to 72 strokes a minute the mechanical efficiency was 55 per cent, but the ram used only 4 gallons of which 2.9 gallons were wasted and 1.1 gallons were pumped.

come 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 is probable.

Figure 33 shows a ram installation upon a farm in St. Marys County, Md. The supply is obtained from a 1½-inch flowing artesian well 265 feet deep and is raised to an elevated tank in the house yard. Figure 34 shows a design for a Pennsylvania farm where the supply is taken from springs and raised to an underground concrete reservoir (fig. 44) on a hill near the buildings.

FRICTION LOSS AND PUMPING HEAD.

Where a ram or other pump is to deliver water through a very long pipe or into an air-pressure tank, other factors enter in to increase the true pumping head. Motion of water produces friction, a form of resistance that increases with the length and roughness of the pipe and the rapidity with which the water moves. Hence, 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. In effect, it increases just so much 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. The table [1] following 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.

[1] Hydraulic tables, Williams and Hazen, N. Y., 1909. Coefficient here used is 100, a fair value where the interior of iron pipe is somewhat roughened by rust and sediment.

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	3.25	.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	1.8	2.9	6.2	11.1	18.0	38.3	68.9	111.3

[1] Based on diameters raised to the 2.63 power. Comparative discharges are fair approximations only. 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 or capacity about 6 times.

A column of water 1 foot high and having a base equal in area to 1 square inch weighs about $\frac{7}{16}$ of a pound, and of course presses that amount on the base. Double the height, and obviously both 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 the table following is computed.

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

An example will show the use of the last two tables. What is the pumping head where a ram or other pump is delivering 3 gallons a minute through 1,000 feet of 1-inch pipe to an air-pressure tank carrying 39 pounds per square inch situated 20 feet higher than the ram? Solution: To the vertical height water is raised, 20 feet, must be added friction loss, 12.6 feet $\left(\frac{1,000}{100}\times 1.26\right)$ and equivalent height of the 39-pound tank pressure, which is 90 feet, $20+12.6+90=122.6$ feet, the true pumping head (dynamic head).

PUMPS.

The principle underlying the operation of pumps is the displacement of water from a casing, tube, barrel, or cylinder by a movable piston, plunger, or impeller. The medium through which power is transmitted to the piston is called the stock, stand, standard, or working head. Farm pumps usually are suction, lift, force, deep-well, or some combination of these types.

Suction and lift pumps do not raise water above the pump nor discharge it under pressure. Suction pumps require the cylinder to be above the water level of the supply. If a perfect vacuum could be created within the cylinder, water could be raised vertically by suction 33.9 feet at sea level. Due, however, to pump imperfections, air leaks, and vapor and air in water itself, actual suction lift is usually not more than two-thirds of the theoretical height which, together with atmospheric pressure, diminishes with elevation above sea level. The following table gives the limiting suction lift for the satisfactory operation of pumps at stated elevations up to 8,000 feet above sea level.

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]
Feet.	*Feet.*	*Feet.*
0	33.9	22.0
1,000	32.6	21.2
2,000	31.4	20.4
3,000	30.2	19.6
4,000	29.1	18.9
5,000	28.0	18.2
6,000	27.0	17.5
7,000	26.0	16.9
8,000	25.0	16.2

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

Suction pipes must be absolutely air-tight. Methods of making tight joints are described under Driven Wells, page 33. Horizontally, suction pipes may extend long distances,[1] provided the

[1] Suction pipes 100 to 1,000 feet long are frequent. One nearly $1\frac{1}{4}$ miles in length has been used many years by a town in Massachusetts.

friction loss (see table, p. 44) plus the vertical height from water level to pump valve does not exceed the limiting suction lifts shown in the table preceding. Suction pipes should be straight, slope uniformly upward from well to pump, and never be smaller than the suction connection on the pump. Long lines should be of larger size than such connection and should have a vacuum chamber near the pump and a foot valve on the end in the well. A strainer on the end prevents entrance of obstructions. The strainer may be combined with the foot valve and always the total area of the openings should be large. Figures 14, 26, and 27 show simple suction pumps with cylinders forming a part of the standards.

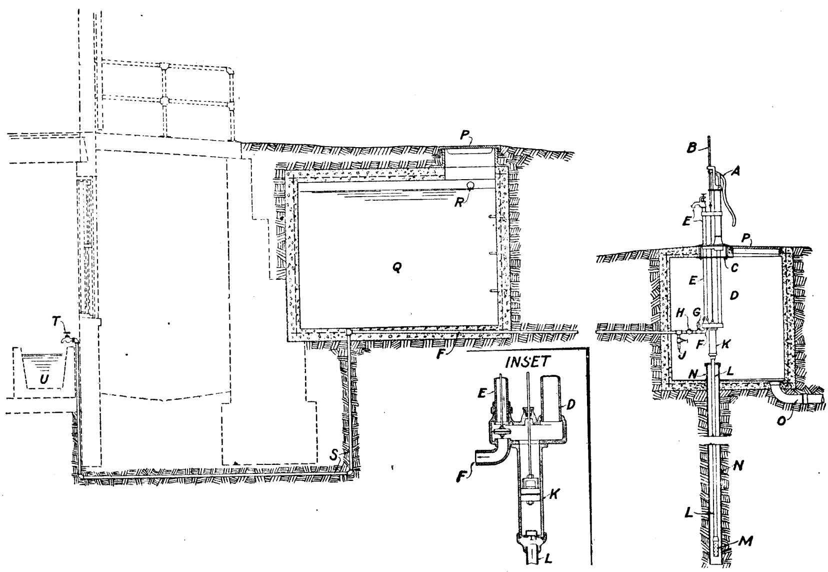

FIG. 35.—Combined hand and windmill force pump, with underground and surface discharges and storage tank under driveway to second story of barn. *A*, Pump; *B*, connecting rod; *C*, clamp to secure standard to concrete; *D*, air chamber; *E*, surface discharge pipe; *F*, underground discharge pipe; *G*, relief valve; *H*, check valve; *J*, waste and blow-off; *K*, pump cylinder; *L*, suction pipe; *M*, strainer; *N*, well casing; *O*, 4-inch drain; *P*, cast-iron frame and manhole cover; *Q*, storage tank; *R*, overflow; *S*, supply pipe to trough; *T*, faucet; *U*, watering trough. Inset shows details of pump cylinder and connections; letters refer as above.

Where a pump can not be placed so that the limiting suction lifts mentioned in the table will not be exceeded, it is necessary to lower the pumping cylinder into the well, raising water from the cylinder to the spout by the direct lift of the piston. A set-length lift pump (sufficient pump or connecting pipe and plunger rod to place the bottom of the cylinder 4 feet below base of standard) is shown in figure 15. This type of pump is used in wells 25 to 28 feet deep. However, water can be pushed more easily than it can be pulled, and hence rather than resort to extreme suction lifts it is preferable to lower the cylinder to within 15 feet of the supply, or still better, to submerge it. Submergence keeps the cylinder primed and the pump leathers pliable. With the cylinder thus lowered into or near the water, this type of pump may be used in very much deeper wells, the depth varying with the weight of the pump, the size of the cylinder, and the power. A drip hole drilled in the connecting pipe a few feet below the platform (always above the cylinder) allows the water to drop back to that point, and, providing the platform is tight, prevents freezing.

Where water is discharged against pressure a force pump is necessary. A combined suction and force pump installed at a kitchen sink is shown in figure 28. Delivery pipe *G* may be taken to an attic tank or an outside elevated reservoir, and thus a light pressure supply be maintained throughout the house. Figure 35 shows a combined hand and windmill force pump with discharge either below or above ground. Figure 36 shows a suction and force pump driven by a gasoline engine, both mounted on one base.

