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Oregon Agricultural College
Experiment Station

Department of Soils
Department of Farm Mechanics

The Small Irrigation Pumping Plant

By
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CORVALLIS, OREGON

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THE SMALL IRRIGATION PUMPING PLANT

The advantages of artificial watering of land have appealed to the enterprising Oregon farmer. Irrigation in the dry season provides moisture for growth of plants, liberation of plant food, and bacterial activity during the best growing weather. This makes it possible to secure late cuttings or pasture on meadows, a second crop on the truck farm, or an intercrop on the fruit ranch. Proper irrigation improves the yield and quality of crops and makes possible a more intensive, diversified system of farming. With irrigation it is possible to crop all of the land each year, to plow deeper, to use more manure without danger, and to grow and incorporate legume sod in the land. This improves the tilth and builds up the fertility and water capacity so as to lessen the irrigation requirement. It is highly important, especially in connection with irrgation by pumping, that a rotation of crops be practiced which will include cultivated crops and legumes, with legume sod and manure plowed in every few years, thus building up the water-capacity and available fertility of the soil and permitting the most permanently profitable returns.

IRRIGATION BY PUMPING

The increased use of mechanical equipment and accessibility of water at moderate lifts have contributed to extension of irrigation by pumping. About 40,000 acres in Oregon are now so irrigated. It is believed feasible under prevailing conditions approximately to double the area watered by pumping.

Advantages. A pumping plant offers an independent source of water for irrigation. With a well-designed plant, properly installed, the owner has no vexing regulations imposed upon him and has no one to blame but himself if water is not supplied when crops need it. Over-irrigation is unlikely where every acre foot pumped represents a direct cash outlay. Much land that would be greatly benefited by irrigation is so situated that the only means of supplying water is by pumping. Many large hydro-electric plants are now in use where water is lifted and delivered through canals to supply large areas. Plants supplying single farms are more numerous.

"Will It Pay?" The problem confronting the landowner who contemplates irrigation by pumping is: Will it pay? What is the minimum amount of water which, together with the best time and manner of use and of cultivation, will yield the crop of highest value and greatest returns upon the water and land used? Every effort should be made to deal with this problem fairly, even at the risk of finding out that pumping is not as profitable as may at first be supposed. Where the cost of irrigation is low, where the crop raised is large, where the amount of increase due to irrigation is sufficient, and where the crop secured through irrigation is valuable, pumping for irrigation at moderate lifts will generally pay. The total cost of pumping increases rapidly with the increased lift, and fuel cost increases almost directly with the lift. The local price of fuel and the factors affecting duty of water, such as crops, soils, climate, rainfall, evaporation, drainage conditions, skill of the irrigator, and amount of water available, will have their effect. Experimental results given in the following discussion are not based on crop yields alone. A thorough study has been made of soil, crop, and weather conditions in order to make possible the application of the results to a variety of soils and climatic conditions.

Profits. The profit in irrigation by pumping depends on the amount of lift, the market and soil conditions, and the economic use of water. This method of irrigation may be used with most success on the well-drained soils and with valuable crops such as vegetables and fruit.

To determine the net profit from the irrigation treatment at the Oregon Agricultural College Experiment Station, the total cost of production of various crops has been carefully estimated for all field operations required in good farming. The value of the total crop and of the increase secured by irrigation has been obtained by using an average normal market value. As an average of all trials extending over a period of twelve years, the depth of water used is approximately five acre inches per acre each season. This is a net duty of six acre inches per acre for the brown silt loam of the Willamette Valley, allowing for a little loss in distribution. Irrigation has increased the yield of all crops. Table I shows the results for ordinary field crops from twelve years experiments with irrigation by pumping at the Oregon Experiment Station.

During this twelve-year period, the average temperature for the five summer months was slightly warmer than normal and the rainfall for May to September, inclusive, was .07 of an inch below normal. Evaporation for the period averaged 22.96 inches. If it pays to pump irrigation water for ordinary field crops in the Willamette Valley, it will more surely pay when applied to the more valuable truck crops or in the more arid sections of the State.

