

SUGGESTIONS CONCERNING SMALL IRRIGATION PUMPING PLANTS

By W. E. CODE



A VERTICAL TURBINE PUMP DIRECT CONNECTED TO AN ELECTRIC MOTOR.

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SUGGESTIONS CONCERNING SMALL IRRIGATION PUMPING PLANTS

BY W. E. CODE, Associate in Irrigation Investigations

Pumping for irrigation is economically feasible in Colorado, and as proper guidance is lacking to the farmer in the development of the water supply for pumping and the selection of the type of equipment best suited to his needs, the following discussion has been prepared to aid him in improving his present installation or in designing a new plant.

Wells

Wells in this state are principally of two classes; those having riveted sheet-metal casing of from 10 to 48 inches in diameter, and those of the pit type from 6 to 15 feet in diameter, using a curb of bricks or concrete blocks.

Riveted casing of galvanized sheet steel in 2- to 3-foot lengths in 12 to 16 gauge, is commonly used. In the smaller sizes, these lengths may be larger at one end than at the other so that they may be slipped together and riveted, or one end of a length may be swedged out to receive the next section. In the larger sizes, the lengths may be butted together and the joint made by riveting the ends to an iron band placed either inside or outside. Perforated sections are made by punching slits about $1\frac{1}{2}$ inches long from the inside without removing any metal and leaving an opening of from $\frac{1}{64}$ to $\frac{1}{4}$ inch wide. Casing may be forced down by loading a long lever arranged across the top of the well, but in the larger sizes, a platform is built on top of the casing and loaded with bags of sand, as shown in Fig. 1.

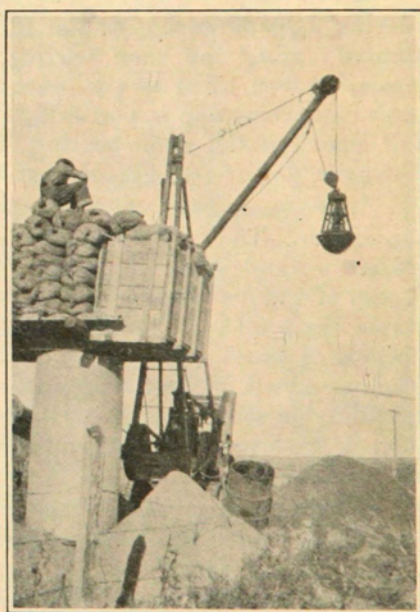


Figure 1.—Sinking a 48-inch steel well casing near Brush, Colo. About a 16-ton load was used on this casing,—much more than usually needed because of difficulties encountered. (Photograph by courtesy of Ross Oliver.)

The smaller sizes of wells are put down by means of a sand bucket, slightly smaller than the casing, except where clay is encoun-

tered and then an auger is used. For shallow depth, these wells may be put down by hand methods, but for the deeper ones using heavy buckets, the standard drilling rig is necessary. When the diameter is 24 inches or over, the orange-peel bucket may be used to remove the material from within the casing. Difficulty may be experienced with an orange-peel bucket when going thru clay which may have to be removed with a spade.

The churning of the sand bucket loosens up the material near the well. One driller takes advantage of this, when the water surface is in clay, by running a large auger hole down on opposite sides of the wall at an angle so that each will intersect its axis near the water surface. While drilling, he feeds into these auger holes small gravel which sinks and follows the casing. This improves the condition for water entry into the well from thin water-bearing strata.

An envelope of gravel may be placed around the well by first sinking a blank casing to the full depth, inserting the final perforated casing and then feeding small uniform gravel into the space between them as the outer one is withdrawn. This gravel screen improves the opportunity for water to enter the casing the full length of the water-bearing area in the well, and prevents the accumulation of fine gravel next to the perforations.

When completed, the well should be developed or worked by the driller. The method usually used is the plunging of the sand bucket up and down, as in the regular drilling operation, in the region of the perforations. This plunging is started usually at the water surface or at the first perforations and applied for short periods of time in 3- or 4-foot stages until the bottom is reached. The movement of the bucket in the areas of perforation will draw considerable sand into the well, that settles to the bottom and can then be removed. This operation should be continued as long as sand enters the well.

In unknown territory, the well driller first puts down a test well to determine the location and extent of the various strata of clay, sand and gravel. In putting down the permanent well, the perforated and the blank casing are assembled so that they will land at the proper depths when the well is completed. It is often desirable to exclude strata of fine sand from the well with blank casing. The size of perforation or slit should be governed by the material found in the test well.

It is very important that a new well be properly pumped for the first time and everything should be in readiness to operate continuously for a day or two. The equipment should be such that the discharge from the pump can be varied, either by valves or by