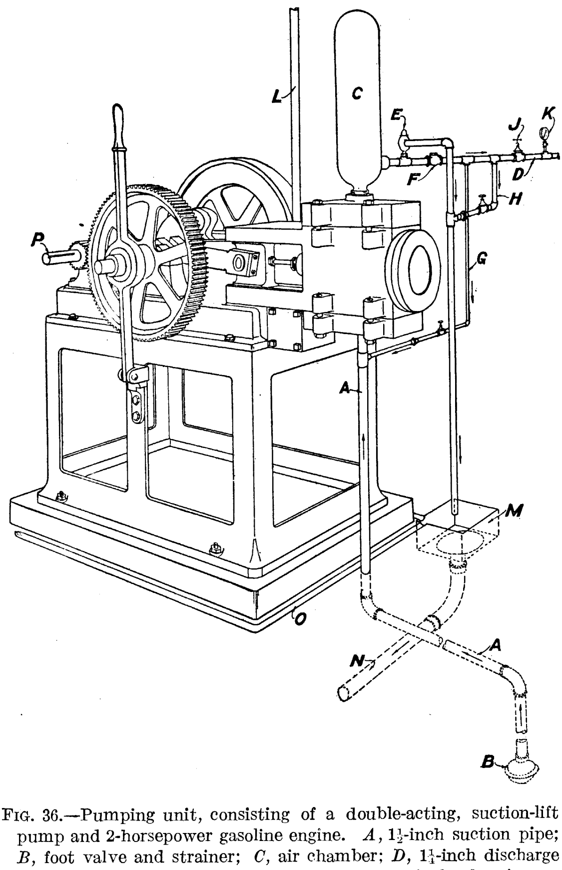

FIG. 36.—Pumping unit, consisting of a double-acting, suction-lift pump and 2-horsepower gasoline engine. *A*, $1\frac{1}{2}$-inch suction pipe; *B*, foot valve and strainer; *C*, air chamber; *D*, $1\frac{1}{4}$-inch discharge pipe; *E*, relief valve; *F*, check valve; *G*, $\frac{1}{2}$-inch charging or priming pipe; *H*, waste and blow-off pipe; *J*, gate valve; *K*, pressure gauge; *L*, engine exhaust above roof; *M*, sump in floor; *N*, 4-inch drain; *O*, floor gutter; *P*, shaft for attaching pulley to drive other machinery. An equipment having a rated capacity of about 17 gallons a minute and erected complete, as shown, at a point 500 miles from the factory, costs approximately $300. (March, 1918.)

Deep-well pumps are heavier and stronger than those heretofore described. They may be of the lift or force type, and the standard or working head always is directly over the well. Two methods of supporting the working barrel or cylinder are used. In one method a plain tubular cylinder about one-fourth inch smaller than the bore of the well is attached securely at the desired depth to the well pipe or casing. In the second method the working barrel screwed to a connecting or drop pipe is hung from the standard or working head. With either method the cylinder should be near (within 15 feet) or else below the lowest water level which pumping and drouth may create. (See Wells, page 26.) Submergence always is preferable. In the first method there is no drop pipe, and a cylinder of maximum

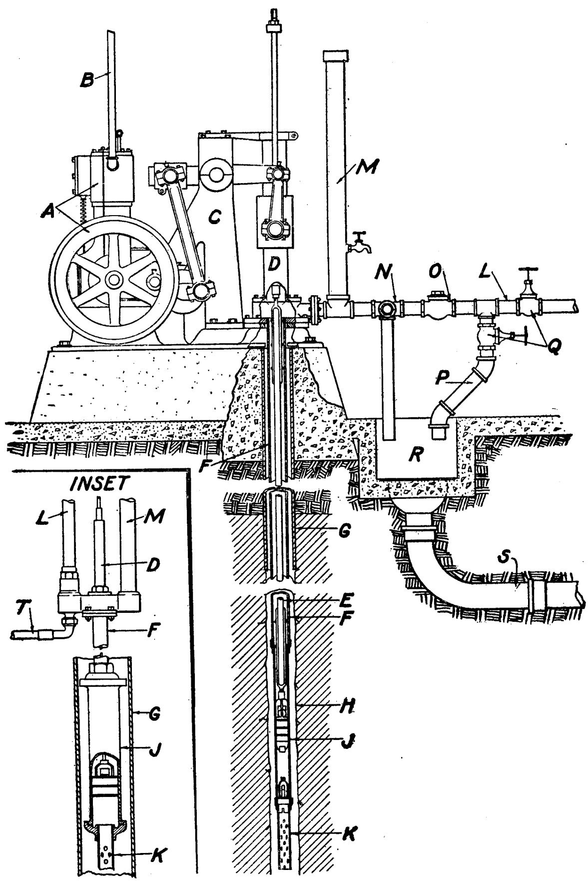

FIG. 37.—Pumping unit, consisting of a single-acting deep-well pump and 2-horsepower gasoline engine. *A*, Engine; *B*, exhaust above roof; *C*, working head; *D*, differential or upper cylinder; *E*, sucker rod; *F*, drop or column pipe; *G*, well casing; *H*, well in rock, uncased; *J*, lower cylinder; *K*, strainer; *L*, 1½-inch discharge pipe; *M*, air chamber; *N*, relief valve; *O*, check valve; *P*, waste and blow-off; *Q*, 1½-inch gate valve; *R*, sump in floor; *S*, 4-inch drain. Not including the well itself, an average installation as illustrated costs about $400. Inset shows details of a deep-well pump suitable for hand or windmill operation. *L*, Surface discharge pipe; *T*, underground discharge pipe; other letters refer as above.

diameter may be used. A saving of pipe thus is effected, but the cylinder can not be removed as easily as when hung with the drop pipe, nor can it be lowered beyond the casing, often desirable where a well is in rock that stands without lining. Where a drop pipe is used it is a great convenience to the farmer to have it of such size that the plunger can be pulled up for the replacement of cup leathers or other repairs. This is true particularly when the length of the drop pipe exceeds 75 or 100 feet. Pump or sucker rods are made of wood, steel or iron pipe, or steel rod. They come in lengths of 10 to 20 feet, and the joints should be made securely. Where a double-acting cylinder is used, in order to keep the pump rod in true alignment some type of guide coupling at intervals of 10 to 15 feet is used. The guide couplings may be carried on the pump rod. The same purpose is gained sometimes by using couplings having a center guide on the drop pipe. In all cases pump-rod joints should come well above the joints in the drop pipe. A hole should be provided in the roof of the building to facilitate the handling of rods and drop pipe.

Usually deep-well farm pumps are single acting; that is, water is lifted and forced on the upward stroke. When operating thus against an elevated reservoir or a hydro-pneumatic (water-air) tank, a heavy variable load is placed upon all working parts. A differential plunger, carried by the pump rod and located in or near the working head, is employed to divide the work between the up and down strokes. In this way all or part (depending on the relative size of the two plungers) of the water lifted to the surface by the lower plunger is forced to the delivery pipe by the down stroke of the differential plunger. Figure 37 shows a deep-well pump driven by a gasoline engine, both mounted on one base.

In all installations the size of the pumping cylinder must be determined from the size, depth, and yielding power of the well, the quantity of water required, and the available power. Deep wells and hand and windmill outfits take the smaller cylinders. The following table shows the capacity [1] of pumps per stroke for one single-acting cylinder.

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.

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 (see Wells, p. 26), and the maximum yield. (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, whether hand, windmill, gasoline or oil engine, or electric motor, and desired method of transmitting the power.

The table on the following page shows trade data on pumping units of the suction-lift type and the deep-well type. Capacities are based on plunger displacement, with no allowance for slippage or other losses.

AIR LIFTS.

Air lifts are useful in raising large quantities of water from deep wells. The essential features of an installation are shown in figure 38. The advantages of the method are simplicity, large capacity, noninterference by cold, grit, or sand, and adaptability to drawing from several wells at one time. On the other hand, air-lift installations are costly, the mechanical efficiency may be low, both the depth and yield of the well must be large, and where the discharge is far horizontally the air tends to slip over the water. In many institutional and public systems air lifts are used to bring water to the surface, after which it is handled with steam pumps.

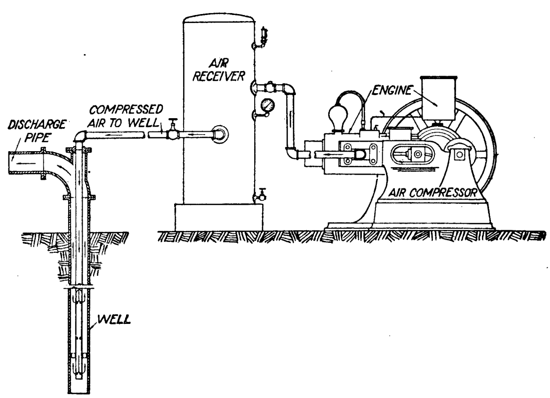

FIG. 38.—Air-lift installation.

Trade data on pumping units (combined double-acting, suction-lift pumps and gasoline engines).