COST OF A SMALL PUMPING PLANT

In order to direct attention to the various operating and maintenance charges involved in pumping for irrigation and to arrive at the actual profit or loss incurred from the irrigation of crops, the cost of irrigation treatment on the State Experiment Farm is here given. The items of expense may be summarized as follows:

A. First Cost. This includes the engine, pump, flume, and, in cases, the well or shelter for machinery.

B. Operating expense. Labor, fuel, and lubricating oil.

C. Maintenance charges. Interest on the first cost, depreciation, and repairs.

D. The total annual cost. This is the sum of "B—Operating Expenses" and "C—Maintenance Charges."

A. The first cost of a pumping plant such as the one at this Station is as follows:

Four H. P. engine	$215.00
Pump, 3½-in. Jackson Centrifugal	66.00
Forty feet of 6-in. iron pipe	20.00
Straightway round valve, 6 in.	15.30
Foot valve and strainer, 6 in.	12.55
Lumber, 1500 ft. at $13 (Flume)	19.50
Setting engine and pump	5.00
Carpenter labor	6.00
Leveling land	10.00
Total	$369.35

Where a well is required the additional expense should be added to the first cost. In any case it is useless to invest in expensive machinery unless a sufficient supply of water is assured.

B. Operating expenses:

	Per hour
Labor, at $2 per day	$ .20
Fuel, ½ gal. distillate (1 pt. per h. p. per hour)	.05
Lubricating oil (5c per h. p. per hour)	.002
Total operating expense per hour	$ .252

Where a gasoline engine is used, the pumping plant, when in running order, will demand less than half of one man's time, and where land is properly prepared for irrigation, the same man can look after distribution of water. With the engine in good running order it was found that the fuel used did not exceed one pint of distillate per horse power per hour.

A pumping plant of this kind will lift water twenty feet at the rate of one-half cubic foot per second, and this will cover an acre a foot deep in twenty-four hours.

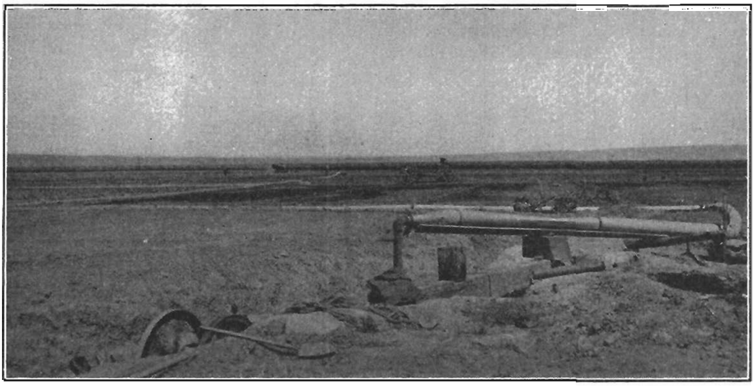

Fig. 1. Irrigation Pumping Plant and Distribution System, Oregon Agricultural College Branch Experiment Station, Harney County.

D. In figuring the annual cost, the maintenance charges and operating expenses must both be taken into consideration. The total annual cost, when calculated on a ten-acre basis, is as follows:

Maintenance charges:	
Interest on plant at 6 percent	$ 22.16
Depreciation and repairs (if plant is renewed in ten years)	36.93
Operating expenses (to pump ten acre feet):	
Fuel, at 5c per hour, 10 hours, 24 days	12.00
Labor, 20c per hour, 10 hours, 24 days	48.00
Lubricating oil, 2 mills an hour, 10 hours, 24 days	.48
Total annual cost of irrigating ten acres one ft. deep	$119.57
Cost per acre foot	11.95
Cost per acre inch	1.00
Cost per acre foot per foot of lift	.58

The cost per acre foot would be less for larger areas and larger pumping plants. The engine is the largest single item of expense, but may be used for other farm purposes outside the irrigation season. If this plant were used regularly during a 40-day irrigation season, 20 acre feet could be pumped and the cost would be 77c an acre inch. With

