UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1067

Contribution from the Bureau of Public Roads
THOMAS H. MacDONALD, Chief

Washington, D. C. PROFESSIONAL PAPER June, 1922

TESTS OF DRAINAGE PUMPING PLANTS IN THE SOUTHERN STATES

By

W. B. GREGORY, Irrigation Engineer

CONTENTS

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CONTENTS.

INTRODUCTION.

Agriculture in the southern portions of Louisiana was first practiced along the rivers and bayous. Since the alluvial soil was deposited by the rivers the highest land is found near the banks, and there is a gradual slope from the rivers and bayous back to the swamp. Previous to the last decade the only reclaimed agricultural lands in southern Louisiana were in the rear of the sugar plantations. The early planters cultivated the narrow strip of land along the streams which could be drained by gravity. The width of these strips varied greatly, but usually the distance from the levees back to the swamp was from one-half mile to 2 miles. The cultivation of sugar cane created a demand for more land, and this demand was met by extending the plantations toward the swamps, removing the water by means of pumps from lands too low to drain by gravity.

About 150,000 acres of agricultural lands in the State of Louisiana have been reclaimed or are at present in process of reclamation. The drainage of these agricultural lands and the drainage of the city of New Orleans, which was largely built in a swamp, have given a notable impetus to the development of pumps and pumping plants in this State. This development has been so rapid that it is now possible to find all types of drainage pumping plants in operation, from the old drainage wheel to the latest design of screw pump. Both in capacity and in excellence of design the pumping plants of this section are unique, although among the many plants erected there are some that are conspicuously superior to others. Department Bulletin No. 652, "The Wet Lands of Louisiana and their Drainage," and Volume XI, No. 6, of the Journal of Agricultural Research, contain much interesting information relating to the reclamation of these lands.

This bulletin contains a short description of the various types of drainage pumping plants found in the southern coast country, and gives the results of tests that have been made since 1909 by the Division of Agricultural Engineering, Bureau of Public Roads.

TYPES OF PUMPS.

DRAINAGE WHEEL.

The first pumps used in the Gulf Coast country for artificial drainage were of the drainage wheel or scoop wheel type. Many of the steam-driven drainage wheels are still in use in Louisiana. Large wheels of this type range from 28 to 32 feet in diameter, with a width of from 4 to 7 feet. In most localities, however, the cost of foundations stable enough to hold the wheels rigidly in place has increased the cost of the drainage wheels to such an extent that they have been practically eliminated from competition with other cheaper forms of pumping plant. Another point against the drainage wheel is the difficulty involved in adjusting its height. Once set, the depth to which the water may be lowered is definitely fixed. As a rule these wheels are expected to pump against a maximum head equal to one-fourth the diameter. The humus of the drained land in time disappears as the land is cultivated, and the level of the land falls, the amount of shrinkage varying with the depth of humus. As a result of this shrinkage it has been found desirable after a few years to pump to a lower level. With a drainage wheel this requires either lengthening the paddles or lowering the foundations and power plant.

CHAMBER-WHEEL PUMP.

The chamber-wheel pump, certain types of which have been used for drainage, is practically a meter, the discharge being proportional to the speed. Because of the pulsations set up, due to the alternate accelerating and retarding of the water that is being pumped, there are well-defined limits of speed that may not be exceeded without injury to the pump. While the centrifugal pump may be forced to an extent that is limited only by the power of the engine or motor driving it, the limitations of capacity for the chamber-wheel type are found in the pump itself.

CENTRIFUGAL PUMPS.

The centrifugal pump in some of its various forms has proved to be a favorite for drainage work, where large volumes of water must be elevated only a few feet. There are many reasons for the popularity of the centrifugal pump, among which might be mentioned first cost, reliability of operation, simplicity of construction, and its ability, when forced, to develop a capacity much greater than the rated capacity. It is efficient if properly designed for the conditions under which it is operated.

A cheap but fairly efficient form of centrifugal pump that was much used a few years ago is the vertical-shaft, wooden-box pump. Many are still in use, but of late they have given way to more substantial pumps made entirely of metal. The older pumps usually were driven by belt or rope drive, while the modern plants often have pumps and engines direct connected.

HORIZONTAL CENTRIFUGAL PUMPS.

Centrifugal drainage pumps with horizontal shafts ususally have double suction pipes. The suction and discharge pipes with the pump form a siphon, with the pump at the top at a convenient height for examination and for repair. Variations in level of the suction and discharge sides do not affect the pump, and the lift is always equal to the actual difference of level while the head the pump must develop is the lift plus the various friction losses in the pump and piping. These pumps are made by many firms and differ considerably in minor details. Their popularity is shown by the fact that a large majority of all the drainage plants installed during the last 10 years are of this type.

SCREW PUMPS.

Screw pumps range from 3 to 12 feet in diameter, the largest having a capacity of 700 cubic feet per second. The lift ranges up to 10 feet or more.

A combination centrifugal screw pump has been developed that is especially suited to electric motor drive or internal-combustion engines. The blades of this type of pump are so designed that the load is practically constant from a minimum to a maximum lift when running at a constant speed.

SUCTION AND DISCHARGE PIPES.

In drainage installations, where the lift is usually between 4 and 10 feet, the losses at the entrance of suction pipes and the kinetic energy thrown away at the end of the discharge pipe together make up a large percentage of the energy used. These losses increase with the square of the velocity of the water at entrance and discharge, and the velocity in turn depends upon the diameter or area of the pipe at the two ends. The larger the area at these ends the less will be the velocity and energy loss, and vice versa. For this reason the practice, formerly common, of designing the suction and discharge pipes to have the same diameter throughout is now being very generally abandoned, though occasionally descriptions of such plants, in which the fundamental laws of hydraulics are disregarded, find their way into the technical press.

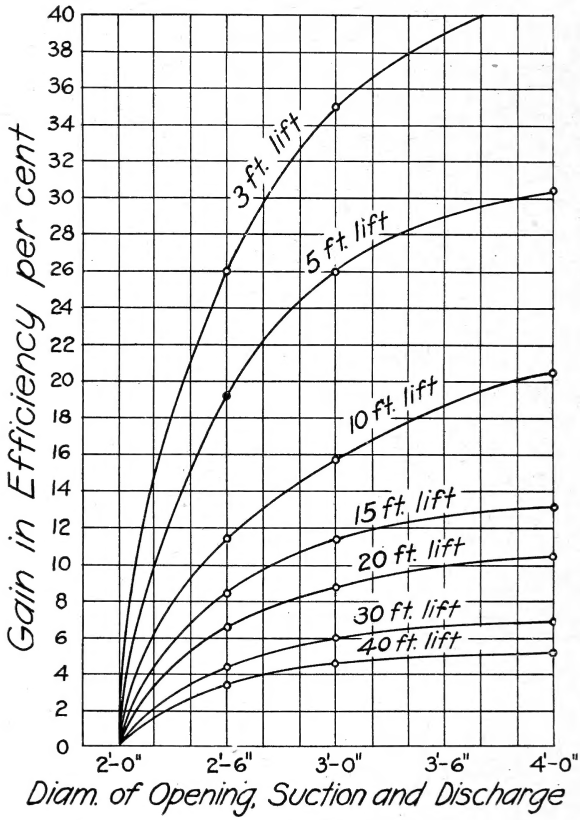


FIG. 1.—Gain in efficiency due to expanding suction and discharge pipes.

Until lately the entrance loss has usually been estimated at 0.93 of the velocity head at the entrance. Bulletin 96 of the Engineering Experiment Station, University of Illinois, contains evidence that this coefficient is too high and suggests a value of 0.62. The discharge loss is equal to the velocity head at the end of the discharge pipe. If the pipes are round and the diameter be doubled at the suction and discharge ends, the areas will be multiplied by 4; and with pumping at a constant rate there will be entrance and discharge velocities one-fourth as great as with pipe of uniform size. Losses vary as the square of the velocity, so they will be reduced to one-sixteenth of the loss in a pipe of uniform size, if the diameter of the ends of suction and discharge pipes be gradually enlarged to twice the diameter of the rest of the pipe, or, in case the pipe is not round, if the end area be increased four times.

The importance of this matter of pipe expansion is illustrated by figure 1. It is assumed that the pump flange is designed for a discharge pipe 2 feet in diameter and that the mean velocity is 10 feet per second. The length of straight pipe is taken as 15 feet.

SOURCES OF POWER FOR PUMPING PLANTS.

STEAM ENGINES.

Steam engines were used to furnish power for the earliest pumping plants. The simpler and less efficient types first employed have been replaced by more efficient types as improved pumps have taken the place of the drainage wheel and less efficient pumps. Plants now in use employ simple, noncondensing engines, compound condensing engines with high-pressure water-tube boilers, Corliss engines direct-connected to centrifugal pumps, and one plant inspected used superheated steam in a compound-condensing engine of the poppet-valve type. Steam plants of all types are reliable in operation, and when the pumps are of the centrifugal type the capacity may be increased to a marked degree, at the expense of efficiency, by merely increasing the speed. Steam plants are easily run and if cared for by a competent operator will have a reasonable length of life.

Unfortunately, however, they frequently do not receive the necessary care. The principal cause of deterioration is the character of water that is used in the boilers. Generally the only water available is the drainage water from the wet prairies, containing acids and organic compounds which corrode and cause trouble with feed pipes, boiler accessories, and boilers.

Besides the boiler troubles to which they are liable steam plants are often wasteful of fuel, while the opposite is true of plants using the internal-combustion engine. For these and other reasons the most recent pumping plants erected in Louisiana have in many instances used internal-combustion engines as a source of power.

INTERNAL-COMBUSTION ENGINES.

In the last few years the internal-combustion engine has been so far improved and perfected that lack of reliability is no longer considered a hindrance to its use. For several years four-stroke cycle engines were used almost exclusively, and the fuels employed varied from heavy low-grade crude oils to kerosene. Recently, two-stroke cycle oil engines of the semi-Diesel type have come into favor. These engines employ comparatively low compression, usually from 125 to 250 pounds per square inch. The speed is relatively high, the engines usually running 200 to 260 revolutions per minute for sizes from 50 to 150 horsepower. They are generally of the horizontal type, but some are of the vertical type. Ignition is by means of a hot bulb or a hot plate partially cooled by water circulation. The details of design differ considerably. In providing scavenging air some compress into the crank case or on the front side of the power piston, while others use a large piston in front of the power piston. Some have governors that may be adjusted while the engine is running, while others must be stopped when an adjustment of the governor is to be made. Some have crossheads, others have trunk pistons. Some inject water with the fuel or into the combustion chamber, others do not. Lubricating oil may be recovered from some of these engines, while that employed in others is useless after being used once. Some owners complain of the large amount of lubricating oil used.

A point worthy of note is that all engines of this type must be operated well under their maximum load to avoid trouble, and this is especially true of the crude-oil engines. The exhaust from engines using crude oil, unless of the Diesel type, is always smoky and often contains tarry matter that will foul the cylinders and eventually cause trouble. Absence of valves tends to minimize this trouble, but does not entirely remove it. Coke sometimes forms in the exhaust pipe if a low grade of oil is used, and the pipe must occasionally be removed and cleaned.

For the smaller plants, two-cycle crude-oil engines are being installed to the exclusion of nearly every other type. The future probably will see some of the present difficulties eliminated, and further use will familiarize operators with such peculiarities as require close attention and care.

ELECTRIC POWER.

Electricity as a source of power for drainage pumping plants has not come into extensive use in southern Louisiana and Texas. It has the advantage of greater convenience than other sources of power, and where adequate transmission lines are easily accessible this advantage may make it desirable, notwithstanding its higher cost as compared with power from steam or internal-combustion engines.

TESTS OF PUMPING PLANTS.

CONDITION OF TESTS.

Tests of pumping plants should be made during fair weather, after allowing the reservoir canals to fill to the maximum depth. If the test is continued until the water is drawn down to a low level the results may be divided into hourly periods in such a way as to show the behavior of the plant throughout the range of lift. The reservoir capacity per unit tested will determine the length of time required for such a test. If it is desired to determine the behavior of a plant under average lift, either the test must be comparatively short or there must be a supply of water furnished by rain during the test, though the water possibly may be siphoned back through a pump that is not being operated. The latter plan is applicable only to plants having more than one unit. In any case the test usually will be more accurate if it extends over a considerable length of time. Although many of the tests described covered only a comparatively short period, the accuracy of fuel measurements is high because the fuel has been oil. Tests made with this fuel used in internal-combustion engines or burned in boiler furnaces are much more accurate than those made for corresponding periods of time with coal as a fuel. A boiler test with oil fuel can be made without disturbing the normal operation of the plant. With coal as fuel there are many irregularities introduced, due to the measurements necessary to the test. Fortunately all the tests here recorded were made with oil as fuel.

The showing made by a pumping plant depends in some measure on conditions surrounding the test. If a guarantee of efficiency and fuel consumption has been made by the parties erecting the plant and the test is made to show whether the guarantee has been met, the plant is likely to make its best showing. If, however, the same plant has been turned over to a careless operator and has not been kept in first-class condition a casual test made without particular preparation may show results quite different from those of the acceptance test. The amount of this difference will vary greatly with different types of plant and with the conditions of operation.

Centrifugal pumps operate efficiently only at proper speeds. There are, however, many instances where capacity and not efficiency is the controlling element in a pumping plant. If an unusual rainfall has occurred it is desirable to remove the water before damage results to crops, regardless of fuel cost. Steam pumping plants have in general more overload capacity than internal-combustion engine plants. Steam engines usually are selected on a basis of size that enables them to force the pumps beyond normal capacity, while an increase of steam pressure in case of liberal boiler capacity always will insure overloads. On the other hand, the internal-combustion engine usually may not be forced to an output of power greatly in excess of its normal rating. When in the best possible condition a maximum of 10 to 15 per cent in excess of the rating may be expected.

The showing made by a pumping plant will depend to some extent on the amount of vegetation in the water and consequently on the time of year the test is made. A screen in the suction canal to keep weeds from reaching the pump is a necessity. Even where there is a good screen, weeds of small size will pass through and be caught on the blades of the impeller of the pump. The effect is to reduce both capacity and efficiency. There is urgent need for some form of cutter that may be operated while the pump is in use. Such a device has been applied to one form of screw pump. It consists of a heavy cylinder of metal that is forced in and out by a hydraulic piston and so placed that the blades of the impeller barely clear; any trash caught by the blades is thus sheared off and passes on through the pump. The patent involved also covers the application of the device to centrifugal pumps, but so far as observation extends it has not been applied to that type of pump.

Some pumping plants are operated at an improper number of revolutions per minute because of lack of data regarding the proper speeds for different lifts. Without a series of tests to determine the best speed of rotation a plant may be operated at considerable disadvantage. Because of the limited time ordinarily devoted to such a series, and the many limitations affecting the outcome of the tests, it is quite probable that the results do not represent the best performance of the class to which the plant belongs.

The tests described hereafter were run by W. B. Gregory and J. M. Robert, of Tulane University, and C. W. Okey, Senior Drainage Engineer, United States Department of Agriculture, assisted by B. S. Nelson, Charles Kirschner, and several members of the senior class in mechanical engineering at Tulane University.

TEST OF DRAINAGE WHEEL ON THE SOUTH SIDE PLANTING CO.'S TRACT, NEW ORLEANS, LA.

This test was made in 1905 on a drainage wheel used to drain 1,700 acres. The wheel was typical of its class, but had distinct features in the double gearing and in the number of paddles. Care was exercised so to design the wheel that the water would not be lifted unnecessarily. Its diameter was 28 feet and its width 6 feet. It was driven by a simple noncondensing engine of the slide-valve type, with a cylinder 16 inches in diameter and a stroke of 24 inches.

The method of testing consisted in traversing the discharge flume with a current meter and taking indicator cards and other observations as quickly as possible after the traverse was finished. By this means the indicated horsepower was a little less than the mean corresponding to the water measurement, but as the latter required only about 10 minutes the error was not great.

The results given in Table 1 are very satisfactory, as they show an efficiency of engine, transmission gears, and pump in every case exceeding 38 per cent and in two cases considerably above that figure, while the actual lift of the pump varied from 2.4 feet to 2.86 feet. During the last observation the paddles dipped into the water to a depth of approximately 1 foot, and the slip or backward flow was quite large. The clearance on the side of paddles was about three-fourths inch.

TABLE 1.—*Engine and pump test, South Side Planting Co.'s drainage wheel.*

Boiler pressure.	Indicated horse-power.	Speed of engine.	Speed of wheel.	Actual lift.	Discharge.		Useful water horse-power.	Efficiency.
Lbs. per sq. in.		*R. p. m.*	*R. p. m.*	*Feet.*	*Sec.-ft.*	*G. p. m.*		*Per cent.*
40	13.43	61	2.00	....	....	....	....	....
40	12.61	66	2.17	2.4	20.71	9,299	5.59	44.3
38	10.37	68	2.24	2.8	17.20	7,723	5.41	52.2
36	8.80	67.5	2.22	2.7	11.23	5,042	3.41	38.8
37	6.95	68	2.24	2.86	8.21	3,686	2.66	38.3
[1] 38.2	[1] 9.68	[1] 66.1	[1] 2.22	[1] 2.69	[1] 14.34	[1] 6,437	[1] 4.27	[1] 43.4

[1] Mean.
Duration of test, 1 hour.

These results are confirmed by a test of a similar drainage wheel in the old London Avenue pumping station in New Orleans, made in August, 1900, by W. M. White. In this test between 50 and 60 cubic feet per second were pumped through a height varying from 4 to 5 feet. The efficiency of engine, gearing, and pump ranged from 45 to 50 per cent. The duty per 100 pounds of coal was approximately 13,000,000 foot-pounds. The water rate of the engine was 50.5 pounds per indicated horsepower-hour. The engine was of the type used in Mississippi River steamboats; diameter of cylinder 18 inches; length of stroke 54 inches. During the test the engine made about 35 revolutions per minute.

TEST OF CHAMBER-WHEEL PUMP ON WILLSWOOD PLANTATION, WAGGAMAN, LA.

In a drainage pumping plant composed of large units such as are required ordinarily in drainage work, the pumps lift the water higher than is necessary, and while they are efficient if credited with the higher lift, they lose their efficiency on low lifts when the actual difference in level is considered.

This point is well illustrated by the test made at the drainage pumping plant of Willswood plantation. At the time there were three pumping units on this plantation, steam being furnished by two water-tube boilers and one horizontal return tubular boiler. The fuel was crude oil and a feed-water heater was used. Following is a description of the three units:

1. A 16 by 24 inch automatic noncondensing engine connected by rope drive to a rotary chamber-wheel pump. Maximum capacity of 40,000 gallons per minute.
2. A similar engine connected by rope drive and bevel gear [1] to a 42 by 16 inch Menge pump.
3. A double vertical engine direct-connected to a 36-inch centrifugal pump.

Pumps 1 and 2 discharge into open flumes at an average head on the pump of 10 feet, which was 5 feet greater than necessary. The bottom of the discharge flume was placed at the elevation of the top of the back levee, which normally was about 5 feet higher than the water of the swamp behind the levee.

In testing pump No. 1, the quantity of water was measured by means of a weir without end contractions placed in the discharge flume. Table 2 shows the results obtained by the test.