Plunger.		Diameter of pipes.		Revolutions per minute.	Capacity.		Maximum working pressure.		Engine.				Floor space.	Shipping weight.
									Cylinder.		Revolutions per minute.	Horsepower.		
Diameter.	Stroke.	Suction.	Discharge.		Per minute.	Per hour.			Diameter.	Stroke.				
Inches.	*Inches.*	*Inches.*	*Inches.*		*Gallons.*	*Gallons.*	*Pounds.*		*Inches.*	*Inches.*			*Inches.*	*Pounds.*
2	4	1¼	1	50	5.4	324		125	3½	3½	500	1	28 x 30	500
2¾	4	1¼	1¼	50	10.3	618		60	3½	3½	500	1	28 x 30	500
2½	4½	1½	1¼	54	10.3	618		150	4	5	450	2	30 x 46	700
3¼	4½	1½	1¼	54	17.4	1,044		90	4	5	450	2	30 x 46	700
					(Combined single-acting, deep-well pumps and gasoline engines.)									
2	6	[1] 1¼	1	40	3.3	198	[2] 100	[3] 138	3	3½	500	1	16 x 36	500
2½	6	[1] 1¼	1	40	5.1	306	[2] 75	[3] 138	3	3½	500	1	16 x 36	500
3	6	[1] 1½	1	40	7.4	444	[2] 50	[3] 138	3	3½	500	1	16 x 36	500
3¼	10	[1] 3½	1½	35	12.6	756	[2] 150	[3] 208	4	5½	450	2	32 x 44	1,000
3¾	10	[1] 4	1½	35	16.7	1,002	[2] 75	[3] 208	4	5½	450	2	32 x 44	1,000
2¼	16	[1] 2½	2	36	9.9	594	[2] 150	[3] 230	......	......	......	2	......	......
2¾	16	[1] 3	2	36	14.8	888	[2] 100	[3] 173	......	......	......	2	......	......
3¾	18	[1] 4	2½	30	25.8	1,548	[2] 150	[3] 208	5	7	375	4	42 x 60	1,800
4¾	18	[1] 5	2½	30	41.4	2,484	[2] 75	[3] 208	5	7	375	4	42 x 60	1,800

[1] Drop pipe. [2] Depth of well in feet. [3] Maximum lift above well in feet.

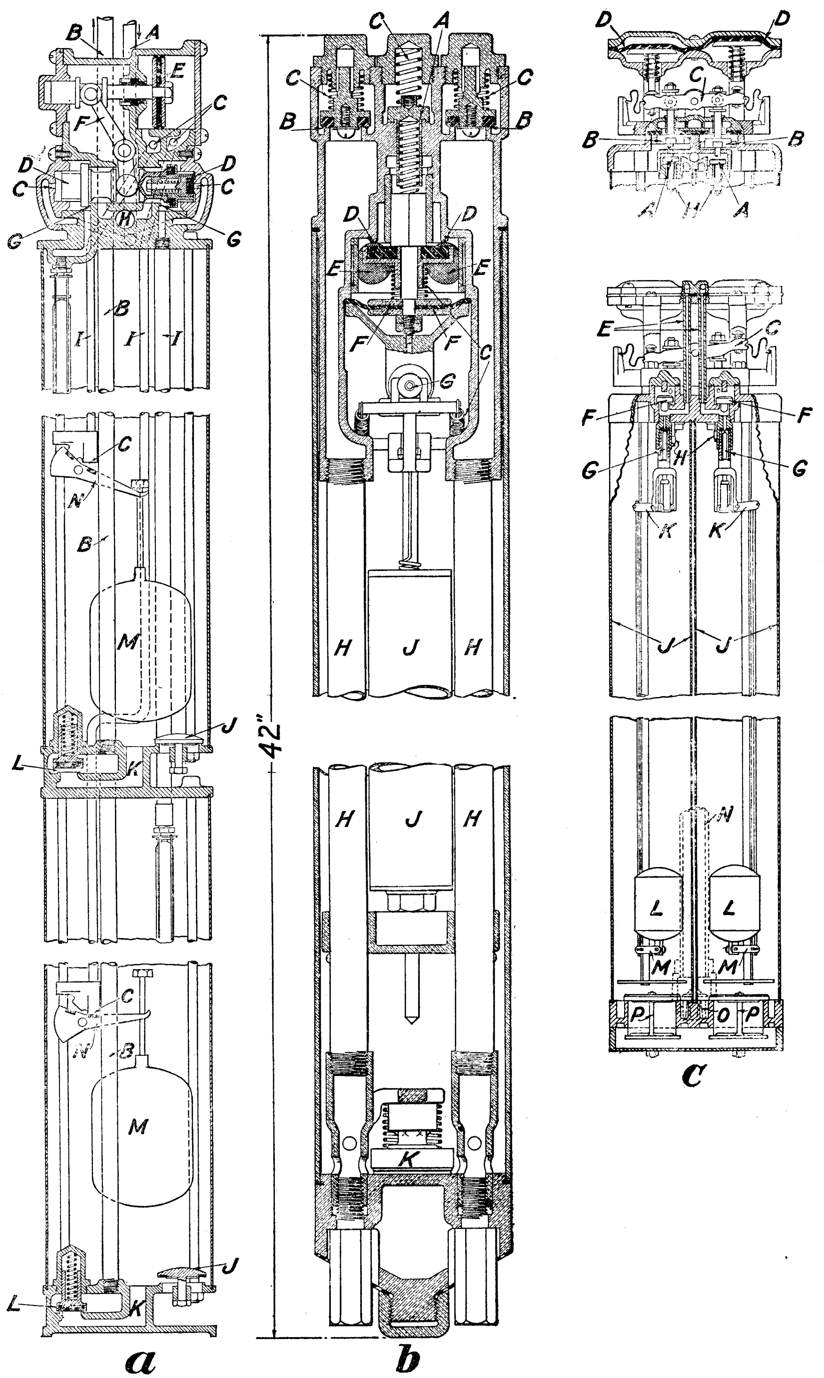

FIG. 39.—Three types of air-displacement pump.

(*a*) *A*, Air-inlet pipe; *B*, water-discharge pipe; *C*, air port; *D*, air valve; *E*, air piston; *F*, rocker arm; *G*, exhaust port; *H*, air discharge; *I*, air pipe; *J*, water-inlet valve; *K*, water port; *L*, check valve; *M*, float; *N*, lever arm.
(*b*) *A*, Air-inlet valve; *B*, water-discharge valve; *C*, springs; *D*, exhaust valve; *E*, screen; *F*, diaphragm; *G*, reversing valve; *H*, water-discharge pipe; *J*, water motor; *K*, water-inlet valve.
(*c*) *A*, Air-inlet valve; *B*, air-exhaust valve; *C*, shifting lever; *D*, diaphragm; *E*, air tube; *F*, diaphragm release valve; *G*, air-controlling valve; *H*, lifting bar; *J*, water cylinder; *K*, controlling-valve lever; *L*, float; *M*, float lever; *N*, water-discharge pipe; *O*, water-discharge valve; *P*, water-inlet valve.

AIR-DISPLACEMENT PUMPS.

Pumping by means of compressed air is very old, but the systems in use prior to 1909 required the air supply to be turned on or shut off according to whether water was or was not needed. Based on a patent granted in 1909, a two-cylinder, air-displacement pump submerged in the water supply and controlled by the opening and closing of a faucet was devised. The cylinders side by side filled and discharged by admitting compressed air to and exhausting it from each chamber alternately. The shifting of the air pressure from one cylinder to the other was effected by an automatic valve mechanism at the top of the pump. Each cylinder had four valve openings, two for inlet and outlet of water and two for inlet and outlet of air. Pumps of the type described, particularly those of galvanized-iron construction, and installed under conditions none too favorable, were often a source of trouble. Among the troubles were racing of the pump when the water supply gave out, worn and leaky valves because of sand and sediment in the water, corrosion of the working parts, and their failure from various minor causes to function properly.

The essential parts of an installation are an air-displacement pump, an air compressor, an air-storage tank, an engine or motor, together with air and water pipes, and minor attachments. Air is piped from the air tank to the pump, and water is piped from the pump to the faucets. The pump operates only when water is used, starting whenever a faucet is opened and continuing until all faucets are closed. Three types of all-brass and bronze, air-displacement pumps are shown in figure 39 (*a*, *b*, and *c*). The outer barrels are removed to show the interior parts. Figure 40 shows the essentials of a complete installation. The mechanical equipment shown costs about $450. Freight, installing, concrete work and well are additional.