TABLE I. SUMMARY—TWELVE YEARS EXPERIMENTS ON ECONOMICAL USE OF WATER—CORVALLIS

(Ave. all Comparisons)*

Crop	No. years in trial.	Ave. Irr. Inches	Yield per acre bushel or ton		Increase from irrigation				Net profit Whole Crop		Lbs. Water per lbs. dry matter whole crop		Gain in net profit Irr. over Dry
			Dry.	Irrigation.	Gain per acre.	Gain per acre inch.	$ per acre	$ per acre inch	Dry	Irrigation	Dry	Irrigated	
Potatoes	12	3.69	156.930	215.530	58.590	14.060	24.06	6.58	72.10	96.06	738	644	23.96
Clover	10	6.97	3.910	5.220	1.311	.307	9.26	1.41	30.11	38.05	676	636	7.94
Alfalfa	8	7.96	3.135	4.547	1.412	.225	10.33	1.39	21.20	30.36	961	739	9.16
Corn	8	4.56	6.559	9.062	2.637	.674	2.23	.51	12.18	13.06	794	831	.88
Beans	7	3.66	12.529	17.600	5.356	1.706	12.88	4.04	22.60	34.79	2364	1761	12.19
Beets	8	4.37	10.817	13.884	3.078	1.279	4.492	1.12	9.84	12.22	566	535	2.38
Kale	3	4.33	10.611	13.952	3.273	.692	2.33	.85	4.48	15.32	945	937	10.84

*Note: The averages are for all comparisons and are not weighted averages.

electrical power, at the local meter rate, this cost for pumping 10 acre feet is 92c; and for pumping 20 acre feet, 71c an acre inch. Pumping 30 acre feet with electricity at 2c a kilowatt would place the total annual cost of the plant at 48c an acre inch. The maximum cost of $1.00 an acre inch, however, is used in calculating the profits for irrigation of crops described below.

Where a convenient reservoir site is obtainable, particularly with the electric plant, more continuous operation will permit a smaller plant with lower first cost.

THE WATER SUPPLY

Amount of Water Required. The duty of water or amount of water required by crops is usually a small quantity where secured by pumping. More water will be required for sandy soils, in more arid sections, and for larger yields of dry matter even though good modern methods of irrigation farming are practiced. The quantity of water required for alfalfa is not likely to be less than five or six acre inches, equivalent to five or six inches rainfall for each ton increase secured by irrigation. A four-ton crop will require about twenty-four inches of soil water or rain or irrigation water. Meadow crops require relatively large amounts of irrigation, grains and field peas a moderate amount, and cultivated crops comparatively small amounts for each season. There are few places in Oregon where potatoes will require more than six acre inches or other row crops more than twelve inches of irrigation for each season. Under similar conditions grain and peas may require nine to eighteen inches depth an acre.

The minimum depth it is feasible to apply to row crops is usually two or three inches at an irrigation; meadow crops will usually require four or five inches. The pump capacity should be sufficient to cover the area served every three or four weeks, and an irrigating stream of less than 200 gallons a minute is not economical. It may be advisable to provide a small reservoir with the smaller pumping plants, especially for truck crops, so that some water will be available at any hour without pumping, or to enable more continuous operation by storing at night to afford a larger irrigating head by day.

Sources of Water. The source of water for pumping usually is a running stream, although wells, ponds, or other sufficient supply may be used. Where lake or river valleys are underlaid with a layer of sand and gravel in which a strong underflow may be encountered, a favorable condition exists for well irrigation. A small test well may be necessary to determine whether the proper quantity and quality of water is present. The average dug well suitable for domestic use is generally inadequate for irrigation, due to its relatively small capacity.

The well for irrigation should be a dug pit nearly to the water line, if water is at a moderate depth, but drilled below this water plane far enough to insure a head which will force the water into the well during pumping. A solid casing four inches to eight inches in diameter should extend below the water plane, say twenty feet or more, to overcome the greatest possible draw down of the water plane about the well when pumping. The casing below must be perforated, or a strainer provided, extending twelve or fifteen feet below this in the water-bearing strata, to allow water to enter. The lower end of the perforated casing or strainer should be screened. The diameter of the casing should be thirty-three to fifty percent larger than the diameter of pump desired, and perforations should provide a total area at least twelve times that of the cross-section of the casing. With this condition fulfilled, some sand will be pumped out and the flow may be increased without eroding or carrying coarse material into the casing.