TABLE 2.—*Test*[1] *of pump No. 1, Willswood plantation, June 15, 1909.*

Boiler pressure.	Indicated horsepower.	Speed.		Discharge.		Actual lift.	Head on pump.	Water horsepower.		Efficiency of engine, transmission, and pump.	
		Engine.	Pump.					Based on actual lift.	Based on head on pump.		
Lbs. per sq. in.		*R. p. m.*	*R. p. m.*	*Sec.-ft.*	*G. p. m.*	*Feet.*	*Feet.*			*Per cent.*	*Per cent.*
89	153.5	108.5	89.0	78.2	35,200	5.2	10.0	46.0	88.4	29.9	57.5
89	163.0	115.0	94.5	83.0	37,300	5.3	10.3	49.6	96.5	30.4	59.1
89	155.8	112.5	92.0	80.8	36,300	5.4	10.3	49.3	94.0	31.6	60.3
90	166.8	116.5	95.5	83.9	37,700	5.5	10.5	52.1	99.5	31.3	59.8
92	166.8	117.5	96.0	84.3	37,900	5.5	10.5	52.3	100.0	31.4	60.0
87	152.2	109.0	89.5	78.7	35,400	5.5	10.5	48.8	93.3	32.1	61.3
86	145.6	106.0	87.0	76.4	34,400	5.6	10.5	48.4	90.8	33.2	62.3
....	....	....	....	....	....	....	....	....	....	[2] 31.41	[2] 60.04

[1] Duration of test, 1 hour and 30 minutes.
[2] Average.

When the pump was credited with the head through which the water was elevated at the pump the average efficiency of engine, transmission, and pump was found to be 60 per cent. Based on the actual lift it was only 31 per cent. Assuming the mechanical efficiency of the engine as 90 per cent and the efficiency of transmission as 95 per cent, the efficiency of the pump, if credited with the whole lift, is a little more than 70 per cent.

TEST OF MENGE PUMP, PARADIS, LA.

Several efficiency tests of Menge pump installations, both for drainage and for irrigation, show that where the pumps were favorably located and the plants in good condition the efficiencies were excellent.

The results given in Table 3 were obtained from a test of a drainage plant made at Paradis, La. The plant consisted of a 48 by 18 inch Menge pump run by means of a rope drive from a steam engine;

[1] This has since been changed to a quarter-twist rope drive, thus eliminating the bevel gears.

diameter of cylinder 14 inches, stroke 20 inches. Various speeds of rotation were employed for the purpose of finding the best efficiency. The results were excellent and have been confirmed by tests of other plants. If the mechanical efficiency of the engine be assumed as 90 per cent and the efficiency of transmission 95 per cent, the efficiency of the pump would be approximately 55 per cent with a 5-foot lift.

TABLE 3.—*Test*[1] *of Menge pump, Paradis, La., Sept. 16, 1909.*

Boiler pressure.	Indicated horsepower.	Speed.		Actual lift.	Discharge.		Water horsepower.	Efficiency of engine, transmission, and pump.
		Engine.	Pump.					
Lbs. per sq. in.		*R. p. m.*	*R. p. m.*	*Feet.*	*Sec.-ft.*	*G. p. m.*		*Per cent.*
76	11.4	67	78	2.67	1.28	575	0.39	3.4
77	39.6	92	98	3.55	39.6	17,800	15.9	40.2
80	40.1	92	99	3.65	39.6	17,800	16.3	40.6
75	59.6	107	117	4.24	54.5	24,500	26.1	43.8
77	22.1	80	87	3.42	20.8	9,360	8.0	36.2
79	37.7	93	101	3.90	35.5	15,970	15.6	41.4
69	59.3	107	116	4.30	53.7	24,150	26.1	44.0
70	41.7	97	104	4.15	37.9	17,050	17.8	42.7
68	65.8	111	121	4.80	52.0	23,400	28.2	42.8
55	48.4	100	111	4.55	42.8	19,300	22.0	45.5
55	71.0	114	123	5.00	55.5	25,000	31.4	44.2
50	65.3	110	122	5.00	54.5	24,500	30.8	47.1
48	60.6	109	118	4.90	51.2	23,000	28.4	46.8
70	76.5	116	128	5.30	56.3	25,350	33.7	44.1

[1] Duration of test, 3 hours 13 minutes.

TESTS OF PUMPING PLANT OF THE PHILLIPS LAND CO., PLAQUEMINES PARISH, LA.

DESCRIPTION OF PLANT.

This pumping plant is used to drain 2,500 acres of wet prairie land in Plaquemines Parish, about 15 miles below New Orleans. The plant consists of two units, a 36-inch double-suction centrifugal pump driven by a 14 by 18 inch simple slide-valve engine, and a 24-inch double-suction centrifugal pump driven by a 10 by 14 inch simple slide-valve engine. Both engines are noncondensing. The suction pipes of the large pump are 26 inches in diameter, while those of the smaller pump are 18 inches. The pumps are direct connected to the engines through flexible couplings. The exhaust of the engines is conducted through a common exhaust pipe to a closed heater and then to an exhaust head. Steam is furnished by two horizontal return tubular boilers rated at 80 horsepower each. Oil is used as fuel. Steam is required to atomize the oil and to run the oil and boiler feed pumps. The pumping plant is housed in a steel frame building covered with galvanized iron.

METHOD OF CONDUCTING THE FIRST TEST.

The plant was operated under normal conditions for the first test. Fuel was measured in a barrel. Feed water was measured by a Worthington meter, which was calibrated after the test. No attempt was made to measure the moisture in the steam, the amount of which at times was quite large. Observations were taken at half-hour intervals. The quantity of water pumped was measured by means of Pitot tubes, one being placed in the discharge pipe of each pump. Velocity was measured at 10 points in the pipe, so chosen that the arithmetical mean of the separate velocities gave the mean velocity of water in the pipe.

Gages set in still water in the suction and discharge canals were read, and the difference of the readings used as head of actual lift in computing the useful water horsepower. The heads on the pumps were found by providing openings in the suction and discharge pipes near the pumps and reading the negative heads by means of a mercury column. The suction head was taken in each case as the mean of the two readings on the suction pipes. The head on pump was computed from the formula

$$H = h_d - h_s \pm h'' + \frac{V_d^2 - V_s^2}{2g}$$

h_d = head in discharge pipe in feet of water shown by mercury column; it may be positive or negative.
h_s = head on suction pipe in feet of water shown by mercury column; it is usually negative.
h'' = difference of level of openings in suction and discharge pipes; this term is + if opening in discharge pipe is above that in suction and − when the opposite is true.
V_d = mean velocity in discharge pipe.
V_s = mean velocity in suction pipe.

Table 4 shows the results obtained by the test and Table 5 gives a summary of the results of the engine and pump test and the boiler test.

TABLE 4.—*First test of Phillips Land Co. pumping plant, Oct. 19, 1912.*

36-INCH UNIT.

Time.	Boiler pressure.	Horsepower.	Speed.	Actual lift.	Head on pump.	Discharge.		Useful water horsepower.	Pump horsepower.	Efficiency. Based on useful water H. P.	Efficiency. Based on pump H. P.
	Lbs. per sq. in.		*R. p. m.*	*Feet.*	*Feet.*	*Sec.-ft.*	*G. p. m.*			*P. ct.*	*P. ct.*
10:00	118	94.0	176	3.85	6.93	62.2	27,910	27.20	48.90	28.9	52.1
10:30	118	92.2	176	4.01	6.61	63.0	28,280	28.70	47.25	31.1	51.3
11:00	117	86.7	172	4.13	....	61.2	27,480	28.70	....	33.1	....
11:30	120	90.9	174	4.21	6.63	61.0	27,390	29.15	45.80	32.1	50.5
12:00	126	90.6	174	4.29	6.63	60.6	27,2 0	29.60	45.70	32.7	50.4
12:30	120	93.1	177	4.40	....	61.2	27,480	30.60	....	32.9	....
1:00	120	91.6	177	4.49	7.08	61.7	27,700	31.50	49.60	34.4	54.1
1:30	117	88.4	177	4.59	6.76	60.4	27,100	31.45	46.30	35.6	52.3
2:00	120	88.6	176	4.67	6.92	59.5	26,700	31.55	46.70	35.6	52.7
2:30	125	87.8	177	4.77	6.97	54.8	24,600	29.60	43.30	33.7	49.3
3:00	115	86.9	177	4.86	7.26	53.9	24,190	29.65	44.30	34.1	51.0
3:30	118	86.3	176	4.94	7.10	54.2	24,320	30.35	43.60	35.1	50.5
4:00	117	90.3	177	5.04	7.22	50.5	22,670	28.90	41.40	32.0	45.8
Mean	118.5	89.8	175.9	4.48	6.92	58.7	26,345	29.75	45.75	33.2	50.9

Fuel oil used, both units, 2,256 pounds; feed water used, both units, 27,850 pounds.

TABLE 4.—*First test of Phillips Land Co. pumping plant, Oct. 19, 1912*—Continued.

24-INCH UNIT.

Time.	Boiler pressure.	Horsepower.	Speed.	Actual lift.	Head on pump.	Discharge.		Useful water horsepower.	Pump horsepower.	Efficiency.	
										Based on useful water H.P.	Based on pump H.P.
	Lbs. per sq. in.		*R. p. m.*	*Feet.*	*Feet.*	*Sec.-ft.*	*G. p. m.*			*P. ct.*	*P. ct.*
10 00	118	34.6	210	3.85	6.14	29.5	13,240	12.90	20.60	37.3	59.5
10:30	118	35.0	210	4.01	6.20	29.3	13,150	13.33	20.60	38.1	58.8
11:00	117	26.0	202	4.13	....	27.4	12,300	12.85	....	49.5	....
11 30	120	23.0	182	4.21	5.65	22.6	10,000	10.80	14.50	47.0	63.0
12:00	126	23.8	182	4.29	5.72	26.2	11,760	12.72	17.00	53.4	71.5
12:30	120	34.1	208	4.40	....	28.9	12,970	14.43	....	42.3	....
1:00	120	34.9	209	4.49	6.44	28.7	12,880	14.60	20.90	41.8	59.9
1 30	117	33.7	208	4.59	6.57	27.6	12,390	14.40	20.60	42.8	61.1
2:00	120	34.1	208	4.67	6.40	27.6	12,390	14.65	20.05	43.0	58.8
2:30	125	33.5	208	4.77	6.63	26.5	11,890	14.38	19.95	42.9	59.5
3:00	115	33.8	208	4.86	6.33	25.9	11,640	14.25	18.57	42.2	54.9
3.30	118	33.4	208	4.94	6.56	26.5	11,890	14.85	19.71	44.4	59.0
4:00	117	33.9	209	5.04	6.63	23.6	10,590	13.50	17.78	39.8	52.5
Mean	118.5	31.8	204	4.48	6.30	26.9	12,073	13.67	19.10	43.4	59.9

Fuel oil used, both units 2,256 pounds; feed water used, both units 27,850 pounds.

TABLE 5.—*Summary of first test of Phillips Land Co. plant.*

	36-inch unit.	24-inch unit.
ENGINE AND PUMP TEST.		
Duration of test, hours	6	6
Revolutions per minute	175.9	204.0
Indicated horsepower	89.8	31.8
Steam used, pounds per indicated horsepower per hour, average (uncorrected for moisture)	38.2	....
Discharge in cubic feet per second	58.7	27.5
Discharge in gallons per minute	25,350	12,350
Actual lift, feet	4.48	4.48
Head on pump, feet	6.92	6.30
Head lost in suction and discharge pipes, feet	2.44	1.82
Useful water horsepower	29.75	13.67
Pump horsepower	45.75	19.10
Efficiency of pump, engine, and piping, per cent	33.20	43.40
Efficiency of pump and engine, per cent	50.90	59.90
Efficiency of pump (engine efficiency assumed to be 90 per cent), per cent	56.6	66.6
BOILER TEST.		
Duration of test, hours	6	....
Average steam pressure, pounds per square inch	118.5	....
Total amount of water used, pounds	27,850	....
Total amount of fuel oil used, pounds	2,256	....
Ratio of water to fuel oil (uncorrected for moisture)	12.35	....
Average feed-water temperature, degrees F.	177	....
Factor of evaporation	1.08	....
Ratio of water evaporated to fuel oil (uncorrected for moisture)	13.34	....
Efficiency of boilers (assuming 18,500 B. t. u. per pound of fuel oil), per cent	69.7	....

Two efficiencies are given in Table 5, the first based on the head represented by the difference of level of the suction and discharge basins and the second based on the head on the pump as defined above. The difference between these two amounted to 2.44 feet in the 36-inch unit and 1.82 feet in the 24-inch unit, showing extremely bad design of suction and discharge pipes at the ends where they dip into the water. By way of comparison, in the test made at Gueydan, La., at the pumping plant of Subdistrict No. 1, Gueydan drainage district, the loss of head corresponding to those given above amounted to 0.3 foot.

SECOND TEST.

A second test was made to determine the efficiency of engine, pump, and piping. This test was of special interest, inasmuch as changes had been made in the suction and discharge pipes of two pumps since the previous test of October 19, 1912. The intake ends of the suction pipes and the exit ends of the discharge pipes as originally constructed were very poorly designed. Since the first test was made the pipes had been replaced by others with well-designed ends. The side clearance of the open impeller of the 36-inch pump, which had been nearly three-fourths inch, had been reduced to about one-eighth inch, and the impeller blades in both pumps had been lengthened.

The changes were beneficial to plant efficiency, although it is difficult to say how much each contributed to the improved conditions. Lengthening the impeller blades and decreasing the clearance gave more water for a given lift and number of revolutions, while the elimination of entrance and discharge losses decreased the total head on pump. The second test was run at a greater lift than was the first, and this also contributed to the higher efficiency. The results of the test are given in Table 6, and a comparison made with the first test in Table 7.

TABLE 6.—*Second test of Phillips Land Co. pumping plant, Aug. 11, 1916.*

36-INCH UNIT.

Time.	Speed.	Indicated horse-power.	Actual lift.	Discharge.		Useful water horse-power.	Efficiency of engine, pump, and piping.
	R.p.m.		*Feet.*	*Sec.-ft.*	*G.p.m.*		*Per cent.*
11.15	146	81.20	5.90	64.21	28,800	42.90	52.9
11.20	146	81.25	5.95	63.00	28,300	42.50	52.4
11.25	146	78.80	6.00	61.40	27,600	41.70	53.0
11.30	146	78.60	6.05	62.13	27,900	42.50	54.1
11.35	146	80.30	6.10	62.75	28,200	43.30	53.9
11.40	138	67.20	6.12	48.53	21,800	33.65	50.2
11.45	137	65.72	6.14	47.18	21,200	32.75	49.8
11.50	136	62.95	6.16	43.76	19,650	30.55	48.6
11.55	135	61.70	6.18	43.08	19,350	30.20	48.8
12.35	141	71.65	6.13	59.20	26,600	41.10	57.3
12.45	154	93.15	6.20	69.06	31,050	48.50	52.0
12.50	153	89.10	6.23	69.03	31,000	48.70	54.7
12.55	154	91.60	6.25	69.21	31,100	49.00	53.5
1.00	153	91.35	6.29	68.62	30,800	48.90	53.5
1.05	160	103.25	6.35	74.48	33,400	53.60	51.8
1.10	160	102.50	6.38	74.00	33,250	53.50	52.2
1.15	160	101.90	6.42	74.08	33,300	53.80	52.9
Mean	148	76.6	6.17	61.98	27,817	43.36	52.45

TABLE 6.—*Second test of Phillips Land Co. pumping plant, Aug. 11, 1916*—Contd.

24-INCH UNIT.

Time.	Speed.	Indicated horsepower.	Actual lift.	Discharge.		Useful water horsepower.	Efficiency of engine, pump, and piping.
	R. p. m.		*Feet.*	*Sec.-ft.*	*G. p. m.*		*Per cent.*
1.35	207	33.93	6.25	26.20	11,760	18.55	54.7
1.43	206	32.78	6.30	26.38	11,830	18.81	57.4
1.45	206	32.02	6.34	25.94	11,640	18.62	58.2
2.00	244	50.73	6.44	35.27	15,830	25.72	50.7
2.05	244	50.11	6.45	35.93	16,140	26.23	52.4
2.15	198	26.83	6.45	21.40	9,610	15.62	58.3
2.20	198	26.85	6.45	21.57	9,680	15.72	58.5
2.25	199	26.87	6.45	20.72	9,300	15.13	56.2
Mean	203	35.01	6.39	26.68	11,974	19.30	55.8

TABLE 7.—*Comparison of the results of the two tests of the Phillips Land Co. plant.*

Unit.	Lift.		Rate of pumping.		Efficiency of engine, pump, and pipe.	
	1912	1916	1912	1916	1912	1916
	Feet.	*Feet.*	*Sec.-ft.*	*Sec.-ft.*	*Per cent.*	*Per cent.*
36-inch	4.48	6.17	58.7	61.9	33.2	52.4
24-inch	4.48	6.39	27.5	26.7	43.4	55.8

During the test different speeds were tried. Some of the variations in efficiency are due to change of speed, but the superior efficiencies obtained in the second test bear witness to the great improvement of the pumping units resulting from the changes noted, for the test was made in the same manner and with the same instruments as the first test.

TESTS OF PUMPING PLANT IN SUBDISTRICT NO. 1, LAFOURCHE DRAINAGE DISTRICT NO. 6, LAFOURCHE PARISH, LA.

DESCRIPTION OF PLANT.

This plant is used to drain a tract of land containing about 1,880 acres. At the time of the first test the plant consisted of duplicate units, each having a 24-inch double-suction centrifugal pump driven by a 12 by 12 inch simple slide-valve engine. The suction openings on the pumps are 18 inches in diameter. The intake and suction pipes have been tapered and enlarged so that the area of the intake is 4.2 and the area of the discharge 2.7 times the area of the discharge nozzle of the pump. The pumps were direct connected to the engines by flexible couplings. The exhaust of the engines was conducted through a common pipe to a water heater and then exhausted into the air. Steam was generated by two horizontal marine-type boilers 7 feet in diameter by 13 feet long. Neither boilers nor steam line were covered during the test. The fuel used was Mexican crude oil. Steam was used to atomize the oil in the furnaces and to run the usual oil and boiler feed pumps. The machinery is housed in a corrugated-iron building and is mounted on a concrete foundation supported by piling.

The pumps take the water from the main canal of the district and discharge it into Bayou Des Allemands through about 300 feet of outlet canal. The bulk of the water from the average rain is lifted about 3 feet, so the plant was tested at this lift. When the canals are empty the lift is about 8 feet, but very little water is lifted more than 5 feet. The water on the discharge side varies about 1 foot in height, according to the stage of water in the bayou.

FIRST TEST.

For the first test the plant was operated under normal conditions, using only one of the boilers. Observations were taken at intervals of a half hour. The discharge from the pumps was measured by means of a Pitot tube in each discharge pipe. Gages set in the still water in the suction and discharge canals were read and the actual lift obtained. This lift was used in computing the water horsepower.

The water used in the boiler during the test was measured in a large storage tank. Water was then drawn from this tank and pumped through the heater into the boiler. The oil used as fuel during the test was measured with approximate accuracy in the large storage tank. However, as the tank was about 19 feet in diamater and the oil was lowered only 0.091 foot during the test, it is evident that the oil measurement is only a close estimate, and the error of observation might change the result materially.

The usual method of finding the total head on pump, or dynamic head, was followed, but gave results so erratic that they were considered of no value. The results obtained are set forth in some detail in Table 9. A summary of results is given in Table 8.