The chief advantage of air-displacement pumps is that water may be taken from ordinary depth or lateral distance or from several sources with one power outfit and delivered direct from well to faucet. The power plant may be located wherever convenient, and as many pumps may be used as there are sources for supplying water. Both hard and soft water may be delivered by using two pumps and the necessary piping system. Air-displacement pumps are not adapted at present to lifts of much over 125 feet or to wells less than 3 inches in diameter, nor can they be used where more water than the well can supply is required within a specified period of time. Air pipes and air-displacement pumps must be tight and remain tight in service and the working parts be maintained in good order.

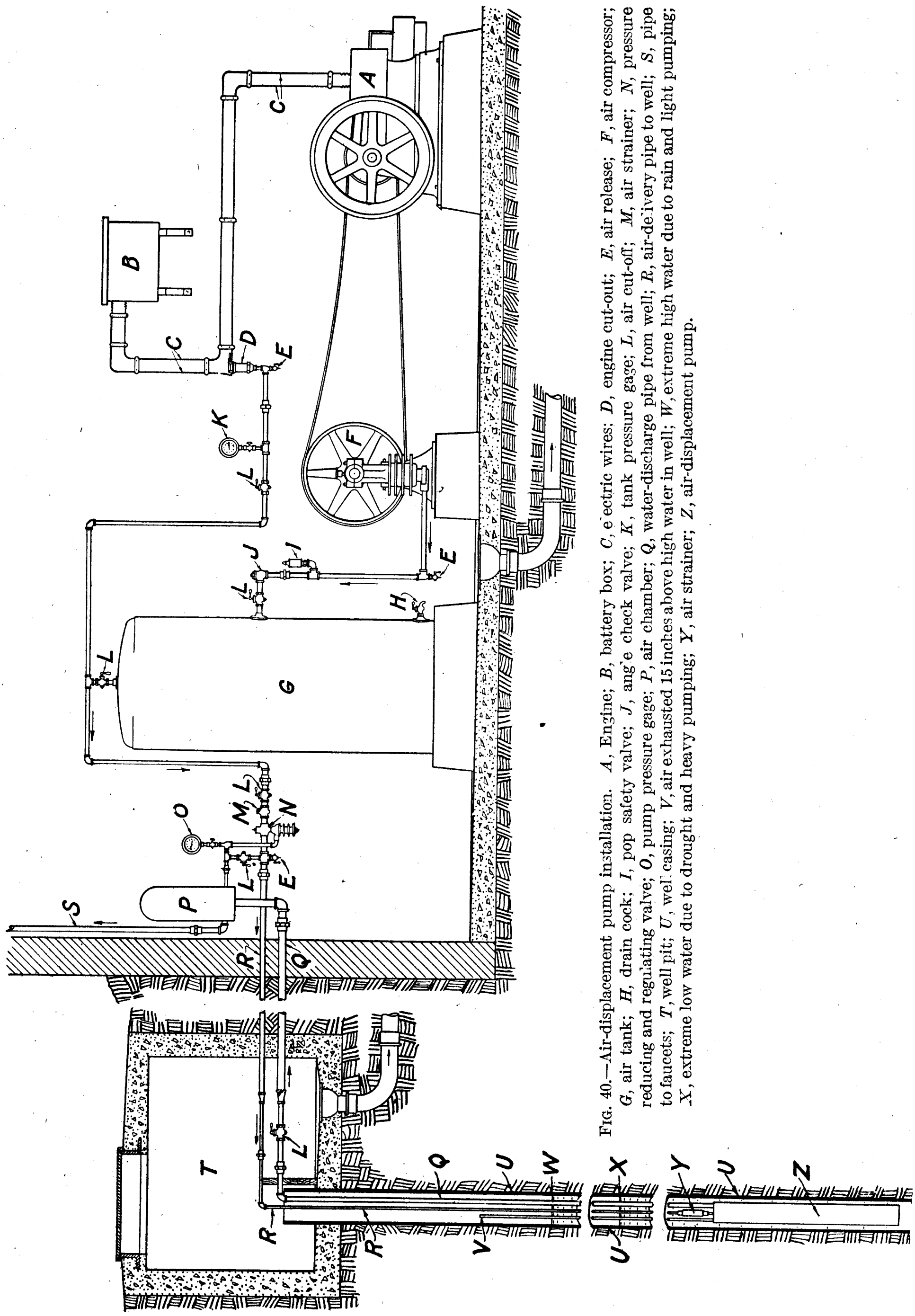

FIG. 40.—Air-displacement pump installation. *A*, Engine; *B*, battery box; *C*, electric wires; *D*, engine cut-out; *E*, air release; *F*, air compressor; *G*, air tank; *H*, drain cock; *I*, pop safety valve; *J*, angle check valve; *K*, tank pressure gage; *L*, air cut-off; *M*, air strainer; *N*, pressure reducing and regulating valve; *O*, pump pressure gage; *P*, air chamber; *Q*, water-discharge pipe from well; *R*, air-delivery pipe to well; *S*, pipe to faucets; *T*, well pit; *U*, well casing; *V*, air exhausted 15 inches above high water in well; *W*, extreme high water due to rain and light pumping; *X*, extreme low water due to drought and heavy pumping; *Y*, air strainer; *Z*, air-displacement pump.

POWER.

The theoretical horsepower necessary to raise water is found by multiplying the gallons pumped in one minute by the total lift including friction (see Friction Loss and Pumping Head, p. 43) in both suction and discharge pipes and then dividing the product by 4,000. The horsepower, as computed, should be multiplied by from 2 to 2½ to overcome losses in the pump and machinery and still provide a reserve of power. Ordinarily, 1 to 2 horsepower engines are sufficient for farm pumping, but it always is safest to compute the amount of power needed.

The latter multiplier (4) should be used where the pump has less capacity than about 30 gallons a minute and is driven by an internal combustion engine or electric motor. Two (2) may be used as a multiplier in large installations or those operated by steam.

Water may be raised by hand, windmill, hydraulic ram, (see Hydraulic Rams, p. 37) steam, hot air, gas, gasoline or other internal combustion engine, and electric motor. Hand power is the readiest applied but is unsuited to large supplies or high lifts. Windmills are used extensively and may be arranged to start and stop automatically according to the height or pressure of the tank supply. Windmills are subject to much wear and tear, are liable to become noisy, and are useless during calms. Experiments[1] at Cheyenne, Wyo., for the months April to September, inclusive, 1904 to 1908, indicate that the most desirable wind velocities for pumping, say 10 to 20 miles per hour, can be expected in that locality only about 28 per cent of the time. With this explanation and caution, trade data on the approximate pumping capacity of windmills in a wind of favorable velocity are given.

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[1] The Use of Windmills in Irrigation in the Semiarid West, U. S. Department of Agriculture Farmers' Bulletin 866.

Trade data on pumping capacity of windmills.

Diameter of wheel.	Length of stroke.	Height water is raised in feet.							
		25		50		75		100	
		Diameter cylinder.	Discharge per hour.	Diameter cylinder.	Discharge per hour.	Diameter cylinder.	Discharge per hour.	Diameter cylinder.	Discharge per hour.
Feet.	*Inches.*	*Inches.*	*Gallons.*	*Inches.*	*Gallons.*	*Inches.*	*Gallons.*	*Inches.*	*Gallons.*
8	6	4	782	3	411	2	307	2¼	217
8	8	3½	799	2½	408	2½	331	2	261
10	6	5	1,071	4	684	3½	522	3½	451
10	8	4½	1,157	3½	699	3	514	2¾	432
12	8	6	1,762	5	1,224	4½	991	3½	599
12	10	6	2,203	4¾	1,610	4	979	3½	750
12	12	6	2,644	4½	1,486	4	1,371	3½	775
14	10	6	1,836	5¼	1,686	4½	1,026	4	816
14	12	6	2,203	5	1,530	4	979	3½	749
16	12	8	3,133	8	3,133	6	2,203	6	2,203
16	16	8¾	4,996	7¼	3,920	6	2,349	5	1,632