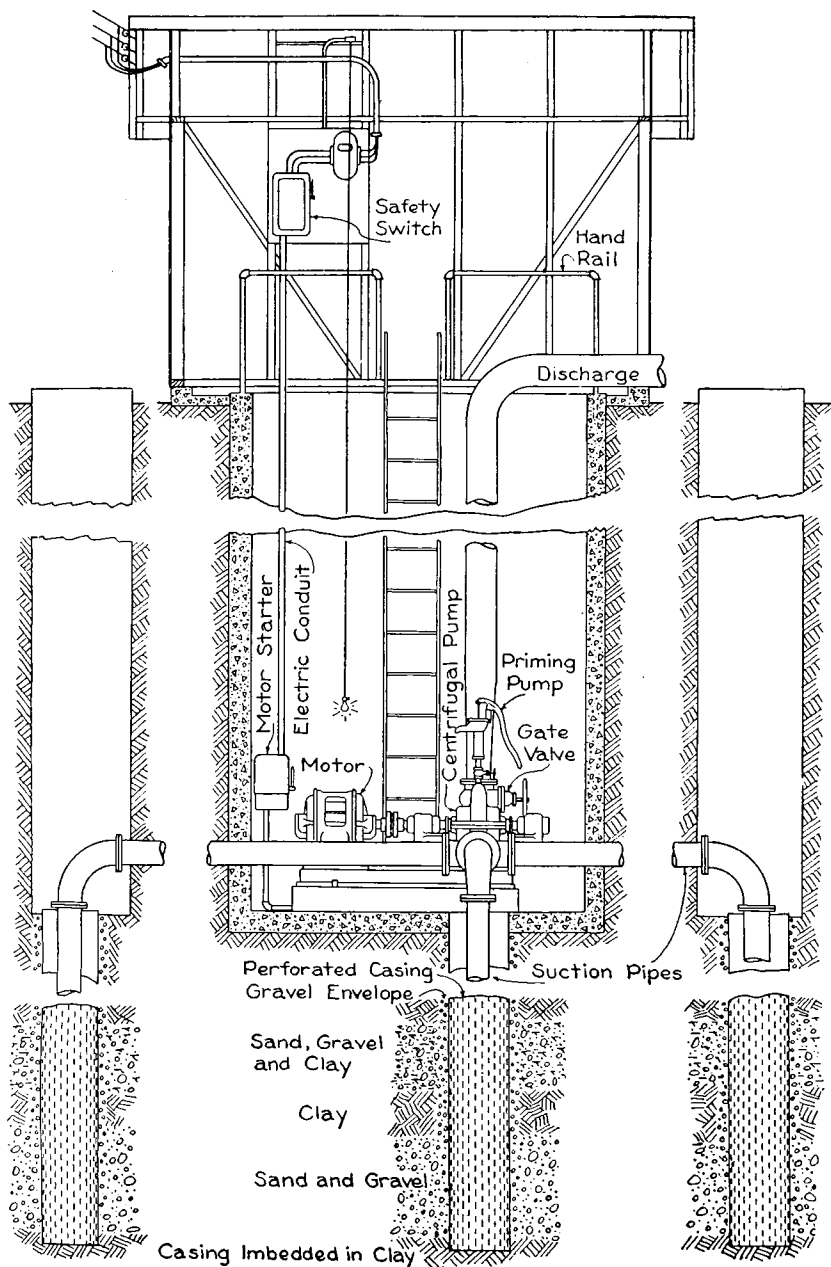


Figure 2.—A horizontal centrifugal pump direct connected to an electric motor in a pit, pumping from three wells simultaneously.

changing the pump speed. At first a small quantity of water should be pumped and the rate maintained until the water becomes clear. The discharge is then increased and usually the water becomes murky again. Pumping is continued until the water becomes clear before the flow is increased. This procedure is carried on until full capacity is reached. New wells operated at full capacity for the first time may become clogged when the pump is stopped, or so much sand may enter the casing as to obstruct the pump, especially if of the turbine type.

The sinking of shallow wells of large size is accomplished usually by hand methods and requires the use of an unwatering pump to keep the water level low enough for men to work. This type of well is dug as an open pit to the water level or to loose sand and gravel where a circular foundation shoe of 2 by 6-inch planks laid flat is built up to a height of 2 or 3 feet. Water enters thru the spaces between the ends of the planks which are staggered in the successive courses. Another type of shoe, offering less resistance to sinking, may be built of beveled 2 by 4-inch lumber set vertically so as to leave narrow spaces between the pieces, and the whole held together by iron bands or horizontal planks cut in arcs of a circle. Bricks or concrete blocks are placed upon the shoe and, as material is removed from underneath, the composite curb sinks by reason of its weight. Considerable caution must be exercised in order to keep the walls plumb. This type of construction is shown in Fig. 4. Large-diameter wells may also be dug by using a reinforced concrete caisson.

It is practically impossible to forecast what the draw-down will be in a well under pumping, especially in an untried district. Wells in a proved area may have similar characteristics and a reasonable estimate may be made of their yield. Since the testing of a well is an added expense, it is frequently considered unnecessary and equipment is purchased wholly unsuited to the conditions that later develop. If the draw-down is excessive, it is usual to sink other auxiliary, adjacent wells which are connected to the main one either by siphoning or by direct connection to the pump.

A practice of obtaining a guarantee from a well driller of a stated quantity of water from a well does not always yield the desired results. Providing the well is deep enough, a wide range of discharges may be obtained, but each will have a different draw-down effect on the well and it may not be economical to lift the water against the head that is required to pump the guaranteed quantity of water. It is safer to contract with an experienced and responsible well driller to complete the well or system of wells that on test proves adequate for the demand imposed upon it.

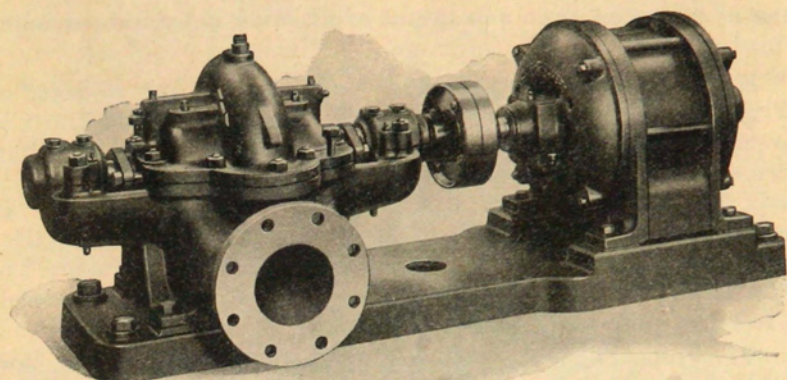


Figure 3.—A horizontal centrifugal pump direct connected to an electric motor. This pump has a divided suction and the case is horizontally split allowing easy access to the impeller. (*Electrotype by courtesy of the Allis-Chalmers Mfg. Co.*)

The cost of pit wells varies according to the size and the difficulties encountered in sinking but may be estimated at from \$20 to \$30 per foot for materials and digging. Estimates for wells with metal casing are given in Table 1.

