966 Issued April 15, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 183.

A. C. TRUE, DIRECTOR.

# MECHANICAL TESTS

OF

# PUMPS AND PUMPING PLANTS

## Used for Irrigation and Drainage in Louisiana in 1905 and 1906.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

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## LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
*Washington, D. C., January 16, 1907.*

SIR: I have the honor to transmit herewith a report on mechanical tests of pumps and pumping plants used for irrigation and drainage in Louisiana, prepared under the direction of Elwood Mead, chief of Irrigation and Drainage Investigations, by Prof. W. B. Gregory, of Tulane University, and to recommend its publication as a bulletin of this Office.

Very respectfully,

A. C. TRUE,
*Director.*

Hon. JAMES WILSON,
*Secretary of Agriculture.*

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# MECHANICAL TESTS OF PUMPS AND PUMPING PLANTS USED FOR IRRIGATION AND DRAINAGE IN LOUISIANA, 1905 AND 1906.

## INTRODUCTION.

Some of the largest pumping plants in the world used for irrigation are located in the rice country of Louisiana and Texas. It is only ten or eleven years since the first of these plants of any considerable size was established.

Rice irrigation had passed through the experimental stage, and lands previously considered suitable only for grazing were being rapidly brought under rice cultivation. The new industry offered exceptional inducements to capital, as rice was an unusually profitable crop. The first pumping plants were located along the rivers, bayous, and small streams, but as the area under cultivation was increased it became desirable to plant rice on land that was out of reach of the large canals. Search for underground waters was usually rewarded; the deep wells of Louisiana and the shallow wells of Texas have served to supply water for irrigating vast tracts that otherwise could not have been used for rice growing.

Many of the large pumping plants, erected during the early period of the development of the industry, showed an entire lack of consideration of economy. A certain amount of water was needed and the pumps were capable of supplying the demand, but the amount of fuel required to do the work was entirely too great. Rice growers were so prosperous that questions of economy did not arise, and lack of experience was accountable for their indifference. It is true that some of the pumping plants built at that time were excellent examples of good engineering, but these were exceptional.

The fuel used was wood and coal. With the former the expense was often only that of cutting and handling, but even so, it was not cheap fuel, and plants designed to use it needed larger boiler equipment than was required if coal was used.

The discovery of oil at Beaumont, Tex., in 1901, and later at many other points in both Louisiana and Texas, has revolutionized the fuel supply of that section. The Jennings oil field is located in the heart of the rice country of Louisiana, and furnishes fuel for nearly all of the pumping plants for miles around.

The life of pumping plants varies with conditions, among which may be mentioned, (1) the quality of the machinery, including merit of design, and (2) the skill with which it is operated and the care bestowed on its various parts when idle as well as when in use. Plants are operated for only three or four months in the year. The proportioning of boilers to supply steam easily and economically contributes not only to the satisfactory operation of a plant, but to the length of life of the boilers as well.

Many of these first plants have become conspicuous on account of the size of their fuel bills. The cost of plants having different types of machinery is almost a constant quantity when based on an equal amount of work to be done by the pumps. In the larger plants reliable figures show that the economical and the wasteful plant will differ in first cost by only a small amount, and that the difference is in favor of the economical plant.

The above refers to first cost only. When the cost of fuel is considered, the economical plant will often do the same work as the wasteful plant for one-third of the amount. These facts have been brought home to owners of the large canals in statements of annual expenses.

Of these earlier plants, those which represent the cheapest and lowest grade of machinery are now about ready for the scrap pile. In fact, many of them would have been replaced ere this had not the three years preceding the season of 1905 been unfavorable from a financial standpoint, as the profits were lower than formerly. The reduction of profits has had the effect of calling attention to sources of waste and has made the study of the economies of pumping of great importance.

In many sections rice farmers have the choice of pumping water from wells or of taking it from canals, paying for the privilege with two sacks of rice per acre or one-fifth of the crop.

The small well plants have been found to use fuel wastefully on account of the fact that economical engines are not made in small sizes, and also on account of the difficulties incident to pumping from wells. More is now known of the life of the average well, and the farmer is asking whether he can afford to continue to operate his little plant if a canal is available.

Changes must come in the near future, and while individual experience is valuable and will aid in the settling of some of these questions, it is not wide enough to cover all. During 1905 and 1906 the Irrigation and Drainage Investigations of the Office of Experiment Stations, United States Department of Agriculture, has conducted tests of typical pumping plants to help in the settlement of these problems. The problem of drainage has also claimed some attention, and some of the plants tested are used exclusively for drainage. It is not claimed that these tests cover the whole range of conditions, but it is believed that they are typical and that the deductions are general.

## INSTRUMENTS USED.

The instruments used were in part furnished by the U. S. Department of Agriculture, while others were loaned by Tulane University, of Louisiana. Among the former were two steam-engine indicators having reducing wheels, a current meter, and a 100-foot tape. The instruments loaned consisted of a Pitot tube, hook gage, pressure and vacuum gages, revolution counters, hydrometer, and thermometers. In one test a Pitot tube loaned by the Mississippi River Commission was also used.

The springs of the steam-engine indicators, the gages, and thermometers were calibrated in the experimental engineering laboratory of Tulane University. The rating of the current meter was furnished by this Department, while the Pitot tube was made of such form that its constant was known to be unity. In a few cases weirs were used to measure the water discharged by the pumps; the weirs were invariably of the Cipolletti form.

The form of Pitot tube used is shown in figure 1. This instrument was used both in open channels, as a current meter, and to traverse pipes to obtain mean velocity. In one case the two Pitot tubes were used in suction pipes of a pump, and therefore under a negative pressure or vacuum, while in another test the Tulane tube was used in the discharge pipe of a pump under a positive pressure. In every case the results were consistent and reliable. Readings from Pitot tubes were invariably taken in feet of water, and the instruments were used only where the velocity was sufficiently great to give a difference of level on static and impact sides that could be read with accuracy. The velocities determined in this way were from 3 to 5 feet per second. The Price current meter was often used alternately with the Tulane tube, and the results were equally satisfactory with both instruments. Following is a brief description of this instrument and statement of the theory on which it is constructed:

The outer tube consists of hard-drawn brass tubing of approximately three-fourths of an inch external diameter. The part which is turned toward the current of water the velocity of which is to be measured is approximately 7 inches long. The inner tube receiving the impact of the current is about one-fourth of an inch in external diameter. This tube is carried inside the outer tube to the upper end of the latter and projects about 1 inch beyond, where it is connected by means of rubber tubing to one of the glass tubes placed in front of a metallic scale graduated in feet, tenths, and hundredths. About two-thirds of the length back from the point of the 7-inch tube already referred to are two holes one-sixteenth of an inch in diameter drilled through the outer tube. These holes are in a horizontal plane when the tube is held in a vertical position. Through these openings water enters the outer tube, at the upper end of which

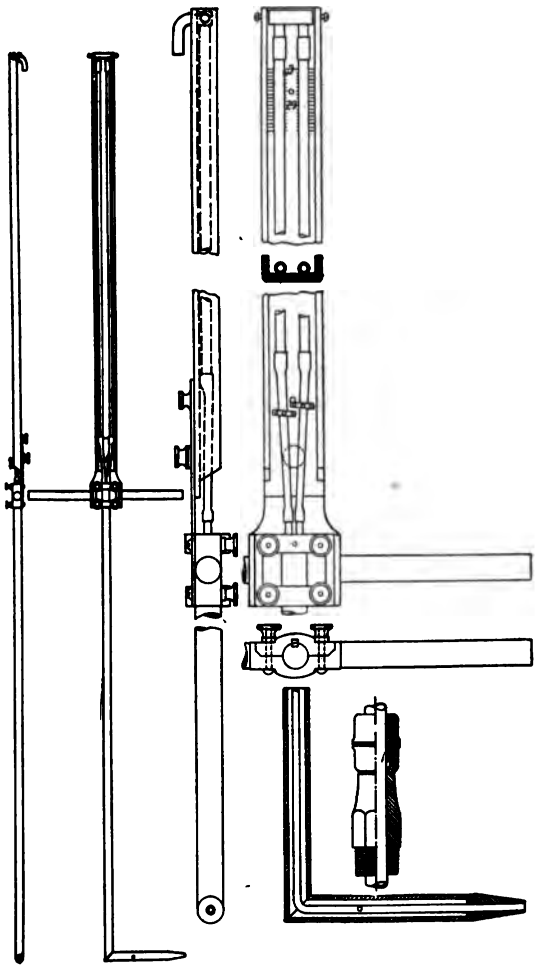

FIG. 1.—Pitot tube.

is a small piece of brass tubing, also projecting about 1 inch and connecting to the second glass tube in front of the graduated scale by means of a short length of rubber tubing similar to that used with the impact tube. The upper end of the outer tube is closed and the two small tubes are held in place by means of solder. The two glass tubes are connected at the top, and a third opening allows a rubber tube to be attached, by means of which the water in both tubes may be raised by suction to a convenient height for reading. A pinch cock is used to close this tube. The channel holding the graduated scale and glass tubes is of aluminum, the light weight of which prevents the instrument from being top heavy. A handle, easily detached by means of thumbscrews, serves to accurately align the point of the tube in the manipulation of the instrument.

A gland and stuffing box is also provided for use when the instrument is used to traverse a pipe either under a vacuum or under pressure.

When the instrument is used to measure velocity, the point is turned to receive the impact of the current of water, while the openings on the side of the tube give its static pressure. The difference between these two pressures, measured in feet of water, is the head corresponding to velocity by the well-known formula $V=\sqrt{2\ gh}$, in which V equals the velocity in feet per second, g is the acceleration of gravity, usually taken as 32.2 feet per second, per second, and h is the difference of head in the two tubes in feet of water One advantage of this instrument over the current meter is that no time observation is required. If properly constructed, no constant is needed in the formula to reduce the reading of head to velocity. Long experience has shown that an instrument constructed as the one shown in figure 1 fulfills this requirement.

## METHODS PURSUED.

In making mechanical tests of pumping plants the following observations were taken where practicable; exceptions are noted in the description of individual tests: (1) Amount and specific gravity of fuel oil used. In every case where this quantity was measured the fuel used was crude petroleum. (2) The amount and temperature of water fed to the boilers and the steam pressure. (3) The indicated horsepower of the engine, obtained from the indicator cards and revolutions per minute of engine. (4) The actual height through which the water was lifted. (5) The volume of water pumped per unit of time. The cost of fuel oil was also obtained, and in some cases numerous other readings of minor importance were taken; they are given in the logs of tests.

The specific gravity of the oil was taken with a hydrometer. It was found to vary but slightly, and for this reason an average value was taken and the number of barrels used in every case was computed on this common basis of specific gravity of 0.895; the average temperature was about 90° F. Fuel oil is bought on a basis of measurements of 42 gallons per barrel, no correction being made for differing temperatures. In most cases the oil was measured in carefully calibrated barrels. In a few instances it was measured by the fall in level in a cylindrical tank.

The height through which the water was lifted was obtained by direct measurement. In the test of well plants the head taken was the distance from the level at which it stood in the discharge pipe or suction pipe when the pump was not in operation to the point to which the pump elevated it. More will be said on this point under the description of individual tests.

In the case of large irrigation plants the discharge from the pumps was invariably measured in the discharge flume by means of the current meter or Pitot tube. The method is given in each case in detail.

The amount of moisture present in the steam was not measured, as many of the plants were in continuous operation, and openings in steam pipes for the insertion of a calorimeter could not be made. Mr. William Kent, the well-known authority on steam boilers, states that in tests of boilers he has never found more than 3 per cent of moisture in the steam from a well-proportioned boiler in a single test, while the average, from a series of tests, never exceeds 1½ per cent. We may therefore conclude that the error in assuming the steam to be free from water, as was done in these tests, was no greater than in some of the other observations.

While the tests reported must not be supposed to be of the highest degree of accuracy, they are believed to be as accurate as possible under existing conditions. The object was to conduct tests under the conditions as they were found to exist, and a rather wide field had to be covered in a limited time.

## PROBABLE ACCURACY OF RESULTS.

The error involved in measurements is the ordinary error of observation. It probably does not exceed one-half of 1 per cent.

The amount of water present in the oil was determined in only one case, and although the error from this source is difficult to estimate, it is believed to be large in some cases. However, commercial crude oil was used, and the amount of water present was not unusual.

In the measurement of water furnished to boilers in the test of the larger plants the error was that in actually measuring the water in calibrated barrels, and was probably as small as one-half of 1 per cent.

In the three cases where a Cipolletti weir was used the error is possibly as great as 3 per cent. The error involved in possible differences in level of water in boilers at starting and stopping of a test will decrease as the duration of test increases. It is believed that errors from this source are small.

In getting the indicated horsepower of the engines the most approved methods were employed. In every case a perfect reducing motion was used. The error involved may possibly be as great as 3 per cent in individual cases, but probably does not exceed half that amount in the average.

Errors in measurements of the discharge of the pumps are those involved in the instruments used. The Price current meter and the Pitot tube will give results that are accurate within 3 per cent. It is probable that the mean error in most tests was less than this amount, while under adverse conditions the error may increase to as much as 5 per cent. In general, it is thought that the error does not exceed that of the weirs used, or about 3 per cent.

During many of the tests indicator cards and revolutions of engine and pump had to be taken alternately with the measurements of the water discharged from the pumps. Slight changes of conditions from various causes undoubtedly caused greater discrepancies than would have resulted from simultaneous observations.

## DESCRIPTION OF PLANTS AND RESULTS OF TESTS.

In general, the tabulated results are self-explanatory.

The steam pressure is given in pounds per square inch above the atmospheric pressure.

The vacuum gage is read in inches of mercury.

The speed of engines and pumps is taken in revolutions per minute.

By water horsepower is meant—

Cubic feet per second $\times$ weight per cubic foot $\times$ head in feet $\div$ 550.

The temperature of water pumped was observed, and the corresponding weight per cubic foot was used in each case.

Indicator cards were taken with 80, 50, or 20 pound springs, depending on the steam pressure carried.

The indicated horsepower is the power developed within the engine cylinder.

### PLANT NO. 1, ABBEVILLE CANAL COMPANY.

The plant of the Abbeville Canal Company is located on the Vermilion River, about 1½ miles below Abbeville. There are 20 miles of main canal and several miles of laterals. The area irrigated in 1905 was 3,650 acres, although the plant has watered as much as 6,900 acres in a season. This plant contains two horizontal return tubular boilers 72 inches in diameter by 16 feet in length, each containing 70 4-inch flues. They furnish steam to two tandem compound condensing Corliss engines having cylinders 14 and 26 inches in diameter, stroke 42 inches. The rods are 3¼ and 2¾ inches in diameter. The engines are direct connected to chamber wheel or rotary pumps by means of rigid flange couplings. No foot valves, such as are often used with centrifugal pumps, are required for this type of pump. The plant is so arranged that either unit may be operated alone or both used together.

An open heater receives the exhaust from the vacuum pump and the boiler feed pump. An inspirator is used to feed the boilers in case of an accident to the latter.

Ordinarily the water fed to the boilers is pumped through the open heater and has its temperature raised by the exhaust from the auxiliaries mentioned, but during the boiler test the heater was cut out and the boilers were fed by means of the inspirator. The condenser is of the jet type, having a single, direct-acting air pump; dimensions, 8 and 14 by 18 inches. During the test it made about eighteen double strokes per minute. This condenser has sufficient capacity for both engines.

The fuel is crude oil. The supply for the season of 1905 cost 23 cents per barrel of 42 gallons at the oil field, and transportation charges amounted to about one-half cent per barrel delivered at the plant.

The engines and pumps are run at different speeds, depending on the demand for water; "high speed" is approximately sixty revolutions, while "slow speed" averages about fifty revolutions per minute.

The test was run at "slow speed," and only one unit was operated.

The mechanical condition of this plant was as near perfection as could be desired. The pumps and engines appeared to be in perfect adjustment and operated with marked smoothness; there was an entire absence of jar or water-hammer. The combined efficiency of pump and engine was extraordinarily high. It seems probable that the slow speed was favorable to a high efficiency.

On June 19, 1905, a boiler test was made, and the following day the efficiency of the engine was determined. This was rendered necessary because of the lack of sufficient observers to carry on a complete test in one day.

Conditions were identical during the two days, as far as the operation of engines and pump were concerned; however, on the second day the plant was operated in the usual way, using the boiler-feed pump and the open heater. The water entered the heater at a temperature of 90° F. and left the heater at 206° F. It was found that a saving of 8 per cent of fuel resulted from this source.

Water and fuel oil were measured in carefully calibrated barrels, two being used for the water and one for oil. The barrels were calibrated by filling with weighed quantities of liquid and establishing marks to which barrels were successively filled; they were emptied into a lower tank, from which the supply was taken. The level of the supply tank was kept constant.

Both the boiler test and that of the engine and pump were entirely satisfactory.

The method of obtaining the efficiency of engine and pump was as follows: The flume had a width of 6.42 feet and a depth varying from a little over 2 feet to about 2.5 feet, depending on the stage of water in the canal, the cross section of which was divided into twenty-one rectangles, approximately square. The current meter or Pitot tube was placed at the center of each rectangle and the velocity of the water at that point determined. The mean velocity was taken as the mean of twenty-one readings. Considerable time, usually from fifteen to twenty minutes, was required for a set of readings. Direct measurements of the depth were taken by means of a thin rule which caused very little disturbance on the surface of the water; this was done at seven stations, and the average used in computing the quantity of water.

As soon as the water measurement was finished cards were taken from the engine and the revolutions counted.

Although the load and all conditions were practically constant there were slight fluctuations in speed, and the indicator cards and revolutions per minute were doubtless taken in some cases under conditions varying slightly from those under which the water measurements were made. The latter may be considered as a better average, as they extended over several minutes, while the indicated horsepower was necessarily computed from instantaneous observations.