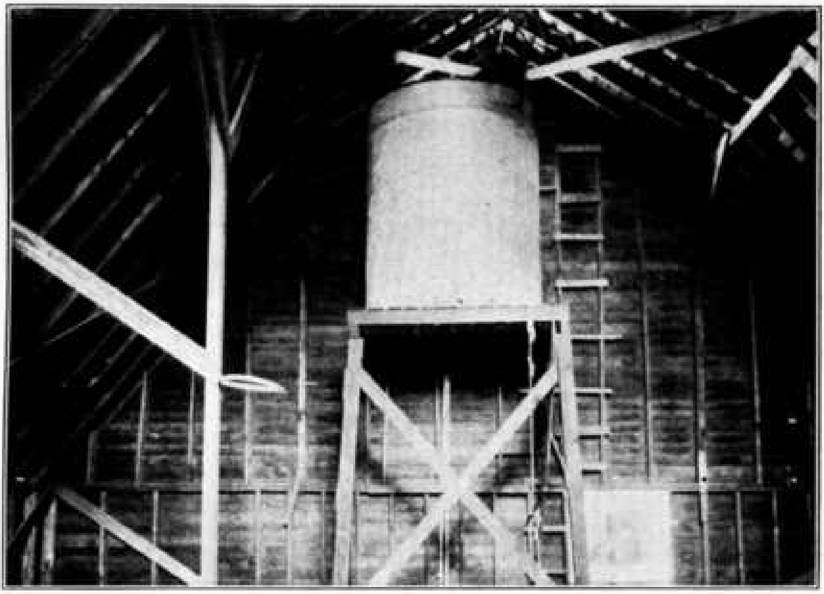

FIG. 41.—Galvanized-iron tank in barn loft, Salina, Kans. Notice the bulge caused by ice near the top.

Gasoline and oil engines are well adapted to farm pumping and may be equipped to stop at any desired pressure in the tank supply. The use of electricity for pumping is increasing rapidly. The method is clean, quiet, and convenient, and starting and stopping 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.

STORAGE OF WATER.

ELEVATED TANKS.

Water may be stored in wood, steel, iron, or masonry tanks. To secure gravity delivery, the tank must be elevated above all faucets. With ordinary sizes of pipe, less than 20 feet elevation (static head) does not give satisfactory flow at the faucet. If the delivery pipe be long, the head should be made more than 20 feet or the size of the pipe be increased. (See Friction Loss and Pumping Head, p. 43). The first three kinds of tanks mentioned are located usually in the

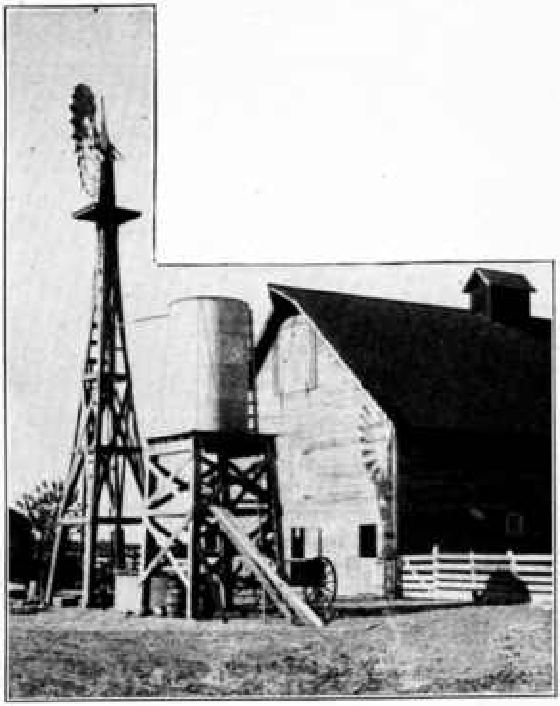

FIG. 42.—Galvanized-iron tank on timber trestle, Herington, Kans. Tank is not used in winter and is unsightly.

attic, barn loft, or upon wood or steel trestles or masonry towers. A masonry tank may be placed upon a silo, hill, artificial knoll, or masonry tower. Tanks placed in attics, barn lofts, and upon light trestles are unsatisfactory. The objections relate to insecurity and leakage, lack of pressure, and unwholesomeness of the water in summer and freezing in winter. Wherever possible, masonry tanks, preferably concrete, should be used, and if placed underground upon a hill, trouble with frost will be avoided, the temperature of the water will be agreeable throughout the year, and a simple, certain, and permanent service will be obtained. Tanks should be of sufficient size to hold at least two days' requirements. For windmill supplies the requirements of a week or more may be needed at times. For emptying and cleaning, tanks should be provided with a waste pipe and valve and without fail should be covered tightly to exclude heat, cold, dust, vermin, and sunlight. When exposed to light, ground and filtered water are very liable to develop growths which impart objectionable odor or taste.

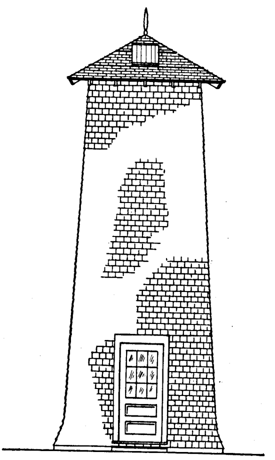

FIG. 43.—A simple frame tower would add to the protection and appearance of the tank shown in fig. 42.

Figures 41 and 42 show galvanized-iron tanks upon farms in Kansas. The first, plainly showing the bulge caused by ice near the top, is located in a barn loft at Salina, and the second is on a timber trestle at Herington. Neither tank is used in winter. Figure 43 illustrates how the unsightliness of the outdoor tank may be eliminated by inclosure in a simple frame tower. If the tower be built with sawdust-filled walls, as was the house shown in figure 27, an excellent cooling and milk room, as well as protection from frost, may be secured. The illustration on the title-page shows a concrete reservoir with wooden roof upon a large dairy farm at Roanoke, Va. The reservoir is 14 feet in diameter and 16 feet deep, and the 8-inch walls are not reinforced with steel. It is situated on a hill about 1,000 feet from the well and 1,900 feet from the buildings. Water is pumped up and delivered to the buildings through 2-inch galvanized pipe. The delivery pipe has a fall of about 35 feet in 1,900 feet and for many years has given sure and satisfactory service. Figure 44 shows a concrete reservoir completely underground. Figure 45 shows a combined reinforced concrete storage tank and cooling room.

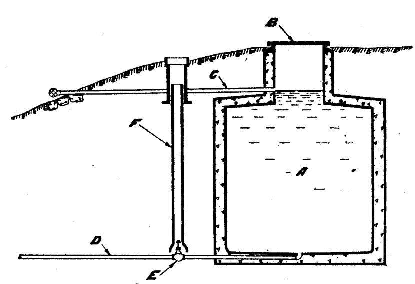

FIG. 44.—Underground concrete reservoir, suitable where high ground is available. *A*, Reservoir; *B*, cast-iron manhole frame and overhanging cover; *C*, screened overflow; *D*, pipe discharge from pump and delivery to buildings; *E*, gate valve; *F*, extension gate box.

HYDROPNEUMATIC TANKS.

Water may be stored and delivered to the faucet by the use of a hydropneumatic (water-air) tank. With this system the tank need not be elevated and usually is conveniently located in a utility room, basement, cellar, or even underground, although the latter situation favors rusting and prevents inspection and painting. Hydropneumatic tanks must be absolutely air-tight, for the principle upon which they operate depends on the expansive force which air when compressed exerts. 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 are pumped into the tank. For house service, generally the pressure ranges between 20 and 50 pounds per square inch. 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 in the successful operation of hydropneumatic systems. Where low pressures are carried a hand air pump used once a month often suffices. It is easier and more convenient, however, to introduce the air with the water when the pump is running. This is accomplished in several ways, such as by using a combined air and water pump, an air compressor, and, in one type of deep-well pump, a combined air inlet and check valve.