TABLE 1.—Approximate Cost per Foot of 16-gauge, Galvanized Steel Well Casing and Drilling.

Size Inches	Cost of Casing	Cost of Drilling
6	\$ 0.75	\$ 1.25
10	1.10	2.00
12	1.20	2.50
15	1.60	3.00
18	1.75	4.00
48	10.00	8.00

When pumping from ditches and lakes, the intakes should be of ample size, substantially built, and deep enough to keep the suction pipe well submerged to prevent the entrance of air. They should be provided with gratings or screens to prevent trash being drawn into the pump.

Pumps

Pumps of various kinds are used thruout the West for irrigation but the most commonly used are the horizontal centrifugal, vertical centrifugal, turbine and propeller pumps. Other types such as the rotary, plunger, bucket, air lift and special forms of the centrifugal are used to a lesser extent under special conditions. The purchaser should consider all the conditions affecting his problem before selecting the equipment. Ordinarily, any one of the first four mentioned types of pump will meet the requirements; however, in the final choice the cost or ease of operation may be the deciding factor. The following brief description of the common

types of pumps is given as a means of assisting in the proper selection of equipment:

Horizontal Centrifugal.—This pump has its axis of rotation horizontal and its rated size is that of the discharge outlet. It is the pump most commonly used, is built in all sizes, and the selling price covers a wide range according to the design and the materials used. Per unit of capacity, it is the cheapest pump obtainable. It may be belt driven and lends itself conveniently to direct electric-motor or auto-engine drive. Since it must be placed above the water level, it is limited by the suction lift which should not exceed 20 feet and preferably 15 feet.

This type occurs in two forms; single or side suction, and double suction, and it should have a convenient, water-sealed packing gland and two bearings. The hydraulic balance of the side-suction pump must be obtained thru some mechanical device that will allow suction pressure to be exerted on both sides of the impeller, while in the double-suction pump this balance is accomplished automatically. Experience shows that the cheap pump lacks mechanical refinements which are necessary for long life and high efficiency. A pitcher pump, attached to the top of the pump case, is the common means of priming and such an arrangement requires a valve in the discharge line, as shown in Fig. 2. If the total lift does not exceed 40 feet, a foot valve at the lower end of the suction pipe may be used and the pump primed by pouring water into the discharge pipe. This method of priming is not always satisfactory because of the uncertain action of this submerged valve. A direct connected, motor driven, horizontal centrifugal pump is shown in Fig. 3.

Vertical Centrifugal.—This type is practically the same as the horizontal centrifugal except that its axis of rotation is vertical. The pump is held in a timber or steel frame which stands vertically in the well and supports the driving shaft to a point above the ground surface where the driving pulley or direct-connected vertical motor is placed. The pump is often placed below the water surface and thus requires no priming; however, the whole frame must be lifted when the packing gland needs attention.

Vibration is a source of trouble in this type of installation and every effort should be made to keep it to a minimum. The frame should be strong, well braced and firmly supported at the top, and the shaft should have bearings at frequent intervals equipped with a convenient lubrication system. Ordinarily a large-sized well is required for its installation but recently a type has been developed that will enter a 24-inch well. Fig. 4 illustrates an installation of this type of pump.

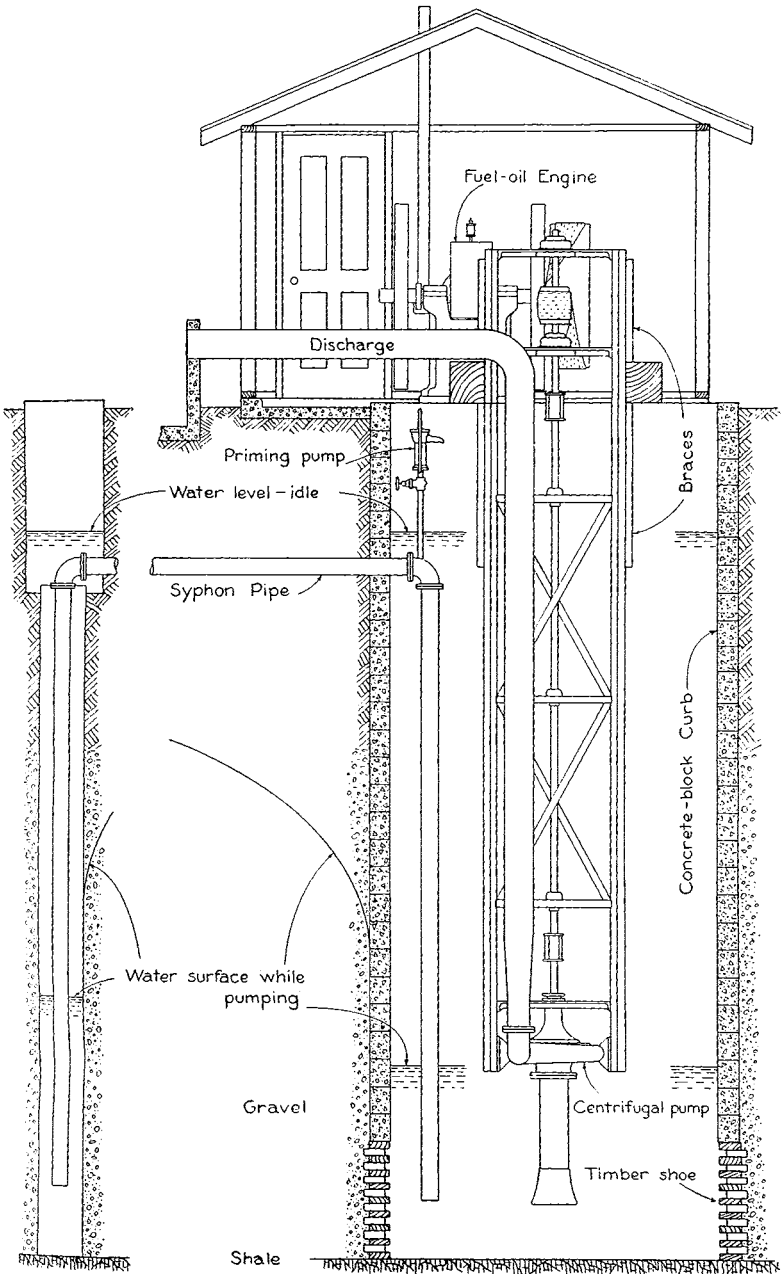


Figure 4.—A vertical centrifugal pump, engine driven, installed in a pit.