TABLE 8.—*Engine and pump test.*

	Unit No. 1.	Unit No. 2.
Duration of test, hours	4	4
Revolutions per minute	172	162
Indicated horsepower	46.8	38.7
Steam used per indicated horsepower, per hour, average pounds	40.7	40.7
Discharge, cubic feet per second	38.7	37
Discharge, gallons per minute	17,340	16,580
Static head, feet	2.97	2.97
Useful water horsepower	13.01	11.34
Efficiency of pump, engine, and piping	28	29.3
Efficiency of pump and piping (assumed engine efficiency, 90 per cent)	31.1	32.6
BOILER TEST.		
Duration of test, hours	4.2	....
Average steam pressure, pounds per square inch	89.01	....
Total water used, pounds	14,611	....
Total fuel oil used, pounds	1,507	....
Ratio of water to fuel oil	9.69	....
Average feed-water temperature, °F	155	....
Factor of evaporation	1.097	....
Ratio water evaporated from and at 212° to fuel oil	10.63	....
Efficiency of boilers (assuming 18,500 B. t. u. per pound of oil), per cent	55.6	....

TABLE 9.—*First test of pumping plant in subdistrict No. 1, Lafourche drainage district No. 6, Nov. 23, 1912.*

UNIT NO. 1.

Time.	Boiler pressure.	Speed.	Indicated horsepower.	Actual lift.	Discharge.		Water horsepower.	Efficiency.	
								Pump, engine, and piping.	Pump and piping.[1]
	Lbs. per sq. in.	*R. p. m.*		*Feet.*	*Sec.-ft.*	*G. p. m.*		*Per cent.*	*Per cent.*
11.45	85	164	40.6	2.60	36.5	16,380	10.75	26.5	29.5
12.15	92	168	46.4	2.65	40.5	18,180	12.15	26.2	29.1
12.45	92	172	46.7	2.72	38.7	17,370	11.92	25.6	28.4
1.15	87	174	48.0	2.84	40.7	18,260	13.10	27.3	30.3
1.45	86	173	49.1	2.95	39.1	17,550	13.06	26.6	29.5
2.15	94	184	55.5	3.07	41.1	18,450	14.30	25.8	28.6
2.45	81	170	44.3	3.17	37.5	16,830	13.45	30.4	33.8
3.15	92	162	37.6	3.29	34.5	15,490	12.85	34.2	38.0
3.45	90	179	53.0	3.42	40.0	17,950	15.50	29.3	32.5

UNIT NO. 2.

Time.	Boiler pressure.	Speed.	Indicated horsepower.	Actual lift.	Discharge (Sec.-ft.)	Discharge (G. p. m.)	Water horsepower.	Pump, engine, and piping.	Pump and piping.[1]
11.45	85	146	29.0	2.60	30.9	13,870	9.12	31.3	34.7
12.15	92	149	30.3	2.65	32.3	14,500	9.70	32.1	35.7
12.45	92	150	30.5	2.72	31.8	14,270	9.80	32.1	35.7
1.15	87	172	44.4	2.84	35.0	15,710	11.25	25.3	28.1
1.45	86	171	44.6	2.95	35.6	15,980	11.90	26.7	29.7
2.15	94	175	48.0	3.07	36.2	16,250	12.60	25.0	27.8
2.45	81	165	41.0	3.17	34.6	15,530	12.40	30.3	33.7
3.15	92	156	34.4	3.29	31.7	14,230	11.80	34.4	38.2
3.45	90	172	45.9	3.42	34.9	15,670	13.50	29.5	32.8

[1] Engine assumed to be 90 per cent efficient.

It will be noted that the lift was less than 3 feet, which is much too low for efficient operation of the pumps. The capacity of the pumps was large and they were undoubtedly run too fast to get the best efficiency. By examining Table 9 it will be seen that when the discharge dropped to 30 cubic feet per second the efficiency of pump and piping was about 38 per cent.

SECOND TEST.

At the time of the first test the static lift of the pumps was low, between 2.6 and 3.4 feet, and the pumps were operated at about 30 per cent over their rated capacities. While this information was valuable in showing overload capacity and the efficiency of the pumps at low lift, it was desired to know what efficiency this type of pump would give when operated at the rated capacity and at a static lift of at least 4 feet. The second test made for this purpose included only the engine and pump of unit No. 1. The first reading was taken while the pump was working at a 50 per cent overload and shows the reduction in efficiency that may be expected to result from such an overload. In computing the average efficiency for the test this first reading is omitted. Table 10 gives the results of the test.

TABLE 10.—*Second test, pumping plant in subdistrict No. 1, Lafourche drainage district No. 6, Oct. 23, 1918—Unit No. 1.*

Time.	Boiler pressure.	Speed.	Indicated horsepower.	Actual lift.	Discharge.		Water horsepower.	Efficiency.	
								Pump, engine, and piping.	Pump and piping.[1]
	Lbs. per sq. in.	R. p. m.		Feet.	Sec. ft.	G. p. m.		Per cent.	Per cent.
12.15	90	188	60.15	3.93	45.09	20,200	20.15	33.5	37.2
12.30	102	152	33.44	4.01	34.30	15,400	15.56	46.5	51.7
1.00	95	144	27.40	4.04	27.77	12,460	12.68	46.3	51.4
1.30	100	146	29.73	3.93	32.92	14,780	14.71	49.5	55.0
2.00	90	152	31.76	3.84	31.08	13,950	13.56	42.7	47.4
2.30	90	151	30.30	3.84	30.74	13,800	13.42	43.8	48.7
3.00	96	154	33.05	3.88	30.72	13,790	13.55	41.0	45.5
3.30	92	150	30.59	3.88	31.18	13,990	13.75	45.0	50.0
4.00	88	150	29.97	3.85	30.37	13,630	13.29	44.3	49.2
4.30	90	148	30.00	3.85	30.06	13,470	13.35	44.8	49.8
Average	94	150	30.69	3.90	31.01	13,920	13.76	44.9	50.0

[1] Engine assumed to be 90 per cent efficient.
The total feed water used in the boiler from 12.15 until 4.30 was 7,590 pounds, or 58.1 pounds per indicated horsepower-hour.

THIRD TEST.

During the fall of 1919 changes were made in the equipment of the pumping plant. A 4-cycle, 50-horsepower Ingeco distillate engine was installed to drive one of the pumps, replacing one of the slide-valve engines. Bevel gears of cast steel, having a ratio of 213 to 164, were used between the pump and engine. The smaller gear was attached to the engine shaft. Both gears were hand-finished and operated with very little noise.

In the test of unit No. 1 of this plant after the above changes the oil used by the engine was carefully weighed, while the output of the pump was measured by means of a Pitot tube in the discharge pipe. The lift was determined from gage readings on the suction and discharge basins. Kerosene oil was used for fuel. Table 11 gives the results of the test.

TABLE 11.—*Third test of subdistrict No. 1, Lafourche drainage district No. 6, Nov. 15, 1919—Unit No. 1.*

Time.	Speed.		Actual lift.	Discharge.		Water horsepower.	Pounds of oil used per 15 minutes.	Pounds of oil used per horsepower hour.
	Engine.	Pump.						
	R. p. m.	R. p. m.	Feet.	Sec.-ft.	G. p. m.			
11.15	212	163	4.27	32.52	14,600	15.73	10.69	2.70
11.30	202	156	4.27	29.95	13,450	14.51	10.00	
11.45	206	159	4.27	29.95	13,450	14.51	10.50	
12.00	209	161	4.27	31.98	14,350	15.50	10.38	
12.15	209	161	4.27	31.78	14,250	15.38	10.38	
12.30	208	160	4.27	31.70	14,230	15.36	10.12	
12.45	208	160	4.27	31.82	14,290	15.41	10.25	
1.00	209	161	4.27	32.32	14,520	15.63	10.44	
1.15	208	160	4.27	32.14	14,430	15.57	10.06	
1.30	[1] 215½	166	4.27	31.86	14,300	15.43	10.06	
1.45	232	179	4.27	37.37	16,770	18.09	12.09	
2.00	227½	175	4.27	36.48	16,370	17.68	12.03	
2.15	217	167	4.27	34.62	15,550	16.78	....	

[1] Variation in speed of engine during this interval.

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 3, LAFOURCHE DRAINAGE DISTRICT NO. 12.

DESCRIPTION OF PLANT.

This plant consisted of duplicate units, each having a 30-inch Lawrence double-suction centrifugal pump driven by a 14 by 16 inch Lawrence vertical slide-valve engine. The suction openings on the pumps are 24 inches in diameter. The intake and discharge pipes have been tapered and enlarged so that the area of the intake is 2.9 and the area of the discharge 1.8 times the area of the discharge nozzle of the pump. The pumps were direct connected to the engines by flexible couplings. The exhaust of the engines was conducted through a common pipe to a water heater and then discharged into the air. Steam was generated by two return tubular boilers of 100 boiler horsepower each. The boilers were in a brick setting covered with asbestos. The fuel used was Mexican crude oil. Steam was used to atomize the oil in the furnaces and to run the usual oil and boiler feed pumps. The machinery was housed in a corrugated-iron building. The average lift was probably less than 3 feet and the maximum lift about 7 feet. The level of the water on the discharge side varied about 2 feet. The area drained is 2,260 acres.

METHOD OF CONDUCTING THE TEST.

It was necessary to siphon considerable water into the district the day before the test in order to have enough water to make a test of both units. As a result the lift was low at first, but rapidly increased to 4 feet at the time of the last reading. A five-hour test was made on unit No. 2, but it was necessary to stop the test of No. 1 after four hours to prevent the débris which had collected around the suction screen from breaking the screen. At noon it was necessary also to shut down one boiler, as the parts of one of the valves in the boiler feed line became detached from the valve stem and jammed so that no water could be pumped into the boiler. By forcing the remaining boiler both pumps were run until the necessary adjustments could be made, although the steam pressure dropped.

The pumps were operated at such speed that they slightly exceeded their rated capacity during the earlier readings. Toward the last, especially after the steam pressure dropped, they were running somewhat under their rated capacity. The discharge of the pumps was measured by means of a Pitot tube in each discharge pipe at distances of about 12 feet from the pump. The first reading taken on unit No. 2 was inaccurate as to quantity pumped, as the velocity of the water was too great to be measured with the Pitot tube.

Gages set in the still water in the suction and discharge canals were read to obtain the actual lift. This lift was used in computing the useful water horsepower. The indicated horsepower of the engines and the total head on the pump were then obtained in the usual manner. The loss of velocity head due to lack of proper enlarging of the ends of the pipes is quite plainly shown. As this loss varies with the square of the velocity of the water, it is greatest when the pump is working at maximum capacity.

The water used during the boiler test was measured by means of a Worthington piston-type water meter, afterwards calibrated. The steam used for all purposes per horsepower per hour was 54.91 pounds. Table 12 shows the results of the test.

TABLE 12.—*Test of pumping plant in subdistrict No. 3, Lafourche drainage district No. 12, Raceland, La., Nov. 14, 1913.*

UNIT NO. 1.

Time.	Boiler pressure.	Speed.	Indicated horsepower.	Actual lift.	Head on pump.	Discharge.		Useful water horsepower.	Efficiencies.[1]		
									1	2	3
		R. p. m.		*Feet.*	*Feet.*	*Sec.-ft.*	*G. p. m.*		*Per ct.*	*Per ct.*	*Per ct.*
9.00	100	142	48.4	1.45	2.17	58.18	26,100	9.57	20.0	22.2	33.2
9.30	104	143	48.4	1.70	2.67	58.28	26,160	11.25	23.2	25.8	40.5
10.00	101	140	46.2	1.95	2.68	54.89	24,630	12.14	26.3	29.2	40.1
10.30	102	144	48.9	2.20	2.76	54.84	24,610	13.69	28.0	31.1	39.0
11.00	103	144	46.8	2.40	2.98	54.16	24,290	14.76	31.5	35.0	43.5
11.30	103	147	49.8	2.75	3.32	54.11	24,280	16.89	33.9	37.7	45.5
12.00	106	146	49.1	3.00	3.74	51.60	23,150	17.57	35.8	39.8	49.5
12.30	104	142	48.1	3.35	4.23	49.44	22,200	18.80	39.1	43.4	55.0
1.00	84	134	39.8	3.62	4.20	42.13	18,910	17.31	43.6	48.4	56.2
Average	100.8	142.3	47.3	2.39	3.19	53.07	23,820	14.55			

UNIT NO. 2.

Time.	Boiler pressure.	Speed.	Indicated horsepower.	Actual lift.	Head on pump.	Sec.-ft.	G. p. m.	Useful water horsepower.	1	2	3
9.00	100	150	88.4	1.45	3.24	66.97	29,900	11.01	12.5	13.9	31.0
9.30	104	124	51.6	1.70	3.05	61.08	27,290	11.80	23.0	25.6	46.0
10.00	104	124	51.1	1.95	3.30	60.54	27,030	13.41	26.2	29.2	49.8
10.30	102	128	53.4	2.20	3.43	59.80	26,720	14.92	27.9	31.0	47.2
11.00	101	127	53.2	2.40	3.52	58.28	26,050	15.86	29.8	33.1	48.5
11.30	103	127	53.0	2.75	3.77	56.66	25,310	17.67	33.3	37.0	50.7
12.00	104	126	52.8	3.00	3.95	55.24	24,690	18.79	35.6	39.5	52.0
12.30	104	124	48.3	3.35	4.24	53.67	23,810	20.39	42.2	46.9	59.4
1.00	84	120	41.7	3.62	4.32	43.65	19,500	17.92	43.0	47.8	57.0
1.30	102	126	50.8	3.90	4.70	41.54	18,570	18.37	36.2	40.2	48.5
2.00	108	128	52.1	4.00	4.97	47.14	21,060	21.38	41.1	45.7	56.6
Average	101.5	127.6	54.2	2.76	3.86	55.00	24,680	16.50			

[1] Efficiencies:
1. Efficiency of engine, pump, and piping.
2. Efficiency of pump and piping, assuming mechanical efficiency of engine at 90 per cent.
3. Efficiency of pump, assuming mechanical efficiency of engine at 90 per cent.

As the lift of the pumps was so variable, no average efficiency was determined. A summary of the boiler test follows:

Boiler test.

Duration of test, hours	5.08
Total water used, pounds	26,760
Total fuel oil used, pounds	2,095
Ratio of water to fuel oil	12.7
Average steam pressure, pounds per square inch	101
Average feed-water temperature, ° F	144
Factor of evaporation	1.11
Ratio of water evaporated at 212° to fuel oil	14.1
Efficiency of boiler (assuming 18,500 B. T. U. per pound of fuel oil), per cent	74

TEST OF PUMPING PLANT IN JEFFERSON DRAINAGE DISTRICT NO. 3, LAFITTE, LA.

DESCRIPTION OF PLANT.

This pumping plant is used to drain a tract of about 5,000 acres. The average lift of the pumps is about 4 feet, and at times the maximum lift is 10 feet.

It consists of two 48-inch double-suction centrifugal drainage pumps direct-connected to two 16 by 36 inch simple noncondensing Corliss engines of the girder-frame type. The engines are fitted with gravity release gear and a special governor for emergency use in case the pumps lose their priming. The cut-off is adjustable by hand while the engine is running. Steam is furnished to the engines by two Brownwell horizontal return tubular boilers of 150 horsepower each. The fuel used is Mexican crude oil. For starting the boilers with oil, steam is supplied by a 10-horsepower boiler fired with wood or coal.

The suction and discharge pipes are respectively 25 feet and 20 feet long and are enlarged so that the areas of the intake and discharge are four times the area of the discharge nozzle of the pump. The suction pipes are tapered uniformly from one end to the other, while the discharge pipes are tapered and flattened so that the outer ends have a rectangualr cross section with the sides rounded to a radius of 24 inches. A steam ejector is installed on each pump for use in expelling the air in priming.

While this plant was guaranteed to deliver at normal load 55,000 gallons per minute against a total head of 6 feet at a speed of 100 revolutions per minute, it was decided to test it at a much lower total head and somewhat greater capacity and speed.

FIRST TEST.

The first test of this plant determined the capacity and efficiency of the pumps for a rather wide range of heads and speeds. During the test the head increased rapidly, making it necessary to take observations on the pumps as frequently as possible. It was decided that a boiler-test run under such varying conditions would be of little value.

Tests were run on each unit separately. In making the tests indicator cards were taken, the speeds of the engines and pumps were recorded, a Pitot tube traverse was made in each suction pipe, the suction and discharge canal gages were read, and the dynamic head was obtained by means of mercury manometers connected to each suction pipe near the pump flange and to the discharge pipe near the discharge flange.

At the beginning of the test of unit No. 2 the difference in water levels was 3.38 feet. This difference rapidly increased to 6 feet, at which point the attempt was made to keep the speed of the pump as nearly constant as possible, so as to obtain the efficiency under normal conditions. Table 13 shows the results of the test. The indicated horsepower given in the table is the mean of the two cards taken at the beginning and end of each observation.

TABLE 13.—*First test of pumping plant in Jefferson drainage district No. 3, Lafitte, La., Feb. 22–23, 1913.*

UNIT NO. 1, 48-INCH PUMP.

Speed.	Indicated horsepower.	Discharge.		Actual lift.	Head on pump.	Useful water horsepower.	Efficiency.	
							Pump, engine, and piping.	Pump and engine.
R. p. m.		*Sec.-ft.*	*G. p. m.*	*Feet.*	*Feet.*		*Per cent.*	*Per cent.*
103	134.8	136.6	61,300	4.00	4.05	62.0	46.0	46.6
120.5	203.5	158.6	71,200	4.40	4.42	79.2	38.9	39.2
101.5	121.3	129.8	58,300	4.80	5.48	70.8	58.4	66.6
95.5	90.9	103.8	46,600	4.85	5.87	57.1	62.8	....
100.5	102.2	94.6	42,450	6.05	6.58	65.1	63.8	69.3
108	137.1	118.3	53,100	5.35	6.29	71.9	52.4	61.6
108	142.6	119.7	53,750	5.42	6.23	73.5	51.6	59.4
109.7	140.7	122.8	55,100	5,45	6.03	75.9	54.0	59.8
[1] 105.8	[1] 134.1	[1] 123.0	[1] 55,200	[1] 5.41	[1] 6.18	[1] 69.4	[1] 52.7	[1] 60.3

UNIT NO. 2, 48-INCH PUMP.

Speed.	Indicated horsepower.	Discharge (Sec.-ft.)	Discharge (G. p. m.)	Actual lift.	Head on pump.	Useful water horsepower.	Pump, engine, and piping.	Pump and engine.
121	212.7	170.4	76,500	3.38	4.40	65.4	30.7	40.1
121	216.9	176.7	79,300	3.40	3.00	68.2	31.4	35.4
109	153.4	147.7	66,300	3.31	4.03	55.5	36.2	44.1
116	185.5	158.7	71,250	3.45	5.16	62.1	33.5	50.1
101.7	125.5	133.1	59,700	3.64	4.01	55.0	43.8	48.3
93.5	95.9	115.4	51,800	3.84	3.71	50.3	52.5	....
81.5	61.0	82.9	37,200	3.70	4.08	34.8	57.1	62.9
114.5	163.8	122.1	54,800	6.25	6.84	86.5	52.8	57.8
119	174.9	120.1	53,900	6.85	7.17	93.5	53.5	55.9
[1] 108.6	[1] 154.4	[1] 136.3	[1] 61,170	[1] 6.55	[1] 7.00	[1] 63.5	[1] 53.2	[1] 56.9

[1] Mean.