It is to be regretted that it was impossible to determine the amount of moisture in the steam, but there was no opening in the pipe for a calorimeter, and one could not be made without the risk of delaying the operation of the plant.

The results of this test are remarkable for the high efficiency of pump and engine, the average combined efficiency being 81.7 per cent. Assuming a mechanical efficiency of engine of 92.5 per cent, the average efficiency of pump would be 88.3 per cent, which is a very high value.

The slip of the pump is also worthy of notice; its average value was 1.6 per cent. Each revolution of the pump gave a theoretic displacement of 660 gallons; the difference between the theoretic displacement and the discharge actually found, divided by the former, is the slip. Variations in results are doubtless due to slight changes in steam pressure and consequent fluctuations in speed of engine and pump.

The velocity observations were taken, alternately, with a Price current meter and Pitot tube, and consequently are more convincing than would have been the case had a single instrument been used.

The results of the boiler and the pump and engine tests follow:

*Boiler test, Abbeville plant, June 19, 1905.*

Duration of test, 7½ hours.
Total fuel oil, 2,568 pounds.
Average steam pressure by gage, 132.2 pounds per square inch.
Average temperature of feed water, 87.2° F.
Factor of evaporation, 1.1758.
Total weight of water fed to boiler, 26,271 pounds.
Equivalent water evaporated from and at 212° F., 30,889 pounds.
Boiler horsepower, 119.
Average temperature of fuel oil, 88° F.
Average air temperature, 87° F.
Water apparently evaporated per pound of fuel oil, 10.23 pounds.
Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 12.03 pounds.
Total feed water per indicated horsepower hour, 22.5 pounds.

*Engine and pump test, Abbeville Canal Company.*

| Time. | Steam pressure. | Revolutions per minute of engine. | Indicated horsepower. | | | | | | Total indicated horsepower. | Head. | Discharge. | Useful water horsepower. | Efficiency. | Slip. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | High pressure. | | | Low pressure. | | | | | | | | |
| | | | Head. | Crank. | Total. | Head. | Crank. | Total. | | | | | | |
| | *Lbs.* | | | | | | | | | *Feet.* | *Cu. ft. per sec.* | | *Per cent.* | *Per cent.* |
| 8.20 | 129 | 49.5 | 45.1 | 45.2 | 90.3 | 36.1 | 36.2 | 72.3 | 162.6 | 16.21 | 69.9 | 128.1 | 78.8 | 4.0 |
| 9.35 | 132 | 49.5 | 43.5 | 42.5 | 86.0 | 34.8 | 35.0 | 69.8 | 155.8 | 15.90 | 71.5 | 128.5 | 82.5 | 1.8 |
| 9.55 | 136 | 50.0 | 44.6 | 42.5 | 87.1 | 36.8 | 36.2 | 73.0 | 160.1 | 15.72 | 71.8 | 127.6 | 79.7 | 2.3 |
| 10.40 | 135 | 51.0 | 44.9 | 43.0 | 87.9 | 35.2 | 35.6 | 70.8 | 158.7 | 15.62 | 74.6 | 131.6 | 82.9 | .6 |
| 12.05 | 134 | 51.5 | 44.4 | 41.6 | 86.0 | 35.0 | 35.2 | 70.2 | 156.2 | 15.40 | 75.3 | 131.1 | 83.9 | .6 |
| 12.30 | 137 | 50.0 | 43.4 | 41.2 | 84.4 | 34.3 | 33.7 | 68.0 | 152.4 | ...... | ...... | ...... | ...... | ...... |
| 1.05 | 132 | 50.0 | 43.7 | 41.0 | 84.7 | 34.2 | 32.3 | 66.5 | 151.2 | 15.24 | 71.6 | 123.2 | 81.5 | 2.6 |
| 2.28 | 128 | 50.0 | 44.3 | 40.4 | 84.7 | 33.5 | 35.3 | 68.8 | 153.5 | 15.17 | 73.4 | 125.8 | 82.0 | .2 |
| 2.46 | 126 | 49.5 | 41.2 | 40.3 | *81.5 | 34.7 | 33.8 | 68.5 | 150.0 | 15.15 | 72.4 | 123.9 | 82.6 | .5 |
| Mean | 132 | 50.1 | ...... | ...... | ...... | ...... | ...... | ...... | 155.6 | 15.55 | 72.6 | 127.5 | 81.7 | 1.6 |

**PLANT NO. 2, ABBOTT-DUSON CANAL, MAIN PUMPING PLANT.**

The main pumping plant of the Abbott-Duson Canal system is located about 2½ miles west of Egan, La., on Bayou des Cannes, one of the streams which unite to form the Mermentau River.

This canal system connects with that of the Acadia Canal. There are 30 miles of main canal and 15 of laterals. These two canals have watered as much as 23,000 acres of rice in a season, but the acreage in 1905 was about 18,480. The main canal is 100 feet wide from center to center of levees.

The plant contains six horizontal return tubular boilers, 72 inches in diameter by 18 feet in length, each containing 72 4-inch flues. This plant was installed previous to the discovery of oil in that section. The boilers have a large heating surface, as they were intended for wood fuel.

During the test, although the boilers were connected to the same steam main, pressures were read from each boiler gage. One of the six gages used was a standard gage, by means of which the others were calibrated while the engines were not running, and where consequently the steam pressure in all the boilers was equal.

The Jennings oil field is located about 2 miles from this pumping plant, and a 2-inch pipe line direct from the field supplies the crude petroleum, which has replaced wood as fuel. The cost of fuel delivered at the plant was 35 cents per barrel of 42 gallons.

There are two direct-acting steam pumps for boiler feed. These pumps have steam pistons 7½ inches and water pistons 5 inches in diameter, with 10-inch stroke. The plungers are inside packed. Either is used ordinarily to supply the boilers. During the test one furnished water from the bayou, and after it was passed through a 6-inch Cipolletti weir and measured it was forced by the other pump through the heater to the boilers. The depth of water over the weir was observed by means of a very accurate hook gage.

Three heaters are used, one on the exhaust pipe of each engine, 42 inches in diameter and 8 feet 6 inches long, each containing 100 tubes 2 inches in diameter; the third is a closed heater, receiving the exhaust from the boiler feed pump or pumps and from the condenser pump. The piping is so arranged that water is forced through all three heaters before going finally to the boilers.

There are two simple condensing Corliss engines having cylinders 24 inches in diameter and 48-inch stroke.

The piston rods are 3¾ inches in diameter.

One jet condenser is used for both engines, diameter of steam cylinder 14 inches, air cylinder 22 inches, stroke 24 inches.

Rope drives are used to transmit power from engines to pumps. The engine fly wheels are 16 feet in diameter and each has 18 grooves; 1,454 feet of 1¼-inch rope is used in each drive.

The sheaves on the pump shaft are 4 feet 3½ inches in diameter.

There are six horizontal shaft centrifugal pumps, having suction pipes 20 inches in diameter and discharge pipes 18 inches in diameter. Although there is a single suction pipe, the water is divided into two equal streams as it enters the pump, by means of cored passages around the sides of vortex chamber, so that at the eye of the pump it receives water from both sides. This pump is identical with that described in test No. 8 of Abbott Brothers pumping plant. Three pumps were driven by each engine. They were arranged with their shafts joined together by flanged couplings, so that all could be operated at once, or only one or two, depending on the level of the water in the bayou and the consequent lift. When the water is very high, as during the test, all the pumps are operated. The water level is subject to considerable fluctuations, and under conditions of extreme low water it may be desirable to operate two pumps or even only one by each engine. The discharge pipe terminates in an elbow in each case, so that the water is discharged down the flume.

In making the test it was found that it would be impossible to measure the water used by boilers, in barrels, as the quantity required was entirely too great. No method was available except to use a weir. The error involved is that due to a 6-inch Cipolletti weir. The measurements of head on weir were taken by means of a hook gage, very accurate readings being obtained by means of a vernier.

The load, and consequently the demand for water, was very uniform, and it is believed that the results obtained contain an extremely small error.

The boilers were examined and correction was made for the small amount of leakage at blow-off.

During the test some difficulty was experienced with the fuel oil, as the tanks were filled only a short time before test was begun. The trouble was due to the presence of water in the oil, and to some extent to sediment getting into the oil pipes because of the low level of oil in the supply tank.

The water discharged from the pumps was measured by means of a current meter, slowly traversing the flume at three different depths. The depths were carefully taken at 10 different points across the section. The flume was about 18.7 feet wide, and the depth was about 2.7 feet. This flume is nearly 2,300 feet long, and is supported by a wooden framework from 6 to 10 feet above the ground. It is several years old, and there was some leakage. On account of the turbulence of the water, due to the high velocity of discharge, it was necessary to go down the flume about 1,000 feet from the pumps in order to find a point where the surface of the water was placid enough to permit accurate measurements of depth. The mean velocity of discharge was 14.75 feet per second, as the elbow at the end of discharge pipe was of the same cross section as the pipe. The velocity head at discharge was therefore 3.38 feet. The losses at entrance of suction pipe, in suction and discharge pipe, and in the pump were all large on account of this high velocity. This fact is clearly shown by a comparison of the results of the one observation, taken at 3.30 p. m., with the results of all the other observations.

It will be seen that a reduction of average speed of pumps from 257 to 217 revolutions per minute gave a reduction of indicated horsepower of over 50 per cent, and that, approximately, two-thirds as much water was pumped as at the high speed. The efficiency of engine, transmission, and pumps was correspondingly raised from 42.9 per cent for the high speed to 53.3 per cent at the low speed. The stage of the water in the bayou was unusually high. With a normal suction head the total head would have been much greater, and a higher speed than that found advantageous during the test would have been required.

The results of the test are given below:

*Boiler test No. 2, main pumping plant, Abbott-Duson canal, August 3, 1905.*

Duration of test, 5 hours.

Total fuel oil, 7,988 pounds.

Average steam pressure by gage, 82.15 pounds per square inch.

Average temperature of feed water, 168.5° F.

Factor of evaporation, 1.081.

Total weight of water fed to boiler, 82,806 pounds.

Equivalent water evaporated from and at 212° F., 89,513 pounds.

Boiler horsepower, 519.

Average temperature of fuel oil, 89° F.

Average air temperature, 96° F.

Water apparently evaporated per pound of oil, 10.36 pounds.

Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 11.21 pounds.

Total feed water (including steam used by auxiliaries) per indicated horsepower-hour, 24.7 pounds.

*Engine and pump test, Abbott-Duson main plant, August 3, 1905.*

| Time. | Steam pressure. | Vacuum gage. | Indicated horsepower. | | | | | | Total indicated horsepower. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Engine No. 1. | | | Engine No. 2. | | | |
| | | | Head. | Crank. | Total. | Head. | Crank. | Total. | |
| | *Pounds.* | *Inches.* | | | | | | | |
| 9.00 | 83 | 22.4 | 178.7 | 169.7 | 348.4 | 176.9 | 163.1 | 340.0 | 688.4 |
| 9.30 | 86 | 22.4 | 179.5 | 167.9 | 347.4 | 174.3 | 164.3 | 338.6 | 686.0 |
| 10.00 | 82 | 22.1 | 174.2 | 170.3 | 344.5 | 168.8 | 158.5 | 327.3 | 671.8 |
| 10.30 | 79 | 22.0 | 177.5 | 166.1 | 343.6 | 167.5 | 158.0 | 325.5 | 669.1 |
| 11.00 | 79 | 21.2 | 176.4 | 168.8 | 345.2 | 162.6 | 155.0 | 317.6 | 662.8 |
| 11.30 | 79 | 22.1 | 177.2 | 168.7 | 345.9 | 164.6 | 155.8 | 320.4 | 666.3 |
| 12 m | 85 | 22.5 | 178.9 | 168.3 | 347.2 | 167.2 | 157.7 | 324.9 | 672.1 |
| 12.30 | 82 | 22.1 | 178.9 | 167.6 | 346.5 | 160.7 | 151.7 | 312.4 | 658.9 |
| 1.00 | 83 | 22.3 | 180.6 | 172.9 | 353.5 | 162.4 | 156.0 | 318.4 | 671.9 |
| 1.30 | 85 | 22.2 | 181.5 | 173.3 | 354.8 | 163.8 | 154.5 | 318.3 | 673.1 |
| 2.00 | 83 | 22.3 | 180.6 | 168.5 | 349.1 | 160.5 | 153.4 | 313.9 | 663.0 |
| Mean | 82.3 | 22.1 | .......... | .......... | .......... | .......... | .......... | .......... | 671.2 |
| 3.30 | .......... | .......... | 82.7 | 85.2 | 167.9 | 70.2 | 75.5 | 145.7 | 313.6 |
| 4.30 | .......... | .......... | 232.3 | 201.9 | 434.2 | 235.2 | 200.5 | 435.7 | 869.9 |

| Time. | Revolutions per minute. | | | | Head. | Discharge. | Useful water horsepower. | Efficiency. |
|---|---|---|---|---|---|---|---|---|
| | Engine No. 1. | Engine No. 2. | Pump No. 1. | Pump No. 2. | | | | |
| | | | | | *Feet.* | *Cubic feet per second.* | | *Per cent.* |
| 9.00 | 69.0 | 69.5 | 258 | 260 | 16.20 | .......... | .......... | .......... |
| 9.30 | 69.0 | 69.0 | 258 | 258 | 16.20 | 155 | 284.5 | 41.5 |
| 10.00 | 68.5 | 69.0 | 256 | 258 | 16.20 | 157 | 288.1 | 42.9 |
| 10.30 | 68.5 | 68.5 | 256 | 256 | 16.20 | 156 | 286.2 | 42.8 |
| 11.00 | 68.25 | 68.0 | 255 | 254 | 16.21 | 154 | 282.8 | 42.7 |
| 11.30 | 69.0 | 68.5 | 258 | 256 | 16.21 | 156 | 286.4 | 43.0 |
| 12 m. | 68.5 | 68.5 | 256 | 256 | 16.21 | 157 | 288.3 | 42.9 |
| 12.30 | 68.5 | 68.0 | 256 | 254 | 16.21 | 158 | 290.1 | 44.0 |
| 1.00 | 69.0 | 68.5 | 258 | 256 | 16.22 | 161 | 295.8 | 44.0 |
| 1.30 | 69.0 | 68.5 | 258 | 256 | 16.23 | 156 | 286.8 | 42.6 |
| 2.00 | 68.75 | 68.25 | 257 | 255 | 16.23 | 155 | 285.0 | 43.0 |
| Mean | 68.7 | 68.6 | 257 | 256 | 16.21 | 156.5 | 287.4 | 42.9 |
| 3.30 | 58.0 | 59.0 | 217 | 220 | 16.23 | 101 | 186.0 | 59.3 |
| 4.30 | 74.0 | 75.0 | 276 | 280 | 16.23 | 178 | 327.0 | 37.6 |

**PLANT NO 3, ABBOTT-DUSON CANAL, FIRST RELIFT.**

This test was made of the pumping plant forming the first relift of the Abbott-Duson canal system.

The plant is located at Egan, La., about 2½ miles east of the main pumping plant.

The boiler equipment consists of three horizontal return tubular boilers, 72 inches in diameter by 18 feet long, each containing 72 4-inch tubes.

Under ordinary conditions an open heater is used. A direct-acting steam pump furnishes water to the heaters, and a similar pump takes the water from the heater and delivers it to the boilers. The heater receives the exhaust from these two pumps and also from the condenser pump. During the test the heater was not used, as the water had to be measured. The piping was changed so that one of the pumps furnished water to fill two calibrated barrels, placed so that they could be emptied into a lower barrel, by means of a 2-inch valve and pipe in each.

The suction of the second pump was attached directly to the lower barrel, and this pump was used to feed the boilers.

The crude petroleum used for fuel during the test was measured in a calibrated barrel, the amount per hour being 712 pounds. The cost of fuel oil delivered at plant was 35 cents per barrel of 42 gallons.

The following day fuel oil was measured for one hour and fifty-seven minutes, the feed-water heater being in use. It was found that the consumption of oil per hour was 603 pounds. The temperature of water entering boiler was 200° F. instead of 92° F. as found when heater was not used. The theoretical gain by using the feed-water heater is about 11 per cent, while the actual difference in fuel used amounted to nearly 20 per cent. The discrepancy is accounted for by the difference in the amount of water present in the fuel oil.

During the test on July 31 the amount of water in the fuel oil was sufficient to put out the fires momentarily on two occasions, and to require careful oversight of the oil burners to prevent irregularities in the amount of combustion and, consequently, in steam pressure. On the second day the oil in the supply tank had become quite thoroughly separated from the water, the latter having settled to the bottom, and the result was that there was no trouble with the burners.

More will be said on this subject in comparing the results of the Acadia plant (test No. 5) with that of the Grand Canal plant (test No. 7), where two boilers of the same make were used under conditions that were very similar as regards demands for steam. While in one case with oil which had been stored for some time the best results of any of the tests was made by the boiler, in the other case with oil freshly delivered to supply tanks and containing water well mixed with the crude petroleum a very bad showing for the boiler resulted.

The engine was a simple condensing Corliss, having cylinder diameter of 24 inches and 48-inch stroke and rod 3¾ inches in diameter.

In the rope drive 1,850 feet of 1¼ inch rope are used; there are eighteen grooves on the fly wheel, which is 16 feet in diameter.

The sheave by which power is transmitted to the pumps is located between two centrifugal pumps, each having double-suction pipes 24 inches in diameter.

The pumps are rated as 36-inch pumps, but the lift was so small that the pumps each discharge through a rectangular opening into a separate flume, having gradually expanding cross sections. The two flumes are brought together at a distance of about 50 feet from the pump into a larger flume, which discharges into the canal beyond the plant.

During the test indicator cards were taken at fifteen-minute intervals, and observations were made of steam pressure, vacuum gage, revolutions of engine and pump, and of head pumped against.