The Turbine.—The turbine pump is a development of the vertical centrifugal but instead of the large scroll case for the reception of the water from the impeller, diffusion vanes conduct the water upwards and a pump of small diameter is obtained. Considerable attention has been given to the design of this type of pump to produce a dependable and efficient piece of machinery. It is made in sizes that can be installed in wells of from 6 to 24 inches in diameter. The driving shaft is usually enclosed in a centrally located tube which carries the shaft bearings and the lubrication from the ground surface. The rotating parts and the water in the discharge pipe are carried on a ball or roller bearing in the pump head which is built of cast iron and supports the entire weight of the pump. The depth of setting is limited only by the mechanical difficulties encountered by the increasing weight of the parts when placed deep in a well. This pump is well adapted for lifts of from 40 to 200 feet. It has no draw-down limitations since the pump bowls may be set at any point in the well, or changed later to fit a new condition.

The turbine pump may be obtained with a direct connected motor which is designed as an integral part of the pump head, or with a pulley for belt drive. Its first cost ordinarily is greater than the vertical centrifugal pump and repairs are more costly since the entire pump must be removed from the well with special equipment.

It is not suited to pump from a battery of wells except when the siphon system is used. A derrick over the well is not needed except for the large sizes or when the column pipe is assembled in long lengths. Usually the pump dealer has the equipment necessary to remove the pump from the well for inspection and repairs. Fig. 5 and the cover illustration show installations of the turbine pump.

Propeller Pumps.—In recent years, this type of pump has received a great deal of attention from pump builders and is sometimes classified as a turbine. Essentially it is a long pipe containing the drive shaft along which helical-shaped propellers are placed at definite intervals or grouped at the bottom. The water flows practically upwards at all points and for this reason its hydraulic features are quite different from those of the turbine. For similar conditions this type of pump will deliver more water from a well of small diameter than any other type, with the exception of the air lift.

The principal objection in the past to these pumps was from the mechanical standpoint of maintaining bearings inside the discharge pipe. These bearings are either oil or water lubricated and are now proving to be satisfactory.

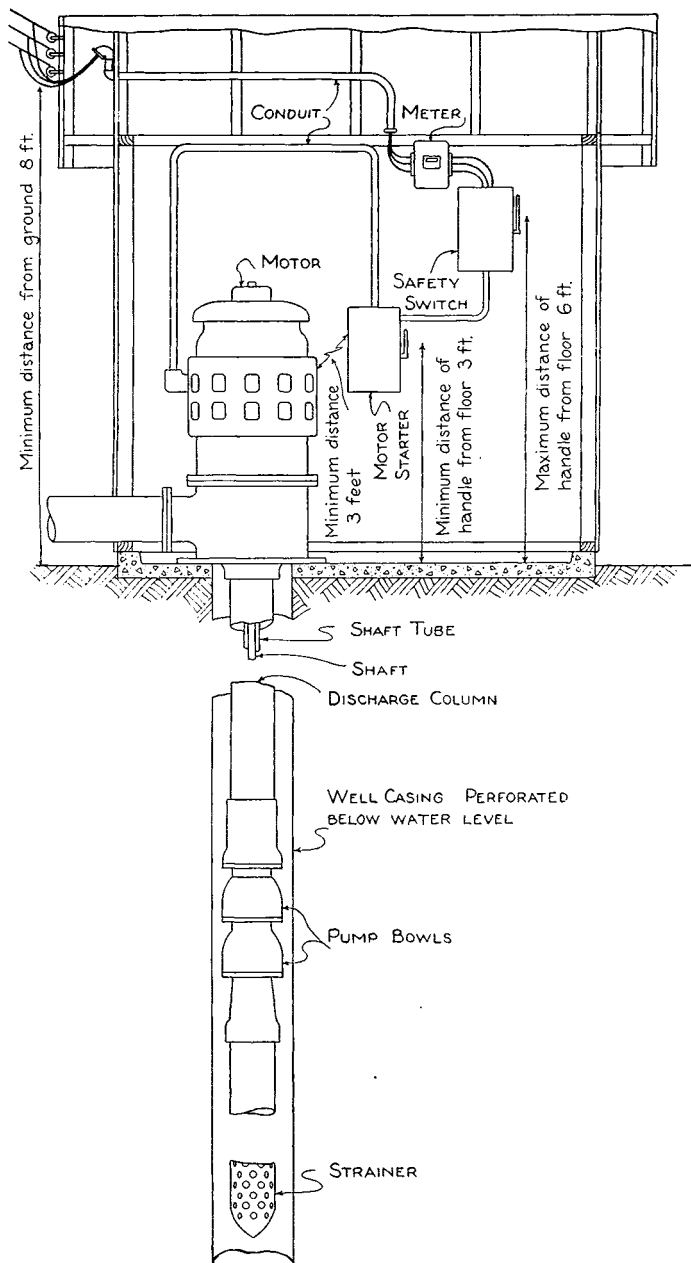


Figure 5.—A vertical turbine pump direct connected to an electric motor. This pump, being self priming, may be arranged for automatic starting after a stop due to a power interruption. Note recommendations for certain clearances.

