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Pump Irrigation in Nebraska

E. E. Brackett

O. W. Sjogren

THE UNIVERSITY OF NEBRASKA

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PUMP IRRIGATION IN NEBRASKA

By E. E. BRACKETT, Associate Professor of Agricultural Engineering, and
O. W. SJOGREN, Assistant Professor of Agricultural Engineering

INTRODUCTION

Yields of the field crops of Nebraska are in a measure due to the farming methods used and to the thoroness with which these methods are carried out, but every Nebraska farmer knows that he has no control over the greatest factor influencing yields—the weather. Crops may be injured by too much rain, by hail, by wind, by frost; but lack of moisture usually causes more loss than all of these.

Injurious shortage of moisture may not be evident when the total rainfall for the season is considered since this tells nothing of its distribution thru the growing season. Nebraska's crops have been curtailed in many seasons by this shortage of moisture during the critical periods of growth, and in few cases will it be found that crop failure was due to shortage of the total rainfall for the season.

The use of water from the rivers of the state for irrigation has grown to a point where the down stream farmer is in jeopardy of crop loss thru shortage of the flow, and this condition has stimulated the installation of pumping plants to supplement an unreliable ditch supply or to serve as a source of supply for an individual irrigation system.

Before one decides to install a pumping plant for irrigating purposes there are a good many factors that should be considered regarding the feasibility of the project and the construction of the plant. The material contained in this bulletin has been obtained from studying pumping plants in actual operation in this and other states and from experience gained while installing plants in this state.

EXPLANATION OF TERMS USED

Head—This refers to the pressure of water. This may be measured as the height of a column of water in feet or as the pounds pressure per square inch. A column of water one foot high has a pressure of .434 pound per square inch; or a pressure of one pound per square inch is equivalent to that of a column of water 2.304 feet high. For example, a column of water ten feet high has a head of ten feet, or a pressure of $10 \times .434 = 4.34$ pounds per square inch. To convert pounds pressure to head in feet multiply by 2.304, as $4.34 \times 2.304 = 10$ feet.

Friction head—When water flows thru a pipe there is friction between the water and the pipe, and the head or pressure necessary to overcome this friction is called the friction head.

Duty of water—In irrigation this expresses the relation between a given quantity of water and the area which it serves. In other words, it is the amount of water used per acre for the season, given in depth in feet or inches. It is also expressed as the number of acres that will be irrigated by a flow of one second-foot thruout the irrigating season.

Acre-foot—An amount of water which will cover an acre to a depth of one foot is referred to as an acre-foot.

Acre-inch—An amount of water which will cover an acre to a depth of one inch is called an acre-inch.

Second-foot—A flow of one cubic foot of water per second is said to be one second-foot.

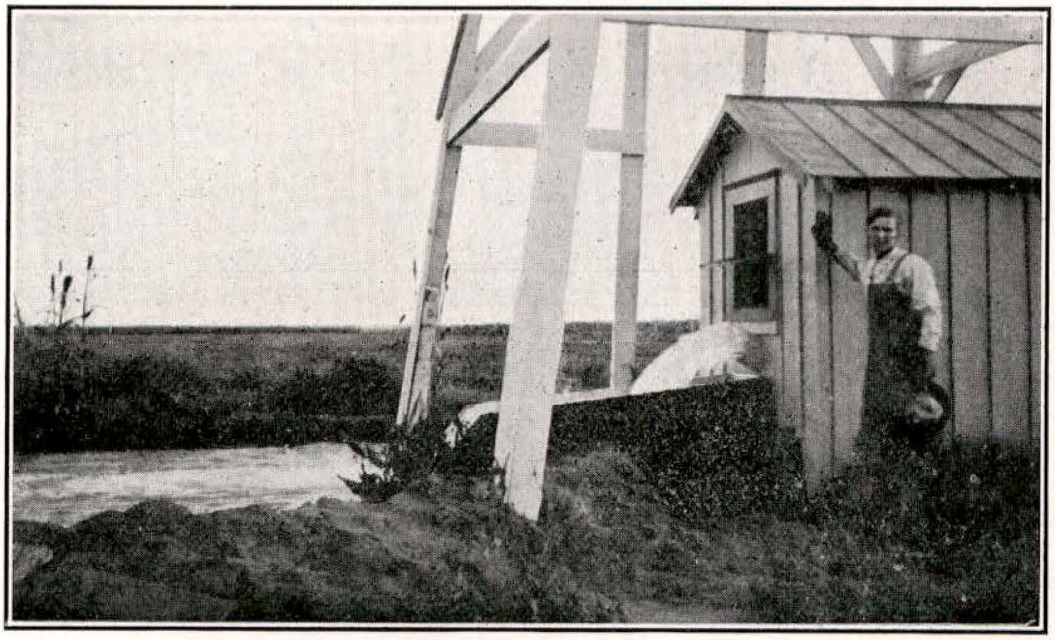
Draw-down—The distance that the water is lowered below its natural level by pumping is the draw-down.

Lift—The height thru which the water is pumped is the lift.

AMOUNT OF WATER REQUIRED

Determining factors—Several factors must be considered in making an estimate of the amount of water to be pumped. These are: the area to be irrigated, the duty of water or depth of water to be applied on the land, length of the irrigating season, nature of the soil, kind of crop, climate or weather conditions, and the distance the water must be carried to get it on the land. Of these the first three are probably most important even tho they are more or less dependent on the other factors. If one knows the area to be irrigated, the depth of water to be applied, and the duration of the application, it becomes an easy matter to determine the amount required. Sufficient allowance must be made for the influence that these other factors may have upon the quantity required. For example, if the water is to be carried over or used on an open soil, more water will be lost in the distribution system, and hence more must be pumped than would be necessary for a close soil.

From data gathered in this state by the Office of Public Roads and Rural Engineering of the United States Department of Agriculture, it was found that the depth of water applied in the Platte Valley during the season of 1914 averaged 4.54 inches over the area irrigated. The maximum depth was 7.02 inches and the minimum depth was 2.3 inches. The season was quite dry, so it seems that when a pumping plant supplements the rainfall, more than one foot of water will rarely if ever be required. If this is considered as the depth of water to be supplied and if the acreage to be irrigated is known, the required capacity of the plant can very easily be computed. The capacity of pumps is given by the manufacturers in gallons per minute. A pump delivering 450 gallons per minute delivers one cubic foot of water per second. This is an amount sufficient to cover an acre to a depth of one inch in one hour or to a depth of two feet in twenty-four hours. If then a pump of this capacity is operated



for ten days of twenty-four hours each, enough water will be pumped to cover 40 acres to a depth of six inches or 20 acres to a depth of one foot. (See table 1.)

TABLE 1[1]

Number of pump or diameter of discharge in inches	Capacity, in U. S. gallons per minute	Capacity, in second-feet, or acre-inches per hour	Number of acres irrigated six inches deep. Pump is operated the following number of 24-hour days each month. (Number of days operation)						
			30	20	15	10	5	2½	1
2	100	0.22	27	18	13	9	4½	2¼	0 9/10
2½	150	0.33	40	27	20	13	6½	3¼	1 3/10
3	225	0.50	60	40	30	20	10	5	2
3½	300	0.66	80	53	40	27	13	6½	2⅔
4	400	0.90	110	71	55	35	18	9	3⅔
5	700	1.60	190	127	95	63	32	16	6⅓
6	900	2.00	240	160	120	80	40	20	8
7	1,200	2.70	320	213	160	107	54	27	10⅔
8	1.600	3.50	430	287	215	143	72	37	14⅓

[1] From University of California Agricultural Experiment Station Circular No. 117.

Length of season and capacity required—Assuming that a 40-acre field of some crop is to be irrigated in five days to a depth of three inches, this will be equivalent to irrigating ten acres to a depth of one foot, or ten acre-feet of water are to be pumped in 120 hours. This will require a pump having a capacity of 450 gallons per minute. If the plant is to be operated for a shorter period than 24 hours each day and it is desired to get the same amount of water on the land in the same time, a relatively larger plant must be installed.

DISTRIBUTION OF THE WATER

If the crop is of such a nature as to permit continuous operation thruout the season a smaller plant can be used. The plant should not be so small that the distribution of the water will be difficult, due to the small amount pumped. A small quantity of water flowing thru a ditch makes its distribution difficult and also causes a relatively larger loss from seepage and evaporation than where a larger quantity flows. The cost of each unit of water delivered on the land is therefore greater for the small plant than for the larger one. On the other hand, the capital invested in a small plant is small, and consequently the fixed charges (interest on investment and depreciation) are low. A short period of operation demands a large plant on which the first cost (and consequently the fixed charges) will be high. The operating expenses, however, are lower per unit pumped than with the small plant. This difference in the cost of pumping may be more than offset by the increased fixed charges.

Planning the system—In planning the distributing system several factors must be borne in mind, such as: method of applying the water, whether by flooding, border, furrow, or check; and location of plant with regard to topography, head available, and distance. In this state, the most general methods of applying the water to the land are the flooding and furrow methods. In locating a plant it is always well to place it on the highest part of the field if other conditions permit. This will make the distribution a simple matter in that the water can be applied to any part of the field. If the plant is located in a low place and it is desired to get the water onto the higher land, it cannot be done without installing pipe lines and forcing the water up to this land which would be very expensive if the pipe lines are of any appreciable length.

Amount of water flowing—The amount of water flowing will determine very largely what type of distribution system to use as a small amount demands a treatment different from that given a large amount. The slope of the land will determine the smallest amount that should be used. The amount should be large enough so that the water reaches the farthest portion of the land without a large ditch loss. When water flows rather deep in a ditch, the velocity is greater and it will distribute better than if the water runs shallow.