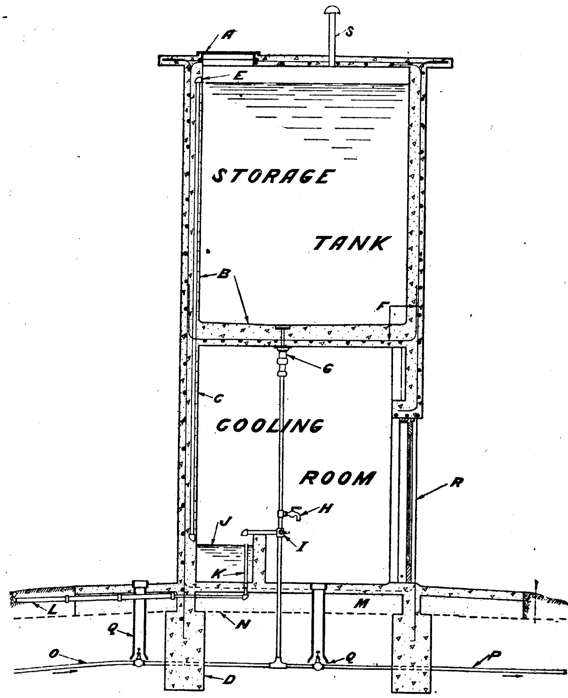

FIG. 45.—Combined storage tank and cooling room. *A*, Cast-iron manhole frame and cover; *B*, reinforced oil-mixed Portland cement concrete 1:2:3 mix; *C*, reinforced Portland cement concrete, 1:2:4 mix; *D*, concrete foundation, 1:2½:5 mix; *E*, overflow, wasting to cooling tank; *F*, steel reinforcement; *G*, expansion joint; *H*, hose bibb; *I*, 3-way valve; *J*, cooling tank; *K*, hollow plug, waste, and overflow; *L*, 4-inch drain; *M*, sand or gravel foundation; *N*, surface after stripping topsoil; *O*, discharge pipe from pump; *P*, delivery pipe to buildings; *Q*, gate valve and box; *R*, doorway; *S*, screened ventilator.

Hydropneumatic tanks are made of steel with either riveted or brazed joints. They may be black or galvanized and be set vertically or horizontally. Vertical tanks require less floor space, but when over 6 feet long a horizontal setting is usually preferred. They may be used in connection with any hand or power force pump, a hydraulic ram, or sometimes even with a flowing well, as shown in figure 46. A typical installation is shown in figure 47. Every outfit should be well constructed, well installed, and well operated. Reliable manufacturers give concise directions as to setting up, testing, repairing, adjusting, and operating their outfits. The farmer should follow the directions faithfully, and if any deficiencies show up, he should notify the manufacturer. Usually, the trouble can be located through corrrespondence and is easily corrected.

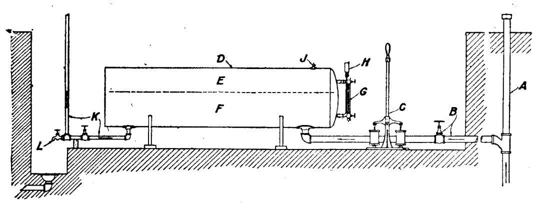

FIG. 46.—Hydropneumatic tank installation suitable for locations having a flowing well or a spring situated slightly higher than the tank. *A*, Flowing well; *B*, 2-inch supply pipe and gate valve; *C*, hand-operated air pump; *D*, tank; *E*, space occupied by air; *F*, space occupied by water; *G*, water gage; *H*, pressure gage; *J*, air cock, to be open when filling the tank with water and closed when pumping in air; *K*, service pipe and gate valve; *L*, blow-off and drain cock. A 500-gallon tank installed, complete, costs on the average about $200.

The table next following gives trade data and approximate cost of good grades of hydropneumatic tanks suitable for working pressures up to 75 pounds per square inch. The water capacity is taken usually as two-thirds of the total capacity, the

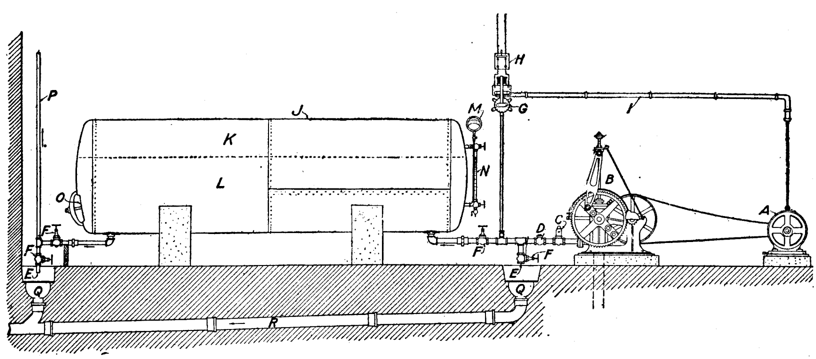

FIG. 47.—Typical hydropneumatic tank installation and working-head belt connected to an electric motor. *A*, Motor; *B*, working head or pumping jack; *C*, relief valve; *D*, check valve; *E*, blow-off and waste; *F*, gate valve; *G*, automatic controller; *H*, line switch; *I*, wires to motor; *J*, tank; *K*, space occupied by air; *L*, space occupied by water; *M*, pressure gage; *N*, water gage; *O*, manhole; *P*, pipe to faucets; *Q*, bell trap; *R*, 4-inch cast-iron drain.

remaining one-third being occupied by air. Because of conditions imposed by the war the prices are liable not to be close to market quotations.

Trade data on hydropneumatic tanks.

Diameter.	Length.	Weight.	Total capacity.	Approximate cost.	Diameter.	Length.	Weight.	Total capacity.	Approximate cost.
Inches.	*Feet.*	*Pounds.*	*Gallons.*	*Dollars.*	*Inches.*	*Feet.*	*Pounds.*	*Gallons.*	*Dollars.*
24	6	370	140	30	42	8	1,420	575	82
24	8	450	190	37	42	10	1,700	720	94
24	10	525	235	42	42	12	1,950	865	107
30	6	560	220	36	42	14	2,200	1,000	116
30	8	680	295	44	48	10	2,070	940	131
30	10	800	365	50	48	12	2,370	1,130	143
30	12	915	440	56	48	14	2,670	1,300	156
36	6	790	315	46	48	16	2,970	1,500	173
36	8	950	420	56	48	18	3,270	1,700	194
36	10	1,120	525	64	48	20	3,570	1,880	209
36	12	1,300	630	71	48	24	4,170	2,260	234
36	14	1,450	735	83					

In order to deliver all the water 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. If a tank be located in the cellar or basement, 10 pounds excess air is sufficient to deliver all the water to the second story, but if far removed or far below the house a greater excess may be necessary. The following table shows what fractional part of any tank, either vertically or horizontally set, contains water under varying conditions of gage pressure and excess air pressure.

Amount of water in fractional part of total capacity of any hydropneumatic tank.

Gage pressure.	Excess air in tank in pounds.					Gage pressure.	Excess air in tank in pounds.				
	0	10	15	20	25		0	10	15	20	25
Pounds.						*Pounds.*					
100......	0.870	0.783	0.739	0.696	0.652	50.......	0.769	0.615	0.538	0.462	0.385
95.......	.864	.773	.727	.682	.636	45.......	.750	.583	.500	.417	.333
90.......	.857	.762	.714	.667	.619	40.......	.727	.545	.455	.364	.273
85.......	.850	.750	.700	.650	.600	35.......	.700	.500	.400	.300	.200
80.......	.842	.737	.684	.632	.579	30.......	.667	.444	.333	.222	.111
75.......	.833	.722	.667	.611	.556	25.......	.625	.375	.250	.125	....
70.......	.824	.706	.647	.588	.529	20.......	.571	.286	.143	....	....
65.......	.812	.687	.625	.562	.500	15.......	.500	.167	....	....	....
60.......	.800	.667	.600	.533	.467	10.......	.400	....	....	....	....
55.......	.786	.643	.571	.500	.429	5........	.250	....	....	....	....

This table has broad application. For example, it shows that if water is pumped into any tank having no initial pressure above that of the atmosphere until the gage shows 5 pounds, the tank will be one-fourth filled with water; at 15 pounds it will be one-half full; at 30 pounds it will be two-thirds full; at 45 pounds it will be three-fourths full; at 60 pounds it will be four-fifths full. Inspection of the table shows also the value of excess air in a tank. If 25 per cent of the total capacity be drawn from a tank three-fourths filled with water and having a gage pressure of 45 pounds, the pressure will be reduced to 15 pounds. Had the tank contained 10 pounds excess air, 42 per cent of the total capacity $(0.583-0.167=0.416)$ could have been drawn between pressures 45 and 15 pounds. Under the latter condition, therefore, the working capacity of the tank would have been nearly doubled, the exact ratio being as 42 to 25.

PIPES.