In testing unit No. 1 the actual head at the beginning of the test was 4 feet and readings were taken up to 6 feet. It was then found that the increase in head was too rapid to get proper readings, due to the fact that the only water available for pumping was then in the canal. It was therefore decided to siphon water back into the canal with No. 2 unit while testing No. 1. This was done for the last three observations, and as a result the actual head for those three readings was 5.41 feet. The difference between the dynamic and static head gives the friction losses in the pipes and at the entry and discharge. Several inconsistencies appear in the friction losses recorded which can only be accounted for by the fact that it is impossible to make very accurate readings on the suction and discharge manometers of drainage units. Velocities were rather high, and the suction and discharge pipes were so short that there seemed to be a surging effect through the whole system at each revolution of the engine corresponding to the variation in angular velocity at different parts of the stroke.

SECOND TEST.

The results of the second test are given in Table 14. Although they appear to be quite consistent, the quantity of water entering the suction pipe on the engine side was about 50 per cent more than the quantity entering the other suction pipe. This is probably to be attributed to the fact that the end of the suction pipe which had the low capacity was close to the bottom of the canal. The same condition existed during the first test. The water used in the boiler test was measured by a Worthington piston meter. The amount of steam used per horsepower per hour for all purposes was 33.7 pounds. The fuel oil burned during the test was measured in a calibrated barrel.

TABLE 14.—*Second test of pumping plant in Jefferson drainage district No. 3, Lafitte, La., Dec. 13, 1913—Unit No. 2, 48-inch pump.*

Time.	Boiler pressure.	Speed.	Actual lift.	Discharge.		Useful water horsepower.	Efficiency.[1]		Horsepower indicated.
							Pump, piping, and engine.	Pump and piping.	
	Lbs. per sq. in.	*R. p. m.*	*Feet.*	*Sec.-ft.*	*G. p. m.*		*Per cent.*	*Per cent.*	
12.00	100	115	2.80	125.8	55,750	39.9	23.5	25.5	170.0
12.30	100	118	2.90	130.5	58,600	42.8	22.3	24.1	192.9
1.00	100	111	2.90	128.0	57,450	42.1	26.5	28.7	159.0
1.30	100	113	3.00	130.8	58,720	44.5	25.6	27.9	173.7
2.00	100	115	3.10	124.6	55,910	43.8	24.0	25.9	182.8
2.30	106	117	3.30	127.2	57,100	47.5	28.2	30.4	168.6
3.00	100	110	3.45	125.7	56,410	49.2	32.0	34.0	153.7
3.30	100	108	3.60	121.4	54,480	49.6	33.9	36.6	146.5
4.00	100	109	3.80	118.6	53,250	51.1	33.9	36.6	151.0
Mean	100.7	112	3.20	125.8	56,480	45.6	27.8	30.0	166.5

[1] Mechanical efficiency of engine shown by friction cards to be 92.5 per cent.

THIRD TEST.

Nearly three years after the second test a third test was run, this time on No. 1 unit. The useful lift, or actual head, varied from 6.04 to 6.5 feet. The results are given in Table 15.

TABLE 15.—*Third test of pumping plant in Jefferson drainage district No. 3, Lafitte, La., Aug. 14, 1916—Unit No. 1, 48-inch pump.*

Time.	Speed.	Indicated horsepower.	Actual lift.	Discharge.		Useful water horsepower.	Efficiency.	
							Engine and pump.	Pump.[1]
	R. p. m.		*Feet.*	*Sec.-ft.*	*G. p. m.*		*Per cent.*	*Per cent.*
11.15	116	161.7	6.04	110.89	48,900	75.9	46.9	50.7
11.20	116	165.9						
11.25	117	173.7	6.10	117.29	49,000	81.2	46.7	50.5
11.30	116	175.5						
11.35	116	168.9						
11.40	118	171.8	6.34	113.86	52,600	81.8	47.7	51.5
11.45	118	172.3						
11.50	117	171.0	6.40	109.02	49,000	79.2	46.3	50.1
11.55	118	165.7						
12.00	118	167.4						
12.10	112	136.9	6.50	94.59	42,900	69.6	50.8	55.0
12.15	112	138.4						
12.20	114	152.4						

[1] Engine efficiency at 92.5 per cent.

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 1, GUEYDAN DRAINAGE DISTRICT, FLORENCE, LA.

DESCRIPTION OF PLANT.

This pumping plant is a good example of a high-grade steam plant with simple Corliss noncondensing engines and two 54-inch Worthington double-suction pumps. The pumps are direct connected to two 16 by 36 inch slow-speed Corliss engines, the pump shaft being solid with the engine shaft, thus doing away with flanged couplings. Part of the exhaust is utilized in a 400-horsepower open feed-water heater which raises the temperature of the feed water to 210° F.

The steam-generating equipment consists of two 72-inch by 18-foot return tubular boilers rated at 150 horsepower each and designed for a 125-pound working pressure. Oil is fed to the burners, of which there is one under each boiler, by a pumping outfit which heats and delivers it to the burners at a uniform pressure. The suction and discharge pipes are tapering and well designed.

Each pumping unit has a capacity of 65,000 gallons per minute against a 5-foot difference in level between suction and discharge canals. Each unit has a 40 per cent overload capacity when pumping against a 3-foot head and if necessary is capable of pumping against a 10-foot head with a reduced discharge.

METHOD OF CONDUCTING TEST.

Unit No. 2 of the plant was tested to find the actual operating efficiency. The simultaneous tests which were run on the pumping unit and boiler lasted six hours. The quantity of discharge from the pump was obtained with a Pitot tube. The total head and the actual head on the pump were obtained in the usual way.

During the test it was impossible to utilize the heater, as there was no way of delivering hot water to the weighing barrel. The tank pump was therefore piped to take water from the canal and deliver it into two barrels placed above a third barrel from which the feed pump took suction. The amount of oil used during the test was recorded by an oil meter installed in the oil line to the burners. After breaking the vacuum and draining the pump the mechanical efficiency of the engine was obtained by taking cards from the engine when running at the speed maintained during the test.

During the test the static head was less than 5 feet and the discharge considerably more than 65,000 gallons per minute. These conditions were not those for which the plant was built and undoubtedly resulted in a pump efficiency that is less than it would be under proper conditions. The results of the boiler test are given below and those of the test on the pumping plant in Tables 16 and 17.

Boiler test.

Duration of test, hours	6.07
Average stack temperature, °F	498
Average steam pressure, pounds per square inch	120
Average furnace draft, inches of water	0.28
Average feed temperature, °F	72
Water evaporated, pounds	31,555
Equivalent water evaporated at 212°, pounds	37,560
Factor of evaporation	1.19
Boiler horsepower developed	179.3
Total fuel oil, pounds	2,975
Ratio of actual water evaporated to fuel oil	10.61
Ratio of equivalent water evaporated at 212°, to fuel oil	12.63
Efficiency of boiler (basis 18,500 B. T. U. per pound), per cent	66.1

TABLE 16.—*Test of unit No. 2 of pumping plant of subdistrict No. 1, Gueydan drainage district, Florence, La., Oct. 1, 1912.*

Speed.	Indicated horse-power.	Actual lift.	Head on pump.	Discharge.		Useful water horse-power.	Efficiency.	
							Pump and engine.	Pump, engine, and piping.
R. p. m.		*Feet.*	*Feet.*	*Sec.-feet.*	*G. p. m.*		*Per cent.*	*Per cent.*
71	83.8							
81	122.2	5.15	5.81	137.9	61,900	80.5	74.3	65.9
82	132.7	4.85	5.24	155.1	69,600	85.3	69.5	64.3
85	154.5	4.95	5.08	170.9	76,700	96.0	63.8	62.2
89	183.4	4.95	5.08	180.8	81,200	101.5	57.0	55.3
98	225.9	4.95	5.08	200.4	90,000	112.6	51.1	49.9
101	249.7	5.10	5.55	211.9	95,100	122.6	53.3	49.1

TABLE 17.—*Test of engine and pump of unit No. 2 of subdistrict No. 1, Gueydan drainage district No. 1, Florence, La., Oct. 1, 1912.*

Time.	Boiler pressure.	Speed.	Indicated horse-power.	Discharge.		Actual lift.	Head on pump.	Useful water horse-power.	Efficiency.[1]	
									Pump, engine, and piping.	Pump and engine.
	Lbs. per sq. in.	*R. p. m.*		*Sec.-feet.*	*G. p. m.*	*Feet.*	*Feet.*		*Per cent.*	*Per cent.*
11.15	118	90	177.1	185.4	83,200	4.36	4.83	91.6	51.7	57.3
11.45	115	89	171.4	188.3	84,500	4.50	4.79	96.2	56.2	59.8
12.15	115	91	178.4	194.8	87,500	4.55	4.87	105.0	58.9	60.3
12.45	117	90	181.6	190.5	85,500	4.54	5.21	98.4	54.2	62.2
1.15	118	89	171.3	195.8	87,900	4.60	5.04	102.4	59.8	65.4
1.45	125	94	201.1	198.7	89,200	4.70	4.87	106.0	52.8	54.7
2.15	125	94	201.1	199.4	89,500	4.70	4.87	106.4	52.9	54.8
2.45	125	91	196.6	194.8	87,500	4.80	5.15	106.2	54.1	58.0
3.15	123	92	195.4	195.1	87,600	4.85	5.06	107.5	55.0	57.3
3.45	125	92	197.3	190.0	85,300	4.90				
4.15	120	91	188.0	192.0	86,200	4.95	5.09	107.6	57.2	58.9
4.45	120	91	188.0	184.9	83,000	4.95	5.23	103.9	55.3	58.4
5.15	112	90	172.8	181.9	82,100	4.90	5.37	101.6	58.8	64.5
Mean	120	91.1	186.2	191.8	86,077	4.72	5.02	102.7	55.6	59.9

[1] Pump efficiency was 65.7 per cent, based on 91.1 per cent mechanical efficiency of engine and pump from friction cards.

TEST OF PUMPING PLANT NO. 3, AVOCA DRAINAGE DISTRICT, ST. MARY PARISH, LA.

DESCRIPTION OF PLANT.

This plant is of especial interest, inasmuch as it is the only steam pumping plant in this section in which superheated steam is used. The equipment consists of a cross-compound Lentz engine, a water-tube boiler with 2,487 square feet of heating surface, a 72-inch centrifugal drainage pump with two 48-inch suction pipes, a superheater composed of 2-inch elements about 6 feet 2 inches long (amount of surface unknown), a condenser, a duplex service pump which supplies water to the open heater and to the water seal of the centrifugal pump, and a duplex pump which takes the water from the heater and forces it into the boiler.

The engine cylinder dimensions are 18½ and 31 inches with a 21-inch stroke; the rods are each 4 inches in diameter. The valves are of the poppet type, operated by eccentrics and cams from a lay shaft with axis parallel to that of the cylinder. The conditions for operating the engine called for a pressure of 175 pounds at the throttle, 200 degrees of superheat, and 26 inches of vacuum. The superheater was not erected in the direct path of the hot gases, and therefore the superheat is less than 200 degrees. The condenser is of the jet type. The boiler walls are lagged with cork, which is in turn covered with cement mortar. The suction and discharge pipes of the pump are greatly increased in cross-section at their outer ends.

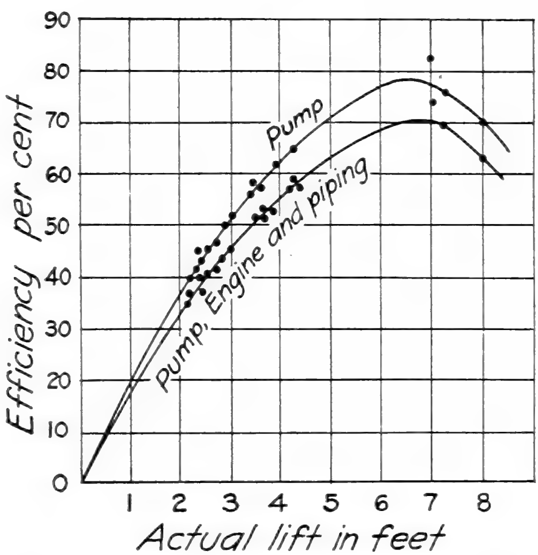


FIG. 2.—Efficiency of pumping plant No. 3, Avoca drainage district, as indicated by test of Sept. 13 and 14, 1914.

The test was begun in the morning and continued through the day, but as there was no provision for lighting the plant except by oil lanterns it was discontinued when night came on and resumed the next day.

The oil used during the test was Oklahoma crude oil with a specific gravity of 0.885 at 92° F. The quantity used was weighed in a bucket on a spring balance. The feed water was pumped through a hot-water meter. At the close of the test an attempt was made to calibrate the meter, but the results obtained varied about 25 per cent, showing that the water quantities measured are unreliable. Indicator cards were taken on the high-pressure cylinder with an outside-spring Tabor indicator. The thermometer on this cylinder showed an average of 74.5° F. of superheat. The indicator used on the low-pressure cylinder was an inside-spring Thompson. The thermometer on this cylinder indicated an average of 49.2° F. of superheat. A counter attached to the valve gear of the engine, read usually at intervals of 10 minutes, gave the revolutions. The quantity of water pumped was measured by two Pitot tubes inserted in the suction pipes, traverses of the pipes being made at half-hour intervals. Readings of the gages in the suction and discharge canals were taken at half-hour intervals. Table 18 shows the results obtained during the test, and figure 2 is a graph showing the efficiency of the plant at various lifts.

With the exception of the feed-water measurements the test was satisfactory. The only irregularity was due to the presence of air in the pump. As there was nothing to act as a flywheel except the impeller of the pump, there was a tendency for the engine to change speed rapidly on account of pockets of air in the water. This caused considerable variation in the indicator card from the high-pressure cylinder. Because of this variation six cycles were taken for each card, and in this way a very close mean was obtained.

TABLE 18.—*Test of 72-inch unit of pumping plant No. 3, Avoca drainage district, Sept. 13–14, 1916.*

Time.	Boiler pressure.	Speed.	Indicated horse-power.	Actual lift.	Discharge.		Useful water horse-power.	Efficiency.	
								Pump, engine, and piping.	Pump.
	Lbs. per sq. in.	*R. p. m.*		*Feet.*	*Sec.-ft.*	*G. p. m.*		*Per cent.*	*Per cent.*
10.30	146	105.9	188.83	2.22	278.35	125,000	70.05	37.08	41.1
11.00	152	106.1	190.68	2.19	276.85	124,100	68.70	36.02	40.4
11.30	151	106.0	191.65	2.36	278.08	124,900	74.40	38.80	43.2
12.00	153	105.9	187.15	2.46	275.25	123,500	76.45	40.84	45.3
12.30	148	105.9	194.28	2.60	273.20	122,600	80.40	41.38	45.9
1.00	149	105.9	197.48	2.73	272.05	122,100	84.20	42.63	47.3
1.30	149	105.3	196.75	2.86	272.85	122,300	88.40	44.92	49.9
2.00	141	105.9	200.70	2.98	272.95	122,500	92.20	45.83	51.1
2.30	151	106.1	202.45	....	....	....	....	....	....
3.00	152	105.4	208.15	3.48	269.40	121,000	106.20	51.03	56.6
3.30	138	105.8	202.40	3.59	267.65	120,100	108.80	52.43	58.2
4.00	156	105.8	214.90	3.68	266.05	119,400	110.90	51.61	57.3
4.30	145	105.9	214.85	3.96	264.80	118,800	118.80	55.37	61.4
5.00	151	105.6	216.75	4.16	265.00	118,900	124.90	57.65	64.0
5.30	148	105.4	216.85	4.23	262.65	117,750	125.80	58.06	64.5
6.00	134	105.2	218.15	4.26	259.60	116,500	125.30	57.20	64.0
9.00	95	103.9	245.00	7.03	228.00	102,300	181.60	74.18	82.3
9.20	....	104.7	256.03	7.23	217.25	97,700	178.00	69.78	77.4
9.30	142	105.2	266.18	....	....	....	....	....	74.4
10.00	140	105.4	277.40	7.98	194.60	87,300	175.90	63.40	70.3

TEST OF PUMPING PLANT NO. 2, OF AVOCA DRAINAGE DISTRICT, ST. MARY PARISH, LA.

DESCRIPTION OF PLANT.

The equipment of this plant consists of a cross-drum boiler with 1,162 square feet of heating surface, and a Corliss compound condensing engine with cylinder diameters 10 inches and 20 inches and 30-inch stroke with drop cut-off, direct connected to a double-suction centrifugal drainage pump. The pump has a discharge pipe 48 inches in diameter and suction pipes 36 inches in diameter, all pipes measured at the flange. Both the suction and discharge pipes are enlarged at their outer ends.

The test was made with the plant in normal operation. The instruments and methods were the same as those used in the test of pumping plant No. 3 of Avoca drainage district. The average temperatures observed in degrees F. were as follows: Feed water 198°, air 99°, oil 93°, water pumped 80°. The weight of fuel oil used in 2½ hours was 934 pounds. The rate of use was quite regular, and the best economy was shown near the end of the test. Friction cards were taken at the end of the test with no water in the pump. The results are given in Table 19.

TABLE 19.

Revolutions per minute.	Indicated horse-power.
84	8.32
101	11.01
110	13.64

Table 20 gives the results obtained during the test.

TABLE 20.—*Test of pumping plant No. 2, Avoca drainage district.*

Time.	Boiler pressure.	Speed.	Indicated horse-power.	Actual lift.	Discharge.		Useful water horse-power.	Efficiency: Pump, engine, and piping.
	Lbs. per sq. in.	*R. p. m.*		*Feet.*	*Sec.-ft.*	*G. p. m.*		*Per cent.*
2.00	115	101.6	123.75	2.76	141.30	63,400	44.2	35.70
2.30	130	113.8	125.35	2.81	138.35	62,100	44.0	35.10
3.00	135	118.8	170.50	3.41	139.25	62,500	53.8	31.54
3.40	127	111.3	149.63	4.45	133.73	60,000	67.4	45.00
4.05	127	111.6	150.78	4.93	127.63	57,300	71.3	47.30
4.19	....	112.0	118.95	5.84	110.72	49,700	73.2	61.56
4.30	142	108.6	116.69	6.21	99.81	44,800	70.3	60.21

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 4, JEFFERSON DRAINAGE DISTRICT NO. 4, JEFFERSON PARISH, LA.

DESCRIPTION OF PLANT.

In Plate I are shown interior and exterior views of this plant, and figure 3 is a cross-sectional view showing the shape of the suction and discharge pipes and method of supporting the plant. The pumping equipment consists of two duplicate units, each with a capacity of 59 cubic feet per second at a 2-foot lift and capable of pumping at any head between zero and 10 feet, the capacity decreasing as the head increases. The pumps are 30-inch, double-suction, slow-speed drainage centrifugals with special radial and axial flow impellers having a nearly constant horsepower input at all heads. They are direct-connected through friction-clutch couplings to 60-horsepower distillate engines designed to make 190 revolutions per minute and operating on cheap distillate of 39° Baumé gravity.