Favorable conditions for high efficiency in centrifugal and turbine pumps range between capacities of from 400 to 4,000 gallons per minute and heads of from 20 to 80 feet. An efficiency of between 45 and 50 percent may be expected in pumping 200 gallons per minute against a 20-foot head, while 70 to 75 percent may be obtained in pumping 1,500 gallons per minute against a 60-foot head. Under very favorable conditions, efficiencies exceeding 80 percent have been obtained. Propeller pumps may give better efficiencies for small discharges than those mentioned above but, in general, they follow the same ranges.

The vertical centrifugal, turbine and propeller pumps, being self-priming, are well adapted to the automatic feature of electric drive. This feature consists of a special electrical device which allows the motor to start again after a stop, due to a power interruption such as is caused by lightning during a storm.

Other Types.—There are many varieties of centrifugal pumps designed to meet special conditions or of temporary experimental manufacture. Ordinarily, the pump irrigator should select standard machinery and avoid new or untried pumps.

There are many designs of the rotary pump which depend on a rubbing or rolling contact to obtain a positive displacement of the water. As the rotating elements wear in this pump, its initial high efficiency is considerably impaired. In general, this type is not suitable for irrigation pumping.

Bucket pumps find their place in raising water from lakes or ditches where a constant water level at the source is maintained.

The air-lift requires a depth of water in a well not less than twice the distance that the water is to be raised. Air under pressure is forced into the discharge pipe thru a special device at the bottom, which is so designed that the air will be broken up into small bubbles. Large quantities of water may be pumped from a small well by this method and it has a distinct advantage in that there are no moving parts in the well. Its disadvantages are in its relatively low efficiency, seldom greater than 45 percent, the depth of submergence required, and the relatively high first cost.

Plunger pumps are of low capacity and used mainly for high lifts. When double acting with overlapping stroke, their efficiency is very high. In Colorado, the ordinary single-acting pump, driven by a windmill or small engine, is used to irrigate lawns or small gardens.

Under favorable circumstances of obtaining water and head, the hydraulic ram may be employed to furnish water cheaply in small quantities.

Power

Gasoline and oil engines are rated on brake horsepower and to obtain ease and reliability of operation, they should not be fully loaded. For stationary work, the heavy, slow-speed engine should be used because of its long life. In the larger sizes, distillate or fuel oil may be used, which can be purchased for about two-thirds the price of gasoline. Hot-head engines are designed to operate on the lower grade fuels, such as "27 plus," which may not be readily obtained on the local market, as well as kerosene and distillate. The fuel economy of a hot-head or semi-Diesel engine is usually greater than that of an ordinary, electric-ignition engine but is more costly. Generally speaking, the Diesel engine, altho the most efficient, is not suitable as power for small installations because of the high cost and expert attendance required in its operation. Internal combustion engines, unless of ample proportions, will seldom develop their rated horsepower at altitudes that obtain in Colorado. Allowance should be made also for depreciation in efficiency as the cylinders, piston rings and other moving parts become worn. Poor performance and a dropping off in speed, with a consequent diminution in the amount of water pumped, result from not having a surplus of power when the engine is new. The tractor often proves the most economical source of power for pumping when not required for other farm operations. This is especially true if the pumping plant is used but a short time each year.

The full horsepower rating of an electric motor can always be relied upon and often a slight continuous overload. Automatic electrical devices may be installed whereby the motor will start again after a stop due to power interruptions. A motor has a much longer life than the internal combustion engine and its ease and convenience of operation and automatic features make it the ideal source of power.

Plant Design

The smallest practicable plant is the most economical from the standpoint of cost of operation. However, certain conditions of farm management, the method of irrigation and the cost of water distribution may prove such a plant to be too small. All these factors must be considered as a group in order to select a plant which is of the proper size for the convenient and economic operation of the farm as a whole.

Oversized plants cause the following additional cost:

- 1—Extra first cost of pump and motor or engine;
- 2—Greater draw-down in the well, or additional wells;
- 3—Greater "readiness-to-serve" charge on a motor, or more power to be paid for at the maximum rate.

In order to determine the size of the plant, certain assumptions must be made, viz.: The number of hours per day and the number of days per month of maximum use that a plant will be operated. The general method of determining the requirements of pump capacity and power is illustrated in the following problem:

Assume that on an 80-acre farm, one 5-inch irrigation is to be applied during a period of 30 days by pumping for one-third of the time, and that the water is to be lifted against a total head of 30 feet.

The total quantity of water to be pumped will be $5/12 \times 80 = 33.33$ acre-feet, or at the rate of 1.11 acre-feet per 24-hour day. This rate requires a continuous flow of 0.56 cubic-foot per second¹. Since the plant is to be operated but one-third of the time, then the pump must deliver three times this rate or 1.68 cubic-feet per second (755 gals. per minute)². The power represented by lifting this quantity of water 30 feet is $(1.68 \times 30) \div 8.8 = 5.73$ water horsepower³. If the pump is 60 percent efficient, then the necessary power to be applied to the pump is $5.73 \div 0.60 = 9.55$ horsepower. The motor size, either for direct or belt drive, will be 10 horsepower, or a gasoline engine of at least 12 or preferably 15 horsepower.

The kind of well required will be governed by the particular local conditions. In many areas the well is limited in depth to 30 or 35 feet by a thick stratum of sandstone or shale, and the water-yielding material may be but 10 or 15 feet thick. These conditions limit the draw-down and are unfavorable for a large yield. Within reasonable limits under such conditions, the larger the well diameter the greater the yield; however, this point cannot be determined until fully tested. To augment the yield it is usual to drill other small wells at a distance of 30 or 40 feet and connect them to the pump suction pipe, or to siphon them into the main well. Sometimes a battery of small wells is drilled, the number depending on the quantity of water desired and the character of the gravel stratum, all connected to a common suction pipe to the pump. Where a depth of 50 feet or more is obtainable in good water-bearing material, a single drilled well may produce the required amount of water. The yield conditions from any well in water-bearing material improve with the depth, and the size of well becomes of lesser importance.