Water pipes of wood, lead, brass, black and galvanized (zinc coated) wrought iron, steel, tin, cement-lined iron and steel, and cast iron have been used at various times and places. The use of wooden pipes is confined mainly to the West and to sizes above 2 inches. Lead, brass, or lead-lined pipes should not be used for conveying water for drinking and cooking. This caution applies with especial force to lead pipe and to cases where the water is soft and contains much free carbonic acid and oxygen or stands for some time in the pipes. Different waters and soils vary greatly in their power to attack and corrode metals. In general, alkaline and cinder soils promote corrosion faster than do clay soils and very much faster than do sands and gravels. Steel pipes corrode more rapidly than wrought iron pipes. Galvanizing does not always add greatly to the life of the pipe. But galvanized pipe is cleaner than black pipe and is generally preferred. Tin and tin-lined pipes have been used considerably and are durable and safe. Cast-iron pipe is preferred for 4-inch or larger sizes, and ordinarily, if well coated, its life is very great but may be shortened by alkaline soils.

One of the best and most practical linings for keeping the bore of iron pipes free from rust is cement. On the writer's desk is a piece of 1-inch wrought-iron pipe lined with cement to a three-fourths-inch bore and taken from a line laid in Massachusetts in 1872. Although the pipe was in use more than 40 years, the bore is unrestricted and in perfect condition. The exterior is badly pitted and corroded. New cement-lined pipe of the size above mentioned was worth about 9 cents per foot in October, 1915. The process of lining is simple, and if understood the work can be done rapidly and well with the ordinary labor of the farm. The work does, however, require some special appliances and must be handled with care and judgment. One farmer hardly would be warranted in attempting to cement-line his pipe, unless a large quantity were needed. It would be entirely practicable, however, for two or three to combine and line the pipe for a neighborhood or locality. Essentially, the process consists in forcing with a press a quantity of neat or at least very rich Portland cement mortar into single lengths of pipe and then boring out the mortar while soft by pulling through a wire to which is attached a pointed brass pipe having an exterior diameter the same as that of the bore desired. The lining in small wrought pipes usually is about one-eighth of an inch thick.

All water pipes should be laid below frost, should be tested under pressure before back filling the trench, and should be flushed out before the installation has been put to actual use. Pipes through cellar walls are particularly subject to rust, and it is prudent to embed them in cement at that point. At points liable to be caught by frost, pipes may be boxed and surrounded with pea or nut-size coke, ground cork, felt, mineral wool, or other nonconducting material. Sawdust, excelsior, or straw may be used for this purpose, but are perishable and introduce more or less fire hazzard.

FIRE PREVENTION.

A high percentage of farm fires is due to carelessness and is preventable. The more common preventable causes of fire are carelessness in handling matches, pipes, and cigarettes, children playing with fire, accumulations of rubbish, litter and greasy rags, defective and sooty chimneys and flues, unchecked and overheated stoves and furnaces, sparks from grates and chimneys, hot ashes against wood, ignition of oil and hot grease, drying green wood in ovens, thawing out frozen water pipes by flame, defective electric wiring, and failure to turn off the current after using various small electrical devices. In short, carelessness is the great fire hazard, and the watchword upon every farm should be prevention first and protection second.[1]

To fight a well-ignited fire successfully requires more water and higher pressure than ordinarily are obtained with farm water systems. A small ragged stream directed at a large fire is practically of no avail 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. These matters are, of course, fully understood and recognized by underwriting associations, and farm water systems are not, as far as the writer knows, given credit in insurance ratings. To obtain such credit, the following probably would be necessary: A gravity supply capable of furnishing two streams of 250 gallons a minute each for at least one hour at a pressure sufficient to cover all major buildings, together with hydrants at such locations and hose in such quantities as would enable the two streams to be applied to such buildings, and sufficient continuous attendance to operate these appliances. Although farm water systems seldom can comply with this specification, 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

[1] Methods of preventing and fighting fire are described fully in Farmers' Bulletin 904, United States Department of Agriculture, "Fire Prevention and Fire Fighting on the Farm," and in Circular 75, "Safety for the Household," issued by the Bureau of Standards, United States Department of Commerce,

a liberal number of hose connections, the preferable locations being the engine room, house basement, kitchen, and second floor. An automatic sprinkler system is a great aid in preventing serious fire. Such installation in large, costly farm buildings may be a wise step, adding greatly as it does, to the value of the plant considered as a going business.

WATER SOFTENING.

An excess of salts of lime, magnesia, and iron dissolved in water makes it hard, and therefore undesirable for drinking and cooking, ineffective and costly for cleaning and laundry purposes, and destructive to kettles, pipes, and boilers. Water softening is the process of removing the dissolved minerals mentioned above. It is a chemical process and therefore is distinct from the removal of floating or settled solids such as silt or mud. Filtration alone will not soften water. Hardness caused by lime, magnesia, and iron carbonates held in solution by carbonic acid may be removed in part by boiling the water. Hardness caused by the sulphates, chlorides, and nitrates of lime, magnesia, and iron can not be removed by boiling. Taken together, these compounds constitute the principal scale-forming ingredients found in hard water. Such water may be treated chemically to form a more or less insoluble precipitate which may be removed by sedimentation (subsidence) followed by filtration.

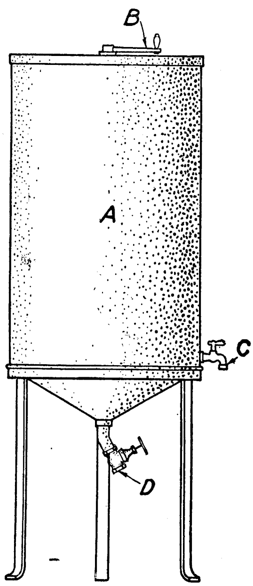

FIG. 48.—Household water softener. *A*, Cylindrical tank; *B*, crank attached to a vertical shaft carrying blades or paddles to secure thorough mixing of the chemicals with the raw water; *C*, faucet for drawing softened water; *D*, valve for drawing off the settled solids (mud).

Another group of impurities found in alkaline waters are sodium chloride (common salt), sodium sulphate (Glauber's salts), and sodium carbonate (soda-ash). The first two constitute what is known as white alkali, and the third constitutes black alkali. Unless present in large quantities, these compounds are non-scale forming, but their presence in more than normal amounts unfits water for domestic consumption. The sodium salts are very soluble in water, nor can they be precipitated by heat or chemicals or removed by filtration. Their successful removal has been accomplished only by distillation.

Two types of water softener are used, the intermittent and the continuous. In the intermittent a definite quantity of raw water is treated with a fixed amount of such chemical reagents as analysis of the water indicates are needed. Lime, soda-ash, trisodium phosphate, barium hydrate, and barium chloride are among the reagents used.

Figure 48 shows a simple household water softener of the intermittent type. It may be used for preparing water for laundry purposes, but is not suitable for drinking or other potable waters. Softeners of the continuous type, because of their large capacity and cost and the close attention they require, have been little used upon farms. Individuals who can afford such softeners or farmers combining to install them can, if the necessary attention be given the installations, obtain very satisfactory results. It should be remembered, however, that, although a water softener may remove most or even all of scale-forming ingredients, the alkaline salts are not removed and, in fact, are likely to be increased.

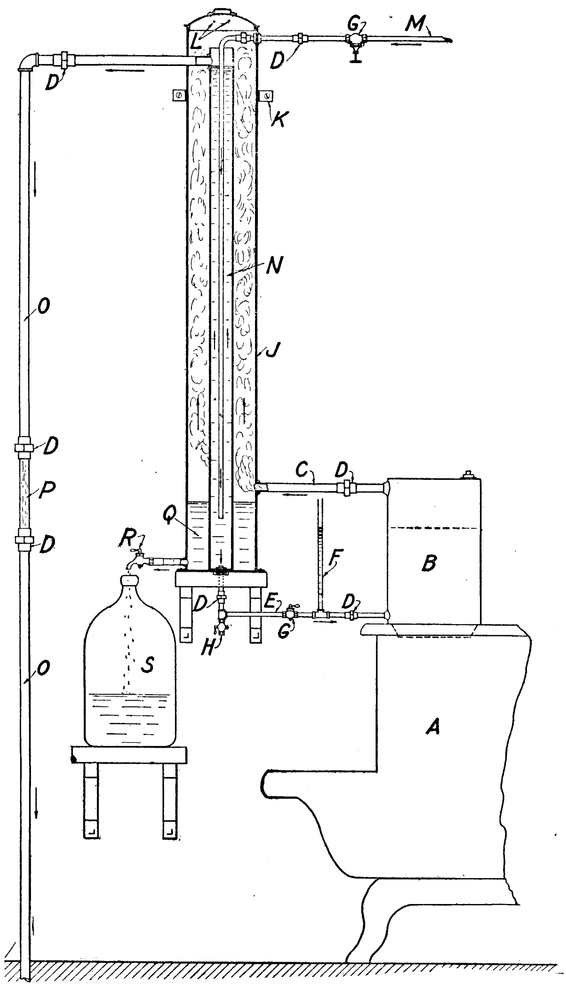

Fig. 49. Household still.—*A*, Stove; *B*, boiler; *C*, steam pipe; *D*, union; *E*, raw-water feed pipe; *F* water gage (glass tube open at top); *G*, valve; *H*, drain cock; *J*, condenser; *K*, strap; *L*, vents in cover; *M*, raw-water supply pipe; *N*, cooling tank; *O*, waste pipe; *P*, observation glass; *Q*, distilled water; *R*, cock for drawing distilled water; *S*, glass vessel.