PUMPS AND PIPES

Three kinds of pumps may be considered. A **reciprocating** pump is one in which a plunger reciprocates in a closed cylinder provided with inlet and outlet valves and alternately draws in and discharges water from the cylinder. Such a pump will draw a moderate amount of water from a deep well. In a **rotary** pump two gear-like pistons, which rotate in a case, draw in and discharge the water. This type is used for low lifts in rice irrigation. A **centrifugal** pump, the action of which is implied by its name, consists of a fan-like wheel revolving in a case. The type of pump to use will depend upon height of lift and quantity of water desired.

The Centrifugal Pump. The centrifugal pump is most suitable for large quantities and moderate lifts. Such a pump may be operated by a

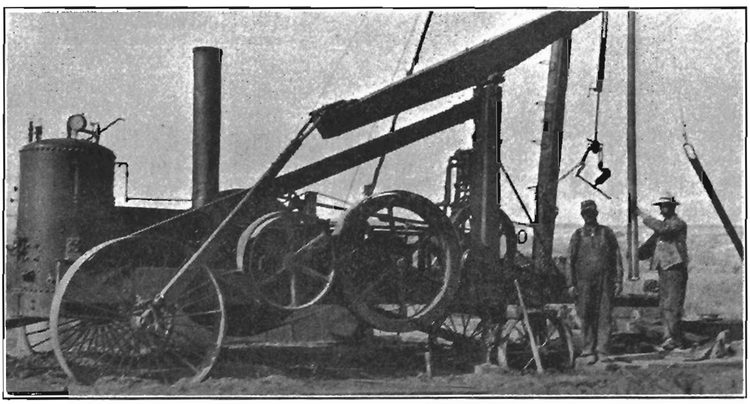

Fig. 2. Well Driller Suitable for Making Well for Irrigation.

vertical or horizontal shaft. Usually the suction lift will not exceed a few feet, and the pump may be placed at or near the surface and be of the horizontal type. It can then be mounted and supported better than the vertical type. Where the low-water level is no more than 18 feet below the surface, the pump may be installed in a pit and operated by a belt running in an inclined position. High-grade centrifugal pumps are constructed with split casing to facilitate cleaning and with double suction to reduce friction and to balance the force of the water, while the bearings are water cooled. The approximate capacity of centrifugal pumps is shown in Table II.

Suction Pipes. Suction pipes must be air tight, and in order to reduce friction, from thirty-five to fifty percent greater in diameter than the pump.

The suction lift should be as short as practicable, not over twelve feet in length. It should be placed either vertically or on an incline, avoiding air pockets. If a foot valve is used, a vertical position should be arranged for the suction end of the pipe. The suction end should be submerged from two to six feet, depending on the size of the pipe. If the pipe is over six inches in diameter, a screwed casing should not be used. Flanged connections are desirable for four-inch pipe or larger in a pit where space is limited. Where tight casing extends twenty-five feet below the water plane, suction may be connected to casing direct.

TABLE II. APPROXIMATE CAPACITY OF CENTRIFUGAL PUMPS

Size of Pump Inches	Economic capacity. Gallons per Minute	Capacity cubic feet per sec. or inches depth on one acre per hour	Horse power recommended for each foot of lift
2½	150	.33	.085
3	225	.50	.142
3½	300	.67	.16
4	450	1.00	.20
5	750	1.50	.34
6	900	2.00	.39
8	1600	3.60	.67
10	3000	6.70	1.17

Discharge Pipes. To reduce friction, the discharge pipe should be not less than one-third larger in diameter than the pump discharge. When the pump is above the level of the discharge the end of the discharge pipe should be submerged. This is to utilize the siphon effect which is an important item in large installations. The mounting of the pump and pipes should be such as to avoid undue strain on the pump, since the weight of large pipes is considerable. A check valve placed above the pump in the discharge pipe retains water and closes the discharge pipe when producing a vacuum for priming. For high lifts a gate valve should be provided in the discharge pipe just above the pump.