There is but one set of conditions of speed, head and discharge for the centrifugal, turbine or propeller pumps at which the efficiency is a maximum. A change in any one of these factors affects

¹One cubic-foot per second flowing for 24 hours equals approximately 2 acre-feet per day.

²One cubic-foot per second equals approximately 450 gallons per minute.

³Water horsepower = $\frac{\text{cubic-feet per second} \times \text{lift in feet}}{8.8}$

the others; an increase of speed ordinarily causes an increase in discharge or gives the same discharge at a higher head, or if the speed remains constant and the head is increased, less water will be pumped. It is seldom that the conditions are such that a pump will deliver its peak efficiency but it is possible to purchase one that fits reasonably close. The rated size of stock pump may deliver the desired quantity of water but still be poorly suited to the conditions to give reasonable efficiency. Impellers are made in various diameters and with various shapes of vanes for the same pump case in order to meet specific conditions.

The horizontal centrifugal pump must be placed so that the suction lift does not exceed the practicable limit of about 20 feet. It may be set in deep pits when direct connected to an electric motor but the operation becomes inconvenient when the pit is over 40 feet deep. The maximum depth at which this type of pump can be set is about 20 feet when belt driven from the ground surface. The vertical centrifugal pump usually requires a pit at least 5 feet in diameter for its installation and the depth of setting is limited to about 50 feet because of the long shaft and frame. Its use is particularly indicated for a fluctuating water level or where the draw-down in the well is beyond the reach of the horizontal centrifugal pump. The turbine and propeller pumps are adaptable for pumping from greater depths than are possible with the vertical centrifugal, and from wells of small diameter. Conditions for the use of the turbine and the vertical centrifugal overlap for the moderate depths.

As a protection against the entry of silt or sand into the sealing gland of a centrifugal pump, it may be necessary to provide a settling tank so arranged that only clear water will be used thru the gland. This precaution should always be made when the well is first pumped. See Fig. 6.

In the selection of piping, the pump should be set in such a position that unnecessary elbows, tees and other fittings are eliminated. In connecting a small pipe to a larger one, a tapering section of length equal to $2\frac{1}{2}$ times the small pipe diameter should be used, and on turns, an elbow of long radius.

Good material is usually the cheapest. Standard flanged pipe should be used on the suction side of the pump and if pumping from a battery of wells, the size of pipe should be proportioned so that the friction loss will be low and equalized. Usually a long discharge line is made larger than the discharge outlet of the pump to reduce the friction head.

When steel pipe is used on long lines, it should be carried above the ground surface and given an occasional coat of preservative.

LEGEND

- 1—Casing.
- 2—Enclosed Runner.
- 3—Casing Wearing Ring.
- 4—Runner Wearing Ring.
- 7—Shaft.
- 8—Stuffing Box Bushing.
- 9—Shaft Sleeve.
- 12—Packing.
- 13—Waterseal Ring.
- 14—Gland.
- 15—Shaft Sleeve Nut.
- 16—Oil Hole Covers.
- 17—Bearing Shell.
- 18—Bearing Cap.
- 21—Thrust Bearing.
- 22—Thrust Sleeve.
- 27—Retaining Nut.
- 29—Oil Ring.
- 31—Pump Half Coupling.

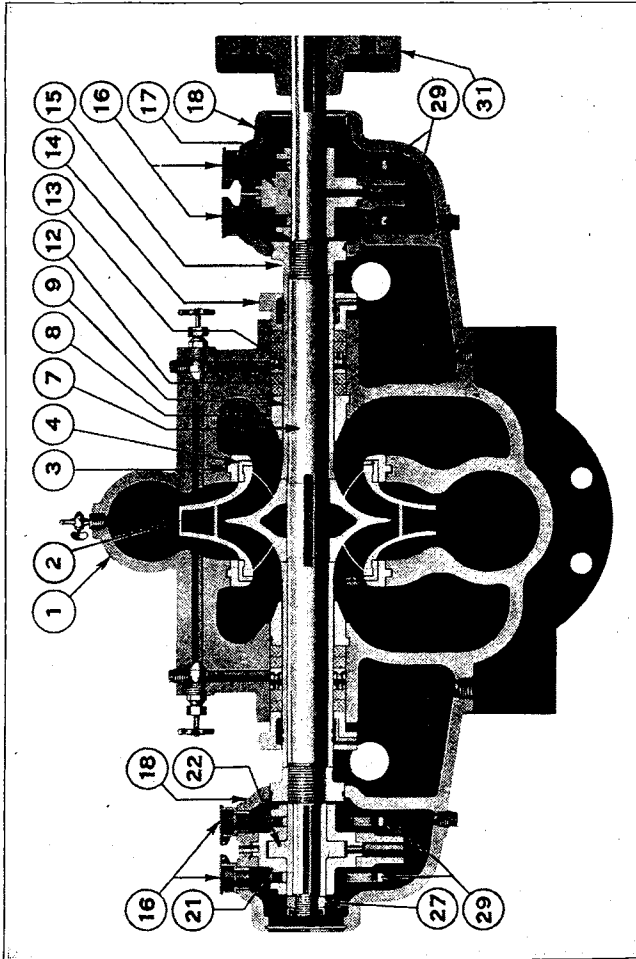


Figure 6.—A vertical section thru a horizontal centrifugal pump showing construction details.
(*Electrotype by courtesy of Allis-Chalmers Mfg. Co.*)

Such exposed line of riveted 16- or 18-gauge steel should be serviceable for at least 20 years. Pipe lines under pressure have longer life than those operating under suction conditions.

The use of valves in connection with priming deserves careful study. Check valves and foot valves should not be put in long lines. A foot valve should not be used if the total head is greater than 40 feet or the discharge pipe is longer than 50 feet because, being quick acting, a water hammer is set up when the pump stops and rupture of the pump or piping may result. On a low lift, a foot valve alone may suffice for priming when water can be poured into the discharge pipe. For the higher lifts, a gate valve is placed in the discharge pipe just above the pump, and a pitcher or tank pump used to exhaust the air from the system in priming. In a battery-well installation, involving a long suction line, it is often desirable to use a power-driven priming pump. Air leaks in the pump or suction pipe greatly extend the time of, or prevent priming, and decrease the pump efficiency.