At intervals of a half hour water measurements were taken in the flume, and the temperature of water, oil, and air was noted. The amount of water and fuel oil used was also carefully noted.

The measurements of the water discharged by the pumps was made by means of the Pitot tube. The discharge flume in which the measurements were made was 18.75 feet wide. The depth of water varied from about 1.5 feet to a little over 1.6 feet. The cross section was divided into twenty rectangles of equal size and the mean velocity obtained at the center of each rectangle, or, in other words, the velocity was observed at ten different stations across the flume and at two different depths at each station.

The efficiency of engine, transmission, and pump is excellent—in fact, the best of any of the plants tested in 1905 in which centrifugal pumps are used. This efficiency had an average value of 64.2 per cent. If the efficiency of the rope drive is assumed to be 95 per cent and the mechanical efficiency of the engine as 90 per cent, the efficiency of the pump is found to be about 75 per cent.

The results of the tests are as follows:

*Boiler test No. 3, first relift, Abbott-Duson Canal, July 31, 1905.*

Duration of test, 4 hours.
Total fuel oil, 2,886 pounds.
Average steam pressure by gage, 65.6 pounds per square inch.
Average temperature of feed water, 92° F.

**Factor of evaporation, 1.1566.**

**Total weight of water fed to boiler, 28,629 pounds.**

**Equivalent water evaporated from and at 212° F., 33,112 pounds.**

**Boiler horsepower, 240.**

**Average temperature of fuel oil, 171° F.**

**Average air temperature, 92° F.**

**Water apparently evaporated per pound of oil, 9.92 pounds.**

**Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 11.47 pounds.**

**Total feed water (including steam used by auxiliaries) per indicated horse-power-hour, 31.2 pounds.**

*Engine and pump test, Abbott-Duson first relift.*

| Time. | Steam pressure. | Vacuum gauge. | Revolutions per minute of engine. | Indicated horsepower. | | | Revolutions per minute of pump. | Head. | Discharge. | Useful water horsepower. | Efficiency. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Head. | Crank. | Total. | | | | | |
| | *Pounds.* | *Inches.* | | | | | | *Feet.* | *Cu. ft. per sec.* | | *Per ct.* |
| 2.30 | 52 | 22 | 66.0 | 115.8 | 109.0 | 224.8 | 117 | 11.06 | ........ | ........ | ........ |
| 2.45 | 68 | 21 | 66.0 | 121.7 | 119.0 | 240.7 | 117 | 11.04 | ........ | ........ | ........ |
| 3.00 | 65 | 21 | 66.5 | 108.1 | 115.3 | 223.4 | 118 | 11.07 | ........ | ........ | ........ |
| 3.15 | 66 | 22 | 67.0 | 122.8 | 125.0 | 247.8 | 119 | 11.12 | ........ | ........ | ........ |
| 3.30 | 68 | 23 | 67.0 | 115.5 | 124.8 | 240.3 | 119 | 11.17 | 118 | 149 | 62.0 |
| 3.45 | 67 | 23 | 67.0 | 112.4 | 121.1 | 233.5 | 119 | 11.19 | ........ | ........ | ........ |
| 4.00 | 65 | 23 | 67.0 | 115.6 | 118.5 | 234.1 | 119 | 11.22 | 116 | 147 | 62.9 |
| 4.15 | 65 | 23 | 66.5 | 105.8 | 115.8 | 221.6 | 118 | 11.25 | ........ | ........ | ........ |
| 4.30 | 67 | 23 | 66.5 | 111.4 | 116.8 | 228.2 | 118 | 11.25 | 114 | 145 | 63.6 |
| 4.45 | 65 | 23 | 67.0 | 111.4 | 114.1 | 225.5 | 119 | 11.24 | ........ | ........ | ........ |
| 5.00 | 63 | 23 | 67.0 | 114.0 | 113.4 | 227.4 | 119 | 11.31 | 114 | 146 | 64.2 |
| 5.15 | 67 | 23 | 67.0 | 116.8 | 119.3 | 236.1 | 119 | 11.36 | ........ | ........ | ........ |
| 5.30 | 68 | 23 | 66.8 | 108.7 | 119.8 | 228.5 | 118 | 11.33 | 115 | 147 | 64.4 |
| 5.45 | 68 | 23 | 67.0 | 112.7 | 112.9 | 225.6 | 119 | 11.34 | ........ | ........ | ........ |
| 6.00 | 67 | 23 | 66.5 | 111.2 | 115.8 | 227.0 | 118 | 11.33 | 117 | 150 | 66.1 |
| 6.15 | 67 | 23 | 67.0 | 115.6 | 107.7 | 223.3 | 119 | 11.39 | ........ | ........ | ........ |
| 6.30 | 67 | 23 | 67.0 | 111.8 | 107.6 | 219.4 | 119 | 11.36 | 114 | 146 | 66.5 |
| Mean | 65.6 | ........ | 66.8 | ....... | ....... | 229.8 | 118.5 | 11.24 | 115.4 | 147.1 | 61.2 |

## PLANT NO. 4, ABBOTT-DUSON CANAL, SECOND RELIFT.

Located about 3½ miles north of Egan, La., on the main canal of the Abbott-Duson canal system, is the second relift. The height through which this plant elevates the water varies with the changing level of the canals above and below the plant. During the test the water was raised from 4.22 to 5.33 feet.

The pump has a double suction and vertical shaft. The body of the pump is built entirely of wood, is 7 feet square on the inside, and has corner posts and cross timbers to which the bearings are attached. The impeller of the pump is 42 inches in diameter and 18 inches deep. The main thrust is taken by a ball bearing above the driving sheave.

The boiler is a horizontal return tubular, 72 inches in diameter and 16 feet in length. Water used by the boiler was measured during the test by means of calibrated barrels. It was then pumped direct to the boiler. The plant contains a closed heater, but it was not in use, as it had sprung a leak. The fuel was crude petroleum. The engine is of the slide-valve, noncondensing type, having diameter of piston of 16 inches and 20-inch stroke. It is connected to the pump by means of a 1½-inch rope. Total length of rope, 440 feet. There are four grooves in the two wheels. Diameter of sheave on engine, 7 feet 6 inches; on pump, 46 inches. This rope drive is badly designed, as excessive weight is required to prevent slipping. Ropes on this drive have very short lives, because of the excessive tension and the wear due to slipping. A new rope had been put on just previous to starting the test. The stiffness of this rope probably detracted from the efficiency of transmission.

During the test it was found that the rope was slipping on the pump sheave, which had become very hot, and even in a few hours the rope showed unmistakable signs of wear. Slipping was prevented in part by increasing the weights on the take-up and so increasing the tension of the ropes. Under these conditions more power is required to wedge the rope into the grooves and to pull it out as it leaves the sheave than would be required in a well-designed drive. The friction due to the increased pull on engine and pump bearings is also unfavorable to a high efficiency. There ought to have been a greater number of ropes used.

The combined efficiency of engine, transmission, and pump was found to be rather low, averaging a little less than 27 per cent. The results show a tendency to increase as the height increased through which the water was lifted. There is good reason for believing that the efficiency of this type of pump is greater under more favorable conditions. Tests made elsewhere also bear out this statement.

The measurements of the water pumped were made in the flume about 30 feet from the pump, where the water ran smoothly and measurements could be made with the usual accuracy.

A current meter was used, and traverses were made at two different depths. The width of flume was 14.9 feet, and the depth varied from about 1.1 feet to 1.5 feet.

The results of the test are as follows:

*Boiler test No. 4, second relift, Abbott-Duson Canal, August 10, 1905.*

Duration of test, 4 hours.
Total fuel oil, 1,567 pounds.
Average steam pressure by gage, 81.2 pounds per square inch.
Average temperature of feed water, 87.9° F.
Factor of evaporation, 1.164.
Total weight of water fed to boiler, 17,369 pounds.
Equivalent water evaporated from and at 212° F., 20,218 pounds.
Boiler horsepower, 147.
Average temperature of fuel oil, 89° F.

Average air temperature, 97° F.

Water apparently evaporated per pound of oil, 11.08 pounds.

Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 12.90 pounds.

Total feed water (including steam used by auxiliaries) per indicated horsepower-hour, 35.6 pounds.

*Engine and pump test, second relift, Abbott-Duson Canal.*

| Time. | Steam pressure. | Revolutions per minute of engine. | Indicated horsepower. | | | Revolutions per minute of pump. | Head. | Discharge. | Useful water horsepower. | Efficiency. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Head. | Crank. | Total. | | | | | |
| | *Pounds.* | | | | | | *Feet.* | *Cu. ft. per sec.* | | *Per cent.* |
| 11.30 | 80 | 103.5 | 59.3 | 58.1 | 117.4 | 194 | 4.22 | ........ | ........ | ........ |
| 11.45 | 85 | 106 | 61.6 | 59.7 | 121.3 | 198 | 4.25 | 64.4 | 30.9 | 25.5 |
| 12 m | 84 | 106 | 68.3 | 66.5 | 134.8 | 198 | 4.33 | 65.1 | 31.9 | 23.7 |
| 12.15 | 71 | 103 | 61.0 | 56.1 | 117.1 | 185 | 4.55 | 65.6 | 33.7 | 28.8 |
| 12.30 | 82 | 107 | 63.9 | 62.6 | 126.5 | 196 | 4.55 | 62.4 | 32.1 | 25.4 |
| 12.45 | 92 | 119 | 68.1 | 66.9 | 135 | 212 | 4.56 | 62.2 | 32.1 | 23.8 |
| 1.00 | 80 | 117 | 64.3 | 63.8 | 128.1 | 190 | 4.58 | 63 | 32.6 | 25.4 |
| 1.15 | 79 | 116 | 60.0 | 58.5 | 118.5 | 214 | 4.63 | 59.9 | 31.4 | 26.5 |
| 1.30 | 85 | 117 | 62.8 | 61.8 | 124.6 | 215 | 4.69 | 59.8 | 31.7 | 25.4 |
| 1.45 | 82 | 110 | 62.0 | 61.3 | 123.3 | 197 | 4.75 | 64.5 | 34.7 | 28.1 |
| 2.00 | 81 | 110.5 | 62.9 | 60.7 | 123.6 | 195 | 4.83 | 61.5 | 33.6 | 27.2 |
| 2.15 | 80 | 107.5 | 59.6 | 57.9 | 117.5 | 197 | 4.87 | 58.5 | 32.2 | 27.4 |
| 2.30 | 80 | 105 | 60.2 | 59.1 | 119.3 | 194 | 4.96 | 60.1 | 33.8 | 28.3 |
| 2.45 | 80 | 102 | 58.9 | 57.6 | 116.5 | 186 | 5.05 | 58.2 | 33.3 | 28.6 |
| 3.00 | 80 | 100 | 56.2 | 55.3 | 111.5 | 196 | 5.14 | ........ | ........ | ........ |
| 3.15 | 80 | 102.5 | 58.5 | 57.1 | 115.6 | 196 | 5.15 | 60.2 | 35.1 | 30.4 |
| 3.30 | 80 | 103 | 61.5 | 60.0 | 121.5 | 196 | 5.33 | 59.2 | 35.7 | 29.4 |
| Mean | 81.2 | 107.9 | ........ | ........ | 121.9 | 197.6 | 4.73 | 61.6 | 33.0 | 26.9 |

## PLANT NO. 5, ACADIA CANAL.

The pumping plant of the Acadia Canal is located about 2½ miles west of Iota, La. It receives water from Bayou des Cannes through a dredged canal several hundred feet long. This plant furnished water for 7,000 acres of rice in 1895, of which 4,000 acres were beyond the relift. As already stated, the Abbott-Duson and the Acadia canals are joined together. The pumps discharge the water into a flume having an inside width of about 15 feet. The depth of water in this flume during the test was a little less than 2 feet. This flume is supported by a wooden framework; the distance from the surface of the ground to the bottom of the flume is as great as 30 to 35 feet in some places. The length of this flume is 1,800 feet. The flume had been in use for several years, and although the leakage was small, the supporting timbers had rotted badly. This was shown by an occurrence which happened some two or three weeks after the test was made. One day about 10 a. m., while the plant was running as usual, a length of about 1,000 feet of flume fell without the least warning. The work of restoration was begun promptly, and in about two weeks the plant was again in operation.

The boiler equipment consists of two water tube boilers, rated by their builders at 300 horsepower each. The feed water for the boilers flows from the flume to two open heaters, each of which is supplied with a pump that takes the hot water from the heater and pumps it into the boiler. The heaters receive the exhaust from these two boiler feed pumps and from the two condenser pumps.

In order to make a test changes had to be made in the piping and the plant operated as follows: The water flowed to one heater and was taken from heater and furnished to the 6-inch Cipolletti weir, where it was measured. The other feed pump then delivered the water to the boiler. By this method only one heater was used during the test. It received the exhaust of both vacuum pumps and of both boiler feed pumps. The water was heated from a temperature of about 88° F. to 172° F.

The fuel oil was measured in a calibrated barrel.

The results of the boiler tests are the best of all the boilers tested; the ratio of weight of water from and at 212° F. to the weight of fuel oil was 15.09. This result has been surpassed in some cases where boilers have been tested elsewhere with crude oil as a fuel. The result is, however, above the average and represents good conditions. An attempt was made during the next day to measure the fuel oil used for a run under normal conditions, but the breakdown of a vacuum pump and other abnormal conditions rendered the result useless.

Two simple condensing, heavy-duty Corliss engines furnish the power to drive the pumps. The diameter of cylinder of these engines is 22 inches and the stroke 42 inches. The piston rods are $3\frac{13}{32}$ inches in diameter. The parts of these engines are proportioned much heavier than the ordinary Corliss. Each is provided with a jet condenser. Diameter of steam and air cylinders, 12 and 18 inches, respectively, and length of stroke 18 inches.

Rope transmission is used. The fly wheels of the engines are 14 feet and the sheaves on the pump shafts 3 feet 6 inches in diameter. There are 15 grooves for $1\frac{1}{4}$-inch rope. The length of rope required in each case is 1,454 feet.

Each engine drives two horizontal-shaft centrifugal pumps having discharge pipes 18 inches in diameter and suction pipes 20 inches in diameter.

The pumps are identical with those of the Abbott-Duson plant, previously described, and the plant of the Abbott Brothers, to be described later. The head through which the water was lifted was slightly over 30 feet, while that at Abbott Brothers' lower farm was only about half this amount and at the Abbott-Duson a little more than one-half. The pumps are provided with flap valves in suction pipes.

The mean velocity of water as it is discharged from the elbows at the end of the discharge pipe and into the flume was 13.16 feet per second, corresponding to a velocity head of 2.87 feet. Comparing the velocities and efficiencies with those found at the Abbott-Duson, it will be seen that the velocity is lower in this case and the efficiency higher.

The results of the tests are given below:

*Boiler test No. 5, Acadia plant, August 5, 1905.*

Duration of test, 4.22 hours.

Total fuel oil, 5,641 pounds.

Average steam pressure by gage, 106.7 pounds per square inch.

Average temperature of feed water, 171.7° F.

Factor of evaporation, 1.083.

Total weight of water fed to boiler, 78,610 pounds.

Equivalent water evaporated from and at 212° F., 85,135 pounds.

Boiler horsepower, 585.

Average temperature of fuel oil, 85° F.

Average air temperature, 102° F.

Water apparently evaporated per pound of oil, 13.93 pounds.

Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 15.09 pounds.

Total feed water (including steam used by auxiliaries) per indicated horsepower-hour, 28.7 pounds.

*Engine and pump test, Acadia plant.*

| Time. | Steam pressure. | | Vacuum gages. | | Revolutions per minute of engines. | | Indicated horsepower. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Engine No. 1. | | |
| | Gage No. 1. | Gage No. 2. | No. 1. | No. 2. | No. 1. | No. 2. | Head. | Crank. | Total. |
| | *Pounds.* | *Pounds.* | *Inches.* | *Inches.* | | | | | |
| 1.30 | 107 | 108 | 16.7 | 23 | 80.5 | 81 | 165.1 | 153.9 | 319.0 |
| 2.00 | 108 | 109 | 19.5 | 23.2 | 80.5 | 81 | 164.2 | 161.9 | 326.1 |
| 2.30 | 110 | 112 | 19.7 | 23 | 81 | 81.5 | 164.9 | 161.2 | 326.1 |
| 3.00 | 105 | 107 | 19 | 23 | 80.5 | 81 | 165.6 | 157.2 | 322.8 |
| 3.30 | 109 | 111 | 19 | 23 | 81 | 81 | 169.6 | 160.2 | 329.8 |
| 4.00 | 102 | 104 | 19 | 23 | 80.5 | 81 | 167.7 | 155.2 | 322.9 |
| 4.30 | 101 | 103 | 19 | 22.8 | 80.5 | 81 | 163.0 | 161.1 | 324.1 |
| 5.00 | 102 | 104 | 19 | 22.8 | 80.5 | 81 | 163.0 | 160.5 | 323.5 |
| 5.30 | 108 | 110 | 20 | 22.5 | 80.5 | 81 | 166.9 | 166.2 | 332.1 |
| Mean | ........ | ........ | ........ | ........ | 80.6 | 81 | ........ | ........ | 325.3 |

| Time. | Indicated horsepower. | | | | Revolutions per minute of pumps. | | Head. | Discharge. | Useful water horsepower. | Efficiency. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Engine No. 2. | | | Total. | | | | | | |
| | Head. | Crank. | Total. | | No. 1. | No. 2. | | | | |
| | | | | | | | *Feet.* | *Cu. feet per sec.* | | *Per cent.* |
| 1.30 | 163.1 | 157.0 | 320.1 | 639.1 | 322 | 324 | 30.21 | ........ | ........ | ........ |
| 2.00 | 163.8 | 158.5 | 322.3 | 648.4 | 322 | 324 | 30.21 | 88.8 | 303 | 46.7 |
| 2.30 | 162.9 | 158.2 | 321.1 | 647.2 | 324 | 326 | 30.21 | 95.9 | 328 | 50.7 |
| 3.00 | 160.5 | 160.7 | 321.2 | 644.0 | 322 | 324 | 30.21 | 95.5 | 326 | 50.6 |
| 3.30 | 163.8 | 162.2 | 326.0 | 655.8 | 324 | 324 | 30.22 | 94.8 | 324 | 49.4 |
| 4.00 | 164.2 | 157.2 | 321.4 | 644.3 | 322 | 324 | 30.21 | 92.4 | 316 | 49.1 |
| 4.30 | 164.2 | 160.7 | 324.9 | 649.0 | 322 | 324 | 30.22 | 92.0 | 314 | 48.4 |
| 5.00 | 161.5 | 160.1 | 321.6 | 645.1 | 322 | 324 | 30.23 | 92.4 | 316 | 49.0 |
| 5.30 | 164.3 | 161.8 | 326.1 | 659.2 | 322 | 324 | 30.25 | 93.6 | 320 | 48.5 |
| Mean | ........ | ........ | 322.7 | 648.0 | 322 | 324 | 30.21 | 93.2 | 318 | 49.0 |

## PLANT NO. 6, ACADIA RELIFT.

About a mile north of Iota, La., on the main Acadia Canal, is located the Acadia relift. The equipment of this plant includes two horizontal return tubular boilers 72 inches in diameter by 18 feet in length, each containing seventy-two 4-inch tubes.