Distance—The distance that the water must be carried also influences the design of the system in that the seepage losses, sometimes called ditch losses, become larger the greater the distance from the supply. It should always be the aim, when conditions will permit, to place the pumping plant as close as possible to the fields that are to be irrigated.

DESIGN OF PLANT

If a plant is to operate efficiently it must be properly designed for the conditions under which it is to operate. The pump should be of the proper capacity and the engine should be of the proper size so that the power will be used most efficiently. The pump selected will depend upon the quantity of water desired and upon the depth of the well or head against which it must operate. The size of the engine depends upon the capacity and efficiency of the pump and upon the depth of the well. A large pump will ordinarily have a greater efficiency than a smaller one of the same type. The type of pump also affects the efficiency. The accompanying table indicates the efficiency of single stage single suction centrifugal pumps and the horsepower required for each foot of lift.

TABLE 2

Size of pump	Capacity		Average efficiency, per cent[1]	H. P. per ft. of lift		Cost of pump
	Gal. per minute	Cu. ft. per sec.		Theoretical	Actual	
2	Normal 100	0.22	30	.025	.083	$37.50
	Max. 150	0.33		.037	.090	
$2\frac{1}{2}$	Normal 150	0.33	35	.037	.105	45.00
	Max. 225	0.50		.057	.163	
3	Normal 225	0.50	40	.057	.142	55.00
	Max. 300	0.67		.076	.190	
4	Normal 400	0.89	45	.101	.220	65.00
	450	1.00		.113	.252	
	Max. 550	1.22		.138	.310	
5	Normal 700	1.53	50	.176	.350	82.50
	Max. 900	2.00		.227	.450	
6	Normal 900	2.00	50	.227	.450	110.00
	Max. 1,200	2.67		.303	.600	
8	Normal 1,600	3.56	55	.404	.730	150.00
	Max. 2,100	4.67		.530	.960	

[1] University of California Agricultural Experiment Station Circular No. 117.

Horsepower required—If the discharge of the pump is given in gallons per minute, the theoretical horsepower can be computed by the following formula:

$$\text{Theoretical H. P.} = \frac{\text{Gal. per min.} \times \text{wt. of 1 gal. in lbs.} \times \text{lift in ft.}}{33{,}000}$$

A gallon of water weighs approximately $8\frac{1}{3}$ pounds. The total lift in feet should include the head due to the friction of the water in the pipe. By head is meant the lift. If the efficiency of the pump is known, the actual horsepower can readily be obtained as follows:

$$\text{Actual horsepower} = \frac{\text{Theoretical horsepower}}{\text{Efficiency in per cent}} \times 100$$

Characteristics—The accompanying curves (plates 1 and 2) show how the efficiency, actual horsepower, and the speed of the pump vary with different discharges for a certain head or lift. For example, from the curves of the 4-inch pump (plate 1), the greatest efficiency is shown to be obtained when the discharge is about 450 gallons per minute. The horsepower curve indicates that 13½ horsepower are necessary for this discharge. If, instead of the necessary power, a 10-horsepower engine is used the maximum discharge would be only 300 gallons per minute, thus causing the pump to be operated far below its maximum efficiency and capacity. It is thus seen that the pump and engine must be properly proportioned if the best of service is to be obtained at the lowest cost.

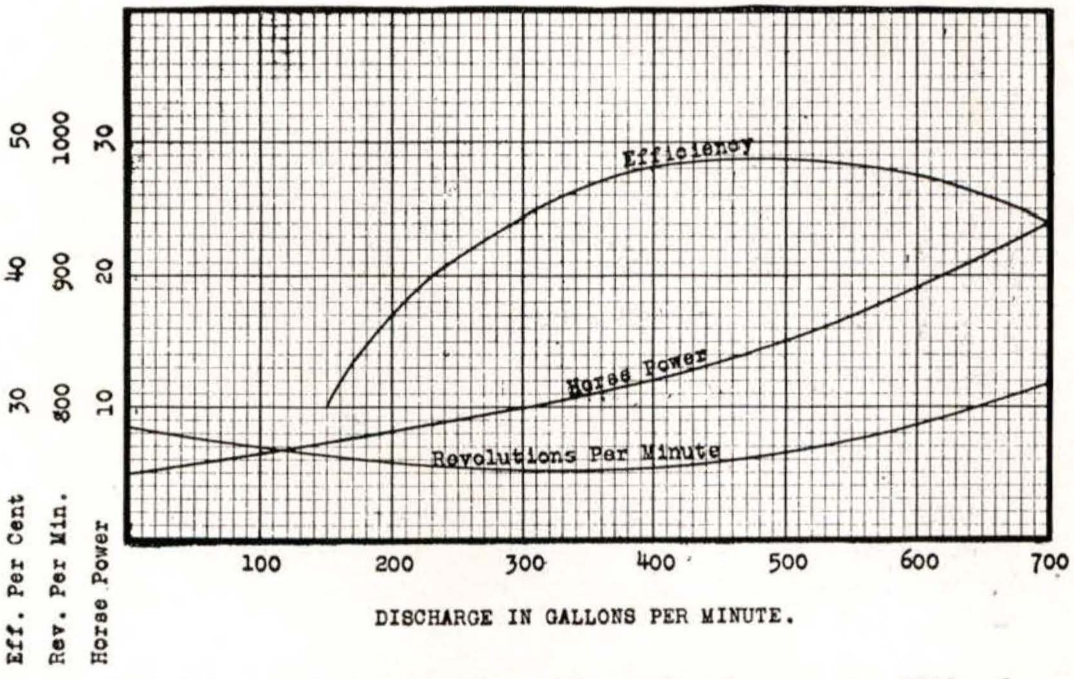


Plate I—Characteristic curves for a 4″ centrifugal pump at a 60′ head
(Data from New Mexico Bulletin No. 77)

Size of pipes—It is also important to use proper size of suction and discharge pipes. The suction pipes are generally large enough if they are of the same diameter as the suction opening. This is generally two inches larger in diameter than the discharge opening. An increaser should be used at the discharge so as to make it possible to use as large a pipe for the discharge as is used for the suction line. In this way, a considerable saving in power will result. For example, if a No. 4 pump is installed in a well pit 20 feet deep and the suction pipe extends 20 feet below the pump and a discharge of 450 gallons per minute is desired, the following amount of pipe is necessary: 20 feet of vertical and about 4 feet of horizontal discharge pipe, and one connecting elbow; 20 feet of 6-inch suction pipe, and one elbow. If the water is lowered almost to the bottom of the suction pipe when pumping, there would be a total lift of 40 feet not including friction. The friction head would be as follows when delivering 450 gallons per minute:

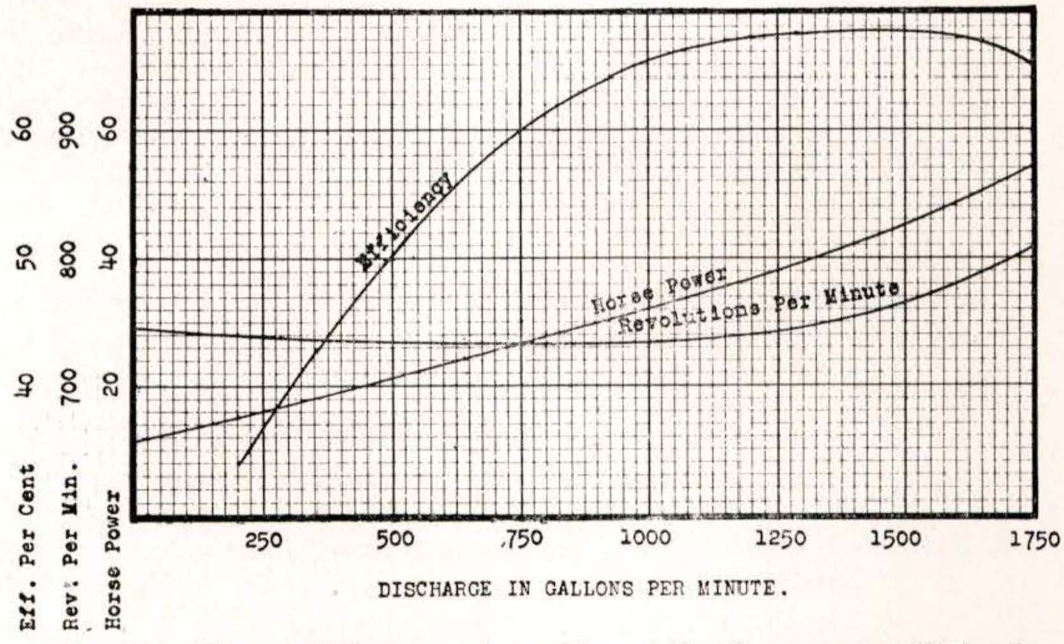


Plate II—Characteristic curves for a 6″ centrifugal pump at a 60′ head (Data from New Mexico Bulletin No. 77)

Head lost thru friction in 20 ft. 6 in. pipe del. 450 g. p. m.	0.092 ft.
Head lost thru friction in 1 6 in. elbow del. 450 g. p. m.	0.392 ft.
Head lost thru friction in 24 ft. 4 in. pipe del. 450 g. p. m.	3.331 ft.
Head lost thru friction in 1 4 in. elbow del. 450 g. p. m.	2.015 ft.
Total friction head	5.830 ft.
Vertical lift	40.000 ft.
Total head	45.830 ft.