Excessive belt tightness and the use of idlers are to be avoided in preventing slippage which is better accomplished by the weight of the belt when the distance between pulleys is correct. Gasoline engines require a greater distance between pulley centers than motors, usually not less than 20 feet. The belt should be of the correct thickness and width, according to the horsepower transmitted and the pulley diameters. A thick belt should not be used on a pulley of small diameter. If a horizontal centrifugal pump is belt driven, the inclination of the belt should not exceed 45 degrees.

Most gasoline engines are designed to pull from the bottom of the pulley and therefore must be set on the proper side of the pump to produce correct rotation. The recommendation of the manufacturer should be followed as to the size of the foundation.

It is usually desirable to have a tank cooling system rather than to use the circulating water direct from the pump, for, if the pump should lose its priming, the engine would soon become overheated and injured. It is often necessary to raise the water above the useful lift in order to force water thru the cooling system of the engine, thereby adding extra cost to the pumping operation.

An electric motor should be carefully leveled in order to prevent end thrust and be securely bolted down to adequate foundations. Should the motor be developing its full power, it is essential that it have ample ventilation, especially during hot weather. It is recommended that the wiring of motors for farm pumping be done by or under the supervision of the power company furnishing the electricity. Outside wires are to be kept at least 8 feet from the

ground. All power wires inside the pump house should be in conduit. Knife switches should be of the enclosed safety type. The starter should be of the size and type recommended by the motor manufacturer and placed not closer than 3 feet from the pump or motor except in the case of the push-button line starter.

In damp places, as in the bottom of pits, it is often advisable to operate the starter while standing on a glass insulated stool. Protection against lightning should be provided on the nearest power pole. Power voltage should be either 220 or 440, preferably the former. The use of 2,200 volt current thru the motor is positively dangerous and should not be considered, regardless of savings in power equipment.

When the plant is completed, a permanent and safe means of conducting the water away from the pump should be built immediately. A concrete box should be built, so designed that the water may be easily diverted in any desired direction. The discharge pipe should not be carried higher than flow conditions in the box necessitate.

Plant Care

A shelter should always be provided for the plant, even if of crude design or cheap material. Protect the machinery; the better its appearance the more likely it will be to receive attention, as rusty or grimy equipment promotes an attitude of laxity in proper care. Keep the shelter house clean and avoid water on the floor by providing drains to the well or out of doors.

The pump packing glands need attention periodically. They should not be drawn up so tight that heating results, as this wastes power and the pressure may scar the shaft. Packing will not stay in a satisfactory condition if the shaft is rough. Ordinarily the nuts can be set tight enough with the fingers or a light wrench. Where hard grease is used in sealing, the grease cup will probably need filling once a day and if water-sealed, the water flow will need daily inspection. Before freezing weather, the horizontal centrifugal pump in an exposed position should be drained, as well as all connected piping. The priming pump should be kept in repair and convenient in its operation.

Belts should not be kept in full tension during long periods of disuse. Motors usually have screws in their base for making belt adjustments and should be loosened to release the tension. The belt must be removed from the pulley of the gasoline engine to accomplish this result. The belt splice must be inspected frequently to see if it is pulling uniformly because unequal strain on the splice will cause the belt to run unevenly and may damage a rubber belt by

ripping. Belts of any sort should not be exposed to the weather and should be properly stored after the pumping season.

Motors require but little attention, the most important thing being to keep the oil at the proper level in the reservoirs, using the best quality of oil designated for that purpose. Dust caps should always be kept closed. If the motor accidentally becomes submerged, attempt should not be made to operate it again without advice from someone thoroly familiar with motors. As an index to plant condition, the operator of an electrically driven plant should learn to compute the demand on the motor by counting the revolutions of the meter disk over a period of time. This will serve as a check on the condition of the pump and its bearings. A record should be kept each season of the number of hours of pumping, number of kilowatts used, and the power bill, for the purpose of comparing operation costs.

Gasoline engines need frequent daily attention for the inspection of all points of lubrication, the temperature of the cooling water, and fuel oil supply. Care must be taken to drain all water in freezing weather and it is always good practice to leave the piston out to the extreme stroke when the engine is not in use, to prevent dust from settling on the cylinder walls.

Clean oils and greases for their respective uses should always be on hand.

Wells should not be covered in such a way that they are inaccessible. It is often desirable to inspect the well and note the water level when idle or while pumping, as a matter of record, because a lowered water table may be a reason for an increase in power demand. It may be desirable to sound the well occasionally to determine the extent of accumulation of sand in the bottom. The well should be protected against the entrance of any surface water, trash, or small animals. Attention is drawn to the fact that small pieces of wood entering a well will become water-logged and sink, and, on being drawn into the suction, may cause trouble by lodging in the pump runner, thus causing a diminished flow and an unbalanced condition. There is also the element of danger in breakage of the impeller or pump case by the lodging of such trash.

Estimates of Cost

The prospective irrigation pumping-plant owner should investigate, as completely as possible, its probable cost. It is not possible in this bulletin to give in detail all the items of the cost of a plant since each will have its own peculiarities of construction and these items necessarily must be obtained from a pump dealer or well driller. When investigating the cost of a motor, it is necessary to know the speed at which it runs as well as the horsepower and

whether it is equipped with a base, pulley or starting device. Transformers are sometimes furnished to large users of current by the power company as well as short pole lines. In cases where the transformers must be purchased, they are usually sold at no profit. Their cost is dependent on the primary voltage as well as the capacity. Pole lines for three-phase service will cost about \$1,000 per mile. Engines may or may not be fully equipped with a pulley, clutch, cooling water system, or fuel tank. A centrifugal pump may be for belt drive or on an extended base for motor drive. The cost of a turbine pump varies according to its size, number of bowls and the length of the discharge column. In order to obtain guarantees for satisfactory operation, it is desirable that the major units of a plant be purchased from the same dealer so as to avoid divided responsibility.