Fuel oil is used. The boilers are fed by means of two direct acting steam pumps. The first has its steam cylinders $4\frac{1}{2}$ inches in diameter and water cylinders $3\frac{3}{4}$ inches in diameter; stroke 4 inches. This pump takes water from the canal and furnishes it to the open heater.

The second has its steam cylinder 6 inches in diameter and water cylinder 4 inches in diameter. The stroke is 6 inches. This pump takes the water from the heater and pumps it into the boiler. Both pumps and the engine exhaust into the heater. During the test the water in the canal was found to have an average temperature of 88° F., while the water coming from the heater had an average temperature of 194° F.

The engine is a simple noncondensing Corliss, having piston diameter of 22 inches and stroke of 42 inches. The rod is $3\frac{13}{32}$ inches in diameter.

Rope transmission is used. There are 10 grooves in the engine fly wheel and on the sheave of pump; 958 feet of $1\frac{1}{2}$-inch rope is used.

The pump is similar to those at the Abbott-Duson first relift. It is nominally a 36-inch pump, having two suction pipes 24 inches in diameter. The pump discharges through a square opening into a gradually expanding flume.

It was found practically impossible to make necessary changes in the piping to make water measurements for a complete boiler test. Fuel oil was measured by means of a calibrated barrel and the only omission was in the amount of water furnished the boiler.

The discharge from the pump was measured in the flume about 50 feet from the pump. At this place the flume had a uniform cross section and was found to be 9.27 feet wide and the depth about 1.8 feet.

A current meter was used and the cross section slowly traversed at three different depths to obtain the mean velocity in all but two observations, when the Pitot tube was used. These observations were at 1.15 and 2.15 p. m. With the latter instrument the velocity was observed at ten different stations across the flume and at three different depths in the first and at two different depths in the second.

The arrangement of the plant is similar to that of the Abbott-Duson first relift, except that there is only one engine and one pump instead of one engine and two pumps, as in the plant referred to. There was one engine and a rope drive in each case. Both the engine and the rope drive were larger in the case where two pumps were used, but the loss due to friction in the two cases probably was not very different. The height through which the water was lifted was a little greater with the two pumps than with the single pump of the Acadia relift, and this probably had some effect on efficiency.

*Partial boiler test, Acadia relift.*

Duration of test, 4.45 hours.
Total fuel oil, 1,567 pounds.
Average steam pressure by gage, 79.4 pounds per square inch.
Average temperature of feed water, 194° F.
Average temperature of fuel oil, 87° F.
Average temperature of air, 95° F.

*Engine and pump test, Acadia relift.*

| Time. | Steam pressure. | Revolutions per minute of engine. | Indicated horsepower. | | | Revolutions per minute of pump. | Head. | Discharge. | Useful water horsepower. | Efficiency. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Head. | Crank. | Total. | | | | | |
| | *Pounds.* | | | | | | *Feet.* | *Cu. ft. per sec.* | | *Per cent.* |
| 11.15 | 80 | 68.5 | 69.5 | 66.5 | 136.0 | 117 | ...... | ...... | ...... | ...... |
| 11.45 | 80 | 69.5 | 73.9 | 70.9 | 144.8 | 119 | 9.53 | 70.6 | 76.1 | 52.6 |
| 12.15 | 79 | 68.7 | 70.8 | 68.6 | 139.4 | 117 | 9.55 | 71.1 | 76.7 | 55.0 |
| 12.45 | 78 | 68 | 65.8 | 62.8 | 128.6 | 115 | 9.48 | 69.6 | 74.6 | 58.0 |
| 1.15 | 80 | 69 | 70.7 | 67.7 | 138.4 | 118 | 9.50 | 73.7 | 79.1 | 57.1 |
| 1.45 | 80 | 68.5 | 68.8 | 68.0 | 136.8 | 118 | 9.51 | 67.8 | 72.8 | 53.2 |
| 2.15 | 79 | 68.7 | 71.6 | 67.8 | 139.4 | 117 | 9.45 | 75.0 | 80.1 | 57.5 |
| 2.45 | 78 | 68 | 67.6 | 65.1 | 132.7 | 116 | 9.46 | 73.0 | 78.0 | 58.7 |
| 3.15 | 81 | 70 | 74.2 | 69.1 | 143.3 | 118 | 9.45 | 70.2 | 74.9 | 52.3 |
| Mean. | 79.4 | 68.8 | ........ | ........ | 137.7 | 117.2 | 9.49 | 71.4 | 76.5 | 55.6 |

## PLANT NO. 7, GRAND CANAL, OLD PLANT.

The pumping plant of the Grand Canal is located on Bayou Nez Pique about 7 miles west of Iota, La. Bayou Nez Pique and the Mermentau River from the western boundary of Acadia Parish, dividing it from Calcasieu Parish.

This canal watered about 6,100 acres in 1905, although it has in previous years watered as many as 9,200 acres of rice. There are 17 miles of main canals and 13 miles of laterals.

The two boilers used in this plant are of the water-tube type, of the same make as those of the Acadia plant. They have a nominal capacity of 250 horsepower each.

An open heater was used. Water flowed from the flume to this heater and was then pumped to the weir tank, where the amount was measured by means of the 6-inch Cipolletti weir used in the tests of the Abbott-Duson and the Acadia plants. Another pump then forced the water into the boilers. The heater receives the exhaust from feed pumps and condenser pump.

The engine is a simple condensing Corliss with piston diameter of 28 inches and stroke of 48 inches. The piston rod is 4⅞ inches in diameter. There is a jet condenser having a vacuum pump with diameter of steam cylinder 18 inches, diameter of air cylinder 24 inches, and 24-inch stroke.

Rope transmission is used. The fly wheel is 20 feet in diameter and has fifteen grooves for 1½-inch rope. The sheave on the pump shaft is 5.35 feet in diameter.

There are two horizontal shaft centrifugal pumps, having single suction pipes 24 inches in diameter; the pumps have cored passages, so that the water divides and enters the eye of the pump on both sides. The discharge pipes are 24 inches in diameter at the pumps and are enlarged just above the pumps to 30 inches in diameter. Pump No. 1 discharged directly into the bottom of the flume, while pump No. 2 had a 30-inch elbow at the top and discharged into the end of the flume.

The measurements of the amount of water discharged were made in the flume about 150 feet from the pumps. The flume was 19.2 feet wide and the depth varied from about 1.25 feet to about 1.4 feet during the various observations.

The current meter was used and traverses were slowly made at two different depths.

On each side of the sheave driving the pumps is a flanged coupling, by means of which either pump, or both, may be connected to the driving shaft.

During the forenoon a test was made of pump No. 1, lasting two hours.

Beginning at 2.30 p. m. a test was run for four hours, using both pumps. During this time the boiler test was made.

At 7 p. m. two observations were made, using pump No. 2 only.

The crude oil used during this test was pumped into the storage tank only a short time previous to the test. It was from the Jennings field, but was obtained from a different firm from that supplying the fuel for the Acadia plant, the test of which has already been described. The oil used at the Grand Canal contained quite a quantity of salt water, and considerable trouble had occurred from this cause during operations previous to the test.

No special trouble was had during the test from the salt water, but the bad effect of using fuel containing water is plainly seen by a comparison of the results of the boiler tests of this plant with that of the Acadia plant, where with the same make of boilers the best result of any the boilers tested was obtained, while at the Grand Canal the results were the worst.

The same methods were used in these two tests and the results are equally reliable.

Reports from the Jennings field show that the percentage by volume of water present in the oil varies from almost zero to 13 per cent.

If sufficient time is allowed, water will settle to the bottom and can be drawn off. Commercial crude oil is supposed to contain but 2 per cent of water, but this amount is sometimes exceeded.

The results of the tests are as follows:

*Boiler test, Grand Canal, August 12, 1905.*

Duration of test, 4.07 hours.

Total fuel used, 5,328 pounds.

Average steam pressure by gage, 128.8 pounds per square inch.

Average temperature of feed water, 154.9° F.

Factor of evaporation, 1.105.

Total weight of water fed to boiler, 52,873 pounds.

Equivalent water evaporated from and at 212° F., 58,425 pounds.

Boiler horsepower, 416.

Average temperature of fuel oil, 86° F.

Average air temperature, 92° F.

Water apparently evaporated per pound of oil, 9.92 pounds.

Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 10.96 pounds.

Total feed water (including steam used by auxiliaries) per indicated horsepower-hour, 25.8 pounds.

*Engine and pump tests, Grand Canal.*

| Time. | Steam pressure. | Vacuum gage. | Revolutions per minute of engine. | Indicated horsepower. | | | Revolutions per minute of pump. | Head. | Discharge. | Useful water horsepower. | Efficiency. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Head. | Crank. | Total. | | | | | |
| | *Lbs.* | *Inches.* | | | | | | *Feet.* | *Cu. ft. per second.* | | *Per cent.* |
| 2.30 | 128 | 25.5 | 62.5 | 244.2 | 255.9 | 500.1 | 234 | 28.7 | ........ | ........ | ........ |
| 3.00 | 129 | 25.8 | 62.5 | 242.5 | 259.0 | 501.5 | 234 | 28.7 | 68.3 | 221.6 | 44.2 |
| 3.30 | 132 | 25.8 | 63.0 | 254.5 | 263.5 | 518.0 | 236 | 28.7 | ........ | ........ | ........ |
| 4.00 | 127 | 25.7 | 62.2 | 241.5 | 249.7 | 491.2 | 233 | 28.7 | 65.6 | 212.8 | 43.3 |
| 4.30 | 129 | 25.7 | 62.7 | 247.0 | 259.5 | 506.5 | 234 | 28.7 | 68.7 | 223.0 | 44.0 |
| 5.00 | 130 | 25.8 | 62.5 | 247.0 | 255.2 | 502.2 | 234 | 28.7 | 69.4 | 225.2 | 44.8 |
| 5.30 | 129 | 25.8 | 62.5 | 247.5 | 261.2 | 508.7 | 234 | 28.7 | 66.7 | 216.4 | 42.5 |
| 6.00 | 128 | 25.9 | 62.8 | 247.8 | 258.5 | 506.3 | 235 | 28.7 | 70.6 | 229.2 | 45.3 |
| 6.30 | 127 | 25.8 | 62.5 | 248.0 | 252.8 | 500.8 | 234 | 28.7 | 71.4 | 231.5 | 46.2 |
| Mean. | 128.8 | 25.8 | 62.6 | ........ | ........ | 503.9 | 234.2 | 28.7 | 68.7 | 222.8 | 44.3 |
| **TEST OF PUMP NO. 1.** | | | | | | | | | | | |
| 10.15 | 118 | 25.1 | 70.0 | 260.0 | 258.1 | 518.1 | 262 | 29.13 | 68.26 | 224.8 | 43.4 |
| 10.35 | 121 | 25.2 | 70.0 | 259.8 | 260.3 | 520.1 | 262 | 29.13 | 67.21 | 221.4 | 42.5 |
| 11.00 | 118 | 25.0 | 69.5 | 258.0 | 252.0 | 510.0 | 260 | 29.13 | 69.30 | 228.3 | 44.8 |
| 11.25 | 118 | 24.6 | 72.8 | 301.0 | 294.5 | 595.5 | 272 | 29.38 | 74.25 | 246.6 | 41.4 |
| 11.45 | 118 | 25.2 | 67.5 | 239.8 | 235.0 | 474.8 | 253 | 29.10 | 63.67 | 209.5 | 44.1 |
| 12 | 119 | 25.6 | 63.0 | 162.8 | 159.0 | 321.8 | 236 | 28.68 | 46.46 | 150.6 | 46.8 |
| 12.15 | 120 | 25.9 | 60.0 | 104.2 | 110.1 | 214.3 | 224 | 28.57 | 24.66 | 79.6 | 37.2 |
| **TEST OF PUMP NO. 2.** | | | | | | | | | | | |
| 7.00 | 122 | 25.5 | 65.0 | 192.5 | 185.8 | 378.3 | 243 | 28.85 | 49.75 | 162.3 | 42.9 |
| 7.15 | 120 | 25.0 | 68.5 | 238.5 | 236.5 | 475.0 | 256 | 28.85 | 65.10 | 212.3 | 44.7 |

## PLANT NO. 8, GRAND CANAL, NEW PLANT.

Between the pumping seasons of 1905 and 1906 extensive changes were made in the equipment of the pumping plant of the Grand Canal. The pumps were removed and new ones, also of the centrifugal type, were installed. The boilers and the simple condensing Corliss engine were retained, but the fly wheel 20 feet in diameter was replaced by another of approximately 14 feet in diamenter. The rope drive connecting this engine to one of the pumps consists of sixteen strands of 1¾-inch rope.

A new water tube boiler, a tandem compound Corliss engine, and another pump were installed. The condenser used with the new engine is of the jet type; size of pump, 14 by 20 by 24 inches. It makes about 28 double strokes per minute. The boiler feed pump has dimensions 8 by 5 by 14 inches and makes about 9½ double strokes per minute. These outfits are complete and separate pumping plants, although located in the same building.

On September 20, 1906, a test was made to determine the mechanical efficiency of the simple engine rope drive and pump. This test lasted from 3.30 to 6.20 p. m. The efficiency when operating at proper speed averaged 69.8 per cent—quite a contrast to the results obtained in 1905.

On September 21, 1906, a test was made of the new pumping equipment already referred to. This test lasted only three hours and forty-three minutes. Fuel consumption during that time was extremely regular, the water level of the boiler was fairly constant, and all conditions favorable for accurate results. However, a longer test would in all probability give a greater degree of accuracy, especially in the water evaporated by the boiler and used as steam by the whole plant. As the test was made late in the irrigating season there was very little demand for irrigation water, and when the canal was filled to the danger line the pumps had to be stopped.

During the test fuel oil was carefully measured in a calibrated barrel. The heat value of the fuel oil was determined by means of a Parr calorimeter and found to be 17,834 British thermal units per pound, the lowest heat value the writer has ever found in an oil from the Jennings field. No water was present in the oil. Boiler feed water was measured by means of a 6-inch Cipolletti weir, so arranged that the heater could be used during the test.

The steam-engine indicators used in both these tests had been calibrated just previous to the test. Revolutions of the engine in each case were determined by means of a continuous counter, read at intervals of five minutes. The average number of revolutions obtained from these readings was used in computing indicated horsepower. Revolutions of the pump were obtained from the known ratio of pitch diameter of engine and pump sheaves.

Water measurements were made with the current meter. The flume which conducts the water from the discharge to the canal is 19.2 feet in width at the point where the water measurements were made.

The current meter was slowly moved across the flume at three different depths, the direction of movement then reversed, and the path retraced in an opposite direction. On account of the unusual width of flume it was found necessary to correct the current meter readings for the component of motion at right angles to the axis of the flume in each case.

The height through which the water was lifted was carefully obtained by means of a tape that had been compared with a steel tape.

The average mechanical efficiencies of engine, pump, and rope drive in the two cases agree remarkably well. The average in the case of the simple engine was 67.4 and in case of the compound 69 per cent for observations where the proper speed was maintained.

The centrifugal pumps show a remarkably high efficiency for a pump of that type. Their excellence is primarily due to good design, but one other cause is worthy of note. The double suction pipes enlarge from 24 inches near pump to 34 inches at a distance of about 4 feet from the flange of pump; again at the lower end of the suction pipes there is a conical frustrum 9 feet long, with a diameter of 42 inches at intake. The vertical discharge pipes in each case are enlarged to 42 inches a short distance above the pumps, and just below where they enter the bottom of the flume they are enlarged in the last 5 feet, changing the cross section from a circular section 42 inches in diameter to a section 51 inches square at entrance to flume. Enlargement of suction pipe reduces the velocity of the entering water and reduces the entrance loss, while the enlarged discharge pipe reduces the velocity of the water discharged and consequently the " velocity head " lost at entrance to flume.

The results of the test are as follows:

*Boiler test, Grand Canal, September 21, 1906.*

Duration of test, 3.717 hours.

Total fuel oil used, 2,476 pounds.

Average steam pressure by gage, 153.4 pounds.

Average temperature of feed water, 188.5° F.

Factor of evaporation, 1.074.

Total weight of water fed to boiler, 28,944 pounds.

Equivalent water evaporated from and at 212° F., 31,086 pounds

Boiler horsepower, 242.2.

Water apparently evaporated per pound of oil, 11.69 pounds.

Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 12.56 pounds.

Total feed water (including steam used by auxiliaries) per indicated horsepower hour, 17.7 pounds.

*Test of compound engine and pump, Grand Canal, September 21, 1906.*

| Number. | Time. | Pressures. | | | | Revolutions per minute of— | | Indicated horsepower. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | High. | |
| | | Near engine. | Boiler. | Receiver. | Vacuum. | Engine. | Pump. | Head. | Crank. |
| 1 | 11.46 | 148 | 148 | 18 | 25 | 79 | 169.4 | 103.5 | 89.3 |
| 2 | 1.15 | 150 | 156 | 8 | 25.2 | 74.8 | 160.4 | 111 | 93.4 |
| 3 | 1.45 | 145 | 151 | 8 | 25.1 | 78.1 | 167.5 | 128.6 | 106.3 |
| 4 | 2.15 | 149 | 155 | 9 | 25 | 78.7 | 168.7 | 135.6 | 108.9 |
| 5 | 2.45 | 145 | 151 | 8.7 | 25 | 78.5 | 168.3 | 129.3 | 108.6 |
| 6 | 3.15 | 148 | 154 | 9 | 25.1 | 78.6 | 168.5 | 127.8 | 108.8 |
| 7 | 3.45 | 149 | 155 | 7.5 | 25 | 78.5 | 168.3 | 134.2 | 113.4 |
| 8 | 4.15 | 147 | 153 | 7.6 | 24.9 | 78.3 | 167.9 | 132.3 | 111.1 |
| 9 | 4.45 | 146 | 152 | 7.3 | 24.8 | 78.6 | 168.5 | 133.6 | 115.8 |
| 10 | 5.06 | .......... | .......... | .......... | .......... | 86.75 | 186 | 204.2 | 168.9 |
| | Mean | .......... | .......... | .......... | .......... | 79.0 | 169.3 | .......... | .......... |

| Number. | Time. | Indicated horsepower. | | | Discharge per second. | Gallons per minute. | Head. | Useful water horsepower. | Efficiency, engine drive and pump. |
|---|---|---|---|---|---|---|---|---|---|
| | | Low. | | Total. | | | | | |
| | | Head. | Crank. | | | | | | |
| | | | | | *Cubic feet.* | | | | *Per cent.* |
| 1 | 11.46 | 108.4 | 125.8 | 427 | 79.7 | 35,780 | 31.47 | 284 | 66.5 |
| 2 | 1.15 | 80.7 | 91.2 | 376.3 | 66.2 | 29,720 | 31.49 | 235.9 | 62.7 |
| 3 | 1.45 | 97.9 | 108 | 440.8 | 86.1 | 38,620 | 31.56 | 307.1 | 69.7 |
| 4 | 2.15 | 97.1 | 109.3 | 450.9 | 88.4 | 39,650 | 31.57 | 315.7 | 70 |
| 5 | 2.45 | 98.2 | 105.7 | 441.8 | 86.9 | 39,000 | 31.65 | 311.2 | 70.5 |
| 6 | 3.15 | 96.7 | 106.6 | 439.9 | 85.6 | 38,430 | 31.67 | 306.8 | 69.8 |
| 7 | 3.45 | 93.8 | 101.1 | 442.5 | 82.6 | 37,090 | 31.70 | 296.4 | 67 |
| 8 | 4.15 | 86.8 | 96 | 426.2 | 81.9 | 36,760 | 31.74 | 294.1 | 69 |
| 9 | 4.45 | 89.2 | 98.4 | 437 | 83.6 | 37,530 | 31.75 | 300.3 | 68.7 |
| 10 | 5.06 | 130.1 | 137.3 | 640.5 | 115.5 | 51,870 | 31.87 | 416.7 | 65 |
| | Mean | .......... | .......... | 452.3 | 85.65 | 38,445 | 31.66 | 306.8 | 67.89 |

*Test of simple engine and pump, September 20, 1906.*

| Number. | Time. | Revolutions per minute of— | | Indicated horsepower. | | Total. | Discharge per second. | Gallons per minute. | Head. | Useful water horsepower. | Efficiency, engine drive and pump. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | High. | | | | | | | |
| | | Engine. | Pump. | Head. | Crank. | | | | | | |
| | | | | | | | *Cubic feet.* | | | | *Per cent.* |
| 1 | 3.43 | 81.5 | 174.8 | 255.5 | 254.3 | 509.8 | 95.7 | 42,980 | 31.84 | 345.2 | [a] 67.7 |
| 2 | 3.50 | 81.5 | 174.8 | 251.1 | 262.3 | 513.4 | 99.2 | 44,520 | 31.85 | 357.5 | [a] 69.6 |
| 3 | 4.05 | 81.6 | 175 | 246 | 251 | 497 | 100.7 | 45,210 | 31.85 | 363 | [a] 73 |
| 4 | 4.15 | 81.7 | 175.2 | 251.2 | 251.7 | 502.9 | 97.1 | 43,580 | 31.85 | 350 | [a] 69.6 |
| 5 | 5.10 | 76.4 | 163.8 | 179 | 181.9 | 360.9 | 70.3 | 31,550 | 31.65 | 251.8 | [a] 69.8 |
| 6 | 5.19 | 76 | 163 | 176.5 | 180.9 | 357.4 | 69.4 | 31,140 | 31.63 | 248.3 | [a] 69.5 |
| 7 | 5.35 | 79.2 | 169.8 | 211 | 213.7 | 424.7 | 82.4 | 36,980 | 31.73 | 295.8 | [a] 69.7 |
| 8 | 6.02 | 73.4 | 157.4 | 119.4 | 137.5 | 256.9 | 44.3 | 19,870 | 31.44 | 157.3 | 61.3 |
| 9 | 6.08 | 73.4 | 157.4 | 117.3 | 131.6 | 248.9 | 45 | 20,200 | 31.44 | 160 | 56.2 |

[a] The average of Nos. 1 to 7, inclusive, 69.8.

## PLANT NO. 9, ABBOTT BROTHERS' LOWER FARM.

The test was made at the Abbott Brothers' lower farm, about 2 miles northwest of Crowley, La. The pumping plant supplies water to 9 miles of main canals and 15 miles of laterals, and has watered as many as 7,200 acres of rice. During the season of 1905 it furnished water for about 4,000 acres.

The plant contains four horizontal tubular boilers 66 inches in diameter and 18 feet in length, each having fifty-seven 4-inch tubes.

There are three slide-valve noncondensing engines, with piston diameter of 16 inches and stroke of 20 inches.

The engine tested is arranged to furnish power by means of a rope drive to a single-suction centrifugal pump, having a suction pipe 20 inches in diameter and discharge 18 inches in diameter. The other two units use belts between engine and pumps. Although the pumps have single-suction pipes, there are cored passages to carry the water around the sides of the vortex chamber and cause it to enter the eye of the pump from both sides. In each case the discharge pipe is provided with an elbow at the top, so that the water is discharged horizontally into the flume.

The fuel used is crude oil, costing 35 cents per barrel of 42 gallons delivered at the plant. The supply is obtained through a pipe line from the Jennings field.

During the test two boilers were used and one engine and pump. The water used by the boilers was first pumped by one of two direct-acting feed pumps, ordinarily used as boiler feeders, to two barrels that had been previously calibrated, where it was measured. These barrels emptied into another placed beneath them, which was connected to the suction of the other boiler feed pump. This latter pump forced the water through a closed heater, which received the exhaust of the engine and feed pumps and in which the temperature was raised from 80.5° F. to 189° F.

The plant has been in use for several years. The piping and stop valves were so arranged that considerable surface of bare pipe used to conduct steam to the engines was exposed, and acting as a condenser, it was also found impossible to close some of the valves completely and thus prevent leakage.

The boilers used were carefully examined and it was found that no water was leaking from blow-off valves or elsewhere, so that all water measured and pumped to boilers was converted into steam. The boiler test was therefore satisfactory. At the completion of the regular test a leakage test was conducted to determine the amount of condensed steam passing through defective valves in the steam pipe, and the water apparently used by the engine and auxiliaries as steam was corrected.

The leakage was found to be 16.83 per cent of the total water used. Steam was being used by oil burners while leakage test was made, and no correction made. As there is some leakage of steam when the entire plant is operated, and as one or two units are often operated alone, the cost of oil was taken from results of tests as found.

The test was made on July 20, after heavy rains. The level of the water was unusually high in Bayou Plaquemine, but considerably lower than it had been two or three weeks previous, when the flood level was the highest since the irrigation of rice began in that section.

The mean lift was 15.4 feet, while ordinarily it ranges from 18 to 24 feet.

The water was measured in a flume 9.05 feet in width; the depth varied from about 0.7 to nearly 0.8 foot. The average velocity varied from 3.98 to 4.26 feet per second; it was found by using the current meter and the Pitot tube alternately, the results obtained being the mean of nine observations of velocity at the centers of areas, each of which was one-ninth of the cross section of the flume.

The results were equally satisfactory with the two instruments.

Indicator cards were taken every fifteen minutes.

The average efficiency of engine, rope transmission, and pump was 41.9 per cent. If the mechanical efficiency of the engine is assumed to be 90 per cent and that of the rope drive 95 per cent, the efficiency of the pump alone was about 49 per cent.

This plant is a type of many of the early installations in the rice country.

The results of the tests are as follows:

*Boiler test, Abbott Brothers lower farm, July 20, 1905.*

Duration of test, 4 hours.

Total fuel oil, 1,929 pounds.

Average stream pressure by gage, 75.1 pounds per square inch.

Average temperature of feed water, 189° F.

Factor of evaporation, 1.058.

Total weight of water fed to boiler, 25,360 poun

Equivalent water evaporated from and at 212° F., 26,831 pounds.

Boiler horsepower, 194.

Average air temperature, 82° F.

Water apparently evaporated per pound of oil, 13.15 pounds.

Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 13.91 pounds.

Total feed water (including steam used by auxiliaries, but not including steam lost through valves) per indicated horsepower hour, 43.1 pounds.

*Engine and pump test, Abbott Brothers' lower farm.*

| Time. | Steam pressure. | Revolutions per minute of engine. | Indicated horsepower | | | Revolutions per minute of pump. | Head. | Discharge. | Useful water horsepower | Efficiency. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Head. | Crank. | Total. | | | | | |
| | *Pounds.* | | | | | | *Feet.* | *Cu. feet per sec.* | | *Per ct.* |
| 11.00 | 72 | 137 | 61.4 | 58.3 | 119.7 | 261 | 15.75 | ........ | ........ | ........ |
| 11.15 | 79 | 140 | 65.4 | 61.9 | 127.3 | 264 | 15.75 | ........ | ........ | ........ |
| 11.30 | 78 | 140 | 68.7 | 65.8 | 134.5 | 263 | 15.70 | ........ | ........ | ........ |
| 11.45 | 76 | 138 | 64.6 | 60.7 | 125.3 | 261 | 15.67 | ........ | ........ | ........ |
| 12.00 | 78 | 141 | 69.7 | 63.0 | 132.7 | 263 | 15.65 | ........ | ........ | ........ |
| 12.15 | 75 | 139 | 65.1 | 62.4 | 127.5 | 264 | 15.62 | 30.59 | 54.1 | 42.4 |
| 12.30 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 12.45 | 72 | 137 | 63.9 | 60.0 | 123.9 | 260 | 15.53 | ........ | ........ | ........ |
| 1.00 | 72 | 139 | 63.7 | 60.5 | 124.2 | 262 | 15.49 | 27.90 | 49.0 | 39.5 |
| 1.15 | 72 | 138 | 63.8 | 60.4 | 124.2 | 262 | 15.47 | ........ | ........ | ........ |
| 1.30 | 74 | 139 | 61.7 | 56.5 | 118.2 | 264 | 15.42 | 28.25 | 49.2 | 41.6 |
| 1.45 | 73 | 137 | 62.4 | 58.8 | 121.2 | 258 | 15.40 | ........ | ........ | ........ |
| 2.00 | 72 | 138 | 63.8 | 60.4 | 124.2 | 262 | 15.36 | 28.97 | 51.6 | 41.5 |
| 2.15 | 80 | 140 | 68.0 | 63.4 | 131.4 | 265 | 15.33 | ........ | ........ | ........ |
| 2.30 | 84 | 137 | 63.2 | 59.0 | 122.3 | 259 | 15.31 | 30.00 | 52.0 | 42.6 |
| 2.45 | 73 | 138 | 62.4 | 58.9 | 121.3 | 264 | 15.28 | 28.81 | 49.9 | 41.1 |
| 3.00 | 72 | 136 | 60.7 | 58.0 | 118.7 | 260 | 15.25 | ........ | ........ | ........ |
| 3.19 | 69 | 135 | 55.8 | 52.1 | 107.9 | 252 | 15.20 | ........ | ........ | ........ |
| 3.36 | 62 | 130 | 49.3 | 44.6 | 93.9 | 247 | 15.17 | 26.40 | 45.3 | 48.2 |
| 3.51 | 72 | 137 | 61.3 | 59.3 | 120.6 | 255 | 15.14 | 29.39 | 50.3 | 41.7 |
| 4.05 | 75 | 138 | 63.9 | 61.8 | 125.7 | 265 | 15.11 | 29.41 | 50.4 | 40.1 |
| 4.25 | 72 | 137 | 61.8 | 59.4 | 121.2 | 259 | 15.08 | 29.55 | 50.4 | 41.6 |
| 4.45 | 73 | 137 | 63.8 | 59.7 | 123.5 | 260 | 15.04 | 29.55 | 50.3 | 40.7 |
| Mean | 73.9 | 137.6 | ........ | ........ | 122.2 | 260.5 | 15.40 | 28.98 | 50.2 | 41.9 |

## PLANT NO. 10, WESSON FARM.

This plant is located on the farm of Mr. H. E. Wesson, about one-half mile northeast of the railway station at Welsh, La.

The well is 175 feet deep; it has a 10-inch casing, with 60 feet of strainer. The number of acres watered in 1905 was 64, while in 1904 135 acres were irrigated.

The boiler is of the locomotive type, having 72 2-inch flues, 9 feet long, and, according to builders' rating, is of 50-horsepower capacity.

The engine is simple noncondensing, and has a cylinder 12 inches in diameter and stroke of 15 inches. The boiler is fed by means of a pump attached to the engine or by an injector.

The pump was a No. 8 centrifugal, with vertical shaft.

The suction pipe was 8⅝ inches and the discharge pipe 6 inches in diameter. Pump was submerged in a pit 31 feet deep and was about 18 feet under water at the time test was made.

Pump was driven by means of a belt from the fly wheel of engine, which was 60 inches in diameter; the pulley on pump was 18 inches in diameter. The fuel used was crude oil, costing 52.5 cents per barrel delivered at plant.

The first cost of this plant, including well and the rough board building, was as follows:

| | |
|---|---|
| Engine, boiler, and shed | $1,175.00 |
| Pump | 175.00 |
| Belt | 50.00 |
| Well, 175 feet, at $3.50 per foot | 612.50 |
| Total | 2,012.50 |

The plant had been in use for three years previous to the season of 1905 and was sadly in need of repairs. The engine foundation consisted of large pieces of timber, to which the frame of the engine was bolted. The engine frame was rather light and, as it was called upon to furnish power considerably in excess of its rating, the combination of light frame and wood foundation was accountable for a great lack of rigidity. The overload was due principally to the lack of alignment of the pump shaft and to the settling of the casing and pump. In plants of this type the casing of the well, to which the suction of the pump is attached, often settles, pulling the pump with it, and, besides, there is more or less change in the position of the sides of the planking forming the sides of the pit. There are bearings for the vertical shaft at intervals, supported by timbers, which are in turn fastened to this pit lining. It is important that the main thrust bearing near the top of shaft, usually above the driving pulley, shall be able not only to support the shaft, but also the pull on the pump impeller, due to unbalanced pressures. Unless the pump and pits are examined from time to time and alignment of shaft carefully maintained trouble will follow.

The condition of the pump was so bad that, after intermittent use for two weeks, the impeller had worn holes through the casing and a new pump had to be installed. This was after the test.

During the test it was only with the greatest difficulty that the plant was operated; it was in as bad a condition as could possibly exist and yet allow pumping.

The water pumped was measured by means of an 18-inch Cipolletti weir; the depth was obtained by means of a hook gage. The head was obtained by getting the difference of level of water in discharge pipe of pump when pump was not running and the point to which the water was elevated by pump.

It was desired that a vacuum gage be attached to suction pipe of pump and a pressure gage to the discharge pipe, so that the total head, including friction, could be obtained. This was impossible, because, as already stated, the water stood in the pump pit several feet above the pump.

In pumping from a well the level of the water falls considerably as soon as the pump is started.

Some head is required to force the water through the screen and the surrounding sand and gravel. In the tests of pumps taking water from the bayous and rivers the head used to compute efficiency was in each case the actual distance through which the water was lifted. In the tests of well plants the head used was that from original level of water before pump was started to height to which water was elevated. It is seen from this statement that this method puts the pumps used on well plants at a disadvantage, as the suction head increased when pumps were run, and there was no way to correct for the fall of water level.

*Boiler test, Wessom plant, June 30, 1905.*

Duration of test, 1.73 hours.

Total fuel oil, 405 pounds.

Average steam pressure by gage, 84 pounds per square inch.

Average temperature of feed water, 88° F.

Factor of evaporation, 1.165.

Total weight of water fed to boiler, 4,477 pounds.

Equivalent water evaporated from and at 212° F., 5,216 pounds.

Boiler horsepower, 87.

Average temperature of fuel oil, 91° F.

Average air temperature, 94° F.

Water apparently evaporated per pound of oil, 11.1 pounds.

Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 12.9 pounds.

Total feed water (including steam used by auxiliaries) per indicated horsepower-hour, 36.1 pounds.