If the discharge pipe is of 6-inch diameter, the following will be the result:

Head lost thru friction in 44 ft. 6 in. pipe del. 450 g. p. m.	0.8228 ft.
Head lost thru friction in 2 6 in. elbows del. 450 g. p. m.	0.7840 ft.
Total friction head	1.6068 ft.
Vertical lift	40.0000 ft.
Total head	41.6 ft.

The water horsepower for the case where a 4-inch discharge pipe is used will be 5.18, while in the case of the 6-inch discharge the water horsepower is only 4.7. From table 2, a 4-inch pump delivering 450 gallons per minute has an efficiency of 45 per cent. If a 4-inch discharge pipe is used, 12 horsepower will be required; while if a 6-inch discharge pipe is used, 11 horsepower will do the work. Four per cent allowance has been made here for belt slippage. Thus, there will be a saving in the fuel that would be required for one additional horsepower. For small engines the fuel required is 1.1 pints per brake horsepower hour. For one horsepower this would amount to 1.65 gallons of fuel oil in 12 hours. At the present price of gasoline which is 17 cents per gallon, this would mean a saving of 28 cents for each 12 hours operation, or a saving of $11.20 for a season's operation of 40 days of 12 hours each.

The discharge pipe should not be carried any higher above the surface of the ground than is absolutely necessary; for, as seen above, every foot added to the lift increases the operating cost.

COST OF A PLANT

The cost of a pumping plant depends upon several factors,—size, type and grade of machinery, method of installation, and kind and depth of well. The depth of the well determines the type of pump, and the operating head; capacity and efficiency of the pump determine the size of engine. Therefore, it may be said that the well is the determining factor in the cost of a plant. Due to the variation under different conditions, no estimate of cost can be made that will apply in all cases. The tables given below give the approximate cost of pumps, engines, and pipe and will enable an estimate to be made for almost any condition. These figures of cost were obtained from dealers very recently. The figures given do not include the cost of transportation but are net at the jobbers'. Other cost items that must be considered are transportation, accessories, and housing. Accessories include such items as pipe and fittings, primer, and belt or other connection between pump and engine. The cost of accessories will vary with the type of plant and method of installation. No certain figure can be given, and the cost must be estimated after the operating conditions have been determined. The cost of transportation will depend on the length of haul by rail and wagon. The cost of installation will vary with the cost of labor and material and also with the size of the plant. A small plant should be installed for not more than ten per cent of the total cost of the machinery. This may be reduced for the larger plants. The cost of housing will be nearly constant for plants of all sizes, so that for a small plant the cost will be high when taken as per cent of the machinery cost, while in large plants this will be low.

Approximate cost of engines at the factory:

Horsepower	Gasoline engines	Kerosene oil engines
3	$56	
4	80	
6	110	$290
8	160	360
10	225	420
12	265	470
15	325	520
20		690

Approximate cost of black iron pipe per foot:

Diameter in inches	Price per foot
2	$0.14¼
2½	.22½
3	.29⅓
4	.46¼
5	.62¾
6	.81¼
7	1.07¼
8	1.12½

COST OF OPERATION AND NET RETURNS

The items to be considered in the cost of operation are: fuel cost, fixed charges, repairs, and attendance. In many instances, the fuel cost only is considered but this does not give the real cost. The money expended for the plant would bring an income if invested in other commercial channels, and it is therefore just to consider the interest on the capital invested as a part of the operating cost.

The plant will decrease in monetary value from year to year so that the depreciation of the plant must be considered. Other items of cost are repairs, attendance, etc. All these can be listed as fixed charges. As a basis from which to reckon the fixed charges the following figures collected by the Department of Agricultural Engineering relative to farm equipment are used:

Depreciation	10%
Repairs and maintenance	2½%
Interest	6%
Total	18½%

Attendance is figured at 25 cents an hour, but inasmuch as the attendant devotes only part of his time to the plant and part to the distribution of the water it is assumed that half of the time the plant will run without attendance.

Gasoline and kerosene engines are used almost exclusively in this state for the motive power, and the following figures are based on this fact:

Assume that a 40-acre field of corn is to be irrigated to a depth of six inches of water during a period of ten 24-hour days. The well has a total lift of 30 feet. A total of twenty acre-feet of water will be required in 10 days or two acre-feet per day.

A 4-inch pump of high efficiency will deliver this amount or 450 gallons per minute. From the table it is seen that this amount of water per minute will require 0.252 brake horsepower per foot lift or a total of 7.5 horsepower to operate the pump. An 8-horsepower engine will therefore be installed.

FIRST COST OF PLANT

No. 4 centrifugal pump	$65.00
8 H. P. engine	160.00
Primer and belt	20.00
Pipe and fittings	20.00
Transportation	35.00
	$300.00
Installation, 10% of above	30.00
Building to house the plant	50.00
Total cost of plant	$380.00

COST OF WELL

Excavating pit 8′x12′ deep	$8.00
Curbing (concrete)	24.00
Labor	10.00
Boring and casing well, 20 feet @ $5.00	100.00
Total cost of well	$142.00
Total cost of plant and well	$522.00

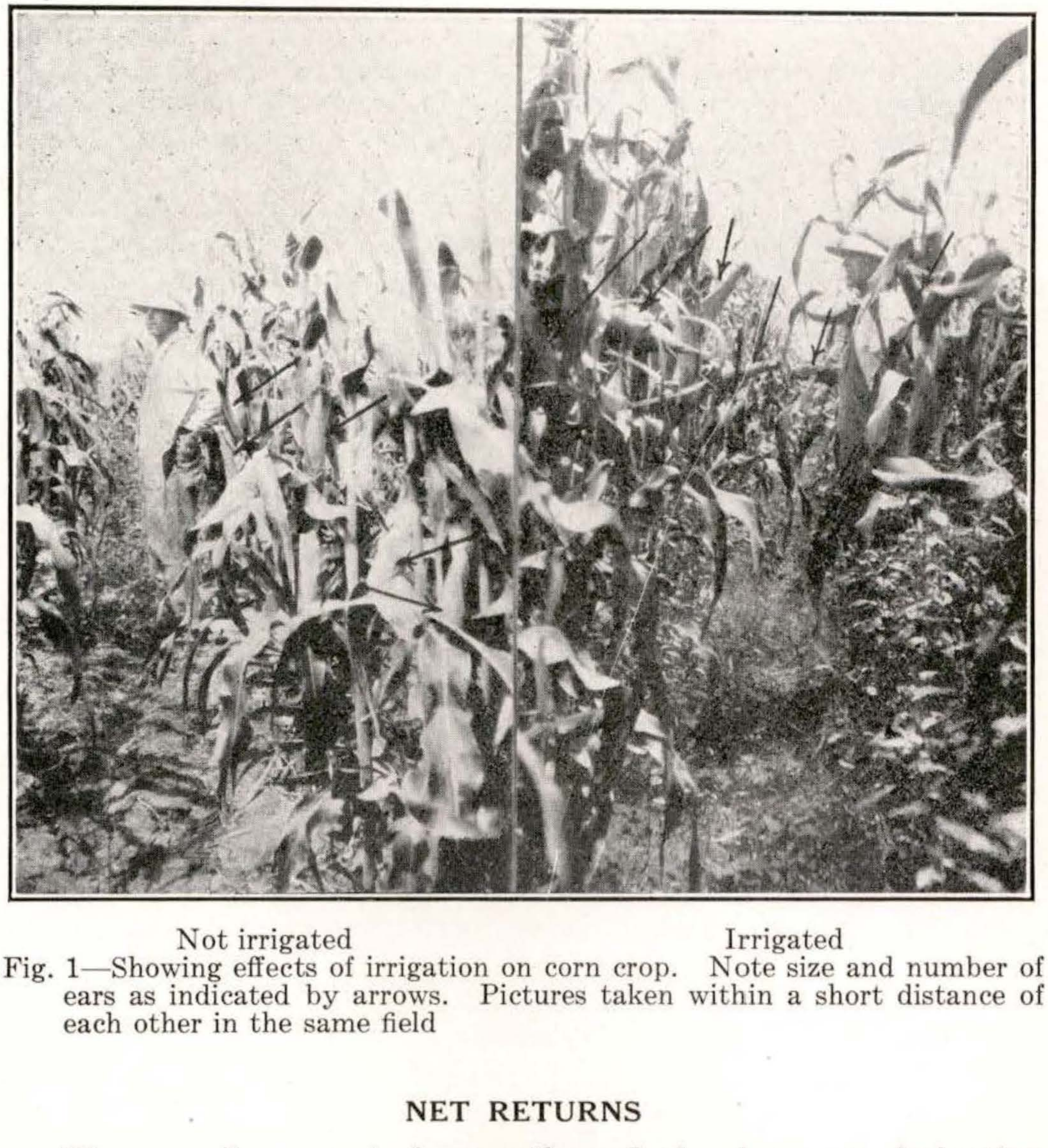
FUEL CHARGE

Pump operated 10 days to supply 6 inches of water to 40 acres. Engine uses 1.0 pint of fuel per brake horsepower hour when using gasoline, or 1.0 gallon per hour for an 8 H. P. engine. The plant being operated for 240 hours requires a total of 240 gallons of fuel for the season. With gasoline selling at the present price of 17 cents a gallon, the fuel cost $40.80

Lubricating oil	5.00
Attendance 120 hours @ 25 cents	30.00
Fixed charges, 18½% of cost	96.57
Total cost	$172.37
Cost per acre	$4.31

Cost per acre-foot of water per foot of lift, 28.7 cents. Fuel and lubrication cost per acre-foot per foot lift, 7.63 cents. If kerosene is used for fuel instead of gasoline, the fuel cost will be reduced considerably as the present price of kerosene is 6½ cents per gallon. For kerosene 1.1 pints of fuel per horsepower hour is used. The fuel and lubrication cost in this case would be $22.16 or 3.69 cents per acre-foot of water per foot lift. The total cost would be $3.718 per acre.