No estimate of cost is complete unless the item of depreciation is taken into consideration. There comes a time when all or part of the machinery will be worn out and replacement necessary. Theoretically, a certain sum should be set aside each year so that when the part is worn out, funds are available for its replacement. Usually the extent of use governs the rate of depreciation, and the plant that is used 4 months per year will have about twice the depreciation of one used but 2 months per year. Besides use, the life of machinery is shortened thru lack of proper care, and depreciation also takes place by its becoming obsolete thru age.

Interest on the investment and taxes are the same, whether the plant is used much or little. These are unseen expenses that influence farm profits and must be taken into consideration, especially when the plant is intended to be used for an auxiliary water supply.

The farmer using a pump as a sole source for irrigation water should be especially interested in obtaining a pump of high efficiency. His is a continual expense, and a difference of a small percentage in efficiency is reflected to a greater degree in his power bill. Often a motor of smaller size can be used with the more efficient pump, and besides effecting a saving in purchase cost, he also profits by a lower power rate. There is less reason for investing extra money in a highly efficient, permanent plant which is to be operated but a very short time each season.

Cost estimates are given below of three alternative plants to provide water for the conditions as given in the problem on page 13. It is assumed that 140 acre-feet of water are to be pumped from a 12-inch well, 65 feet deep in which the water level is 18 feet below the ground surface. For each the discharge will be 755 gallons per minute, the lift 30 feet, and the water horsepower 5.73.

PLANT NO. 1.—Equipment to consist of a high grade, horizontal centrifugal pump direct connected to an electric motor in a pit 15 feet deep. The motor efficiency is to be 89 percent and pump efficiency 60 percent.

Cost of plant:

Well 50 feet deep below bottom of pit, drilling at \$2.50 per foot.....	\$ 125.00
Developing and extra cost because of pit.....	40.00
Well casing 12-inch, 16-gauge, galvanized, 50 feet at \$1.20 per foot.....	60.00
Concrete pit, 6x8x15 feet, 6-inch walls.....	165.00
Five-inch pump, 10 horsepower motor, starter, switches, piping and valves, installed.....	625.00
Transformers.....	300.00
Shelter and wiring.....	150.00
Total cost.....	<u>1465.00</u>

Operating cost:

Interest on \$1465 at 6 percent.....	87.90
Taxes 1 percent.....	14.65
Depreciation on machinery, \$655 at 6 percent.....	39.30
Depreciation on well and shelter, \$510 at 4 percent.....	20.40
Power consumed, 1000 hours at 8 kilowatts per hour—8000 kilowatt hours.....	230.00
Repairs, lubricating oil.....	7.00
Attendance.....	20.00
Total annual cost.....	<u>419.25</u>
Cost per acre per year.....	5.24
Cost per acre-foot.....	2.99

PLANT NO. 2.—Equipment to consist of same quality horizontal centrifugal pump as in the preceding plant, driven by an engine using distillate for fuel. Pump efficiency to be 60 percent.

Cost of plant:

Well, 50 feet deep, drilling at \$2.50 per foot.....	\$ 125.00
Developing and extra cost because of pit.....	40.00
Well casing 12-inch, 16-gauge, galvanized, 50 feet at \$1.20 per foot.....	60.00
Concrete pit 6x6x15 feet, 6-inch walls.....	150.00
Five-inch pump, pipe and valves.....	340.00
Fifteen horsepower engine, accessories and belt.....	625.00
Shelter and installation.....	300.00
Total cost.....	<u>1640.00</u>

Operating cost:

Interest on \$1640 at 6 percent.....	98.40
Taxes, 1 percent.....	16.40
Depreciation on machinery, \$1115 at 9 percent.....	100.35
Depreciation on well and shelter, \$525 at 4 percent.....	21.00
Distillate consumed, 1½ gallons per hour for 1000 hours at 12 cents per gallon.....	160.00
Repairs and lubricating oil.....	35.00
Attendance.....	75.00
Total annual cost.....	<u>506.15</u>
Cost per acre per year.....	6.33
Cost per acre-foot.....	3.62

*Cost of power is based on the following rates:

First 200 kilowatt hours per horsepower per season at 5 cents per Kwh.
Next 100 kilowatt hours per horsepower per season at 3 cents per Kwh.
All additional power at.....2 cents per Kwh.

PLANT NO. 3.—Equipment to consist of a vertical turbine pump direct connected to an electric motor. The pump head is to be set on the well casing at the ground surface. The motor efficiency is to be 89 percent and the pump efficiency 60 percent.

Cost of plant:

Well, 65 deep, drilling at \$2.50 per foot.....	\$ 162.0
Developing	20.0
Well casing, 12-inch, 16-gauge, galvanized, 65 feet at \$1.20 per foot	78.0
Pump and motor, installed.....	800.0
Transformers	300.0
Shelter, switches and wiring.....	150.0
Total cost	1510.0

Operating cost:

Interest on \$1510 at 6 percent.....	90.6
Taxes, 1 percent.....	15.1
Depreciation on machinery, \$850 at 8 percent.....	68.0
Depreciation on well and shelter, \$360 at 4 percent.....	14.4
*Power consumed, 1000 hours at 8 kilowatts per hour—3000 kilowatt hours	230.0
Repairs and lubricating oil.....	20.0
Attendance	12.0
Total annual cost.....	450.1
Cost per acre per year.....	5.6
Cost per acre-foot.....	3.2

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*Cost of power is based on the following rates:
 First 200 kilowatt hours per horsepower per season at 5 cents per Kwh.
 Next 100 kilowatt hours per horsepower per season at 3 cents per Kwh.
 All additional power at.....2 cents per Kwh.