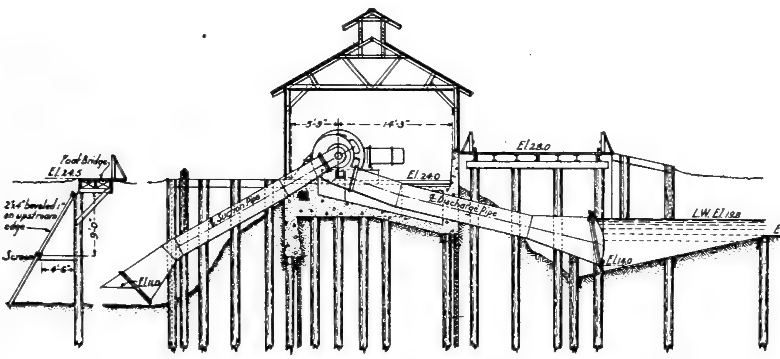


FIG. 3.—Elevation of pumping, subdistrict No. 4, Jefferson drainage district No. 4.

The engines are started on gasoline, run for a few minutes until the jackets warm up, and are then switched to distillate by throwing the handle of a six-way cock. Batteries are unnecessary, as the engines are fitted with oscillating magnetos suitable for starting as well as running, a valuable feature for an isolated plant. Cooling water is supplied by two rotary pumps belted off the hub of the clutch coupling, one to each unit. Each of these pumps is of ample size to supply water to both main engines and to the water-sealed glands of the main pumps. To insure a supply of water for starting and to provide against accidents to the circulating pumps, a 500-gallon elevated tank was erected. This furnished an hour's supply for one engine and is so piped that should the pump stop working, water would still flow to the jackets. An added advantage of this arrangement is that it gives a constant head of water on the jacket at all times.

The suction and discharge pipes on the main pumps are shown in figure 3. These pipes are one-fourth inch riveted steel of such size and design as to reduce the loss of head to about 0.5 foot. This is done by a design of the cross-section of the straight pipe which so reduces the velocity that the friction loss is only 0.25 foot, and by using long taper increasers and liberal bell mouths to reduce the loss due to velocity head. These calculations were made for a normal working head of 4 to 5 feet.

DESCRIPTION OF TEST.

In acceptance test made at this plant, the quantity of water was measured by means of Pitot tubes in the suction pipes. The lift was determined by reading gages in the suction and discharge basins. The fuel was a distillate oil of 42.3° Baumé weighing 6.81 pounds per gallon. The results of the test are given in Table 21.

TABLE 21.—*Test of 30-inch drainage unit No. 2 of the pumping plant in subdistrict No. 4, Jefferson drainage district No. 4, Jefferson Parish, La., Sept. 20, 1916.*

Time.	Speed.	Actual lift.	Discharge.		Oil[1] used per 20 minutes.	Discharge per gallon of oil.
	R. p. m.	*Feet.*	*Sec.-ft.*	*G. p. m.*	*Pounds.*	*Cubic feet.*
11.10	179.6	4.44	49.1	21,900	14.31	28,000
11.30	171.9	4.58	42.8	19,180	13.19	26,500
11.50	175.4	4.61	48.7	21,800	13.19	30,200
12.10	174.9	4.69	46.9	21,000	12.31	31,050
12.30	174.8	4.94	43.7	19,600	12.75	28,000
12.50	177.0	5.17	43.1	19,300	12.37	28,450
1.10	177.1	5.49	42.1	18,830	12.75	26,950
1.30	178.6	5.91	41.1	18,400	12.94	25,900
Mean	176.2	4.98	44.7	20,060	12.98	28,130

[1] Distillate of 42.3° Baumé; 6.81 pounds per gallon.

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 1, LAFOURCHE DRAINAGE DISTRICT NO. 9, FAYPORT, LA.

DESCRIPTION OF PLANT.

This pumping plant drains 2,000 acres. The equipment consists of two 30-inch centrifugal drainage pumps, each driven by a kerosene engine of 50-horsepower rating with pistons 16 inches in diameter and the stroke 18 inches. The engines are supposed to run at about 190 revolutions per minute, but ordinarily run at a slower speed. Water is injected with the kerosene. Air tanks are provided for starting, and a small air compressor may be used in charging the tanks. Circulating pumps are belted to the engines.

DESCRIPTION OF TEST.

The test on one unit of this plant was made with the plant operating at from 169 to 182 revolutions per minute. The lift and the quantity of water pumped were measured in the usual manner. The amount of the fuel oil used was obtained by measuring the change in elevation of the oil in the storage tank. When the test was finished the pump was opened and about a bushel of grass and weeds was taken out. This débris, which must have been accumulated gradually, was nearly equally distributed on the two sides. There were defects in the screen, especially at the ends, but these were soon remedied and it is probable that most of the vegetation came through the screen itself in small pieces. It is certain that the filling up of the pump decreased the capacity and efficiency of the pump. Table 22 gives in detail the results of the test.

TABLE 22.—*Test of pumping plant, subdistrict No. 1, Lafourche drainage district No. 13, Fayport, La., Nov. 24, 1916.*[1]

Time.	Speed.	Actual lift.	Discharge.		Useful water horse-power.
	R. p. m.	*Feet.*	*Sec.-ft.*	*G. p. m.*	
10.45	169	1.94	35.66	16,000	7.86
11.15	168	2.26	33.84	15,200	8.70
11.45	169	2.42	30.40	13,630	8.35
12.15	170	2.59	30.26	13,590	8.90
12.45	170	2.73	28.60	12,830	8.87
1.15	182	2.97	31.82	14,300	10.72
1.45	181	3.10	29.10	13,060	10.22
2.15	182	3.25	29.30	13,140	10.81
2.45	182	3.46	28.18	12,620	11.13
3.15	181	3.57	26.98	12,100	10.93
3.45	181	3.77	24.90	11,170	10.66
4.15	183	3.87	25.34	11,370	11.12
Average	176.5	2.99	29.53	13,250	10.02

[1] Oil used, 244 pounds.

TEST OF DRAINAGE PUMPING PLANT IN DALCOUR DRAINAGE DISTRICT, DALCOUR, LA.

DESCRIPTION OF PLANT.

This pumping plant installed in 1913 at Dalcour, La., about 22 miles below New Orleans, drains 650 acres of land. A 35-horsepower distillate engine is used to drive a 24-inch centrifugal drainage pump. A friction clutch is used to connect engine and pump. A priming pump is run from a jack shaft which in turn is belted to the engine.

The fuel used in the acceptance test was distillate of 45° Baumé at 86° F., which reduced to 60° F. was equivalent to 42° Baumé, weighing 6.8 pounds per gallon. The manufacturer's guarantee was that the plant would consume not more than 3.56 gallons of kerosene or No. 2 Solar oil per hour with pump operating at a capacity of 9,250 gallons per minute and a difference in water level of 5.5 feet. It was impossible to continue the test long enough to pump the water down to a 5.5-foot lift, but it was agreed that the results obtained at the 5-foot lift would govern if satisfactory. Table 23 gives the results obtained during the test.

TABLE 23.—*Test of pumping plant, Dalcour drainage district, Dalcour, La., May 26, 1914.*

Time.	Speed.	Actual lift.	Discharge.		Remarks.
	R. p. m.	*Feet.*	*Sec.-ft.*	*G. p. m.*	Discharge figures should be divided by ten.
11.10	209	4.22	240.0	107,810	Fuel, distillate, 42° Baumé; total oil used from 11.10 a. m. to 2.07 p. m., 78 pounds=3.98 gallons per hour.
11.30	210	4.36	233.8	105,000	
11.55	209	4.57	230.9	103,700	
12.20	209	4.53	218.5	98,200	
12.40	212	4.62	225.0	101,000	
1.10	211	4.64	224.5	100,800	
1.40	211	4.75	223.5	100,400	
2.15	212	4.81	218.9	98,300	
Mean	210.4	4.56	226.9	101,900	
2.50	211	4.90	215.4	95,800	Adjusted carbureter; total oil used from 2.07 p. m. to 4.26 p. m., 45½ pounds=2.99 gallons per hour.
3.25	210	5.00	213.4	95,900	
3.45	210	5.04	211.0	94,800	
4.40	210	5.07	215.1	96,600	
Mean	210.2	5.00	213.7	96,020	

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 1, LAFOURCHE DRAINAGE DISTRICT NO. 20, CUTOFF, LA.

DESCRIPTION OF PLANT.

This plant is made up of two pumping units, each consisting of a 36-inch centrifugal drainage pump driven by a 2-cylinder 4-cycle engine of 120 horsepower at 190 revolutions per minute. The pumps have overhead discharge and are really larger than 36 inches, as they have an oval discharge flange. A flexible coupling is used between engine and pump, but there is no friction clutch. The pumps are primed by means of vacuum pumps run by friction drive from the flywheels of the main engines. The circulating pumps are of the chamber-wheel type. Air tanks and a small compressor driven by a gasoline engine furnish an easy and effective method of starting.

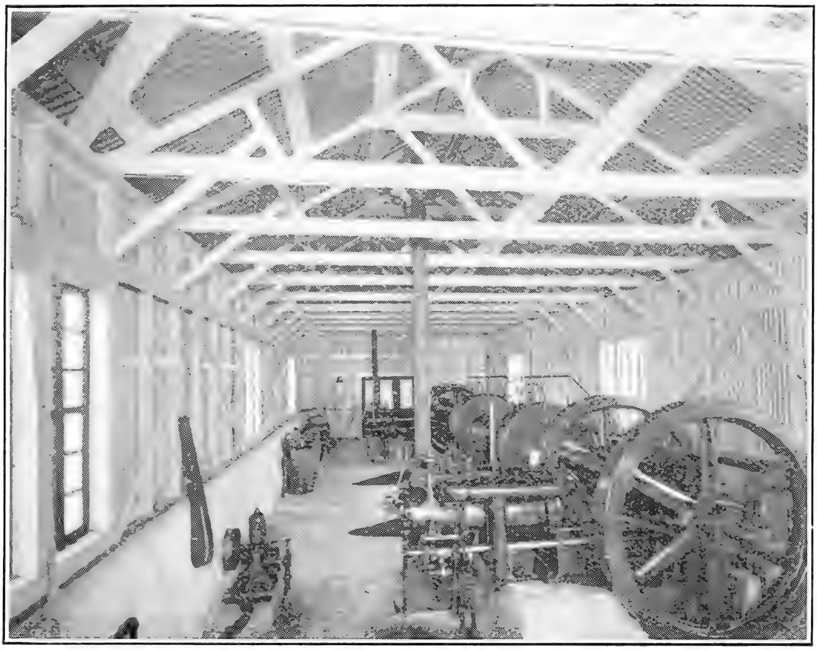
METHOD OF MAKING TEST.

The quantity of water was measured by means of Pitot tubes and the lift was determined by means of gages set in the suction and discharge canals. The fuel used, a distillate of 43.25° Baumé, was weighed by means of a spring balance. The engines were started by gasoline. The results of the test are shown in table 24.

TABLE 24.—*Tests of pumping plant in subdistrict No. 1, Lafourche drainage district No. 20, June 18–22, 1917.*

TEST NO. 1, UNIT NO. 1.

Time.	Speed.	Actual lift.	Discharge.		Remarks.
	R. p. m.	*Feet.*	*Sec.-ft.*	*G. p. m.*	
3.50	190	4.3	102.8	46,200	Fuel, distillate of 43.25° Baumé; from 3:49 p. m. to 4:49 p. m., 95.25 pounds of fuel used.
4.05	184	....	100.0	44,860	
4.20	188	4.4	99.8	44,700	
4.35	187	....	98.2	44,100	
Mean	187.2	4.35	100.1	44,965	



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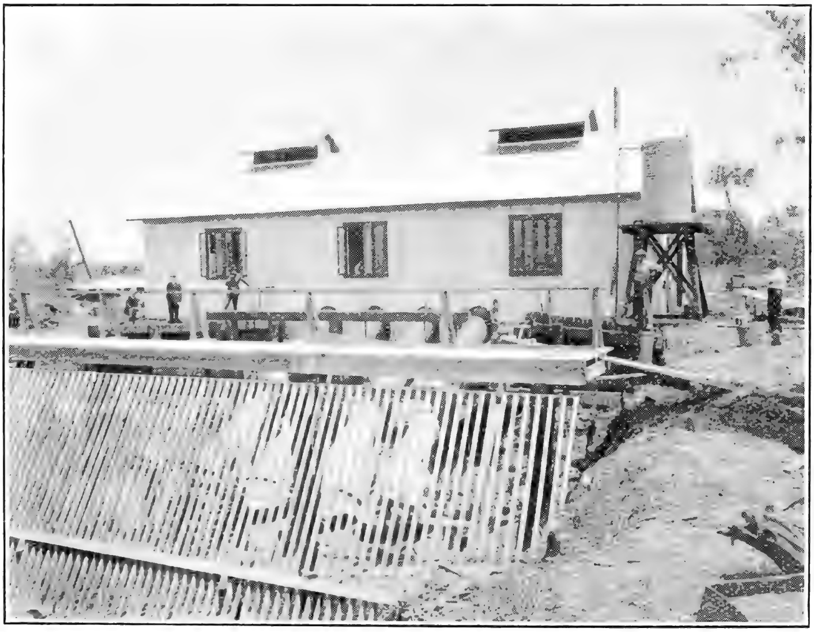

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INTERIOR AND EXTERIOR VIEWS OF PUMPING PLANT, SUBDISTRICT NO. 4, JEFFERSON DRAINAGE DISTRICT NO 4, JEFFERSON PARISH, LA.

TABLE 24.—*Tests of pumping plant in subdistrict No. 1, Lafourche drainage district No. 20, June 18–22, 1917*—Continued.

TEST NO. 2, UNIT NO. 2.

Time.	Speed.	Actual lift.	Discharge.		Remarks.
	R.p.m.	*Feet.*	*Sec.-ft.*	*G.p.m.*	
2.40	184	5.00	94.0	42,200	From 3.16½ p. m. to 4.16½ p. m., 98.25 pounds of fuel used.
3.00	185	5.15	94.1	42,240	
3.20	190	5.25	96.0	43,100	
3.40	191	5.35	96.2	43,200	
4.00	190	5.45	96.2	43,200	
4.20	190	5.55	....	....	
Mean	188.3	5.29	95.3	42,788	

TEST NO. 3, UNIT NO. 2.

Time.	Speed.	Actual lift.	Discharge.		Remarks.
12.15	190	5.54	94.0	42,220	From 12:07:40 p. m. to 1:42 p. m., 153.7 pounds=97.8 pounds per hour of fuel used.
12.35	190	5.60	97.9	43,950	
12.55	189	5.74	93.7	42,100	
1.25	188	5.84	90.1	40,460	
1.35	190	6.07	96.0	43,100	
Mean	189.4	5.79	94.4	42,366	

SUMMARY.

Test.	Mean actual lift.	Mean speed.	Mean discharge.		Oil per hour.	Water per pound of oil.	Water per gallon of oil.[1]
	Feet.	*R.p.m.*	*Sec.-ft.*	*G.p.m.*	*Pounds.*	*Cubic feet.*	*Cubic feet.*
1	4.35	187.2	100.1	44,965	95.25	3,790	26,630
2	5.29	188.3	95.3	42,788	98.25	3,700	26,000
3	5.79	189.4	94.4	42,366	97.80	3,480	24,460

[1] Based on 36° oil=7.03 pounds per gallon.

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 1, LAFOURCHE DRAINAGE DISTRICT NO. 12, RACELAND, LA.

DESCRIPTION OF PLANT.

This plant was designed to pump water from 835 acres. It consists of duplicate pumping units, each having a 24-inch double-suction centrifugal pump connected by means of a clutch to a 14.5 by 21 inch 4-cycle engine. The suction openings on the pumps are 18 inches in diameter. The intake and suction pipes have been tapered and enlarged so that the area of the intake and the area of the discharge are considerably greater than the area of the discharge nozzle of the pump. Engine ignition is by means of a hot bulb at the end of the cylinder. Oil is forced into the combustion chamber by means of a pump, and an overflow is arranged so that if the supply is too great the oil will flow back to a tank located in the foundation of the building.

The average lift of the pumps is approximately 3 feet and the greatest lift about 6 feet. The usual variation of the water level on the discharge side is 2 feet. The suction and discharge pipes are each about 25 feet long, and the main shaft of the pump is about 3 feet above average water level in the discharge canal.

METHOD OF CONDUCTING THE TEST.

Two tests were run on this plant. In the first the discharge of the pumps was measured by Pitot tubes placed in the discharge pipes at a distance of about 10 feet from the pumps. This proved to be so close to the pump that eddy currents interfered with the proper working of the tubes. The results for the quantity of water pumped during the test were found to be too erratic to be of value. A week later the test was run again on one unit with the Pitot tubes placed in the suction pipes. The readings taken on the suction side were very consistent. The lift used in computing the water horsepower was obtained by reading gages set in the suction and discharge canals. The fuel oil used in the engines, a distillate oil of specific gravity 0.875 at 72° F., was weighed in buckets by means of a spring balance.

In the first test the indicated horsepower of the engine was measured by an indicator using a 250 spring. In the second an 80 spring was used with entire success. From 10 to 20 complete cycles were taken on each card and the several areas were averaged. While the results of the first test of the pumps are of no value, the results of the test of the engine compare very well with the results of the second test and are considered of value. Table 25 is a summary of the first engine test.

TABLE 25.

	Unit No. 1.	Unit No. 2.
Length of run, hours	4	4
Revolutions per minute, average	204	211
Average indicated horsepower	32.6	41.6
Minimum indicated horsepower	26.4	28.4
Revolutions per minute at minimum indicated horsepower	193	183
Maximum indicated horsepower	37.7	50.6
Revolutions per minute at maximum indicated horsepower	213	221
Total pounds of fuel oil Nos. 1 and 2	219.2	
Pounds of fuel oil per indicated horsepower-hour	.74	
Pounds per brake horsepower (assuming mechanical efficiency of 80 per cent)	.92	

During the second test on unit No. 1 the speed of the engine was somewhat less than in the previous test, and the engine seemed to be working much more smoothly. The results of the test are given in Table 26.

TABLE 26.—*Test of pumping plant in subdistrict No. 1 of Lafourche drainage district No. 12, Raceland, La., Nov. 22, 1913.*

Time.	Speed.	Indicated horsepower.	Actual lift.	Discharge.		Water horsepower.	Efficiency.[1]		Fuel used per one-half hour.
							1	2	
	R. p. m.		*Feet.*	*Sec.-ft.*	*G. p. m.*		*Per cent.*	*Per cent.*	*Pounds.*
8.45	205	31.4	2.18	36.44	16,370	8.97	28.6	35.7	....
9.15	206	34.0	2.25	35.78	16,060	9.14	26.9	33.6	11.00
9.45	201	32.2	2.47	34.49	15,445	9.60	29.8	37.2	10.44
10.15	206	33.8	2.73	34.36	15,430	10.45	31.6	39.5	20.31
10.45	204	34.1	3.05	33.62	15,100	11.70	34.3	42.8	10.56
11.15	205	34.5	3.29	33.15	14,885	12.41	35.0	43.7	13.75
11.45	210	34.5	3.54	33.64	15,110	13.52	39.2	49.0	13.62
12.15	212	35.4	3.82	32.82	14,740	14.22	40.3	50.5	13.00
12.45	215	35.9	4.12	31.46	14,120	14.65	40.8	51.0	12.87
Mean	207	34.0	3.05	33.97	15,245	11.52	34.1	42.6	13.19

[1] Efficiency: (1) Efficiency of pump, piping, and engine. (2) Efficiency of pump and piping, assuming mechanical efficiency of engine to be 80 per cent.