Installation of Pump. The horizontal centrifugal pump does not require an extra heavy foundation, but it should be sufficiently heavy to hold against belt strain, weight of pipes, and vibration. Foundations for pump and motor may be of wood or concrete. If concrete is used, a mixture of one part cement, two parts clean, coarse sand, and three and one-half parts coarse aggregate should be used after being well mixed. Figure 3 shows method of locating bolts in concrete to conform with base holes of pump and motor. After concrete is placed in form, it should be kept moist for several days before the machines are set on.

Operation. The pump must run at the proper speed and should be tested to see that it runs freely before applying power, and that it runs in the right direction. The pump and engine shafts should be parallel and level and the pulleys of each in line. To level pump and engine make use of nuts below bases as shown in drawing. Allow 16 to 20 feet between engine and pump shafts to secure proper weight of belt. The gate valve on the discharge of high-gear pumps should be closed while priming and opened gradually after pump is up to full speed. This will prevent water hammer in the pipes, and overloading the motor in starting. As soon as the pump reaches full speed, open gate valve a little to prevent churning and undue warming of runners. No damage will result from over-pressure by operating the pump at full speed with the gate valve closed, if the speed is not excessive. For lifts of over fifty feet, Fleming suggests that a stand pipe, air chamber, or quick-acting release valve should be provided to avoid churning and water hammer.

Priming. Suction consists in creating a vacuum, which is then filled with water by atmospheric pressure. A centrifugal pump cannot act as an air pump and must operate below the water to prime itself. A pitcher pump, attached to the jacket of the pump by means of a short gas pipe, may be used to pump out the air in priming, as is shown in Figure 3. The pipe must be provided with an air-tight valve to close it after priming.

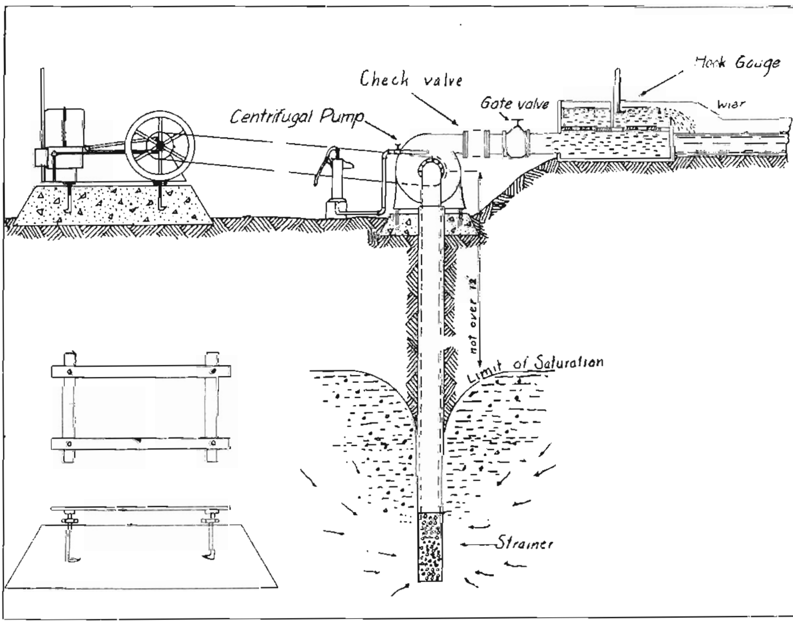

Fig. 3. Gasoline Engine and Pumping Plant Design for Well. Templet at lower left corner for spacing bolts in foundation.

Failure of Pump to Work. When the pump delivers a full stream at the level of the pump but not at a higher discharge point, the speed of the pump is too low. If the pump fails to deliver a full stream of water, the speed and water supply being unchanged, the suction pipe is probably obstructed. Lack of sufficient lubrication, poor alignment, or belt too tight, will cause bearings to heat unduly.

When ordering a pump to go with an engine or vice versa give diameter of pulley and revolutions per minute, so that the pump will run up to rated economic speed. Flexible couplings should be provided between pump and motor in a direct-connected unit. Where water is secured from an open stream a screen should be provided in the intake channel.