STILLS.

Water containing dissolved minerals or other impurities may be softened and purified completely by distillation, a process involving boiling the water and condensing the steam. Objections to distillation relate to the slowness, tediousness, and cost of the process, the cost of stills, the flat taste of distilled water, and the tendency of volatile products to pass through with the steam and be absorbed by the distillate. These objections, together with the high cost of tin, copper, and brass, have tended to prevent the production and use of good, low-cost stills adapted to farm use. Small stills are made to utilize the heat of oil, gas, and coal stoves, gasoline torches, electric heaters, and steam pipes. A household still of simple type is shown in figure 49. A still capable of giving fair results may be constructed by a good village tinsmith. All parts in contact with water or steam should be pure tin or heavily lined with tin, and the distilled water should be kept in tightly-stoppered bottles or a glass vessel. An arrangement of pipes whereby a constant flow of cold water is received in and escapes from the condenser adds greatly to the capacity and ease of operation.

INSIDE PIPES AND FIXTURES.

Figure 50 shows an arrangement of pipes and fixtures in a well-equipped farm home. The cold-water pipes are shown in outline and the hot-water pipes in black. The size of the pipes may be varied according to the pressure from the supply tank and the demands for water at particular points. Under average conditions, say where the pressure is from 20 to 40 pounds, the sizes shown in the figure are ample. All pipe and fixtures should be durable and so installed that inspection, control, drainage, and repairs can be made easily. The fixtures should be of simple, approved patterns. The main supply pipe should have a stop and waste cock just inside the cellar wall. In cold climates and in houses not well heated, pipes should be kept from outside walls. (See Pipes, p. 62, for methods of protection from frost.)

Water pipes not seen are usually of galvanized iron. Pipes exposed to view in the kitchen and laundry look better if made of brass. Nickel plating further adds to the appearance of bathrooms or other places where plumbing is seen. Cold-water pipes, because of the condensation of moisture from the air and the drip on floors, should never run along the ceilings of rooms. All pipes should slope slightly so that the entire hot and cold water systems may be drained at low-situated faucets and at the stop and waste cock in the cellar.

Range boilers may be galvanized iron or copper and are made in various sizes and strengths. Galvanized boilers may be set vertically or horizontally. They usually are riveted, have capacities between 20 and 190 gallons, and sometimes are fitted with a steam coil so that other heat than the kitchen range may be utilized. Copper boilers are seamless or have brazed joints, may be tin lined, and often have inside ribs to strengthen and stiffen them. Capacities run from 30 to 250 or more gallons. Because of better appearance and less liability to leakage and corrosion, copper boilers are preferred to galvanized-iron boilers. Formerly a small gravity tank equipped with a ball cock in an upper room or attic was much used in connection with range boilers, and in such cases lightweight

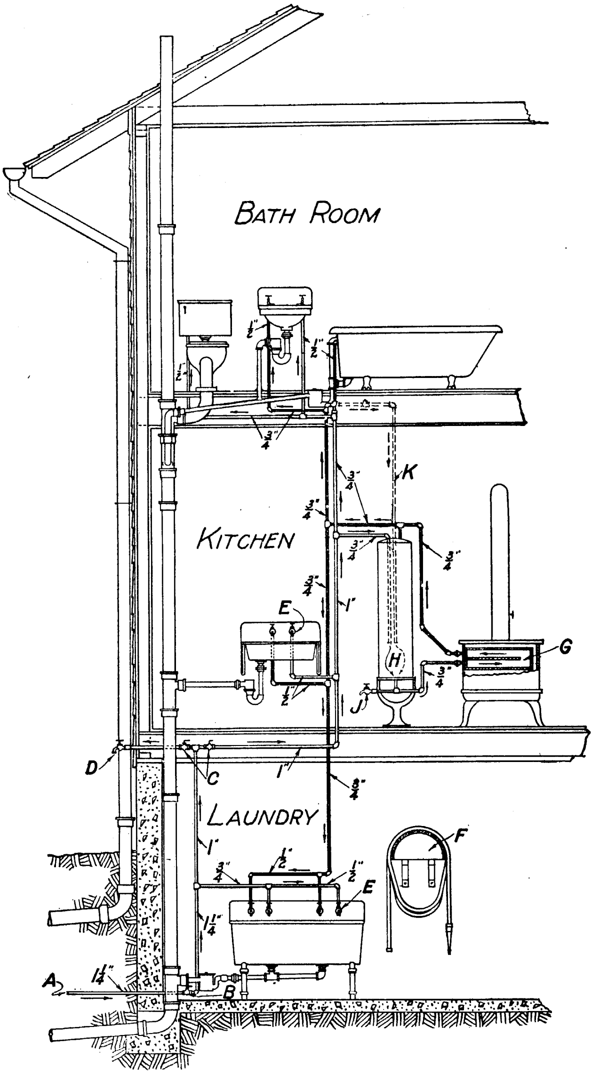

FIG. 50.—An arrangement of pipes and fixtures in a well-plumbed farm house. *A*, Service pipe to house; *B*, stop and waste cock; *C*, stop cock; *D*, sill cock; *E*, hose bibb; *F*, hose and home-made, half-round wooden hose hanger (hanger may be made by nailing lagging to two half-heads of a barrel); *G*, kitchen range and water front; *H*, range boiler; *J*, hose bibb for draining boiler; *K*, return pipe (not absolutely essential, but improves the circulation of hot water and is of particular value where hot-water faucets are located far from the boiler). Prior to 1916 the plumbing installation here shown cost approximately $280. This cost covered all pipes (rain conductor excepted), traps, valves, fittings, fixtures, the stove, and the labor and materials used in installing. The fixtures included a 5-foot enameled-iron bathtub, 20-inch enameled-iron washbasin, vitreous china wash-down water-closet; 30-gallon galvanized-iron boiler, 1-piece enameled-iron sink, 18 inches by 36 inches, and a 2-compartment stone laundry tray. Due to the war-time advance in the cost of labor and materials from $500 to $600 should be allowed for the installation, complete, to-day (March, 1918).

boilers could be used. It is better, however, to have the boiler heavy enough to carry safely the full pressure of the supply tank or reservoir, and such boiler will better resist the corrosion that comes with long use. A suitable capacity of boiler for an average farm or village home is 30 to 40 gallons. With two bathrooms or other large use of hot water the capacity should be increased materially.

Where the winters are severe and water pipes are liable to freeze, one should always assure himself before starting the range fire in the morning that ice has not sealed the water front or its connections. Continuance of the main supply may be ascertained by opening hot and cold-water faucets at the kitchen sink. This procedure, however, does not prove the absence of a freeze-up in the short connections between the range boiler and the water front. To further guard against range-boiler explosions, something that may happen wherever expansion is cut off through closure of a supply-pipe valve or other stoppage, the boiler always should be equipped with a safety valve so arranged that nothing can interfere with its operation.

A word in conclusion: In each instance, before going ahead, study the local conditions. These, finally, must determine the main features of every installation. Were advice to be given in a brief general statement, it would be as follows: Make sure of the purity of the supply. If the supply is a spring or flowing well, deliver to the buildings by gravity, if practicable. Where a well is necessary, use a good, deep, dug or open-end tubular well fed from pure and unfailing sources. Install such type of pumping machinery as best combines simplicity, certainty, capacity, and adaptability. Provide liberal storage capacity, employing if possible an underground concrete reservoir on a near-by hill. Lay galvanized iron or cement-lined delivery pipe of ample size below the reach of frost. Arrange the house piping systems to admit of easy control, drainage, and repair. Use fixtures of simple, durable, yet pleasing patterns.

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