These figures can not be taken as absolute nor will they remain constant for all depths. They serve, however, as an indication of what the cost will be. Figures collected by the Office of Public Roads and Rural Engineering of the United States Department of Agriculture relative to pump irrigation in the Platte and Republican River Valleys of this state during the season of 1914 show that the fuel and lubrication cost for pumping varies widely, from a minimum cost of 4.35 cents per acre-foot of water per foot of lift to a maximum of 13.0 cents. These figures are from 12 different plants. For the season of 1916 four plants have reported completely to date and show costs varying from a minimum of 3.89 cents to a maximum of 10.4 cents per acre-foot per foot of lift.



Not irrigated Irrigated

Fig. 1—Showing effects of irrigation on corn crop. Note size and number of ears as indicated by arrows. Pictures taken within a short distance of each other in the same field

NET RETURNS

The question most frequently asked where an irrigation pumping plant is being contemplated is, will it pay? There are so many factors entering into the reply to such a question that it is impossible to make a definite statement that can be applied to all conditions. The personal factor is a very determining one. One man will make a success of pumping with conditions under which another man would make a failure. Aside from this factor, here are others, such as locality and depth of water.

Where the water is close to the surface so that it will not have to be lifted to any great height it can be placed on the land at a very low cost and a good return will be obtained from the ordinary crops. In the course of the last season a drouth came at the critical time for the corn crop. Where the pumping plants were used at that time for irrigating the corn, the yield was about double the unirrigated yield. At the prevailing prices for corn this netted a big profit. The unirrigated corn yielded from 15 to 25 bushels, while the irrigated corn yielded from 30 to 40 bushels. If an increase of 15 bushels per acre is obtained due to irrigation, this, at 70 cents per bushel, will give a gross increase of $10.50 per acre. If the cost of irrigation as shown in table 2 is $3.718 per acre, a net return of $6.782 per acre would be realized. With ordinary prices this net return would be reduced. The net return would also be reduced as the depth of the well increased, so that there is an economical lift beyond which it would not be profitable to pump for irrigation. The deeper a well, the greater the cost of the water; so that if the cost is too great to realize a fair net return from ordinary crops, higher-priced crops must be grown or the idea of irrigating by pumping must be abandoned. It was found in collecting data last season in coöperation with the Office of Public Roads and Rural Engineering of the United States Department of Agriculture that unirrigated sugar beets yielded 10 to 11 tons per acre, while irrigated beets yielded 15 tons per acre. With beets selling at $6.50 a ton this nets a large profit.

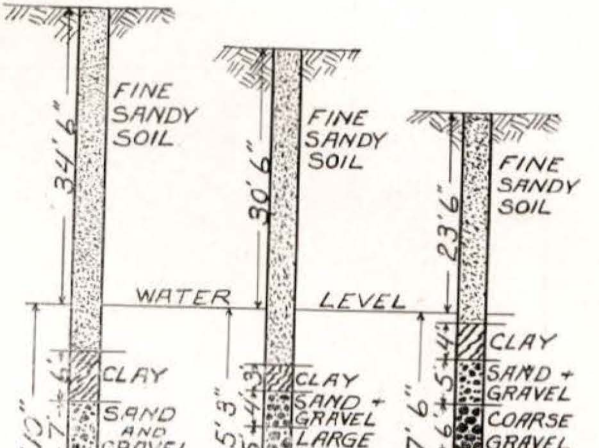
ECONOMICAL LIFT

Just where to place the limit of economical lift is rather difficult, due to the variation in market prices from year to year, in the season, and for different crops. About the only way to arrive at any conclusion regarding this would be to make an estimate of the cost of the plant, of the operating cost, and of the increased crop return due to irrigation and so get an estimate of the net return.

TEST WELLS

The first requisite of a pumping plant is that a supply of water large enough to supply the needs be available. Because this supply is found below ground a survey must be made of conditions below the surface. The method of obtaining some idea of the available supply is by means of test wells. These test wells are merely holes sunk or bored into the ground thru the water-bearing strata. Accurate observations are taken of the different conditions met as the sinking progresses. Generally the first test well is made on the highest part of the land which is to be irrigated. If this first well gives indications of a supply large enough for the requirements, further test wells are unnecessary and the well proper can be constructed in this location. Sometimes, however, several test wells must be sunk in different localities before a suitable location is found or before a definite conclusion can be drawn.

Sinking—Where the water is relatively close to the surface an ordinary post hole auger can be used for boring the hole down to water. The handle is lengthened by means of iron pipe. Care must be taken in making the hole to make it plumb. After water is reached the soil generally gets too sloppy to allow the use of the auger, and a sand pump must then be used to take the material out of the hole. If the soil stands up well one may be able to go to water before the use of casing is necessary. It is advisable to use casing in the hole after the water level is reached so as to prevent the caving in of the sides as the material is taken out by the sand pump. Ordinary iron pipe or sheet iron well casing can be used for casing the well. The casing should be weighted to cause it to sink as the dirt is taken from the inside of it by the sand pump. Casing of four inches diameter is sufficiently large to use for test wells. This will allow gravel of sizes up to three inches to be removed.



(*a*) (*b*) (*c*)

Fig. 2—Logs of three test wells sunk in the same field

(*a*) Does not give promise of a large flow due to absence of a large amount of coarse material

(*b*) Gives promise of a medium flow due to a fair amount of coarse material

(*c*) Presence of a large amount of coarse material gives promise of a large flow

Samples of the material should be taken from the well whenever any change in the nature of the material is noticed, and a careful record should be kept of the thickness of each layer and of its depth from the surface. This will be of great help in estimating the supply of water available after the test well is finished, as by this means a fairly accurate idea is obtained of the nature of the material. Consequently, a prediction of the flow can be made. If the character of material and the depth of the material indicate conditions as in figure 2(a) one can reasonably expect a small flow of water. Conditions in figure 2(b) forecast a somewhat larger supply, while conditions indicated in figure 2(c) with a large proportion of coarse material give promise of a large flow. Where one well does not give a flow as large as is desired one or more additional wells are constructed and connected to the one pump as indicated in figure 7.

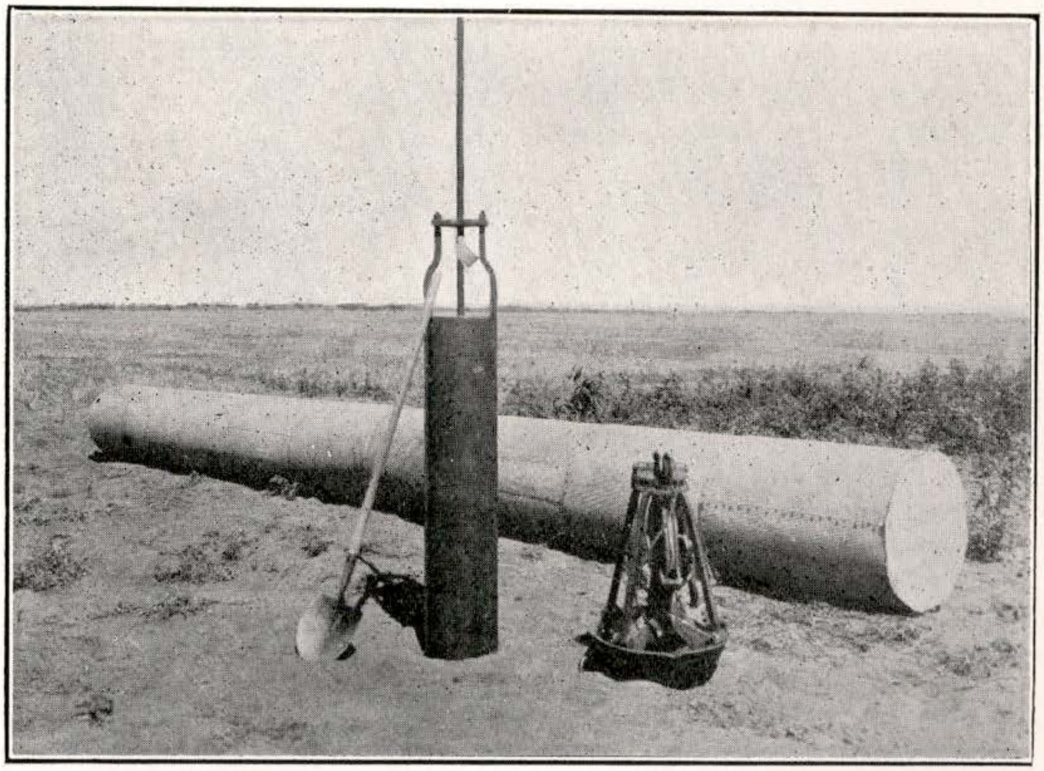


Fig. 3—Showing orange peel bucket and suction bucket which are used in digging the irrigation well. Also shows the well casing riveted together, ready for lowering into the well

IRRIGATION WELLS

Construction—After finding a test well that gives indications of a sufficient supply, the next step is the construction of the irrigation well. A pit four to six feet in diameter is dug to the water level and is then curbed. The casing, 16″ to 30″ diameter, is set into the pit, and weighted by means of rocks or sacks of sand laid on a platform fastened by means of hooks or bolts to the upper end. The casing sinks as the material is excavated from the inside. If it is coarse, an "orange peel" bucket can be used for removing it; while if finer material such as sand or fine gravel is found, more rapid progress is made by using a large sand pump known as a "suction bucket" shown in figure 3. If clay strata are encountered a large auger should be used to bore thru these, as the orange peel or suction bucket will make but very little progress thru clay.