POWER

Kinds of Power. The success of a pumping plant depends largely upon the power used. The selection of an efficient kind of power is of vital importance. The sources of power most often available are: wind, electricity, and gas. Wind is regarded as a cheap form of power, but it is very unreliable and is not recommended for tracts of more than two or three acres. Windmills seldom furnish more than one horse power. As the wind may not blow when irrigation is required, it is well to have a storage reservoir. Where electric power can be secured at a reasonable cost, it offers a very desirable power with a small operating expense, because the cost of attendance may be almost entirely eliminated. Gas-engine power is fairly reliable in the hands of a man with ordinary mechanical ability, and is the power that will be used in most cases. Such a form of power is usually available on the average farm and may be used for irrigation purposes when it otherwise would be idle.

Selecting a Gas Engine. Care should be exercised in selecting the gas engine. The present high price of gasoline demands that only an engine which uses the heavier fuels, such as distillate, kerosene, or crude oil, should be purchased. A throttling engine should be given preference. A magneto is more reliable than dry cells. In some cases the crude-oil engine will be preferable, since fuel may be used costing as low as four or five cents a gallon. The ease of getting and replacing parts for repair at low cost should be considered. Repairs will be needed and delays are often serious. In some localities it will be desirable to use an engine which has the greatest provision for excluding blowing sand from bearings in moving parts. It is much better to select an engine a little too large than too small.

Calculation of Power Required. A horse power will lift a cubic foot of water 8.8 feet per second, and is called a water horse power. To the apparent vertical lift must be added the friction head for the length of pipe used in the proposed discharge, also the friction head due to bends in suction and discharge. The friction value for straight pipes is given in Table III. For each 90° turn of a given-sized pipe add friction equal to fifty feet of straight pipe and for suction one foot and discharge one-half foot, additional lift. Suppose the total head is found to be 26.4 feet and we are to elevate continuously one cubic foot per second or 450 gallons per minute. This should be reduced to actual foot pounds of work per minute: $26.4 \times 62.5 \times 60 = 99,000$, or the number of foot pounds per minute. Dividing this by 3,300 or the foot pounds of work in a horse power, we obtain 3 horse power; therefore, making the ordinary allowance for the efficiency of machinery at 50 percent, 6 horse power would be required.

ECONOMICAL USE OF PUMPED WATER NECESSARY

Careful use of pumped water is necessary if the greatest profits are to be realized. Excessive use of water may injure the quality of soil and crop to the point of unprofitable production even in arid climates. The water therefore should be carefully measured and skillfully applied. Land should be leveled to a uniform slope and laterals should be as near water tight as practicable. Frequently it will be desirable to use underground concrete or wood pipe for laterals. To distribute water from hydrants along this pipe, portable canvas hose or slip-joint black tin pipe may be used. Small furrows or corrugations for distributing water on the field will save water as compared to flooding where the stream is small. The furrows may be three to four feet apart and 220 to 440 feet long, being shorter on sandy soils. For normal soils cutlivation should be given, whenever possible, just as soon after irrigation as the soil is dry enough to crumble and form a mulch, to check evaporation.

TABLE III. SHOWING FRICTION OF WATER IN SMOOTH, STRAIGHT PIPES WHEN DISCHARGING THE FOLLOWING QUANTITIES OF WATER IN U. S. GALLONS PER MNUTE

Friction head in feet.	Inside diameter of pipe in inches 3	4	5	6	8	10	12
1 in 1000	15	32	57	92	195	348	557
2 in 1000	23	48	86	139	292	518	828
3 in 1000	29	61	110	175	367	652	1036
4 in 1000	35	72	128	206	432	766	1228
5 in 1000	38	82	146	234	490	870	1381
6 in 1000	44	91	162	260	542	959	1527
7 in 1000	48	100	177	282	591	1041	1663
8 in 1000	51	107	191	305	636	1123	1790
9 in 1000	55	115	203	325	678	1198	1902
1 in 100	58	122	216	346	718	1270	2021
2 in 100	86	180	317	505	1050	1856	2944
3 in 100	112	223	396	630	1307	2305	3660
4 in 100	126	262	462	735	1527	2590	4270
5 in 100	142	296	522	828	1721	3030	4797
6 in 100	157	326	576	915	1897	3331	5298
7 in 100	172	...	625	994	2060	3650	5751
8 in 100	183	381	674	1067	2206	3891	6172
9 in 100	195	406	715	1136	2342	4142	6570
1 in 10	207	450	757	1198	2490	4380	6946
2 in 10	299	622	1095	1736	3605	6314	10005
3 in 10	372	771	1356	2150	4446	7807	12373