*Engine and pump test, Wesson plant.*

| Time. | Steam pressure. | Revolutions per minute of engine. | Indicated horsepower. | | | Revolutions per minute of pump. | Head. | Discharge. | Useful water horsepower. | Efficiency. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Head. | Crank. | Total. | | | | | |
| | *Pounds.* | | | | | | *Feet.* | *Cu. ft. per sec.* | | *Per cent.* |
| 10.00...... | 89 | 175 | 43.4 | 36.4 | 79.8 | 583 | 14.08 | 2.22 | 3.54 | 4.4 |
| 10.30...... | 70 | 147 | 27.0 | 22.8 | 49.8 | 490 | 14.08 | 2.06 | 3.30 | 6.6 |
| 11.00...... | 90 | 181 | 44.1 | 37.2 | 81.3 | 603 | 14.38 | 2.16 | 3.52 | 4.3 |
| 11.30...... | 87 | 177 | 41.4 | 34.3 | 75.7 | 590 | 14.38 | 2.18 | 3.56 | 4.7 |
| Mean. | 84 | 170 | ........ | ........ | 71.6 | 566 | 14.23 | 2.16 | 3.48 | 5.0 |

## PLANT NO. 11, SAXBY FARM.

There was marked contrast in the condition of the machinery tested at plant No. 10, when compared with that of No. 11.

The plant is located on the farm of Mr. C. A. Saxby, about three-fourths of a mile southeast of Welsh, La. The number of acres watered in 1905 was 160, from which a yield of 2,052 barrels of rice was obtained. The well is 255 feet deep; 60 feet of screen are used. The boiler is of the locomotive type; it had been in use for several years, and, notwithstanding the fact that there were bad air leaks in the breeching, it made a good showing during the test.

The fuel used is crude oil, costing 52.5 cents per barrel of 42 gallons delivered at plant.

A simple, noncondensing engine is used; diameter of cylinder 11 inches, stroke 15 inches, and diameter of rod 1⅝ inches.

The pump is a No. 6 vertical shaft centrifugal, but is provided with 8-inch suction and discharge pipes. The plant has been in use for three seasons. The well is said to be one of the best in that section of the country.

The cost of the pumping plant complete, including well, building, and machinery, was $2,530.

The pump is driven by a quarter-turn belt; the distance between centers of engine and pump pulleys was about 40 feet. Both the engine and pump were in excellent condition.

Three sets of observations were taken of the quantity of water pumped. These measurements were made in a small flume 3 feet in length and 22 inches in width. The depth of water varied from 5½ to 6 inches. The mean velocity was determined by means of a Pitot tube. After three observations had been made it became necessary to conduct the water from the pond in a different direction, and this necessitated the changing of the small flume.

There was not sufficient time to do the work satisfactorily and conditions had been so uniform during the observations that further measurements were not considered necessary.

The discharge from the pump, as shown by the observations made, varied between 1,732 and 1,598 gallons per minute.

Owing to a wet winter and spring the level of the water in the wells of southwest Louisiana was about 10 feet higher in 1905 than during the average season. This was favorable to well plants, as the total head pumped against was less than usual.

The results of the tests are as follows:

*Boiler test, Saxby plant, July 3, 1905.*

Durataion of test, 4 hours.

Total fuel oil, 690 pounds.

Average steam pressure by gage, 98 pounds per square inch.

Average temperature of feed water, 73.5° F.

Factor of evaporation, 1.184.

Total weight of water fed to boiler, 7,210 pounds.

Equivalent water evaporated from and at 212° F., 8,537 pounds.

Boiler horsepower, 62.

Water apparently evaporated per pound of oil, 10.45 pounds.

Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 12.37 pounds.

Total feed water (including steam used by auxiliaries) per indicated horsepower-hour, 58.7 pounds.

*Engine and pump test, Saxby plant.*

| Time. | Steam pressure. | Revolutions per minute of engine. | Indicated horsepower. | | | Revolutions per minute of pump. | Head. | Discharge. | Useful water horsepower. | Efficiency. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Head. | Crank. | Total. | | | | | |
| | *Pounds.* | | | | | | *Feet.* | *Cu. ft. per sec.* | | *Per cent.* |
| 2.00 | 95 | 154 | 15.4 | 14.9 | 30.3 | 520 | 15.25 | 3.56 | 6.16 | 20.3 |
| 2.30 | 103 | 158 | 15.8 | 15.0 | 30.8 | 533 | 15.25 | 3.57 | 6.16 | 20.0 |
| 3.00 | 100 | 157 | 15.3 | 14.9 | 30.2 | 530 | 15.25 | 3.86 | 6.67 | 22.1 |
| 3.30 | 96 | 158 | 15.8 | 15.5 | 31.3 | 533 | 15.25 | | | |
| 4.00 | 100 | 157 | 15.7 | 15.0 | 30.7 | 530 | 15.25 | | | |
| 4.30 | 95 | 156 | 15.2 | 14.6 | 29.8 | 527 | 15.25 | | | |
| 5.00 | 97 | 157 | 15.6 | 15.0 | 30.6 | 530 | 15.25 | | | |
| 5.30 | 96 | 157 | 16.4 | 15.8 | 32.2 | 530 | 15.25 | | | |
| Mean | 98 | 156.7 | | | 30.7 | 529 | 15.25 | 3.66 | 6.33 | 20.8 |

## PLANT NO. 12, CROWLEY FARMING COMPANY.

Test No. 12 was made on a pumping plant on the farm of the Crowley Farming Company (which is a part of the Green-Shoemaker interests). This plant furnished water to irrigate 500 acres of rice in 1905, the total yield from which was 3,552 barrels, or 7.1 barrels per acre.

There are three 10-inch wells, each 200 feet deep, with 32 feet of strainer. The wells are connected to a common suction pipe at the pump, which is located at the middle of the top of a T, formed by three suction pipes, so that the pump is 50 feet from each well.

A simple noncondensing slide-valve engine, rated at 50 horsepower, with cylinder diameter of 12 inches and stroke of 15 inches, is used. It was in good condition. A rope drive is used to connect the engine with a rotary pump. Five 1-inch ropes form the drive, the sheave on the pump being 72 inches and on the engine 66 inches in diameter.

The pump is of the chamber-wheel type; the displacement per revolution is 26.8 gallons, or 3.58 cubic feet.

The boiler was of the stationary, locomotive type, having ample capacity to furnish steam to engine; builder's rating, 60 horsepower.

The fuel used was crude petroleum. As it was stored in a cylindrical tank, from which oil was fed by gravity to the burners, direct measurements of the fall of the level of the oil were taken, together with temperature and specific gravity. From these observations the weight of oil used was computed.

The boiler was fed by means of an injector, the immediate supply being a wooden cistern located near the engine house.

A pipe leading from the flume into which the pump discharged conducted water to the cistern. During the test the valve in this pipe was closed and the fall of water in the cistern was noted and the amount computed from the measurements.

Water measurements were made in the flume about 75 feet from the pump. Traverses were made by slowly moving the current meter across the section at different elevations and the mean velocity thus found. The width of flume was 4.05 feet and the depth varied from slightly over 1 foot to nearly 1.6 feet.

The test was begun at 10.45 a. m. and lasted two and three-fourths hours.

Before starting the test one of the well covers was removed and the depth of water measured. This was done in order to get a comparison with the two other tests of well plants, where the distance through which the water was pumped was taken as the difference in level of the water standing in wells and the discharge.

The head thus obtained was used to compute the "useful work" in the log of test.

A vacuum gage was attached to the suction pipe near pump and was read at each observation during test. The reading of this gage reduced to feet of water and added to the height to which water was elevated above the point where suction head was obtained gave the total head produced by pump in elevating the water, in overcoming friction, and in producing the flow of water. This head appears in the log of results under the title " including friction."

The difference between the two must not be charged entirely to friction, as the water level about the wells undoubtedly fell as soon as the pump was operated.

Two efficiencies were computed, one for each of the heads as stated above.

The conclusion can not be drawn that the efficiencies of the other two well plants tested, near Welsh, would have been increased proportionately, for we do not know what effect was produced by the three wells connected to one pump in the one case and to a single well in the other two cases.

The type of pump in this case was different from that in the other two. The efficiency in each of the three cases that may be compared is strongly in favor of the plant under discussion, but this may be due in some measure to the three wells furnishing the water.

The results of the tests are as follows:

*Boiler test, Crowley Farming Company, July 21, 1905.*

Duration of test, 2.75 hours.
Total fuel oil, 452 pounds.
Average steam pressure by gage, 79.3 pounds per square inch.
Average temperature of feed water, 82° F.
Factor of evaporation, 1.170.
Total weight of water fed to boiler, 4,872 pounds.
Equivalent water evaporated from and at 212° F., 5,700 pounds.
Boiler horsepower, 51.
Average temperature of fuel oil, 93° F.
Average air temperature, 93° F.
Water apparently evaporated per pound of oil, 10.78 pounds.
Equivalent evaporation from and at 212° F. (not corrected for quality of steam), 12.61 pounds.
Total feed water per indicated horsepower-hour, 61.7 pounds.

*Engine and pump test, Crowley Farming Company plant.*

| Time. | Steam pressure. | Revolutions per minute of engine. | Indicated horse-power. | | | Revolutions per minute of pump. | Discharge. | Useful work. | | | Including friction. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Head. | Crank. | Total. | | | Head. | Water horse-power. | Efficiency. | Head. | Water horse-power. | Efficiency. |
| | *Lbs.* | | | | | | *Cu. ft. pr. sec.* | *Feet.* | | *Per cent.* | *Feet.* | | *Per cent.* |
| 10.45 | 77 | 135 | 14.2 | 14.6 | 28.8 | 123 | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 11.00 | 84 | 136 | 14.1 | 14.7 | 28.8 | 125 | 4.77 | 15.75 | 8.51 | 29.5 | 28.87 | 15.60 | 54.2 |
| 11.15 | 77 | 135 | 14.1 | 14.9 | 29. | 124 | 4.79 | 15.75 | 8.55 | 29.5 | 29.16 | 15.82 | 54.6 |
| 11.30 | 83 | 134 | 14.1 | 14.5 | 28.6 | 124 | 4.98 | 15.75 | 8.88 | 31.1 | 29.16 | 16.45 | 57.5 |
| 11.45 | 82 | 136 | 14.2 | 15 | 29.2 | 126 | 4.85 | 15.75 | 8.64 | 29.6 | 29.16 | 16.02 | 54.9 |
| 12.00 | 76 | 134 | 14 | 14.4 | 28.4 | 123 | 4.94 | 15.75 | 8.81 | 31 | 29.16 | 16.32 | 57.5 |
| 12.15 | 77 | 135 | 14 | 14.5 | 28.5 | 123 | 4.81 | 15.75 | 8.58 | 30.1 | 29.16 | 15.89 | 55.8 |
| 12.30 | 76 | 135 | 14 | 14.8 | 28.8 | 123 | 4.89 | 15.75 | 8.73 | 30.3 | 29.16 | 16.14 | 56 |
| 12.45 | 77 | 135 | 13.9 | 14.5 | 28.4 | 123 | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| 1.00 | 80 | 135 | 14.1 | 14.5 | 28.6 | 123 | 4.81 | 15.75 | 8.59 | 30. | 29.16 | 15.90 | 55.5 |
| 1.15 | 83 | 135 | 14 | 14.4 | 28.4 | 123 | 4.71 | 15.75 | 8.40 | 29.6 | 29.16 | 15.56 | 54.8 |
| Mean. | 79.3 | 135 | ...... | ...... | 28.7 | 123.6 | 4.84 | 15.75 | 8.63 | 30.1 | 29.13 | 15.97 | 55.6 |

## PLANT NO. 13, SOUTH SIDE PLANTING COMPANY DRAINAGE WHEEL.

This test was made of a pumping plant used to drain the sugar plantation of the South Side Planting Company, on the right bank of the Mississippi River, opposite New Orleans. It contains 1,700 acres, 1,600 of which were under cultivation in 1905.

Open ditches are used exclusively. The smaller ones are brought together successively and terminate in a large canal leading to the drainage wheel. The water drains away from the river. The flow is obtained by deepening the ditches as they approach the pumping plant, as well as from the natural slope of the land. Here the water is elevated and then flows back into the swamps. The plantation is protected from backwater by means of a levee.

This type of pump is used in northern Italy and in Holland. It has long been a favorite in Louisiana, but was used much more extensively a few years ago than at present.

The wheel tested is a type of its class, but has some distinct features in the double gearing and in the number of paddles, which is greater than is sometimes used. The general design and method of bracing are clearly shown in the drawing (fig. 2).

The diameter of the wheel is 28 feet; the width, 6 feet.

The test was made while pumping out the canal system, and was necessarily short, lasting only about an hour.

A boiler test under existing conditions would have been worthless and was not attempted.

The steam pressure is 40 pounds or less, as this is the allowed pressure for the old boiler. Very little skill is required in operating this plant, and there is a feeling of reliability in connection with the entire outfit. Ordinarily wood is used as fuel. An engine having a cylinder 16 inches in diameter and stroke of 24 inches is used to drive the wheel. It is of the simple noncondensing slide-valve type.

The plant is looked after and operated by an unskilled laborer and it never gives trouble. When a rain comes in sufficient amount to demand pumping he starts a fire, gets up steam, and runs as long as required. Often this is but for an occasional few hours, but sometimes the wheel is run steadily for a week.

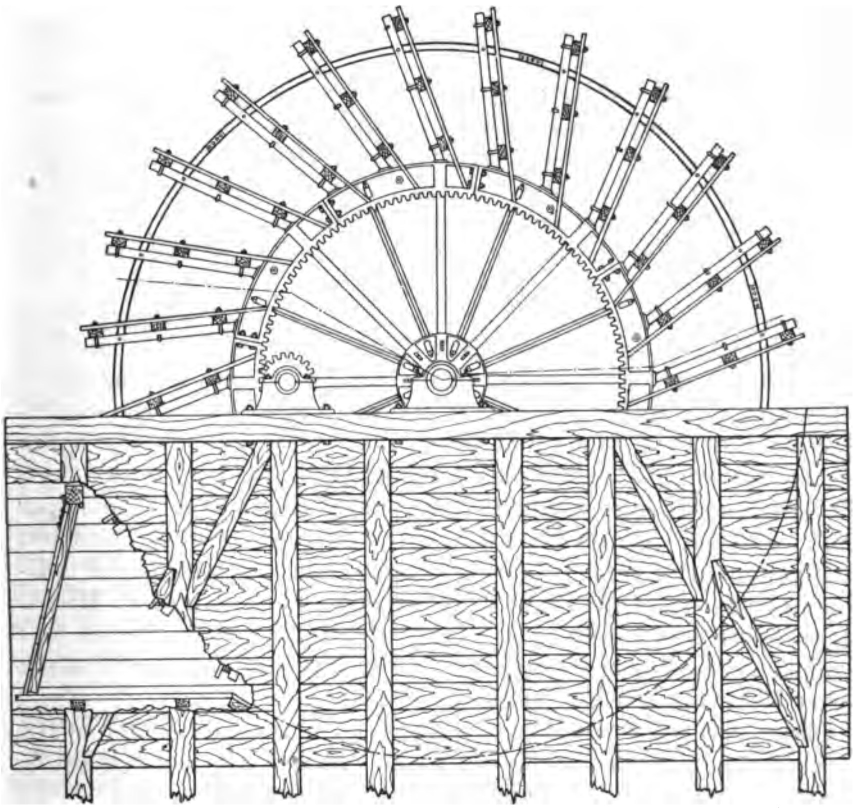

FIG. 2.—Drainage wheel, near New Orleans.

Care was exercised to so design this wheel that the water would not be lifted unnecessarily. The backward flow through the pump wheel when at rest is prevented by the swinging door shown in the drawing.

The results 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.

The quantity of water pumped fell off as the level of the water on the suction side fell, and varied from 20.71 cubic feet per second to 8.21 cubic feet per second.

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 sides of paddles was about three-fourths of an inch.

By referring to the log of results it will be seen that only 6.95 indicated horsepower was required to drive the wheel at the last observation when lifting 8.21 cubic feet per second 2.86 feet, and 12.61 indicated horsepower when lifting 20.71 cubic feet per second through 2.4 feet.

The method of testing consisted of traversing the discharge flume with a current meter and taking indicator cards and other observations as quickly as possible after 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 ten minutes the error is not great. The method used was rendered necessary by lack of observers.

These results are confirmed by the test of a similar drainage wheel in New Orleans in August, 1900. The wheel tested was used at that time in one of the city drainage stations. Since the inauguration of the new drainage system it has been taken down and removed. The log of the test shows that between 50 and 60 cubic feet of water per second was 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; the length of stroke was 54 inches and diameter of cylinder 18 inches. During the test the engine made about 35 revolutions per minute.

One of the chief objections to this type of pump is found in the fact that it is made largely of wood and that the bolts must be screwed up occasionally as the wheel is inspected.

Secure foundations are especially desirable on account of the weight of the wheel and the small side clearance desired for the paddle.