Gravel treating wells—If a great deal of fine sand is encountered in the water strata, the practice of "gravel treating" the well is at times resorted to. This consists of sinking a tight or "blind" casing of a diameter four inches or more larger than the diameter of the well. After the desired depth is reached, the perforated casing is lowered inside this blind casing and centered to place. The space between the two casings is then filled with gravel that will be retained on a ⅜-inch mesh screen. As the gravel is added, the outer casing is withdrawn so that the gravel is kept about a foot above the bottom of the blind casing in order that the fine sand shall be held away from the perforated casing.

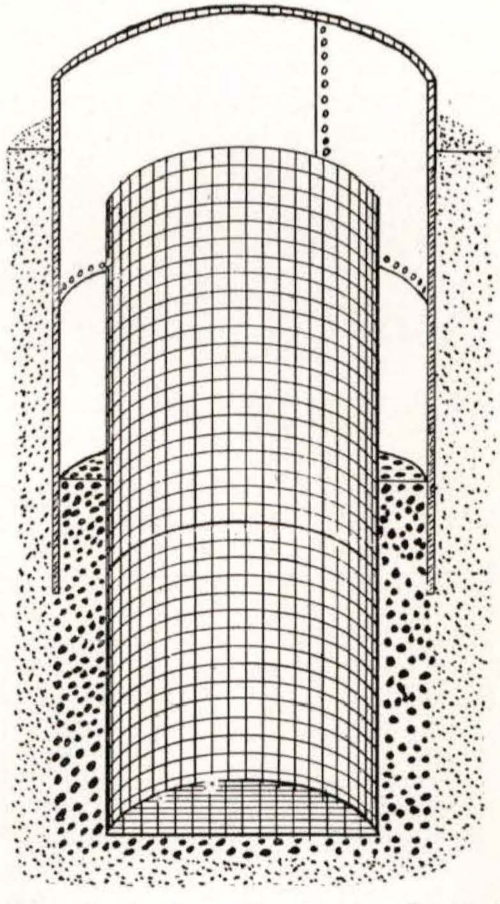


Fig. 4—Section showing perforated casing with a part of the gravel in place and outer "blind" casing being removed

Casings—Several types of casings are used. Figures 5 show three popular types. By means of a special tool, perforations can be cut in the casing after it is in place in the well; but if this method is used, the galvanizing is broken at each opening, leaving the metal exposed. Corrosion will tend to enlarge the slots. This holds true also when the heavy sheet metal is galvanized before being punched. The per cent of perforation is to be considered carefully; if too much material is cut away, the casing will not be rigid enough to withstand the inward pressure of the earth and water, and collapse may occur. The lower end of the casing should be covered to prevent the inrushing of material from the bottom of the well. This is accomplished by placing a sheet of heavy perforated material across the bottom end of the casing before lowering it into place.

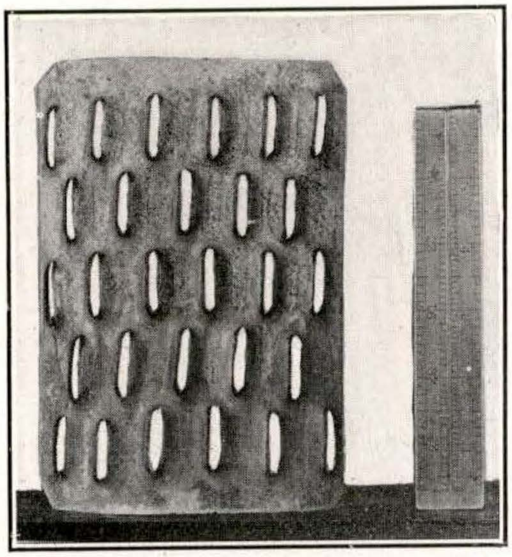


Fig. 5 (*a*)—Perforated sheet metal well casing

If the well is not gravel treated the perforated casing is sunk as the well is being dug. Then a quantity of Portland cement tied loosely in a gunny sack is dropped into the well to seal the bottom.

Developing—After the well is finished, it is advisable to make a preliminary test if a pump is available. This test is to determine the output of the well and also to determine the distance that the water lowers in the well while pumping, commonly called the "draw-down." In the preliminary test, water should be pumped slowly for several hours. It is particularly important that this precaution be observed if considerable fine sand has been encountered in the construction of the well. If a centrifugal pump is used, the control of the flow is best accomplished by a valve in the discharge pipe. The rate of pumping from the well should be increased very slowly in order that sand which comes into the well may be handled readily thru the pump. A safe rule to follow would be *not* to increase the rate of pumping so long as the water carries considerable sand. Rapid pumping at first has ruined some wells. Not only is the pump likely to become clogged with sand, but the

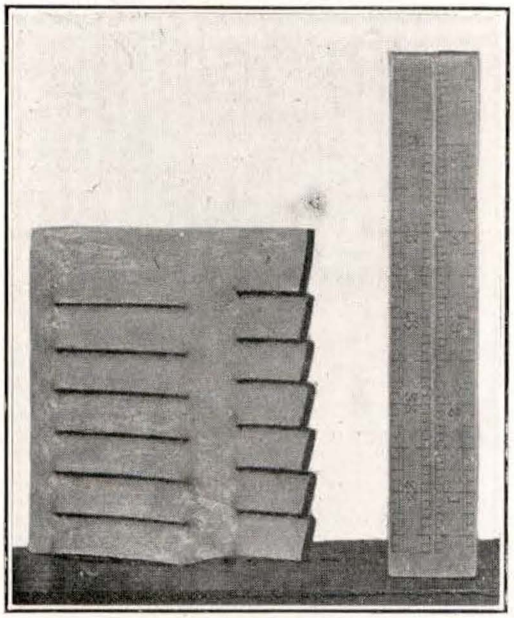


Fig. 5 (*b*)—Shutter screen casing

sudden removal of so much sand near the casing allows the finer material to cave down from above in such large quantities that in some cases it acts as a permanent barricade or dam, shutting off a large portion of the flow into the well. Slow pumping seems to permit these changes to take place gradually, resulting in an increased flow.

Capacity—The limit of the capacity of the well is reached when the water is pumped out as fast as it reaches the suction pipe. If an attempt is made to operate at this capacity, the water will be lowered so that air will enter the suction pipe and this may cause the pump to cease operating until it is re-primed. From the standpoint of satisfactory operation it is therefore necessary that a quantity of water somewhat less than this be drawn from the well.

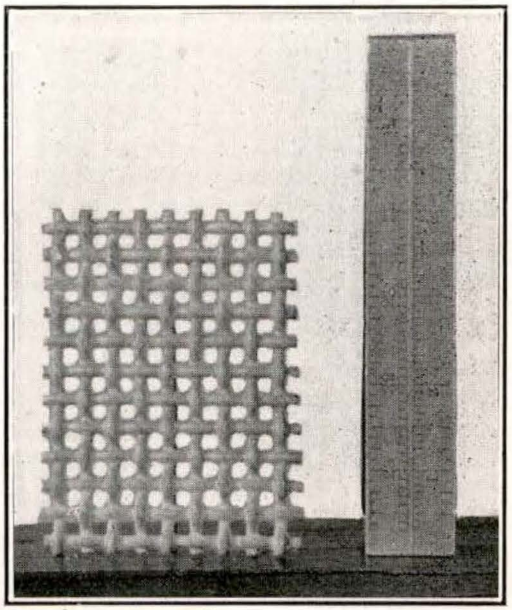


Fig. 5 (*c*)—Wire screen casing

PUMPS

Determining factors in the selection of pumps—The rate of pumping and the total head against which the water is pumped are two factors of vital importance in selecting the pump. Should the well supply more water than necessary for irrigating the proposed area, the pump of the size required to supply water at the desired rate should be selected (see table **1**); but if it is necessary to use all the water the well can supply, then the flow of the well determines the capacity of the pump, and one should be selected that will operate at its highest efficiency when delivering this quantity of water. In both cases the *total* head against which the pump will work must be specified and this can not be accurately stated unless the draw-down is known. This measurement is easily made in connection with the preliminary test, referred to on page 18, if a weir is used to measure the rate of flow. Before pumping begins the vertical distance between the surface of the water and the center of the outlet is measured; the pump is then started and the distance again observed, the difference between the two measurements being the draw-down for the rate of flow indicated by the weir.

Types and selection—There are available upon the market several types of pumps, such as the plunger, rotary, and centrifugal pumps and water elevators. The centrifugal pump is used in most irrigation pumping plants. If this type of pump is chosen, it should be borne in mind that there are several types of centrifugal pumps, and care must be taken that the one selected is best adapted to the needs of the case. The choice must be between the vertical and horizontal types of centrifugals. Some manufacturers will not guarantee satisfactory operation where the suction head exceeds 20 feet, and 25 feet may be considered the limit for any pump. If the test has shown the draw-down to exceed this distance, the choice falls to the turbine type of centrifugal (figure 6), which is small enough to lower into the casing to any desired depth. This is one of the most expensive, as well as most efficient, types of pump. To avoid using it, additional wells may be constructed near-by. The suction pipes from all wells can be connected together, reducing the draw-down and allowing the use of a cheaper pump. This also makes a lower head or pressure against which the pump must be operated. If the pump is to be driven by a belt from an engine placed above ground, it is not advisable to place a horizontal type more than 20 feet below the engine because of difficulties encountered in making the inclined runway for the belt and because an extremely long belt would be necessary. The vertical type (figure 8) of centrifugal pump can be used to a depth of fifty feet. Shafting in greater lengths than this will be difficult to keep lined up, and will give more or less trouble because of the vibration which will be unavoidable on account of lack of rigidity of the bearings and their supporting frame work.