TEST OF PUMPING PLANT IN SUBDISTRICT NO. 2 OF LAFOURCHE DRAINAGE DISTRICT NO. 12, RACELAND, LA.

This pumping plant contains two units similar to those at Raceland subdistrict No. 1 and similar methods of testing were used. The pumps and accessories are practically the same, but the engines, while of the same type and make as those in the previously described plant, have a cylinder diameter of 15 inches with 24-inch stroke. The pumps are 24-inch drainage pumps of the centrifugal type. The behavior of the engine in this test was doubtless affected by the presence of some Mexican crude oil which had been put in the tank more than a year before.

The indicator cards, when taken for several cycles, showed two different areas: One area was the regular card, while the other showed a rise in the compression line earlier than in the large card and no great increase of pressure at the end of compression, but a gradual rise of pressure as expansion proceeded until at exhaust opening the pressure was about the same as for the large card. There was no accurate way to determine how often either of these cards occurred. The evidence from a great many cards showed that the numbers of large and small cards were about equal, but this was too uncertain to make the indicated horsepower reliable enough to compute pump efficiency. Owing to the behavior of the engine the speed of pump was quite variable. Table 27 gives the results obtained.

TABLE 27.—*Test of pumping plant in subdistrict No. 2 of Lafourche drainage district No. 12, Raceland, La., Apr. 19, 1915.*[1]

Time.	Speed.	Actual lift.	Discharge.		Water horse-power.
	R. p. m.	*Feet.*	*Sec.-ft.*	*G. p. m.*	
9.15	198	3.67	29.44	13,210	12.24
9.45	198	3.81	26.08	11,720	11.27
10.15	200	3.98	31.17	14,000	14.05
10.45	200	4.14	23.11	10,420	10.83
11.15	198	4.34	29.42	13,230	14.48
11.45	200	4.49	22.53	10,110	11.45
Average	199	4.07	26.96	12,100	12.46

[1] Fuel-oil consumption, 23.4 pounds per hour.

TEST OF JAMISON RELIFT PLANT OF THE LOUISIANA IRRIGATION & MILL CO., CROWLEY, LA.

This pumping plant contains two units, each consisting of a 60-horsepower Muncie engine direct-connected to a 36-inch centrifugal pump. The pumps are primed by small vacuum pump run from the engines. A small compressor and a gasoline engine are used to fill the air tanks for starting the engines. Although used for irrigation, this pumping plant does not differ in any way from plants used for drainage.

Tests were run on both units of the plant. The results are given in Table 28. The quantity of water pumped was measured by a current meter in a carefully constructed flume in the suction canal. The lift was determined by means of gages set in suction and discharge canals. Fuel oil was accurately weighed by a spring balance.

TABLE 28.—*Tests of Jamison relift pumping plant of Louisiana Irrigation & Mill Co., Crowley, La., May 18–19, 1917.*

Time.	Speed.	Actual lift.	Discharge.		Remarks.
	R. p. m.	*Feet.*	*Sec.-ft.*	*G. p. m.*	
3.00	259	3.57	51.9	23,300	In the first hour 31.44 pounds of oil were consumed. The number of gallons pumped per pound of oil was 43,940; total oil consumption 54.06 pounds.
3.15	261	3.54	51.7	23,200	
3.30	256	3.52	49.9	22,400	
3.45	256	3.50	51.7	23,200	
4.00	256	3.52	50.8	22,800	
4.15	256	3.51	50.1	22,500	
4.30	256	3.53	50.2	22,550	
Average	257	3.53	50.9	22,855	
9.00	255	2.04	52.3	23,500	The total consumption of oil was 29.81 pounds per hour; gallons pumped per pound, 47,750.
9.15	255	2.03	53.5	24,000	
9.30	256	2.01	53.2	23,900	
9.45	255	1.99	52.3	23,500	
Average	255.2	2.03	52.8	23,725	
1.45	258	2.20	49.5	22,200	Consumption of oil, 32.87 pounds per hour; gallons pumped per pound, 40,200.
2.00	257	2.13	49.3	22,100	
2.15	256	2.10	48.3	21,700	
Average	257	2.14	49.0	22,000	

TESTS OF THE FERRE, HINE'S, AND RICHARD RELIFT PUMPING PLANTS OF THE LOUISIANA IRRIGATION & MILL CO., CROWLEY, LA.

During the summer of 1919 the Louisiana Irrigation & Mill Co. installed several pumping units in relift plants. Tests were made to determine the performance of these pumping units, with results as shown in Tables 29, 30, and 31. The equipment in each plant consisted of duplicate units made up of 60-horsepower internal-combustion engines direct-connected to 24-inch centrifugal pumps.

TABLE 29.—*Test of Ferre relift pumping plant, Grand Canal, July 9, 1919.*

[60-horsepower Ingeco engines direct-connected to 24-inch Worthington pumps.]

Time.	Speed of pump.	Actual lift.	Minutes required to use 12 pounds. of oil.	Discharge.	
South unit:	*R. p. m.*	*Feet.*		*Sec.-ft.*	*G. p. m.*
9.50	238.0	3.99	....	45.00	20,200
10.10	238.5	4.00	....	45.90	20,600
10.30	236.0	4.04	21.0	45.62	20,480
10.50	241.0	4.06	21.0	45.12	20,250
11.10	240.0	4.06	20.5	45.12	20,250
11.30	241.5	4.08	20.5	41.98	18,850
11.50	243.5	4.08	20.0	42.40	19,030
Average	239.9	4.04	20.6	44.60	20,080
North unit:					
2.50	233.0	4.40	20.5	44.59	20,000
3.10	228.0	4.39	22.5	45.00	20,200
3.30	231.5	4.38	22.5	41.65	18,700
3.50	236.0	4.35	22.5	43.22	19,400
4.10	231.0	4.33	22.5	42.12	18,900
4.30	231.5	4.33	22.5	42.21	18,950
4.50	233.5	4.33	22.0	44.10	19,800
Average	232.1	4.36	22.1	43.28	19,420
Oil corrected for drip	....	....	22.6	....	....

TABLE 30.—*Test of Hine's relift pumping plant, Grand Canal, July 12, 1919.*

[60-horsepower Bessemer engine belted to 24-inch Lawrence pump.]

Time.	Speed.		Actual lift.	Minutes required to use 12 pounds of oil.	Discharge.	
	Engine.	Pump.				
	R. p. m.	*R. p. m.*	*Feet.*		*Sec.-ft.*	*G. p. m.*
4.00	222.0	167.5	7.38	30		
4.15	217.0	166.0	7.37	....		
4.30	217.0	166.0	7.33	....	18.24	8,190
4.45	217.0	167.0	7.33	30		
5.00	220.0	169.0	7.33	....	....	....
5.15	255.0	193.0	8.33	19		
5.30	256.0	198.5	8.37	....		
5.45	255.5	199.0	8.40	18	27.18	12,200
6.00	256.0	198.0	8.41	....		
6.15	260.0	198.5	8.43	18		

TABLE 31.—*Test of Richard relift pumping plant, Grand Canal, July 11, 1919.*

[60-horsepower Ingeco engine direct-connected to Worthington pumps.]

Time.	Speed.		Actual lift.	Minutes required to use 12 pounds of oil.	Discharge.	
	No. 1.	No. 2.				
	R. p. m.	*R. p. m.*	*Feet.*		*Sec.-ft.*	*G. p. m.*
1.40	....	250.0	7.75	....	39.65	17,800
2.00	....	250.0	7.84	19.5	38.65	17,350
2.20	....	250.0	7.87	20.5	38.65	17,350
2.40	....	249.0	7.85	21.0	36.60	16,450
Average	....	249.7	7.83	20.33	38.38	17,237

The methods followed in testing the Ferre relift and the Richard relift were the same as those already described in the test of the Jamison relift. In making the test of the Hine's relift the quantity of water was measured by means of a weir installed at the end of the flume. As the flow was rather turbulent, the depth on the weir could not be read with great accuracy, and the results may be in error by 5 per cent. As the water was discharged vertically upward from the pump, the discharge gage could not be read as accurately as in the other test, but the readings are substantially correct and the final results satisfactory.

Fuel oil used in these plants was Jennings crude, direct from the wells. A sample from the Richard relift had specific gravity 0.8975 or 26.15° Baumé at 100° F.

DRAINAGE PUMPING PLANT AT PORT ARTHUR, TEX.

This plant was installed to drain the city of Port Arthur, an area of approximately 2,175 acres. It is not an agricultural proposition and the capacity is far in excess of that required for farm lands. The pumping plant contains three units, each consisting of a vertical 2-cylinder 100-horsepower oil engine direct-connected to a 48-inch screw pump. Two of the pumps were sold under a guaranty to deliver 40,000 gallons per minute against a 5-foot lift and 26,000 gallons per minute against an 11-foot lift. The other pump was to deliver 55,000 gallons per minute against a 5-foot lift. All operate at 257 revolutions per minute.

In the test of this plant, water measurements were made with a Pitot tube. The lift was determined by means of gages set in suction and discharge basins. Fuel oil was measured by means of a spring balance. Readings of fuel were taken at 5-minute intervals. The oil used was sold as 28° Baume, weight 7.38 pounds per gallon.

Tests were made on one high-lift and on the low-lift unit. In the course of the work of adjusting and testing the plant it was found that the blades were quite rough. When they were made smooth and sharp a marked improvement in capacity and duty was observed.

Table 32 gives the result of a test on high-lift unit No. 2 before the blades of the pump were smoothed and sharpened. Table 33 gives the results of a test after the improvements had been made. It was believed that a considerably better showing would be obtained from the low-lift pump by sharpening the impeller blades and trimming out the casing, and this work was subsequently done. The results of the test on low-lift unit No. 3 are given in Table 34.

TABLE 32.—*Test of pump No. 2 of drainage pumping plant at Port Arthur, Tex., July 23–26, 1918.*[1]

Time.	Speed.	Discharge.		Actual lift.	Fuel used.	Water pumped per gallon of fuel used.
	R. p. m.	*Sec.-ft.*	*G. p. m.*	*Feet.*	*G. p. m.*	*Gallons.*
2.56	255	89.12	40,000	4.75	....	....
3.00	255	88.68	39,800	4.95	0.139	286,000
3.05	255	88.23	39,600	5.15	.166	238,000
3.09	254	87.56	39,300	5.38	.164	239,000
3.15	254	85.56	38,400	5.60	.156	246,000
3.19	254	86.01	38,600	5.75	.163	237,000
3.23½	252	85.34	38,300	6.05	.175	219,000
3.32	252	84.00	37,700	6.68	.159	237,000
3.37	250	81.10	36,400	7.18	.180	202,000
3.45	244	78.65	35,300	8.64	.210	168,000
3.49	239	71.30	32,000	10.10	.213	150,000
3.53	237	58.87	26,200	11.34	.210	125,000

[1] This test was made W. P. Langworthy before pump blades were sharpened.

TABLE 33.—*Test of pump No. 2 of drainage pumping plant at Port Arthur, Tex., July 23–26, 1918.*[1]

Speed.	Average velocity of flow.	Discharge.		Actual lift.	Fuel used.	Water pumped per gallon of fuel used.
R. p. m.	*Ft. per sec.*	*Sec.-ft.*	*G. p. m.*	*Feet.*	*G. p. m.*	*Gallons.*
254	6.04	89.12	40,000	3.60	0.153	262,000
255	5.87	86.45	38,800	3.75	.156	249,000
253	5.89	86.67	38,900	3.88	.156	249,000
254	6.09	89.57	40,200	3.97	.151	267,000
253	5.91	87.12	39,100	4.35	.154	254,000
253	5.77	85.11	38,200	4.40	.154	248,000
253	5.82	85.78	38,500	4.48	.149	258,000
254	5.85	86.22	38,700	4.60	.149	260,000
253	5.81	86.56	38,400	4.70	.159	241,000
252	5.85	86.22	38,700	5.00	.164	236,000
252	5.70	84.00	37,700	5.18	.164	230,000
252	5.64	83.33	37,400	5.40	.166	225,000
252	5.61	82.88	37,200	5.60	.173	215,000
251	5.44	80.21	36,000	5.82	.173	208,000
249	5.53	81.55	36,600	6.45	.180	203,000
247	5.51	81.32	36,500	6.70	.180	203,000
245	5.48	80.65	36,200	7.10	.169	214,000
243	5.24	77.31	34,700	7.65	.169	205,000

[1] This test was made W. P. Langworthy after pump blades were sharpened.

TABLE 34.—*Test of pump No. 3 of drainage pumping plant at Port Arthur, Tex., made by W. P. Langworthy July 23–26, 1918.*

Time.	Speed.	Average velocity of flow.	Discharge.		Head.	Fuel used.	Water pumped per gallon of fuel used.
	R.p.m.	*Ft.per sec.*	*Sec.-ft.*	*G.p.m.*	*Feet.*	*G.p.m.*	*Gallons.*
11.28½	250	7.91	116.75	52,400	3.00	0.160	327,000
11.36	250	7.84	115.41	51,800	3.38	.157	330,000
11.51	249	7.79	114.75	51,500	3.86	.166	310,000
11.55	246	7.60	112.07	50,300	3.96	.173	291,000
11.59	246	7.51	110.51	49,600	4.06	.174	285,000
12.03	246	7.29	107.39	48,200	4.19	.178	271,000
12.07	245	7.36	108.28	48,600	4.36	.194	250,000
12.15	241	7.27	107.17	48,100	4.63	.174	276,000
12.19	243	7.28	107.39	48,200	4.76	.183	263,000
12.23	244	7.26	106.95	48,000	4.90	.184	261,000
12.27	243	7.21	106.28	47,700	5.00	.163	293,000

TEST OF DRAINAGE PUMPING PLANT IN SUB-DISTRICT NO. 4, LAFOURCHE DRAINAGE DISTRICT NO. 12, RACELAND, LA.

This plant, which drains 4,466 acres of prairie land, was installed in 1915. The machinery consists of two units, duplicates in every way except that the pumps are driven respectively by right-hand and left-hand engines. The pumps are 48-inch centrifugal drainage pumps designed for high speed and a flat power curve. The pump impellers are a combination of the screw propeller and the ordinary centrifugal pump impeller. Each pump has double-suction pipes attached to 48-inch elbows, and both suction and discharge pipes are enlarged at their outer ends. Wooden flap valves are used to cover the discharge ends while the pumps are being primed.

The pumps are driven by 2-stroke cycle Diesel engines 14½ by 24 inches, with variable speed governors. The plant is ordinarily operated between the limits of 190 to 200 revolutions, while for maximum lift of about 9 feet the speed may be increased 220 revolutions per minute.

A test of one of the units was made to determine the oil consumption for a given output of work. Observations were taken every 20 minutes on the speed, lift, suction (with manometers), pounds of oil consumed, and quantity of water pumped. The fuel used during the test was crude oil, specific gravity 0.889, or 27.4° Baumé at 60° F.

The unit tested was situated on the left-hand side of the suction canal looking upstream. The two suction pipes are labeled right and left, as one stands facing the suction canal, and therefore the right-hand suction pump is near the middle of the canal. During the test an eddy was observed in the suction basin, so disposed that water was brought to the right-hand pipe and away from the opening of the left-hand suction pipe. The effect of the eddy was clearly shown in the quantities of water measured in the two pipes, as the right-hand pipe invariably carried more water. Without doubt this condition had some effect upon the efficiency of the pump, and consequently reduced the over-all efficiency. The eddy was caused by unequal depths of water below the suction pipes and by the higher velocity near the center line of the suction canal.

RESULTS OF TEST.

The test, which extended over a period of nearly six hours, was run with a varying difference of levels in the canals, the lift increasing from 3.55 feet at the beginning of the run to 4.96 feet at the close. The speed of the pump was held uniform at 195 revolutions per minute, but the total water pumped varied with the change in actual lift, ranging from 60,050 gallons per minute at the lower lift (3.55 feet) to 54,700 gallons per minute at the higher lift (4.96 feet). The results obtained are given in Table 35.

The economy of the plant can best be realized by a comparison with the steam pumping plant in subdistrict No. 1, Gueydan drainage district, where the equipment consists of high-grade simple noncondensing Corliss engines and volute pumps. When pumping against a head of approximately 5 feet the fuel consumption of the steam plant was to that of the internal-combustion engine plant as 4.28 to 1 for equal output of work.

TABLE 35.—*Test of pumping plant in subdistrict No. 4 of Lafourche drainage district No. 12, Raceland, La., Feb. 21, 1916.*

Time.	Speed.	Actual lift.	Discharge.		Useful water horse-power.
	R. p. m.	*Feet.*	*Sec.-ft.*	*G. p. m.*	
9.40	195				
10.00	196	3.55	133.80	60,050	53.80
10.20	195	3.63	132.79	59,600	54.70
10.40	195	3.69	131.57	59,050	55.00
11.00	195	3.75	131.23	58,900	55.80
11.20	195	3.82	128.23	57,550	55.50
11.40	195	3.90	128.89	57,850	56.95
12.00	195	3.98	129.90	58,300	58.60
12.20	195	4.08	126.22	56,650	58.40
12.40	195	4.17	126.78	56,900	59.90
1.00	195	4.27	128.67	57,750	62.25
1.20	195	4.34	125.00	56,100	61.50
1.40	195	4.43	124.66	55,950	62.55
2.00	195	4.52	126.00	56,550	64.55
2.20	195	4.63	125.55	56,350	65.90
2.40	195	4.74	123.88	55,600	66.50
3.00	195	4.84	123.32	55,350	67.60
3.20	195	4.96	121.88	54,700	68.50

TEST OF DRAINAGE PUMPING PLANT OF LITTLE WOODS TRACT, NEW ORLEANS, LA.

DESCRIPTION OF PLANT.

The New Orleans Lake Shore Land Co. has reclaimed an area of 6,943 acres of prairie land, located on Lake Pontchartrain, inside the city limits of New Orleans. The pumping plant was erected during the latter part of 1913. (See Pl. II.) It consists of two centrifugal pumps, each with a discharge opening equivalent to a circle of $51\frac{3}{4}$ inches diameter, connected by means of herringbone gears to electric motors. Electric energy was used in this case because of the desirability of having the city current for use for other power and in the suburban residences. The cost of electrical energy is greater than that of steam power or that furnished by internal-combustion engines, although the first cost of the electrical plant is less than either of the other types. The plant is very economical when interest on investment and depreciation are considered together with the cost of operating.

The pumps are equipped with a combination of screw and inclosed-centrifugal impeller. They are primed by means of small exhaust pumps of the chamber-wheel type driven by small motors. Greatest capacity is had at the low lifts, where it is desirable. As the lift increases the capacity decreases, but the need of large capacity also decreases. The capacity of the plant when operating at a lift of 4.5 feet is 1.3 inches in depth removed from the area in 24 hours. The motors which drive the pumps run at practically constant speed, and therefore the revolutions of the pump remain constant regardless of lift.

METHOD OF MAKING TEST.

The height through which the water was elevated was obtained by reading gages in the suction and discharge basins. The quantity of water was determined by using a Price current meter in the discharge flume. The voltage and revolutions per minute were also observed. The results of the test are given in Table 36. It is believed that the two units under favorable conditions will show identical results.

TABLE 36.—*Test of pumping plant in Little Woods Tract, New Orleans, La., Nov. 14, 1914.*

UNIT NO. 1.