The details of the test are given below:

*Engine and pump test, Southside Planting Company drainage wheel.*

| Time. | Steam pressure. | Revolutions per minute of engine. | Indicated horsepower. Head. | Indicated horsepower. Crank. | Indicated horsepower. Total. | Revolutions per minute of wheel. | Head. | Discharge. | Useful water horsepower | Efficiency. |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Pounds.* | | | | | | *Feet.* | *Cu. ft. per sec.* | | *Per cent.* |
| 10.10 | 40 | 61 | 5.59 | 7.84 | 13.43 | 2.00 | ...... | ...... | ...... | ...... |
| 10.45 | 40 | 66 | 5.48 | 7.13 | 12.61 | 2.17 | 2.4 | 20.71 | 5.59 | 44.3 |
| 11.10 | 38 | 68 | 4.77 | 5.60 | 10.37 | 2.24 | 2.8 | 17.20 | 5.41 | 52.2 |
| 12.15 | 36 | 67.5 | 3.67 | 5 13 | 8.80 | 2.22 | 2.7 | 11.23 | 3.41 | 38.8 |
| 12.30 | 37 | 68 | 3.15 | 3.80 | 6.95 | 2.24 | 2.86 | 8.21 | 2.66 | 38.3 |
| Mean | 38.2 | 66.1 | (Av. last 4.) | | 9.68 | 2.22 | 2.69 | 14.34 | 4.27 | 43.4 |

## PLANT NO. 14, ALGIERS DRAINAGE PLANT.

Algiers, La., is a suburb of New Orleans, situated on the right bank of the Mississippi River, and forming a part of the city. The drainage plant tested is one of the plants forming the drainage system of New Orleans. It differs from the other drainage plants of the city in that it has its own boiler and engine equipment, while those of the city proper are supplied with electrical power generated at a central power station and distributed to the various pumping plants. Artificial drainage is a necessity, as the mean level of the city is only about 2 feet above that of the Gulf of Mexico, and there are large portions of the city below the mean Gulf level.

The boiler equipment consists of two 200-horsepower water-tube boilers, fed by means of direct-acting steam pumps. Only one boiler was used during the test. One pump was used to furnish water to the calibrated barrels, where it was measured, and the other pump then forced it into the boiler through a closed heater receiving the exhaust of boiler feed pumps and vacuum pump.

The fuel used was crude oil, costing 78 cents per barrel of 42 gallons delivered at plant.

The engine is a triple expansion of the marine type, direct connected to pump. The diameters of steam cylinders are 13, 21, and 34 inches, and the stroke is 24 inches. A jet condenser and vacuum pump of ample size were used.

The pump is centrifugal, having double suction pipes, each 36 inches, and discharge pipe 52 inches in diameter. The pump is several feet above the level of discharge.

Before starting it was primed by means of a steam siphon.

The level of the water on the discharge side was practically constant during the test, while the suction level fell as the canal was pumped out.

During a heavy and uniform rainfall it would be possible to have a constant height through which the water is lifted for several hours. At the time the test was made there was no rain, and the water pumped had been allowed to accumulate in the drainage canal leading to the pumping station. The pump was operated until the canal was nearly emptied, when the test had to stop.

An efficiency test was made of the boiler. It lasted but seventy minutes.

While a boiler test of this duration with any fuel other than crude oil would be ridiculous, and in any case is subject to some error, this test was as satisfactory as possible under the conditions.

The boiler had not been used for some time previous to raising steam for the test, and for this reason did not show as good results as it would had the walls been thoroughly heated before starting.

Water measurements were made by means of Pitot tubes in the suction pipes. These pipes were made of cast iron and were 36 inches in diameter. There were two bends in each, one a long radius bend through 90°, while the other was through about 45° in the opposite direction.

The traverses were made in each case on an axis of symmetry and simultaneously in the two pipes. To obtain the quantity of water from these observations the platted traverse of each cross section was divided into ten annular rings of equal area, and the velocity of the water was taken at the mean radius of each annular ring. The average of these ten velocities was used in computing the quantity of water pumped.

One of the Pitot tubes was that described elsewhere and illustrated in figure 1 (p. 10). The other was one of the tubes used by the Mississippi River Commission in tests of hydraulic dredges in 1902 and 1903.

Indicator cards, the height through which the water was lifted, and the other observations were taken at fifteen-minute intervals. All results were platted on a time basis; and as observations varied regularly, it was thought best to compute results by reading the various quantities from these curves.

The boiler results are about what would be expected under the conditions of the test.

The total steam used by engine, auxiliaries, and oil burners is extremely large for a triple-expansion engine. However, the engine load was considerably less than that which it was designed for, and the two steam pumps and the vacuum pump were very wasteful of steam, especially the latter.

The results of the tests are given below:

*Boiler test, drainage plant, Algiers, La., August 31, 1905.*

Duration of test, 1.17 hours.
Total fuel oil, 700 pounds.
Average steam pressure by gage, 140.6 pounds per square inch.
Average temperature of feed water, 196.2° F.
Factor of evaporation, 1.064.
Total weight of water fed to boiler, 7,257 pounds.
Equivalent water evaporated from and at 212° F., 7,722 pounds.
Boiler horsepower, 191.
Average temperature of fuel oil, 83° F.
Average air temperature, 89° F.
Water apparently evaporated per pound of oil, 10.37 pounds.
Equivalent evaporation from and at 212° (not corrected for quality of steam), 11.03 pounds.
Total feed water (including steam used by auxiliaries) per indicated horsepower-hour, 32 pounds.

*Engine and pump test, Algers drainage plant.*

| Time. | Steam pressure. | | Revolutions per minute of engine. | Indicated horsepower. | | | | | | | Head. | Discharge. | Useful water horsepower. | Efficiency. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | High. | | Intermediate. | | Low. | | | | | | |
| | At boiler. | At engine. | | Head. | Crank. | Head. | Crank. | Head. | Crank. | Total. | | | | |
| | *Lbs.* | *Lbs.* | | | | | | | | | *Feet.* | *Cu. ft. p. sec.* | | *P. ct.* |
| 11.30...... | 137 | 115 | 101.3 | 33.3 | 34.5 | 31.2 | 31.2 | 32.8 | 32.0 | 195.0 | 4.83 | 142.4 | 77.7 | 39.8 |
| 11.45...... | 139 | 117 | 102.7 | 33.4 | 34.9 | 31.4 | 31.5 | 30.4 | 31.8 | 193.4 | 5.56 | 137.8 | 86.5 | 44.7 |
| 12.00...... | 140 | 118 | 102.4 | 33.0 | 34.8 | 30.9 | 31.3 | 29.6 | 30.6 | 190.2 | 6.69 | 132.2 | 100.0 | 52.6 |
| 12.15...... | 141 | 119 | 103.7 | 34.1 | 35.3 | 31.6 | 31.4 | 30.9 | 31.4 | 194.7 | 7.83 | 125.1 | 110.8 | 56.9 |
| 12.30...... | 146 | 124 | 104.1 | 33.6 | 35.9 | 31.6 | 32.1 | 30.4 | 31.2 | 194.8 | 9.24 | 114.2 | 119.3 | 61.2 |
| Mean... | 140.6 | 118.6 | 102.8 | ...... | ...... | ...... | ...... | ...... | ...... | 193.6 | 6.83 | 130.5 | 98.8 | 51.0 |

## PLANT NO. 15, NEW ORLEANS DRAINAGE STATION NO. 3.

The turbine pump tested is located at station No. 3 of the New Orleans drainage system, It was installed as a fire pump and has been used principally to prime the larger pumps at the station. The pump is a two-stage turbine, having a 6-inch suction and a 4-inch discharge pipe. It is driven by a direct current motor on the same bed plate. A rotary converter in the station receives an alternating current from the central power house of the drainage system and furnished a direct current to the motor driving the pump.

The discharge head was measured by means of a pressure gage on the discharge pipe near the pump. The suction was measured by means of a vacuum gage on the suction pipe near the pump. Both gages were carefully calibrated. The total head was obtained by reducing both these observations to feet of water, correcting for the difference of level and adding the difference between velocity heads in discharge and suction pipes. By this means the pump is given credit for the velocity head it produces as well as for pumping the water against pressure equivalent to the given heads.

The water discharged from the pump was measured by means of an 18-inch Cipolletti weir, placed in a tank having baffle plates so arranged that the water flowed quietly to the weir. The depth of water over the crest of the weir was measured by an accurate hook gage.

The electrical losses were measured and corrections made.

The friction of pump and motor was obtained when pump was not primed, and one-half was charged to each in getting the efficiency of pump, assuming the friction to be constant for all loads.

Observations were taken, beginning with the discharge valve closed and then opening it slightly and again taking observations as soon as all conditions were constant; then valve was opened a little more and the process continued until the discharge valve was wide open.

Some trouble was experienced with the thrust bearing, on account of heating, but the test was not seriously interfered with.

The results of the test are given below:

*Pump test, New Orleans drainage station No. 3.*

| Time. | Revolutions per minute. | Volts. | Amperes. | Electrical horsepower. | Head. | | | Depth over weir. | Discharge. | Hydraulic horsepower. | Efficiency of pump and motor. | Efficiency of pump. | Efficiency of motor. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Suction. | Discharge. | Total. | | | | | | |
| | | | | | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Cu. ft. per sec.* | | *Per cent.* | *Per cent.* | *Per cent.* |
| 9.50 | 1,000 | 140 | 101 | 18.95 | 2.20 | 136.2 | 142.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9.55 | 978 | 138 | 126 | 23.31 | 3.06 | 140.0 | 147.6 | .241 | .597 | 9.98 | 42.8 | 50.2 | 85.3 |
| 10.00 | 967 | 136 | 176 | 32.09 | 6.46 | 127.3 | 139.1 | .322 | .923 | 14.54 | 45.3 | 52.0 | 87.1 |
| 10.03 | 955 | 134.3 | 194 | 34.92 | 8.72 | 115.7 | 130.3 | .362 | 1.101 | 16.25 | 46.5 | 53.1 | 87.6 |
| 10.06 | 960 | 134 | 208 | 37.36 | 10.20 | 104.2 | 120.7 | .387 | 1.216 | 16.62 | 44.5 | 50.7 | 87.7 |
| 10.09 | 960 | 134 | 217.3 | 39.03 | 12.23 | 92.5 | 111.5 | .408 | 1.316 | 16.60 | 42.5 | 48.3 | 88.0 |
| 10.12 | 956 | 133.5 | 225 | 40.26 | 13.48 | 81.0 | 101.6 | .427 | 1.409 | 16.20 | 40.2 | 45.6 | 88.1 |
| 10.15 | 956 | 133.5 | 236 | 42.23 | 14.95 | 69.4 | 92.0 | .446 | 1.504 | 15.67 | 37.1 | 42.0 | 88.3 |
| 10.18 | 956 | 133.5 | 242 | 43.31 | 16.20 | 57.8 | 82.0 | .459 | 1.571 | 14.59 | 33.7 | 38.1 | 88.3 |
| 10.21 | 949 | 132.5 | 247.5 | 43.96 | 18.01 | 46.3 | 72.7 | .476 | 1.657 | 13.62 | 31.0 | 35.1 | 88.3 |
| 10.24 | 949 | 132.5 | 254.2 | 45.15 | 19.37 | 34.7 | 62.9 | .489 | 1.727 | 12.30 | 27.2 | 30.8 | 88.4 |
| 10.27 | 949 | 132.5 | 260.5 | 46.27 | 21.01 | 23.1 | 53.1 | .495 | 1.759 | 10.57 | 22.8 | 25.8 | 88.4 |
| 10.30 | 949 | 132.3 | 264.0 | 46.82 | 21.53 | 16.2 | 46.7 | .495 | 1.759 | 9.30 | 19.8 | 22.4 | 88.4 |

## PLANT NO. 16, NEW ORLEANS DRAINAGE STATION NO. 7.

This plant has been recently installed at station No. 7 of the New Orleans drainage system to take care of the ordinary drainage of a portion of the city; for this reason it is called a constant-duty unit. During heavy rains the drainage is disposed of by means of the large centrifugal pumps of the station. The latter are electrically driven.

The gas engine is a 3-cylinder vertical, of the 4-cycle type, each cylinder 12½ inches in diameter, stroke 13 inches. Gas is supplied from a suction producer. The engine is connected by means of a flexible coupling to a horizontal shaft which in turn drives a vertical shaft through bevel gears. At the lower end of the vertical shaft is the impeller of the centrifugal pump. The suction pipe of the pump is 36 inches in diameter, while the discharge pipe enlarges from 20 inches diameter at pump to 30 inches diameter at a distance of a few feet.

The fuel used was pea anthracite coal; it was carefully weighed.

A preliminary test was made, using a prony brake on engine and taking indicator cards. When the engine developed 100 brake horsepower it was found that the indicated horsepower as computed with uncorrected springs was almost exactly the same figure. The springs were nominally rated at 200, but on calibration they were found to be in error by 16.6 per cent. This correction was applied and the indicated horsepower was found to be 120 when the brake horsepower was 100 and the revolutions approximately 300 per minute. The mechanical efficiency of the engine was therefore 83.4 per cent. As the revolutions varied but little from 300, it was thought best to take the indicator cards obtained during the test and, having corrected for the springs to compute the indicated horsepower and then subtract 20 to give the brake horsepower, or, in other words, the developed horsepower of the engine. The horsepower given pump (called in log Pump H. P.) was obtained by subtracting 25 from the indicated horsepower in each case, as a preliminary test had shown the friction of gears and bearings between the flexible coupling and the shaft just above the pump to be 5 horsepower, and the friction of engine, as stated above, was 20 horsepower.

Water horsepower was computed in the usual way. The head was that between suction and discharge basins on the two sides of the pumping station. The water had to pass through 50 or 60 feet of pipe, but enlargements at entrance and discharge ends and low velocity reduced the losses in the piping.

The velocity of the water was obtained by means of the Pitot tube. Traverses were made at fifteen-minute intervals across the discharge pipe about 30 feet from the pump; observations were taken at such distances from the center that the mean velocity could easily be computed. The discharge pipe, 30 inches in diameter, was divided up into ten areas, all of which, with the exception of that at the center, were annular rings. The tube was placed at such positions that the mean velocity in these annular rings was obtained on both sides of the center. For each traverse nineteen observations were made. The results platted in the curves were the mean of three readings for each point. In the circle at the center of the pipe, containing one-tenth of the area of cross section, but one observation of velocity was taken, while in the annular rings two observations were taken, one on either side. In order to give all observations equal weight, the velocity observed at the center of pipe was doubled and added to the other 18 observations; the sum divided by 20 gave mean velocity.

The indicating of gas engines is often unsatisfactory. During this test trouble was experienced with the indicator on cylinder No. 3, and some of the cards were not as satisfactory as could be desired. For this reason the indicated horsepower and results dependent on that quantity may be somewhat in error. The error may amount to 5 per cent or possibly more in the efficiency of the pump, the true value being less than that stated.

The friction of gears, bearings, and so forth had to be determined when running light; the friction loss probably changes slightly for increased load.

The measurements of coal used, the head pumped against, and the amount of water pumped were satisfactory and, fortunately, these are the most important factors.

Approximately 1.1 pounds of coal was used per brake horsepower-hour, or about 0.9 pound per indicated horsepower-hour.

The duty in millions of foot-pounds per 100 pounds of coal was found to be 119.6, while the duty per million British thermal units in fuel was 82.4; this is an excellent showing.

The heat value of the pea anthracite coal was found, by means of a Parr calorimeter, to be 14,374 British thermal units per pound. The percentage of energy in the fuel that appeared as indicated horsepower was therefore 20.75 per cent; as developed or brake horsepower, 16.2 per cent; and as useful work, 10.6 per cent.

Cost of coal, $8 per ton delivered at plant.

*Producer gas plant, Station No. 7, February 1, 1906.*

| Time. | Revolution per minute. | Mechanical efficiency of pump. | Indicated horsepower. | Brake horsepower. | Pump horsepower. | Mean velocity. | Discharge. | Gage. | | Head. | Water horsepower. | Efficiency of pump. | Time. | Coal. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Suction. | Discharge. | | | | | |
| | | | | | | | *Cu. ft. per sec.* | | | *Feet.* | | *Per cent.* | | *Lbs.* |
| 1.15 | 292 | ...... | ...... | ...... | ...... | 6.12 | 30.04 | 8.20 | 20.35 | 12.15 | 41.3 | ...... | ...... | ...... |
| 1.30 | 295 | ...... | ...... | ...... | ...... | 6.43 | 31.56 | 7.30 | 20.35 | 13.05 | 46.7 | ...... | 1.30 | 43.62 |
| 1.45 | 296 | ...... | ...... | ...... | ...... | 6.52 | 32.00 | 7.37 | 20.35 | 12.98 | 47.1 | ...... | ...... | ...... |
| 2.00 | 297 | 147.5 | 88.3 | 68.3 | 66.3 | 6.34 | 31.12 | 7.28 | 20.35 | 13.07 | 46.1 | 69.5 | 1.55 | 91.1 |
| 2.15 | 297 | 151.0 | 90.4 | 70.4 | 65.4 | 6.23 | 30.58 | 7.04 | 20.35 | 13.31 | 46.1 | 70.5 | ...... | ...... |
| 2.30 | 294 | 157.5 | 93.3 | 73.3 | 68.3 | 6.23 | 30.58 | 6.87 | 20.35 | 13.48 | 46.7 | 68.4 | 2.25 | 136.1 |
| 2.45 | 296 | 143.5 | 85.6 | 65.6 | 60.6 | 6.19 | 30.38 | 6.65 | 20.35 | 13.70 | 47.1 | 77.7 | ...... | ...... |
| 3.00 | 296 | 151.0 | 90.1 | 70.1 | 65.1 | 6.18 | 30.34 | 6.80 | 20.40 | 13.60 | 46.7 | 71.7 | 2.55 | 180.1 |
| 3.15 | 297 | 143.5 | 85.9 | 65.9 | 60.9 | 6.15 | 30.19 | 6.85 | 20.40 | 13.55 | 46.3 | 76.0 | ...... | ...... |
| 3.30 | 296 | 147.5 | 88.0 | 68.0 | 63.0 | 6.16 | 30.24 | 6.89 | 20.40 | 13.51 | 46.3 | 73.5 | 3.25 | 222.6 |
| 3.45 | 297 | 145.7 | 87.3 | 67.3 | 62.3 | 6.14 | 30.14 | 6.70 | 20.40 | 13.70 | 46.8 | 75.1 | ...... | ...... |
| 4.00 | 298 | 154.5 | 92.8 | 72.8 | 67.8 | 6.09 | 29.89 | 6.00 | 20 40 | 13.80 | 46.7 | 68.9 | 3.55 | 265.3 |
| 4.15 | 298 | 152.8 | 91.8 | 71.8 | 66.8 | 6.12 | 30.04 | 6.87 | 20.41 | 13.54 | 46.1 | 69.0 | ...... | ...... |
| 4.30 | 297 | 163.2 | 97.8 | 77.8 | 72.8 | 6.18 | 30.34 | 7.30 | 20.43 | 13.13 | 45.1 | 61.9 | 4.35 | 308.8 |
| 4.45 | 298 | 152.2 | 91.4 | 71.4 | 66.4 | 6.12 | 30.04 | 7.05 | 20.45 | 13.40 | 45.6 | 68.7 | ...... | ...... |
| 5.00 | 299 | 162.7 | 98.1 | 78.1 | 73.1 | 6.19 | 30.38 | 6.70 | 20.45 | 13.75 | 47.3 | 64.7 | ...... | ...... |
| 5.15 | 300 | 145.7 | 88.1 | 68.1 | 63.1 | 6.21 | 30.48 | 7.00 | 20.45 | 13.45 | 46.4 | 73.5 | ...... | ...... |
| Mean | ...... | ...... | 90.6 | 70.6 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |

## PLANT NO. 17, NECHES CANAL COMPANY.

The Neches Canal Company furnished water to irrigate approximately 22,000 acres of rice during the season of 1906. The main pumping plant is located on the bank of Pine Island Bayou, a tributary of the Neches River, about 6 miles north of Beaumont, Tex. At this plant the water is elevated from 31 to 35 feet, depending on the stage of water in the bayou. A canal, with levees 150 feet from crown to crown, conducts the water from the main pumping plant to the relift about 2 miles distant, where it is again elevated 10 feet. Beyond the relift plant there are 23 miles of main canal and about 18 miles of laterals through which the water is distributed to the rice fields. The cost of pumping plants, canals, and laterals was $500,000. The system has been operated four seasons.