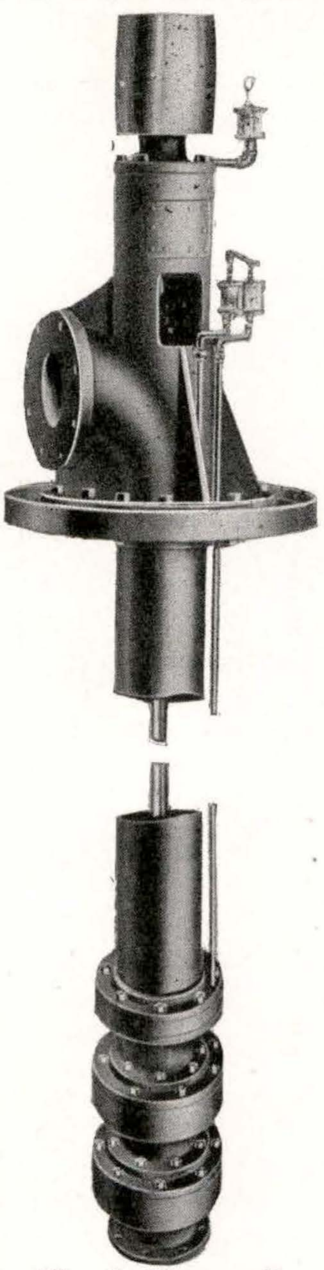


Fig. 6—Deep well turbine pump

Figure 8 represents a typical installation for a vertical pump, the pump being submerged when not running, so that no primer is required. While this simplifies operation, the work of repairing this pump requires more time and is not so convenient as on a horizontal pump.

Figure 9 shows a common method of installing a horizontal pump. The pump is placed as near the surface of the water as possible to make priming easier and to reduce the suction head to a minimum. More excavating is required for this installation, and the belt is longer, running at an angle likely to cause excessive slipping. The convenience for inspection and repairs should not be overlooked.

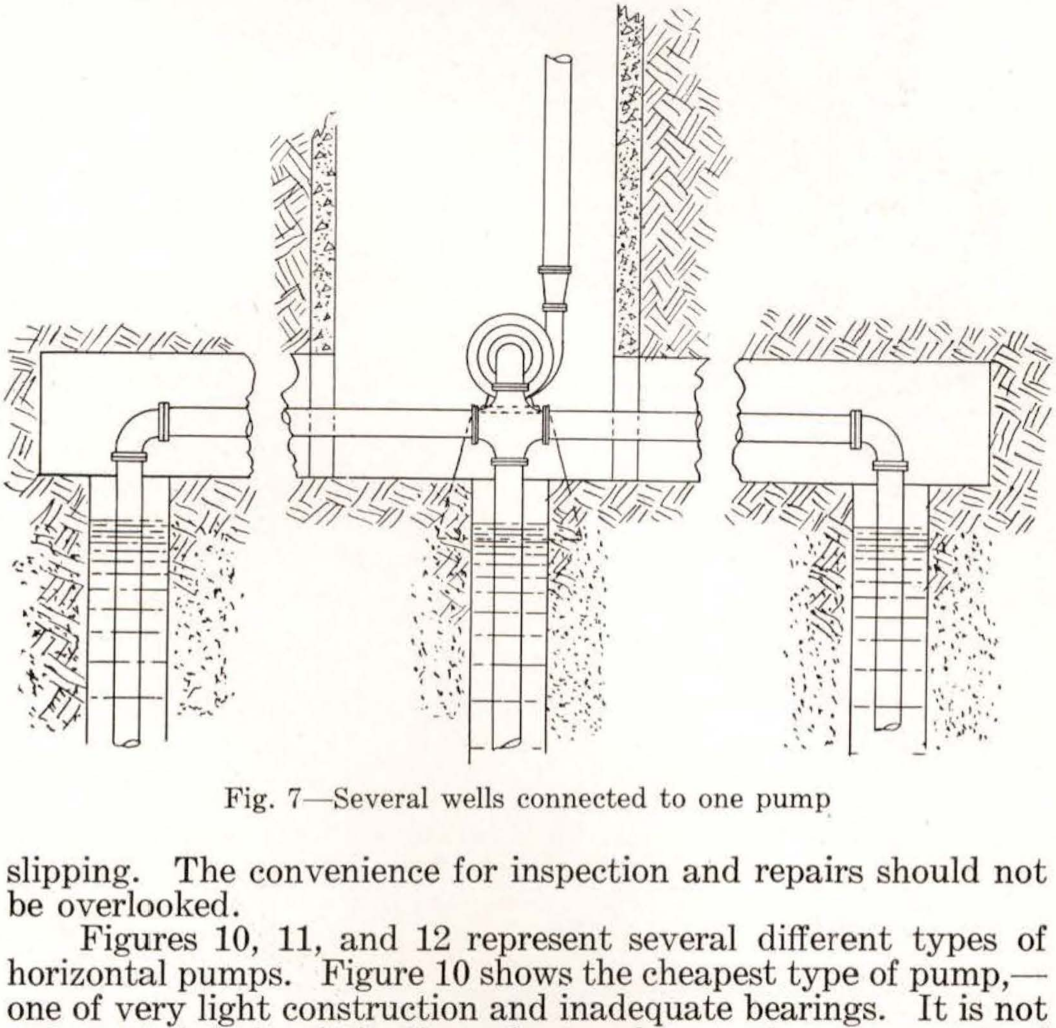


Fig. 7—Several wells connected to one pump

Figures 10, 11, and 12 represent several different types of horizontal pumps. Figure 10 shows the cheapest type of pump,—one of very light construction and inadequate bearings. It is not recommended for irrigation plants where a large amount of pumping will be done.