Time.	Speed.	Volts.	Actual lift.	Discharge.		Kilowatts.	Electrical horsepower.	Water horsepower.	Efficiency.
	R. p. m.		*Feet.*	*Sec.-ft.*	*G. p. m.*				*Per cent.*
10.00	119.8	2,246	5.76	173.7	77,800	174.0	233.0	113.5	48.80
10.15	121.2	2,288	5.83	176.8	79,200	174.9	234.2	116.8	49.75
10.30	120.7	2,300	5.85	177.9	79,700	174.8	234.2	118.0	50.35
10.45	120.7	2,298	5.85	175.5	78,600	175.1	234.6	116.2	49.50
11.00	121.2	2,298	5.87	173.7	77,800	175.0	234.5	115.5	49.25
11.15	121.4	2,304	5.91	172.1	77,100	178.0	238.5	115.3	48.35
3.15	120.8	2,320	6.29	171.0	76,600	174.4	233.7	121.8	52.10
3.30	120.5	2,320	6.39	169.2	75,800	172.6	231.3	122.7	53.10
3.45	120.7	2,320	6.41	170.2	76,200	171.6	230.0	123.5	53.70
4.00	121.1	2,320	6.44	168.1	75,300	173.4	232.3	122.6	52.75
4.15	121.0	2,316	6.46	166.3	74,500	171.0	229.1	121.6	53.10
4.30	120.7	2,320	6.54	167.4	75,000	166.4	223.0	124.1	55.70
Mean	120.8	2,304	6.13	171.4	76,960	173.4	232.4	117.6	51.37

UNIT NO. 2.[1]

Time.	Speed.	Volts.	Actual lift.	Discharge (Sec.-ft.)	Discharge (G. p. m.)	Kilowatts.	Electrical horsepower.	Water horsepower.	Efficiency.
1.15	120.4	2,300	6.10	170.2	76,200	176.5	236.5	117.5	49.7
1.30	121.1	2,308	6.14	171.5	76,800	178.0	238.5	119.3	50.0
1.45	120.8	2,310	6.15	171.2	76,700	176.1	236.0	119.2	50.5
2.00	121.0	2,310	6.20	167.0	74,800	174.0	233.0	117.3	50.4
2.15	120.8	2,320	6.25	169.2	75,800	173.0	231.8	120.0	50.47
Mean	120.8	2,310	6.15	169.8	76,060	175.5	235.2	118.7	50.47

[1] A mud lump was found in suction basin under one suction pipe.

The test showed an average efficiency at 6-foot lift of 50.55 per cent. At a lift of 6.32 feet and while pumping more than 76,000 gallons per minute the guaranteed efficiency of $52\frac{1}{2}$ per cent was attained.

TESTS OF 12-FOOT WOOD SCREW PUMP, NEW ORLEANS DRAINAGE SYSTEM.

The drainage of New Orleans and the sanitary sewers are separate systems. The area drained amounts to 25,000 acres, or a little more than 39 square miles. The capacity of pumping plants for drainage will eventually be equal to 7.33 inches of run-off removed in 24 hours. The pumping units include eleven 12-foot screw pumps. (See fig. 4.)

Tests were made of one of the 12-foot Wood screw pumps at New Orleans pumping plant No. 1, on November 17, 1916, and January

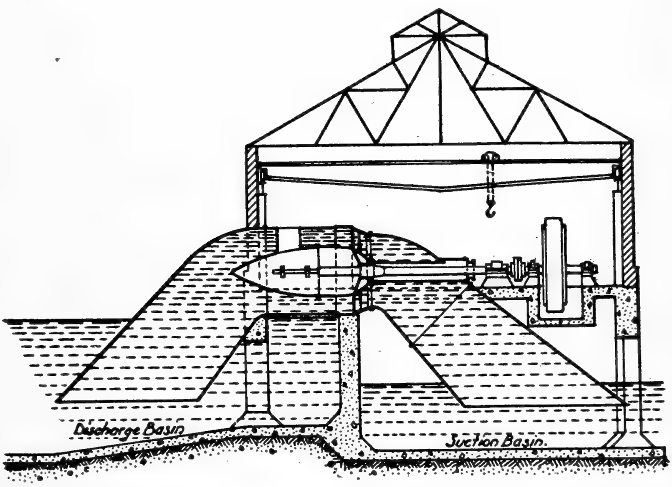


FIG. 4.—Section through 12-foot screw pump, New Orleans drainage pumping plant.

17, 1917. In the test of November 17 the flume was divided into 10 equal areas. As the bottom was V-shaped the width of these sections was greatest at the sides of the flume and least near the middle. Velocities were observed at 0.2, 0.6, and 0.8 depth in each area, and the mean velocity for an area was taken to be the mean of the three velocities observed. The sum of the 10 separate areas multiplied each by its mean velocity gave the total discharge and this divided by the total area gave the mean velocity.

In the test on January 17, 1917, observations were taken of velocity at the same sections as in the previous test but at one-sixth, five-tenths, and five-sixths depth. The mean of three readings was used as the mean velocity of the vertical section, and the total discharge was obtained by summing up the discharges of the separate sections. Table 37 gives the results of the tests.

TABLE 37.—*Tests of 12-foot Wood screw drainage pump at New Orleans pumping station No. 1, Nov. 17, 1917.*

TEST OF NOV. 17, 1916.

No.	Speed.	Quantity pumped. Measured in flume.	Leakage to Broad Street Canal.	Leakage through station.	Correction for storage in canal.	Correction for storage in discharge basin.	Corrected quantity.	Lift.	Water horsepower.	Measured electrical horsepower.	Measured E. H. P. ×0.94 = H. P. input to pump.	Efficiency pump.
	R.p.m.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*		*Feet.*				*P. ct.*
1...	73.7	457.84	1.74	3.26	21.18	−0.90	482.92	7.59	416.0	585.86	551.0	75.45
2...	74.1	475.73	1.74	3.74	11.45	−4.70	487.96	7.48	414.5	586.77	552.0	75.1
3...	74.1	481.54	1.74	4.35	6.96	−4.34	490.25	7.415	412.5	582.52	547.5	75.3
Av.	74.0	471.70	1.74	3.78	13.20	−3.31	487.11	7.495	413.9	585.03	550.2	75.23

TEST OF JAN. 17, 1917.

No.	Speed.	Measured in flume.	Leakage to Broad Street Canal.	Leakage through station.	Correction for storage in canal.	Correction for storage in discharge basin.	Corrected quantity.	Lift.	Water horsepower.	Measured electrical horsepower.	Measured E. H. P. ×0.94 = H. P. input to pump.	Efficiency pump.
1...	75.75	491.35	2.82	2.17	18.25	−0.28	514.31	7.37	430.0	608.5	572.5	75.0
1A.	75.8	488.80	2.82	2.54	15.51	−1.45	508.22	7.41	428.0	610.0	573.5	74.6
2...	76.05	513.10	2.82	3.85	7.85	−3.49	524.13	7.55	448.5	617.0	580.5	77.3
Av.	75.9	497.75	2.82	2.85	13.87	−1.74	515.55	7.44	434.6	611.8	575.5	75.51

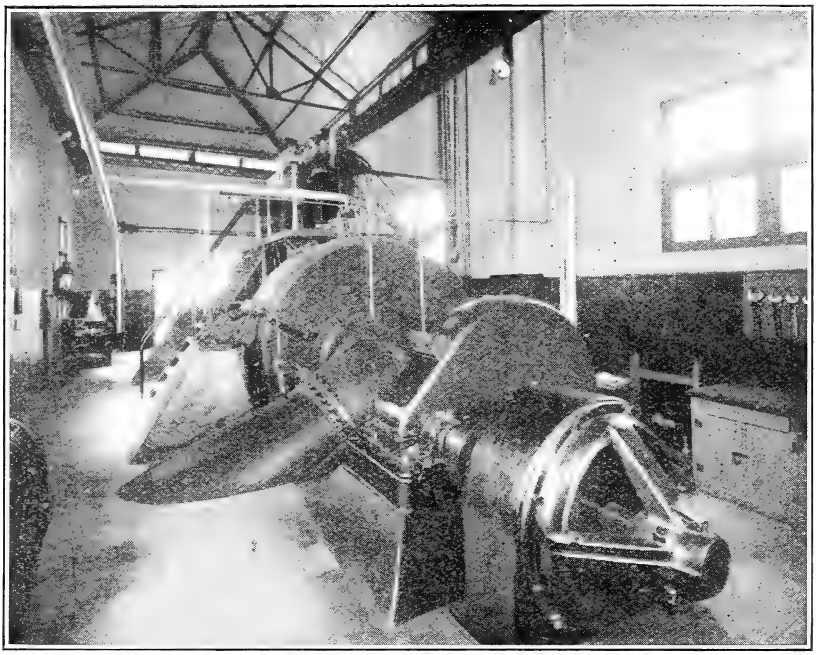
Before each of these tests it was necessary to allow the water to accumulate for about a week, and as the weather was dry the water became rather foul; it carried trash and organic matter which appeared to give off gas.

The lift, or difference of level on suction and discharge sides of pump, was approximately 7.5 feet for all these tests, which is the lift for which the pump was designed. The results obtained from the tests show the efficiency of the pump to be about 75.5 per cent. This is less than was shown by the official test of 1915, when for a lift of 7.15 feet the efficiency of pump was approximately 79 per cent. It is possible that the foulness of the water affected the results to some extent. The efficiency obtained is good in any event.

COST OF OPERATION OF PLANTS.

Information regarding the various pumping plants tested, as well as for some others for which data have been obtained from reliable sources, has been arranged in tabular form (Table 38) and in graphic form (in figs. 5, 6, 7, 8, and 9). All but plants Nos. 19 and 21 have centrifugal pumps. The impellers of the pumps in plants Nos. 8, 9, 10, 11, 12, 20, and 22 (see Table 38) are a combination of the screw and centrifugal principles. Nos. 19 and 21 are screw pumps.

Plants Nos. 1, 2, and 3 are medium-grade steam plants having slide valve noncondensing engines. Plants Nos. 4 and 5 have Corliss noncondensing engines. The former was not tested under the most favorable conditions, while the latter was; No. 5 has a much more elaborate pump than No. 4. Plant No. 6 has a cross-



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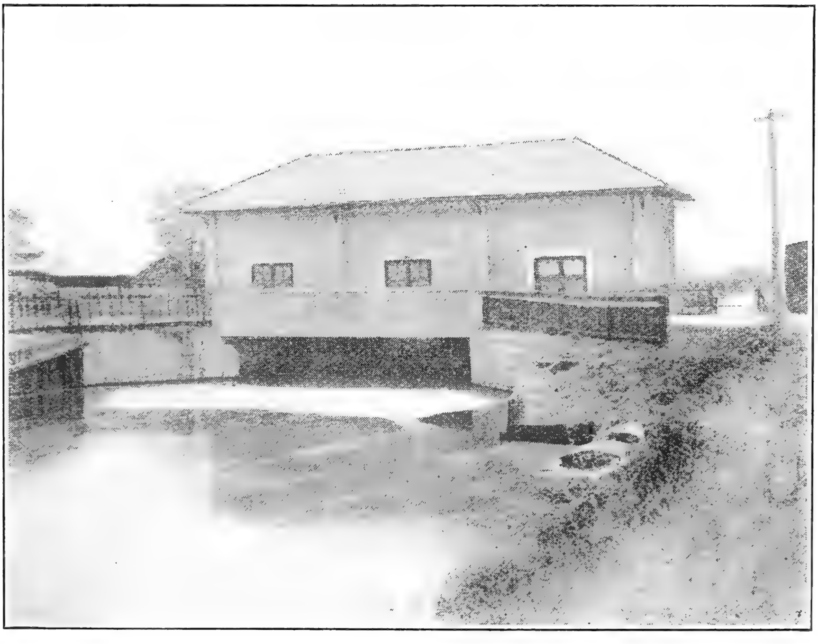

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INTERIOR AND EXTERIOR VIEWS OF PUMPING PLANT, LITTLE WOODS TRACT, NEW ORLEANS, LA.

compound condensing Corliss engine. Plant No. 7 has a compound condensing poppet-valve engine using superheated steam. Plants Nos. 8, 9, 10, 11, and 12 are alike in having internal-combustion engines. No. 9 uses kerosene as fuel, while the others may use distillate or kerosene. They are all 4-cycle engines. Plants Nos. 13

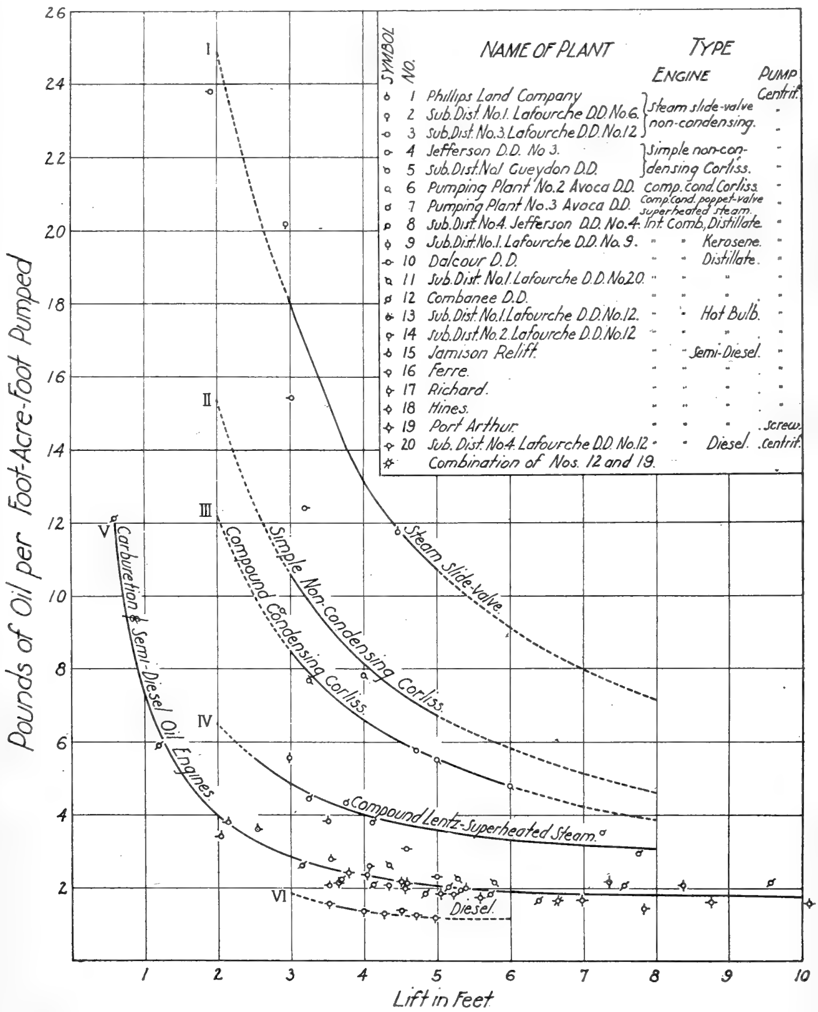

FIG. 5.—Pounds of oil required by different types of engines to pump against various lifts.

and 14 have hot-bulb ignition and operate on the 4-stroke cycle; they use a fairly low grade of fuel oil. Plants Nos. 15, 16, 17, 18, and 19 have 2-cycle oil engines with hot-bulb ignition. Plant No. 20 has 2-cycle Diesel engines using a low grade of fuel oil. Plants Nos. 21 and 22 are electrically driven.

TABLE 38.—*Costs of operating drainage pumping plants of various types in Louisiana, South Carolina, and Texas (interest and depreciation not considered).*

No.	Name of plant.	State.	Area drained.	Plant capacity. Basis 10 second-feet nozzle velocity.		Plant capacity. From test at 5-foot lift.		Area from which plant will remove 1.25 inches per day.[2]	Assumed cost of oil per gallon.	Yearly cost of operation. Fuel to lift 29 acre-inches 5 feet	Fuel for starting, lubricating oil, and supplies.	Total fuel and supplies.	Labor.	Total yearly cost of operation.	Yearly cost per acre.[1] Total fuel and supplies.	Total fuel, supplies, and labor.
			Acres.	*Sec.-ft.*	*Acre-in. per day.*	*Sec.-ft.*	*Acre-in. per day.*	*Acres.*	*Cents.*							
1	Phillips Land Co.	Louisiana	2,500	102.1	0.97	108.0	1.03	2,060	3.5	$1,288	$321	$1,609	$1,320	$2,929	$0.78	$1.42
2	Subdistrict No. 1, Lafourche drainage district No. 6.	do	1,880	62.8	.80	52.0	.66	990	3.5	617	155	772	1,320	2,092	.78	2.11
3	Subdistrict No. 3, Lafourche drainage district No. 12.	do	2,250	98.2	1.04	78.0	.83	1,480	3.5	924	231	1,155	1,320	2,475	.78	1.67
4	Jefferson drainage district No. 3.	do	5,000	251.4	1.20	238.0	1.13	4,530	3.5	1,775	445	2,220	1,740	3,960	.49	.87
5	Subdistrict No. 1, Gueydan drainage district.	do	7,500	318.0	1.01	365.0	1.16	6,950	3.5	2,725	680	3,405	1,740	5,145	.49	.74
6	Subdistrict No. 2, Avoca drainage district.	do	4,350	125.7	.69	127.7	.70	2,420	3.5	774	194	968	2,220	3,188	.40	1.32
7	Subdistrict No. 3, Avoca drainage district.	do	11,250	282.7	.60	256.0	.54	4,870	3.5	1,052	236	1,315	2,220	3,535	.27	.73
8	Subdistrict No. 4, Jefferson drainage district No. 4.	do	1,800	98.2	1.30	91.0	1.20	1,730	9.0	540	135	675	1,500	2,175	.39	1.26
9	Subdistrict No. 1, Lafourche drainage district No. 9.	do	1,760	98.2	1.33	[3] 39.2	.52	747	9.0	233	58	291	1,500	1,791	.39	2.40
10	Dalcour drainage district	do	[1] 650													
11	Subdistrict No. 1, Lafourche drainage district No. 20.	do	2,460	141.4	1.36	192.0	1.86	3,650	9.0	1,140	286	1,426	1,500	2,926	.39	.80
12	Combahee drainage district.	South Carolina.	1,950	80.5	.98	79.4	.97	1,512	9.0	472	118	590	1,500	2,090	.39	1.38
13	Subdistrict No. 1, Lafourche drainage district No. 12.	Louisiana	835	62.8	1.79	59.0	1.68	1,123	6.5	252	63	315	1,500	1,815	.28	1.61

14	Subdistrict No. 2, Lafourche drainage district.	do	940	62.8	1.59	[3] 42.0	1.06	800	6.5	179	45	224	1,500	1,724	.28	2.16
	Louisiana Irrigation & Mill Co.[5]															
15	Jamison relift[5]	do	....	141.4	....	71.4	....	1,350	6.5	302	76	378	1,500	1,878	.28	1.39
16	Ferre relift[5]	do	....	62.8	....	84.7	....	1,613	6.5	362	90	452	1,500	1,952	.28	1.21
17	Richard relift[5]	do	....	62.8	....	120.0	....	2,286	6.5	512	128	640	1,500	2,140	.28	.94
18	Hine's relift[5]	do	....	31.4	....	45.6	....	870	6.5	195	49	244	1,500	1,744	.28	2.01
19	Port Arthur	Texas	2,175	....	....	281.6	....	5,360	6.5	1,200	300	1,500	1,500	3,000	.28	.56
20	Subdistrict No. 4, Lafourche drainage district No. 12.	Louisiana	4,240	251.4	1.41	243.0	1.37	4,630	3.5	334	83	417	1,500	1,917	.09	.41
21	Station No. 1, New Orleans.	do	....	....	....	....	....	....	....	....	....	....	....	....	....	....
22	Little Woods tract	do	6,943	292.0	1.00	364.0	1.25	6,940	....	....	....	....	....	....	....	....