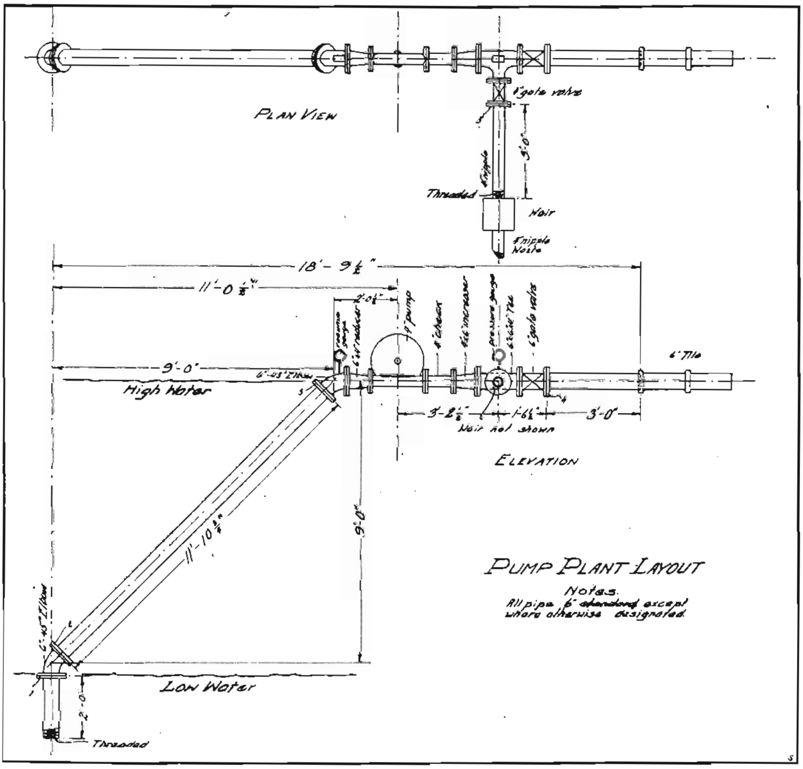

Fig. 4. New Irrigation Pumping Plant, Oregon Agricultural College Experiment Station. Four-inch centrifugal pump directly connected to electric motor.

OTHER PUBLICATIONS AVAILABLE ON IRRIGATION

Ore. Exp. Sta. Bul 122, Soil Moisture and Irrigation Investigations in Western Oregon.

Ore. Exp. Sta. Bul. 140, Economical Use of Irrigation Water.

Ore. Exp. Sta. Bul. 157, Improvement of Marsh Lands in Western Oregon.

Ext. Service Mimeograph, Measurement of Irrigation Water.

Ext. Service Mimeograph, Cir. 42, Methods of Preparing Land and Applying Irrigation Water.

Ore. Exp. Sta. Bul. 119, Report of Experimental Work, Branch Experiment Stations, Moro, Metoleus, Redmond, and Burns.

Ore. Exp. Sta. Bul. 144, Dry Farming Investigations, Sherman County Branch Experiment Station.

Ore. Exp. Sta. Bul. 150, Dry Farming Investigations, Harney Branch Experiment Station.

Ore. Exp. Sta. Cir. No. 3, Border Irrigations for Porous Soils.

Ext. Bul. No. 305, Use of Lime.

MIMEOGRAPHS

Fundamental Principles of Irrigation Practice.

Measurement of Irrigation Water.

Time, Amount, and Frequency of Irrigation.

Irrigation of Potatoes.

Irrigation of Meadow Crops.

Materials and Structures for Irrigation Distributaries.

Maintenance of Irrigation Systems.

Delivery of Water to Irrigators.

Construction of Farm Drainage Systems.

Drainage of Irrigated Lands.

Origin and Formation of Soils.

Classification of Soils.

Physical Properties of Soils and Their Improvement.

Organic Matter of Soils.

Use of Land Plaster.

Use of Fertilizers in Oregon.

Crop Rotation and Permanent Irrigation Agriculture.