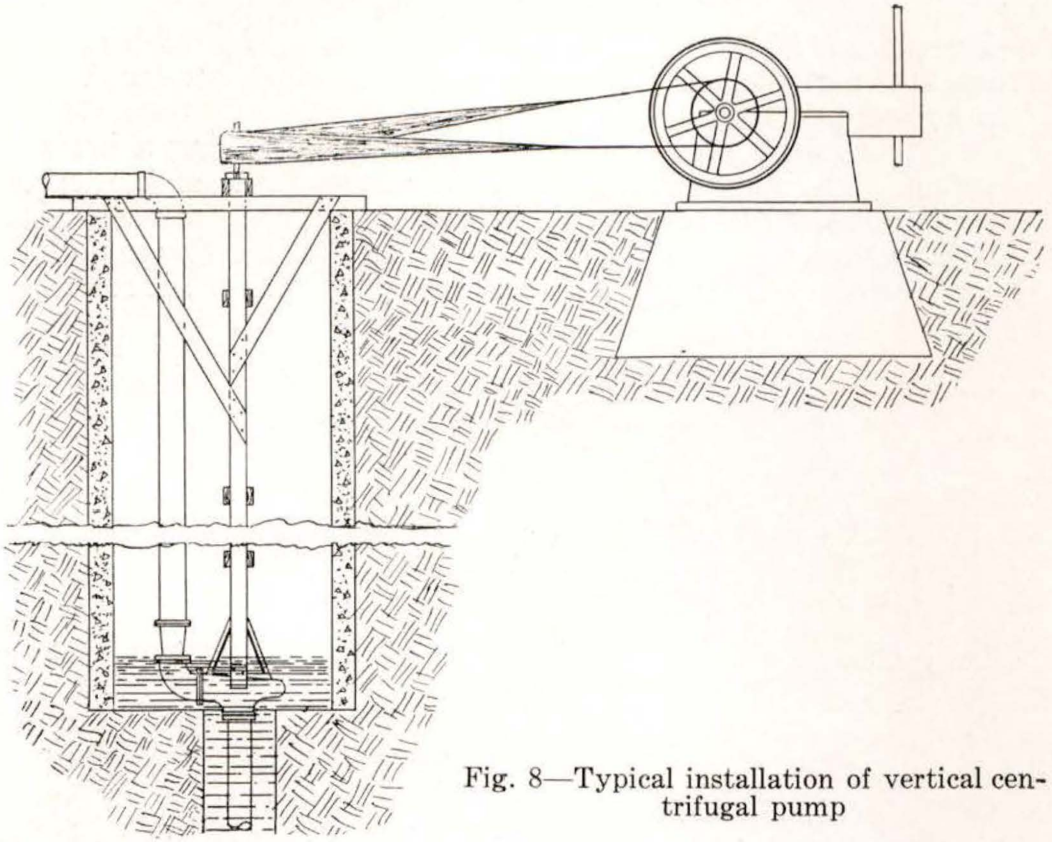


Fig. 8—Typical installation of vertical centrifugal pump

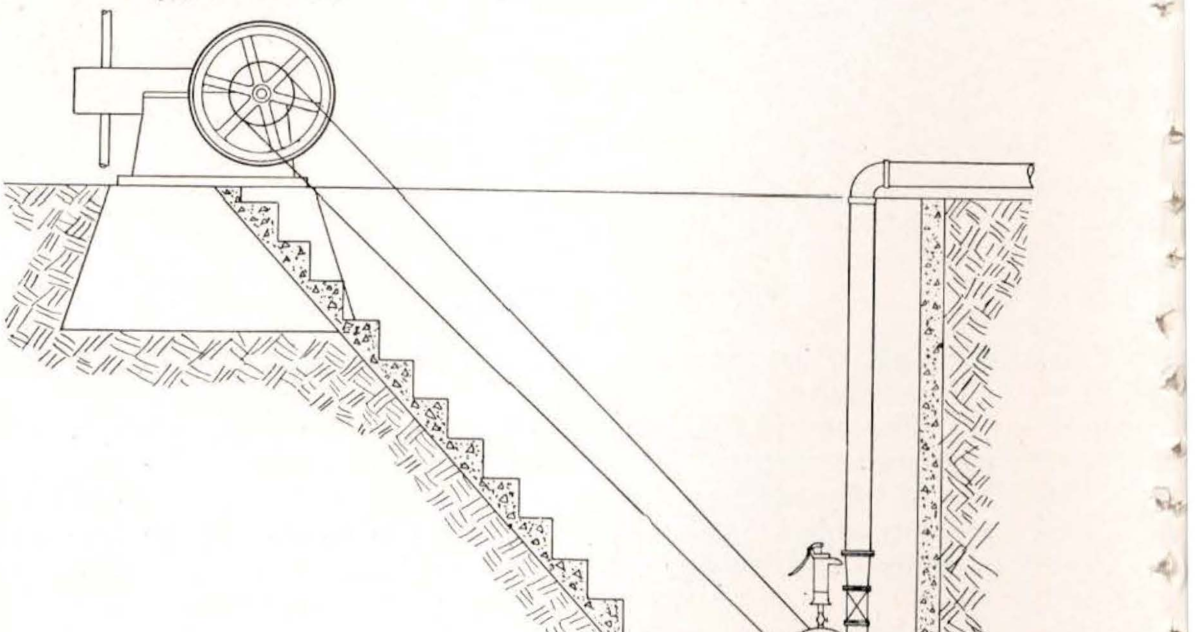


Fig. 9—Showing installation of horizontal centrifugal pump, with pitcher pump primer

Figure 11 shows a better design with two bearings and better construction thruout; figure 12 illustrates a double suction pump of high efficiency; and figure 13 illustrates a rotary pump which has recently been adapted for irrigation plants.

Installation—The installation of any pump requires a good foundation. Pipe sizes should never be smaller than recommended by pump makers. It requires a much smaller amount of power to force a large quantity of water thru a large pipe than to force the same quantity thru a small one.

Pipes should be supported independently of the pump so that it may be relieved of any undue strain. All joints and connections in the suction line should be air tight,—a very small leak may cause unsatisfactory operation and will lower the efficiency.

Priming—Unless installed submerged, the vertical pump (as well as the horizontal) must be provided with some means of priming, or filling the pump shell with water, since the centrifugal pump can-

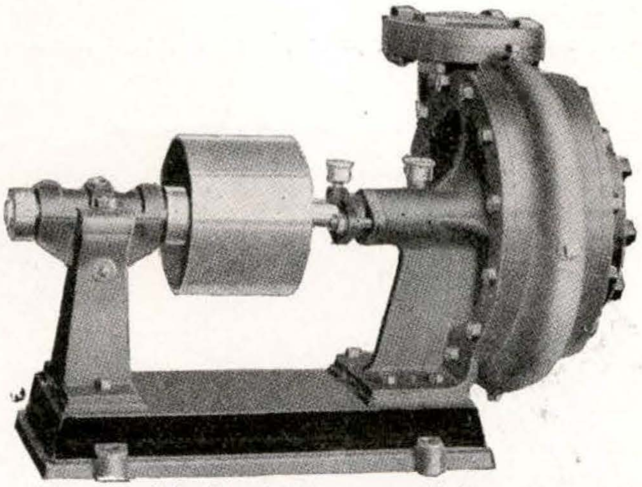


Fig. 10—Horizontal type centrifugal pump, single bearing

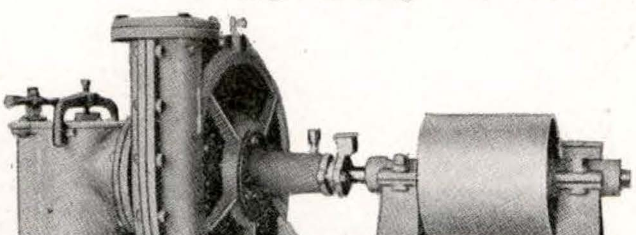


Fig. 11—Side suction horizontal centrifugal with double bearings and hand primer

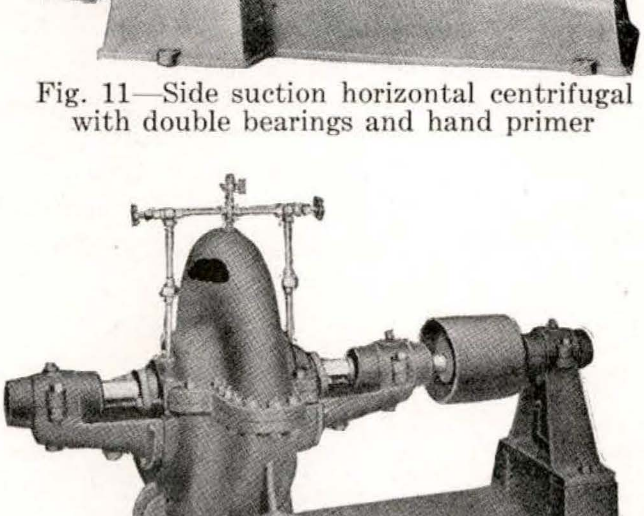


Fig. 12—Double suction centrifugal pump

not raise water to fill itself as does a plunger pump. With a valve at the lower end of the discharge pipe, the upper part of this pipe can be shut off and a small pitcher pump, such as is commonly used on cisterns, can be used for priming (see figure 9). If a foot valve is installed on the suction pipe, the pump can be primed by allowing water to flow in from a small tank above (see figure 14). Some pumps are supplied with a priming attachment as in figure 11.

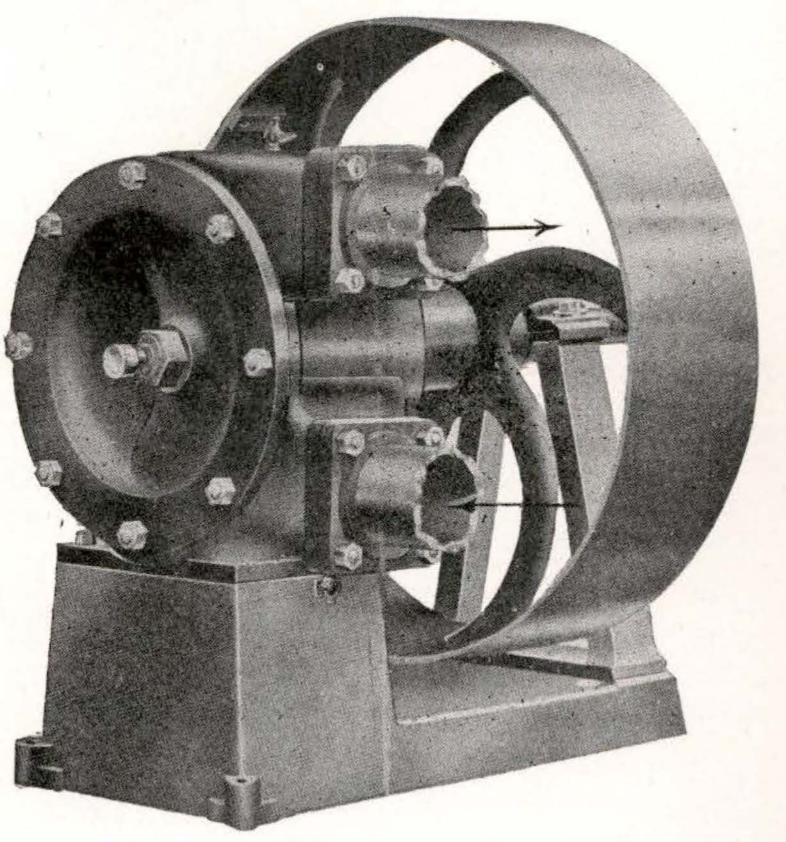


Fig. 13—Rotary type pump. Note large pulley

Manufacturers usually furnish instructions for the operation of their pumps, and such instructions should be followed carefully for best results.

POWER

The most common kinds of power used in this state for operating pumps are gasoline and oil engines. In some instances steam engines are used and probably electric power is utilized to some extent. Very often it is not necessary to consider the purchase of an engine for operating the pump inasmuch as a tractor or portable engine is already owned by the farmer. This engine is not used constantly and it can very well be utilized in irrigation. In such an event, the pump selected must be such that it is not too large for the engine and at the same time will make as efficient use of the power as possible. Another factor in favor of the gasoline or oil engine is that constant attendance is not required as in the case of the steam engine. In choosing the type of engine, the fuel cost must be carefully considered. An oil engine would, at first thought, seem to have a much smaller fuel cost than either a kerosene or a gasoline engine. However, with the present system of distribution, kerosene and gasoline are available in most places from tank wagons; and if another fuel is to be used the purchaser must provide a tank or reservoir of a capacity sufficiently large to hold a carload of oil in order to benefit greatly by the lower price. It seems advisable therefore under present conditions to buy an engine that will use gasoline or kerosene successfully.