[1] Based on acreage from which plant will remove 1.25 inches in 24 hours.
[2] Quantities from tests.
[3] Weeds in pump; see test.
[4] Plant incomplete.
[5] Low-lift irrigation plants.

Plant capacity was rated on a velocity of 10 feet per second at the discharge flange of pump. The capacities of the various plants as shown by the test are also included. The capacity of plant in acres drained was next computed on the basis of 1.25 inch removed in 24 hours.

In selecting engines a limit is set by the size of engines of certain types. Slide-valve steam engines may be had in almost any size or capacity, while Corliss engines are not made in small sizes. It would therefore be impracticable to decide to use a Corliss engine on a proposition so small as to demand special design.

Distillate and oil engines of medium grade are not made by some firms in sizes above 100 to 125 horsepower. To use an internal-combustion engine in a pumping plant of large capacity with correspondingly large units would mean the selection of a Diesel or a semi-Diesel engine, both high-grade engines, costing considerable more per horsepower than the medium-grade engines using distillate.

The original costs of pumping plants and the years they were purchased are shown in Table 39. In using the data contained in this table, however, it must be borne in mind that prices of all materials and equipment of pumping plants have advanced materially. The average plant would probably now (1920) cost as much as 75 to 100 per cent more than before the war.

TABLE 39.—*Costs of pumping plants.*

Name of plant.	Acres.	Cost.	Cost per acre.	Year constructed.
Phillips Land Co.	2,500	$15,000	$6.00	1911
Subdistrict No. 1, Lafourche drainage district No. 6	1,880	10,000	5.32	1912
Subdistrict No. 3, Lafourche drainage district No. 12	2,250	13,500	6.00	1910
Jefferson drainage district No. 3	5,000	28,000	5.60	1912
Subdistrict No. 1, Gueydan drainage district	7,500	40,000	5.32	1912
Subdistrict No. 2, Avoca drainage district	4,350	34,000	7.81	1911
Subdistrict No. 3, Avoca drainage district	11,250	73,000	6.48	1913
Subdistrict No. 4, Jefferson drainage district No. 4	1,800	18,000	10.00	1915
Fayport subdistrict No. 1, Lafourche drainage district No. 9	2,000	14,000	7.00	
Dalcour drainage district	650	10,000	[1] 15.40	1913
Subdistrict No. 1 Lafourche drainage district No. 12	835	10,500	12.57	1915
Subdistrict No. 2 Lafourche drainage district No. 12	940	12,500	13.30	1915
Subdistrict No. 4 Lafourche drainage district No. 12	4,240	31,500	7.42	1913
Little Woods tract	6,943	37,500	5.39	1913
Port Arthur	5,720	54,290	[2] 9.50	1918
Ferre relift		20,000		1918
Richhard relift		15,000		1918
Hine's relift		8,000		1918

[1] Acreage will be considerably increased later.
[2] Plant costs more than it would for an agricultural proposition, as two units must lift water 11 feet i occasion demands it.

GRAPHIC SUMMARY.

Figure 5 shows the pounds of oil per foot-acre-foot of water pumped, plotted against the lift in feet. The several curves represent different types of plant. While, in some instances the data were sufficient to define the curve accurately, in others the exact definition was a matter of judgment. The amount of fuel shown is for normal plant operations and does not include the 25 per cent allowance for starting and lubricating oils. The accuracy of the work is limited by the amount of data available.

It will be noted that curve II does not pass through the point plotted for Jefferson drainage district No. 3 nor through point for subdistrict No. 1, Gueydan drainage district, but is drawn between them to give probable results for an average plant of this type. It must be remembered that the test of the former plant showed greatly unbalanced quantities passing through the two suction pipes. The engines are rather large for the pumps, and this doubtless has a material effect on economy. On the other hand, the Gueydan pumps are volute pumps of much more elaborate design than the drainage pumps of Jefferson drainage district No. 3. The pumps were large and the velocities of water through them comparatively slow; all these factors made for lower fuel rate.

Figure 6 shows the cost per year of pumping 29 acre-inches against various lifts, as obtained from the curves of figure 5. For the average drainage proposition discussed in this report the lift for the first two or three years is approximately 3 feet; later, when a part of the humus disappears and deeper drainage is desired, the lift is increased to 5 feet or more. The general range of lift was from 2 to 8 feet.

In all the tests recorded oil was used as fuel. In order to make a comparison of cost it is necessary to consider the kind of oil used in the different plants. The steam plants and the Diesel-engine plant No. 20 (fig. 5), either used or could use Mexican crude or some low grade of fuel oil. Prices of fuel oil have fluctuated considerably during the last seven years. During 1919 and 1920 the price of oil delivered at New Orleans has ranged from about 75 cents to $3.50 per barrel. The prices of distillates and kerosene have shown variations that make it impossible to arrive at a probable cost for the future because of the great instability of prices.

The average price of the lower grade of fuel oil delivered at the pumping plant for the years 1912–1917 was about $1.10 per barrel of 42 gallons. For hot-bulb engines of the semi-Diesel type a higher grade of crude oil is required. The price for this oil delivered at pumping plants for the same period ranged from $1.40 to $1.80, with the average about $1.60.

Some internal-combustion engines, such as those in plants No. 8 and No. 10, are supposed to use a distillate of low grade, costing about the same as the fuel oil used in the semi-Diesel engines. In some instances distillate has been mixed with kerosene to make a more satisfactory fuel. Plants Nos. 8 and 10 may be operated in this way. Plant No. 9 uses kerosene. The cost of distillate delivered at pumping plants in the period 1912–1917 has been about 4 cents per gallon or $1.68 per barrel, while kerosene has cost about 7½ cents per gallon or $3.15 per barrel. Possibly kerosene in tank-car lots was purchased at a lower figure, but many plants have

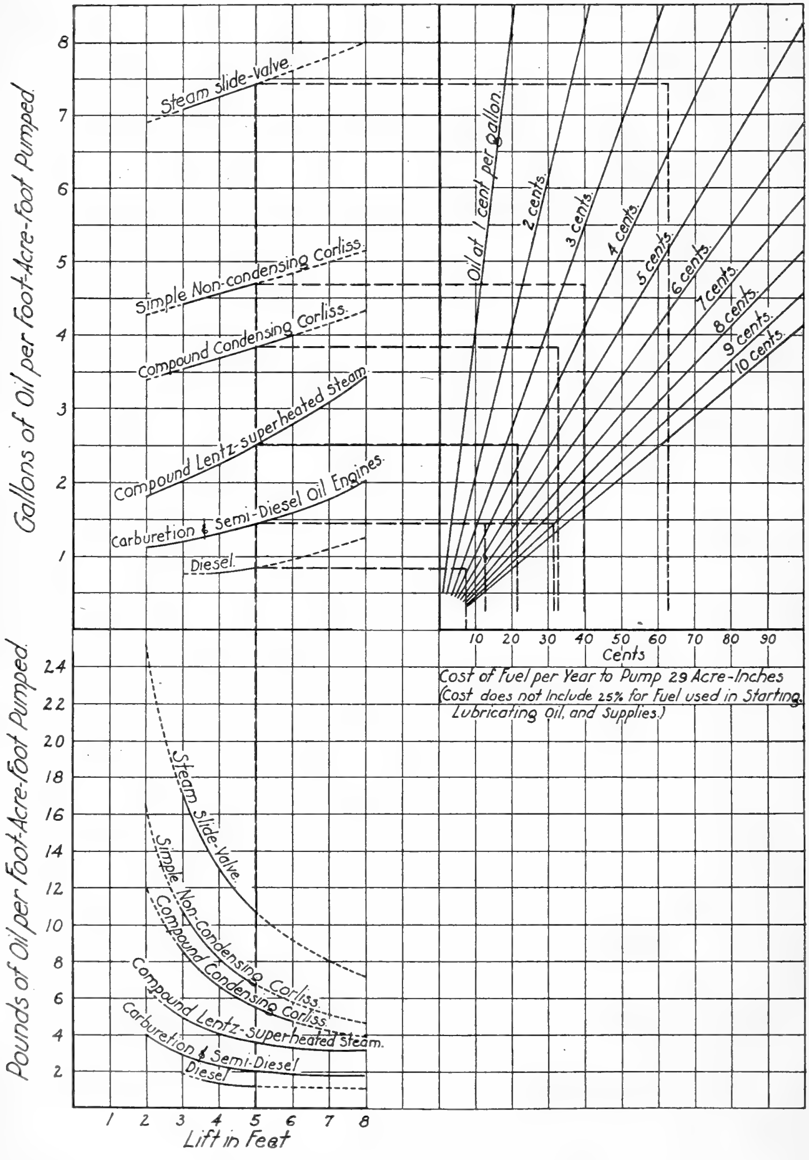

FIG. 6.—Cost of fuel oil to pump 29 acre-inches.

limited storage capacity and fuel is purchased in smaller quantities.

The cost of fuel has been assumed to be as shown in Table 40.

TABLE 40.

	Per gallon.	Per barrel of 42 gallons.
Low-grade fuel oil	$0.035	$1.47
Better grade fuel oil (distillate)	.065	2.73
Kerosene	.090	3.78

An allowance has been made for fuel used in starting, lubricating oil, and supplies, amounting to 25 per cent of the assumed cost of fuel oil. While the prices of fuel oils are so unstable these assumed prices

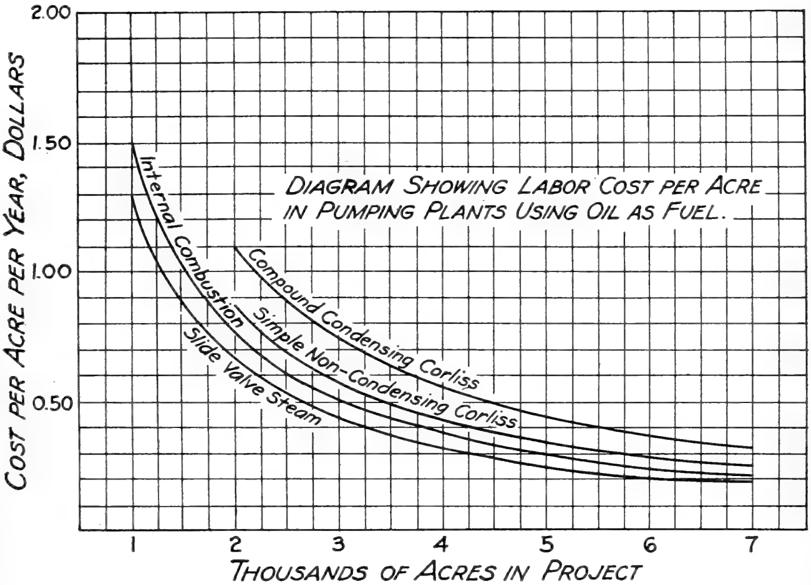

FIG. 7.—Labor cost per acre in pumping plants using oil as fuel.

are probably as good as any others. Figure 6 has been arranged with oil prices varying from 1 cent to 10 cents per gallon, so that corrections may easily be made for changes in fuel costs.

Figure 7 shows the labor costs per acre per year for pumping plants. The basis on which they were computed is shown in Table 41.

TABLE 41.

Type of plant.	Engineers, per month.	Assistants, per month.	Total, per month.
Simple noncondensing steam	$70.00	$40.00	$110.00
Simple Corliss	85.00	60.00	145.00
Compound condensing Corliss	110.00	75.00	185.00
Internal combustion	75.00	50.00	125.00
Electric	75.00	50.00	125.00

The above wages are approximately 25 per cent greater than those paid in 1917. In considering the above table, it must be remembered that the plant operator is usually furnished a house and garden and is able to engage in agriculture on a small scale. In some cases he is able to do considerable repairing of farm machinery in addition to his duties at the pumping plant. Wages therefore are considerably lower than those paid in commercial plants, where full time is required.

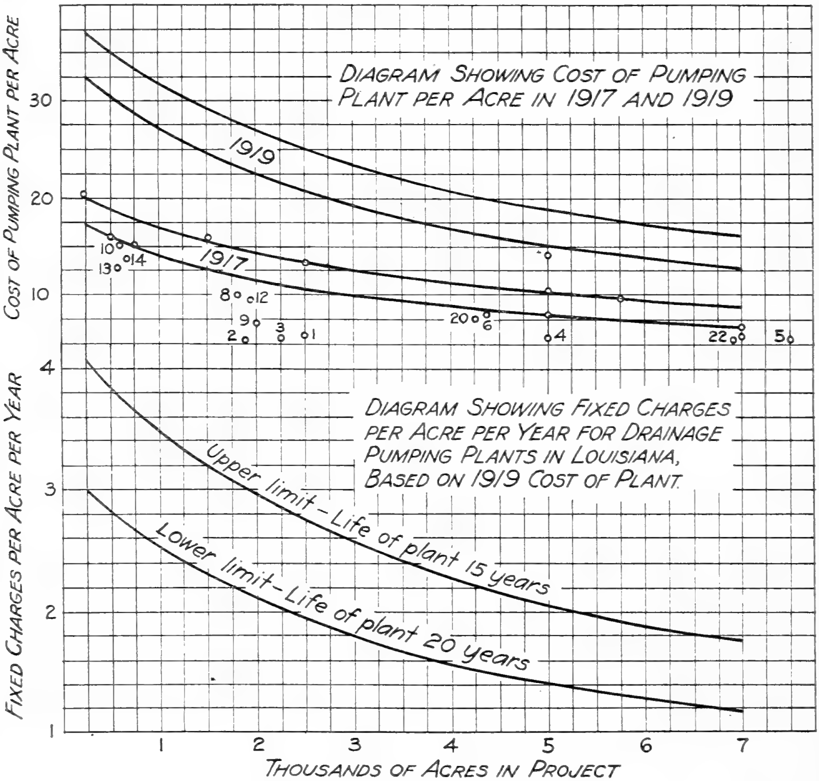

FIG. 8.—Cost of pumping plants and fixed charges per acre per year.

The actual costs of some of the plants tested are shown in figure 8. The costs for 1919 were obtained by increasing the 1917 price by 88 per cent, which is the average increase in the cost of material and labor. The two lines for each year represent approximately the upper and lower limits of cost, depending upon the type of plant constructed.

The upper limit of fixed charges per acre per year was obtained by taking the interest on the upper limit of cost of pumping plant per acre for 1919 computed at 6 per cent and adding an annuity on a basis of 4 per cent that will replace the plant in 15 years; the lower limit was obtained by taking the interest on the lower limit of cost per acre for

1919 and adding an annuity on a basis of 4 per cent and that will replace the plant in 20 years, amounting to $33.58 per $1,000. The life of a pumping plant depends largely on the grade of machinery used and the care it receives. It is believed that the limits of 15 to 20 years

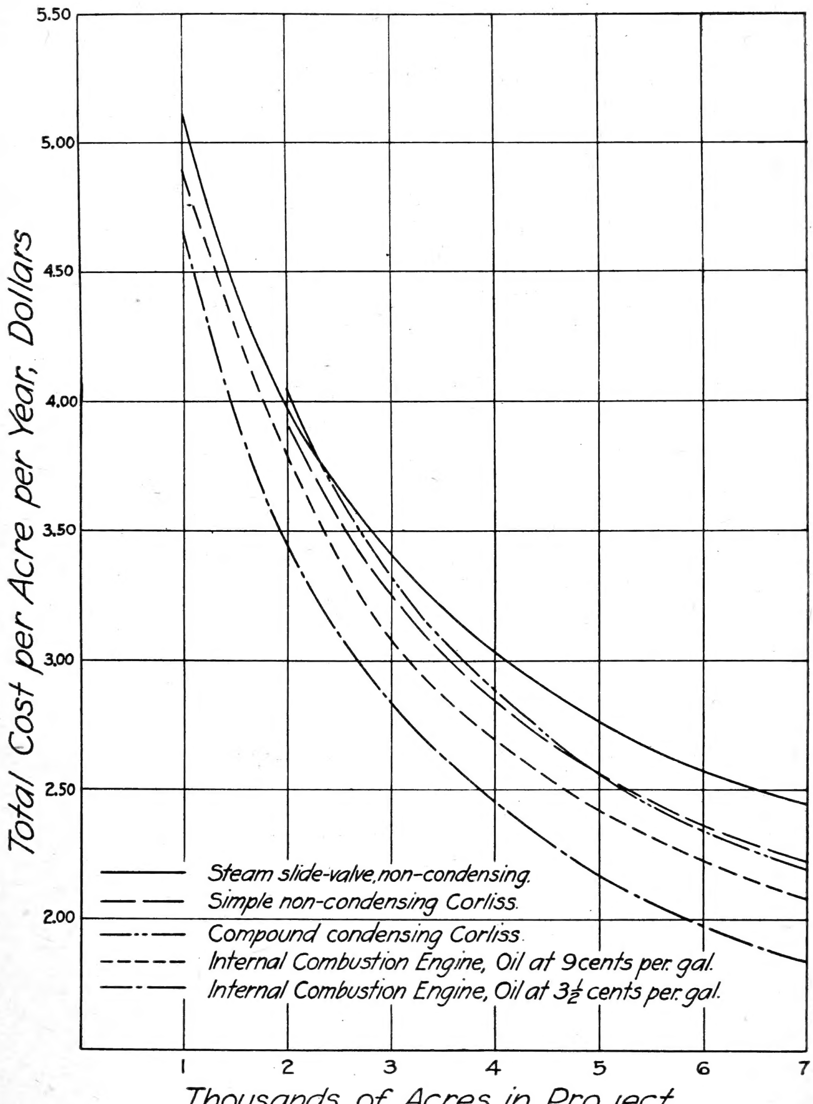

FIG. 9.—Total cost per acre per year, of drainage pumping plants of various types in Louisiana, including fuel, supplies, labor, and fixed charges.

will cover most cases, although occasionally a pumping plant will not last more than 10 years, while another under favorable circumstances may last 25 years.

Figure 9 indicates the total cost per acre per year, including fuel, supplies, labor, and fixed charges, of pumping plants of various types in the southern prairie region, where an average of 29 inches of depth of water is pumped annually. The cost of the fuel, as assumed, is given in Table 36; labor charges are shown in figure 8; the fixed charges are assumed as the mean of the fixed charges for the year 1919, as shown in figure 8. It will be noted that the cost decreases as the size of the project increases. The average cost per acre of operating a pumping plant for a project of 3,000 acres is approximately $1 per acre per year more than for a project of 7,000 acres. This is an incentive toward reclaiming lands by pumping in fairly large units.

From figure 9 it will also be seen that with the assumptions made the most expensive plants for projects with acreage 2,400 or more is the steam plant with slide-valve engine. There is little choice between the simple Corliss engine and the compound condensing type, the former having a slight advantage for projects of more than 5,000 acres and the latter being a little cheaper for projects between 2,000 and 5,000 acres. The cheapest plant of all has internal-combustion engines, and the difference in various plants will depend quite largely on the price paid for fuel.

While the above analysis is for a set of conditions that are assumed as typical, different conditions will modify the results, and corrections in computations may be quickly made to fit special conditions.

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