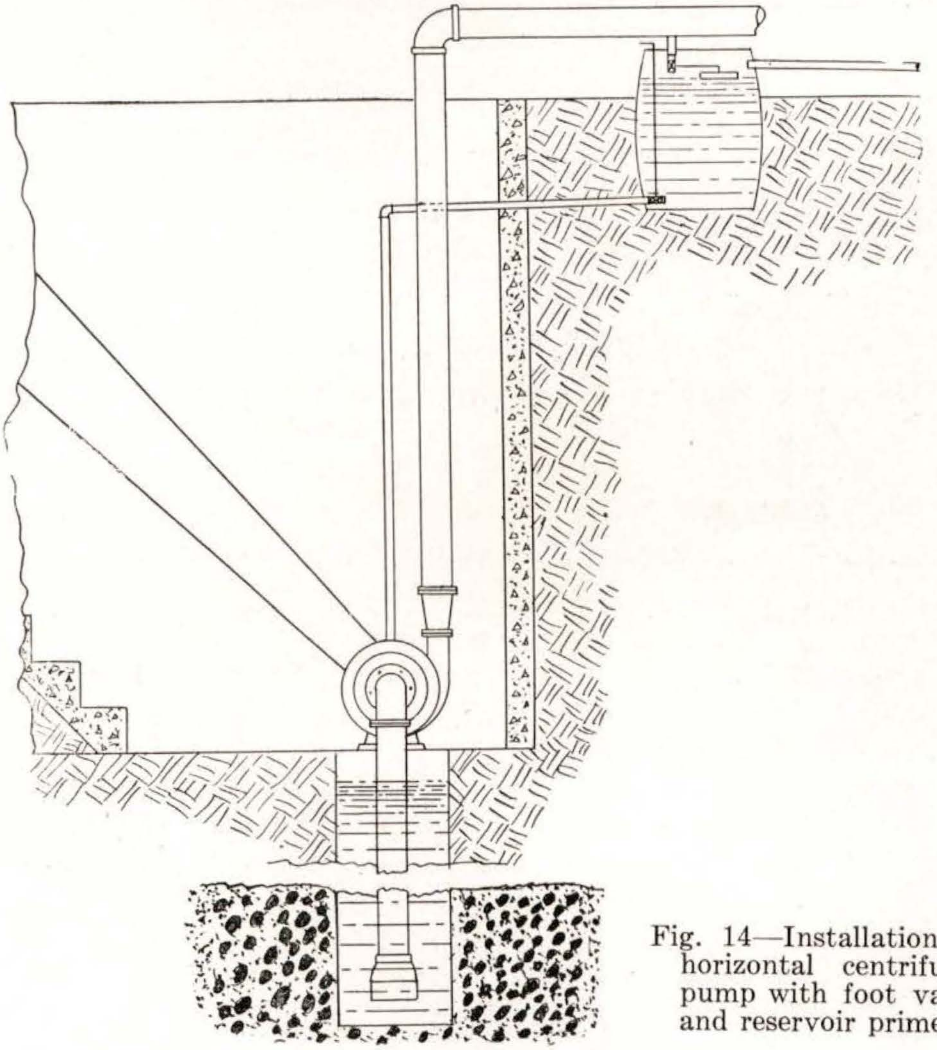


Fig. 14—Installation of horizontal centrifugal pump with foot valve and reservoir primer

Selection—In the selection of an engine it is advisable to consider and compare the following points on several engines:

Lubrication—It should be simple and dependable.

Size and kind of bearings—They should be large enough to give ample bearing surface and be of such material as to be easily replaced in case of necessary repairs.

Cooling system—Simple and positive action is desired.

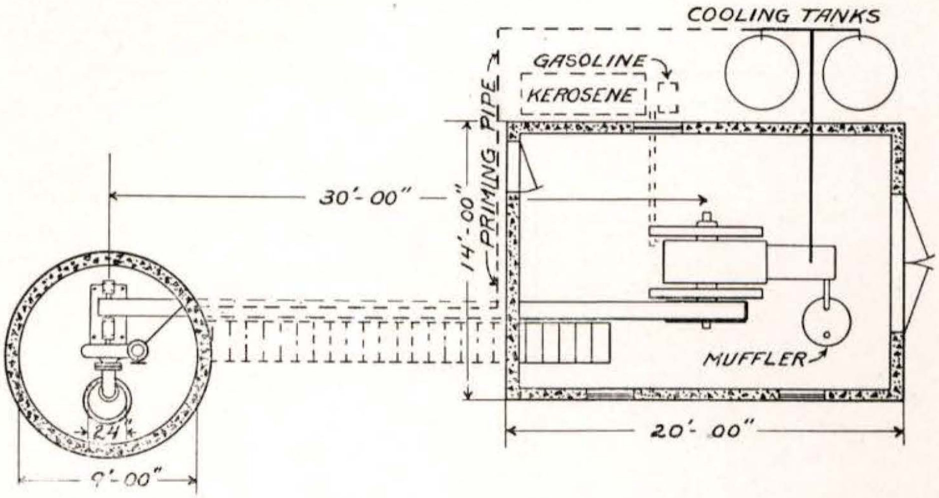


Fig. 15—Plan of pumping plant as installed at North Platte Substation

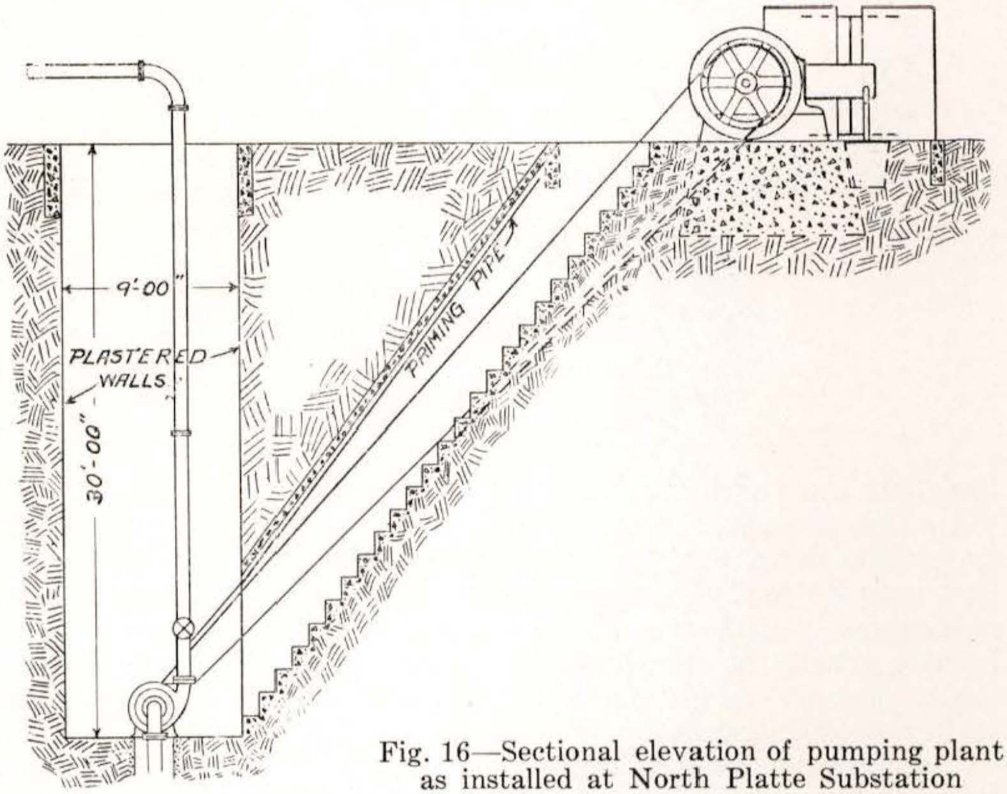


Fig. 16—Sectional elevation of pumping plant as installed at North Platte Substation

Ignition system—It should be simple and effective.

Size and weight of flywheels—They should give uniform speed.

Size of crankshaft—It should be large enough to withstand the shocks to which it will be subjected.

Piston rings—See that they are numerous enough to eliminate any great tendency to leak past the rings.

Valve arrangement—Are valves arranged and located so that their action is always dependable? Are they easily accessible for making adjustments?

Governor—The governor should be of such type and design that it will be sensitive enough to regulate the speed of the engine within five per cent of normal.

Electric power—If electricity can be purchased cheaply, the use of an electric motor is ideal for driving pumps since the first cost of the motor is less than that of an engine and it requires practically no attendance or repairs.

SELECTION AND OPERATION OF THE MACHINERY

Selection—In making the selection of the machinery, it is well to have in mind the reliability of the manufacturers as well as the reputation of their machinery. The manufacturers usually furnish complete working drawings and instructions for the installation of machines and these should be followed to the letter. Where it is possible, it is usually a profitable investment to have a mechanic, who is employed by the manufacturers, superintend the installation if he is available at a reasonable price.

Tests—If the machinery is purchased under guarantee of capacity, fuel consumption, regulation, etc., it is necessary to conduct tests to determine whether the machinery fulfills the guarantee. A third and disinterested party is often called in to supervise these tests. During the test the future operator should be present and have an opportunity to learn as much as possible about the various parts of the equipment, adjustments, care, etc. If a gasoline or oil engine is used, he should make particular note of the exact adjustments of fuel and air valves and of the timing of ignition for minimum fuel consumption when the engine is running the pump under its regular operating conditions. The speed of the pump should be watched during the test and subsequently, since for a given condition of lift there is one speed at which a centrifugal pump is most efficient. Efforts should be made to operate it at that speed. The manufacturer will furnish information as to the best speed for his pump.

Operation—In the regular operation of the plant, lubrication is of prime importance. Cleanliness is essential for careful inspection, and results in discovery of needed adjustments before breakage occurs with its ofttimes expensive delays for repairs.

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