The tests described were made on August 8 and 9, 1906. The plant tested was the first lift or main pumping plant of the Neches Canal Company. On the first day one-half of the plant was operated, while on the second day the entire plant was run.

The boiler equipment of this plant consists of two water-tube boilers, each of 400 nominal horsepower, having 3,675 square feet of heating surface. Each boiler has two drums 42 inches in diameter, 21 feet in length, and 180 4-inch tubes 18 feet long. A breeching 72 inches in diameter conducts the burned gases to a steel stack of the same diameter, resting on a brick base. The length of stack is 90 feet and the total height above furnace about 115 feet.

Steam is conducted from the boilers by separate pipes to a main which supplies the various engines. By means of a stop valve the two halves of the plant may be separated and boiler No. 1 used to supply steam to engines Nos. 1 and 2, and boiler No. 2 used with engines Nos. 3 and 4. There are steam separators above each engine.

The fuel used was crude petroleum. It was fed to the furnaces by gravity, as the storage tanks are located at a height considerably above that of the furnaces. Steam is used to atomize the oil.

There are four tandem compound condensing Corliss engines; dimensions, 18 by 36 by 48 inches; piston rods, 4⅝ and 3¼ inches in diameter. Each engine is direct connected to a rotary pump by means of a flexible coupling. Keys of Babbitt metal are used in the couplings. These keys are made strong enough to carry the load, but will shear in case a piece of wood or other obstacle gets into the pumps.

The pumps are two-lobed cycloidal of 39 inches pitch diameter. The impellers are 52 inches in length and 58½ inches in diameter; the displacement is 605 gallons per revolution; the bearings are 11 inches in diameter by 30 inches in length.

Two vertical vacuum pumps are used, one for engines Nos. 1 and 2 and another for engines Nos. 3 and 4. They are of the jet type.

The dimensions of these pumps are 12 by 28 by 18 inches; the number of double strokes per minute, about thirty-five.

Two direct-acting steam pumps are used for boiler feeders when the entire plant is in operation. They are outside packed, double acting, having dimensions 15 by 8 by 12 inches. The usual number of double strokes is about twenty-one per minute.

There are two No. 7 heaters; each receives the exhaust from one vacuum pump and one feed pump.

The object of the tests was to determine the various efficiencies of the plant, the mechanical efficiencies of pumps and engines, and the cost of operating. Great care was used in measuring the input of energy in the form of fuel oil and the output in the form of useful water horsepower.

On August 8 engines and pumps Nos. 3 and 4 were run. Steam was furnished by boiler No. 2. The stop valve in the steam main between the two halves of the plant was closed. There was some leakage at this valve and also at the two blow-off valves of the boiler used. Leakage of air through boiler No. 1 caused another loss.

A second test was run on August 9, 1906, with the entire plant in operation. During this test there was no leakage from the blow-off pipes of either boiler. The drain pipes from the steam separators were closed on both days; the other leaks from the steam main were small and no attempt was made to measure them.

On the first day continuous counters on engines Nos. 3 and 4 were read at intervals of five minutes. Readings for fifteen-minute intervals are given in the general log. For computing the indicated horsepower the revolutions were taken from the five-minute intervals during which the cards were taken. Indicator cards were taken every half hour.

The discharge from the two pumps was carefully measured in flume No. 2 by means that will be described later. In this way the displacement of pumps and their discharge were compared and the mechanical efficiency of engines and pumps determined.

Observations were also taken at half-hour intervals of boiler pressure, the temperatures of feed water, calorimeter, water pumped, air, and fuel oil. A draft gage connected to an air valve in the breeching gave the draft in inches of water.

Fuel oil was carefully measured in a calibrated barrel and its specific gravity observed throughout the test by means of a hydrometer.

The amount of boiler feed water was measured by means of a weir.

On the second day, when the whole plant was in operation, the total water discharged from both flumes was measured; at intervals of fifteen minutes the water measurements were made, so that they were repeated in each flume at half-hour intervals.

The head was carefully measured in the same manner as on the previous day.

The fuel oil was carefully measured. The steam pressure was held exactly as on the previous day. In this way the total useful work done and the amount of fuel required to operate the entire plant were measured under conditions exactly corresponding to the previous day.

Feed water was measured only during the test of August 8. As the tests were to represent as nearly as possible the conditions of ordinary operation it was desirable to use the heaters, the water level in which was only about 2 feet above the center of the feed pump. The high temperature of the feed water made it necessary to have the water flow by gravity to the pumps. The pipe connections were short and the measurement of feed water in calibrated tanks could only be accomplished by the aid of an extra pump or by taking cold water from the flume. A trapezoidal weir 6 inches in width was introduced between the heater and pump by slight changes in the piping. The discharge from the weir was into a barrel connected to the suction of the feed pump. The height of the water above the sill of the weir was measured by a hook gage. In this way the plant was operated under normal conditions and the water measured with considerable accuracy. The weir had been previously calibrated in the hydraulic laboratory of Tulane University, Louisiana, and its constant determined. It is believed that the error involved does not exceed 2 per cent, and that it is probably only half that amount.

By this method all the water fed to the boiler was measured. The steam generated by the boilers was used by main engines, by vacuum and feed pumps, and for atomizing the fuel oil.

The quality of steam was obtained by means of a throttling calorimeter in the vertical pipe coming from the boiler, a short distance above the junction of the vertical pipe with the horizontal main.

The conditions of the boiler test were extremely uniform; the water level changed very little and the rate at which water was supplied to the boiler was not varied throughout the test. Steam pressure, quality of steam, and the temperature of the feed did not vary perceptibly.

Boiler pressure and vacuum were read by means of calibrated gages. The error of the thermometer used in the calorimeter was known and the correction applied.

Two indicators were used on engine No. 3 and two on engine No. 4. All were supplied with wheel reducing motions. Each cylinder of each engine was supplied with three-way cocks. On the high-pressure cylinders 80-pound springs were used, while 20-pound springs were used on the low. The springs were calibrated after the test and the corrections applied where necessary.

The barrel in which the fuel oil was measured was calibrated by means of an accurate spring balance.

Samples of the fuel oil were taken from time to time during the test and later a careful determination of the heat value was made at Tulane University of Louisiana. The heat units per pound were found to be 18,790; the amount of water present in the oil was 2 per cent. The oil was from the Jennings, La., field.

The height through which the water was lifted was obtained by measuring down from bench marks on the suction side of the pumps to the water level in the suction flume, and again from a bench mark on the discharge side to the level of the water in the discharge flume. The head was extremely constant. All linear measurements taken by means of a tape were corrected by comparison with a steel tape.

The discharge of pumps Nos. 3 and 4 is into a common flume, built of one-fourth-inch steel, having an inside width of 8.71 feet. The depth of water in the flume was obtained by measuring the distance from an angle iron across the top of the flume and subtracting the distance from angle iron to the surface of the water. The depth varied little from 4.17 feet throughout the test; each time six observations were taken and averaged.

Two instruments were used alternately to determine the velocity—a current meter and a Pitot tube.

The average of all readings taken with the current meter gives a discharge of 152.99 cubic feet per second, while the average displacement of the pump for corresponding readings averages 152.90. The average of all readings of discharge obtained by means of the Pitot tube gives 152.79 cubic feet per second; the average displacement for corresponding readings is 152.92. The agreement in both cases is remarkable and can lead to but one conclusion, viz, that the discharge of the pumps is practically equal to their displacement.

The writer believes the results to be as accurate as could be obtained with a weir.

*Boiler test, Neches Canal Company, August 8, 1905.*

Duration of boiler test, 5.592 hours.
Total fuel oil, 6,384 pounds.
Average steam pressure by gage, 140 pounds per square inch.
Average temperature of feed water, 199° F.
Factor of evaporation, 1.053.
Total weight of water fed to boiler, 79,651 pounds.
Equivalent water evaporated from and at 212° F., 83,872 pounds.
Boiler horsepower, 434.6.
Average temperature of fuel oil, 91° F.
Average air temperature, 89° F.
Water apparently evaporated per pound of oil, 12.47 pounds.
Equivalent evaporation from and at 212° F (corrected for quality of steam), 13.14 pounds.

*Engine and pump test, main pumping plant, Neches Canal Company, August 8, 1906.*

| Time. | Boiler pressure. | Revolutions per minute. | | Indicated horsepower. | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Engine No. 3. | | | | |
| | | | | High. | | Low. | | Total. |
| | | No. 3. | No. 4. | Head. | Crank. | Head. | Crank. | |
| 1.30 | 140 | | | | | | | |
| 1.45 | | 54.3 | 57.7 | 95.8 | 95.0 | 65.2 | 57.9 | 313.9 |
| 2.00 | 140 | 55.3 | 58.3 | | | | | |
| 2.15 | | 55.0 | 58.3 | | | | | |
| 2.30 | 140 | 55.1 | 58.3 | 98.6 | 97.8 | 67.1 | 59.4 | 322.9 |
| 2.45 | | 55.1 | 58.4 | | | | | |
| 3.00 | 140 | 55.0 | 58.6 | 97.9 | 94.5 | 74.2 | 62.5 | 329.1 |
| 3.15 | | 55.2 | 57.9 | | | | | |
| 3.30 | 140 | 55.1 | 58.5 | 94.3 | 92.7 | 69.9 | 62.6 | 319.5 |
| 3.45 | | 55.0 | 58.5 | | | | | |
| 4.00 | 140 | 55.1 | 58.5 | 94.9 | 94.1 | 70.1 | 62.8 | 321.9 |
| 4.15 | | 54.9 | 58.5 | | | | | |
| 4.30 | 140 | 54.9 | 58.5 | 95.4 | 93.9 | 67.0 | 59.9 | 316.2 |
| 4.45 | | 55.1 | 58.5 | | | | | |
| 5.00 | 140 | 55.1 | 58.7 | 95.2 | 94.8 | 70.3 | 61.2 | 321.5 |
| 5.15 | | 55.1 | 58.7 | | | | | |
| 5.30 | 140 | 55.1 | 58.4 | 93.2 | 94.3 | 71.3 | 60.7 | 319.5 |
| 5.45 | | 55.1 | 58.4 | | | | | |
| 6.00 | 140 | 55.1 | 58.5 | 94.6 | 94.0 | 72.9 | 60.8 | 322.3 |
| 6.15 | | 55.1 | 58.6 | | | | | |
| 6.30 | 140 | 55.3 | 58.5 | 92.0 | 94.8 | 71.9 | 60.7 | 319.4 |
| 6.45 | | 55.0 | 58.6 | | | | | |
| 7.00 | 140 | 55.1 | 58.7 | 95.6 | 92.2 | 70.3 | 63.3 | 321.4 |
| 7.15 | | 55.2 | 58.5 | | | | | |
| 7.30 | 150 | 55.2 | 58.4 | 95.9 | 93.3 | 70.4 | 63.6 | 323.2 |

| Time. | Indicated horsepower—Continued. | | | | | | Discharge. | Head. | Useful water horsepower. | Efficiency of pump and engine. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Engine No. 4. | | | | | Grand total. | | | | |
| | High. | | Low. | | Total. | | | | | |
| | Head. | Crank. | Head. | Crank. | | | | | | |
| | | | | | | | *Cu. ft. per sec.* | | | *Per cent.* |
| 1.30 | | | | | | | 150.6 | 31.61 | 538.6 | |
| 1.45 | 107.8 | 104.0 | 63.2 | 59.6 | 334.6 | 648.5 | | | | |
| 2.00 | | | | | | | 151.3 | 31.65 | 541.3 | |
| 2.15 | | | | | | | 153.8 | | | |
| 2.30 | 107.9 | 103.2 | 65.4 | 59.9 | 336.4 | 659.3 | 151.3 | 31.63 | 541.1 | 82.02 |
| 2.45 | | | | | | | 154.3 | | | |
| 3.00 | 101.7 | 100.0 | 68.1 | 61.0 | 330.8 | 659.9 | 151.3 | 31.62 | 541.6 | 82.07 |
| 3.15 | | | | | | | 151.8 | | | |
| 3.30 | 105.2 | 101.0 | 69.5 | 62.3 | 338.0 | 657.5 | 153.6 | 31.61 | 549.2 | 83.58 |
| 3.45 | | | | | | | 154.9 | | | |
| 4.00 | 103.5 | 100.0 | 69.7 | 62.0 | 335.2 | 657.1 | 154.7 | 31.62 | 553.3 | 84.20 |
| 4.15 | | | | | | | 151.5 | | | |
| 4.30 | 105.3 | 100.0 | 69.2 | 62.2 | 337.5 | 653.7 | 154.1 | 31.62 | 551.2 | 84.32 |
| 4.45 | | | | | | | 152.3 | | | |
| 5.00 | 105.0 | 101.2 | 69.1 | 62.0 | 337.3 | 658.8 | 155.1 | 31.62 | 554.9 | 84.22 |
| 5.15 | | | | | | | 151.9 | | | |
| 5.30 | 104.1 | 99.2 | 70.5 | 63.8 | 337.6 | 657.1 | 152.3 | 31.62 | 544.8 | 82.80 |
| 5.45 | | | | | | | 153.4 | | | |
| 6.00 | 105.7 | 100.7 | 69.8 | 63.7 | 339.9 | 662.2 | | 31.62 | 548.5 | 82.91 |
| 6.15 | | | | | | | 153.3 | | | |
| 6.30 | 103.1 | 100.0 | 69.1 | 61.1 | 333.3 | 652.7 | | 31.62 | 542.6 | 83.13 |
| 6.45 | | | | | | | 150.2 | | | |
| 7.00 | 102.7 | 99.2 | 71.2 | 62.0 | 335.1 | 656.5 | 152.7 | 31.62 | 546.2 | 83.21 |
| 7.15 | | | | | | | 153.1 | | | |
| 7.30 | 103.6 | 100.4 | 70.5 | 62.5 | 337.0 | 660.2 | | 31.62 | | |
| Averages | | | | | | 657.7 | 152.7 | 31.62 | 546.1 | 83.25 |

## SUMMARY OF RESULTS OF ALL TESTS.

The principal results of all of the tests reported in the preceding pages are summarized in the table following.

*Summary of results of tests.*

| No. | | Plant number. | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | Abbeville Canal Company. | Abbott-Duson, main plant. | Abbott-Duson, first relift. | Abbott-Duson, second relift. | Acadia plant. | Acadia relift. | Grand Canal, old plant. |
| 1 | Type of engine | (a) | (b) | (b) | (c) | (b) | (d) | (b) |
| 2 | Mean indicated horsepower | 155.6 | 671.2 | 229.8 | 121.9 | 648.0 | 137.7 | 503.9 |
| 3 | Number and type of pumps | Rotary. | 6 cent. | 2 cent. | Cent. | 4 cent. | Cent. | 2 cent. |
| 4 | Actual lift | 15.5 | 16.2 | 11.2 | 4.7 | 30.2 | 9.5 | 28.7 |
| 5 | Discharge, cubic feet per second | 72.6 | 157.0 | 116.0 | 61.6 | 93.2 | 71.4 | 68.7 |
| 6 | Water horsepower | 127.5 | 287.4 | 147.1 | 33.0 | 318.0 | 76.5 | 222.8 |
| 7 | Efficiency of engine, transmission and pump | 81.7 | 42.9 | 64.2 | 26.9 | 49.0 | 55.6 | 44.3 |
| 8 | Type of heater | Open. | Closed. | Open. | Open. | 2 open. | Open. | Open. |
| 9 | Number and type of boilers | (j) | [j] 6 | [j] 3 | (j) | [k] 2 | [j] 2 | [k] 2 |
| 10 | Steam-gauge pressure, pounds per square inch | 132 | 82.1 | 65.7 | 81.2 | 106.7 | 79.4 | 128.8 |
| 11 | Temperature of feed water, °F | 87.2 | 168.5 | 92.0 | 87.9 | 171.7 | ........ | 154.9 |
| 12 | Boiler horsepower [m] | 119 | 519 | 240 | 147 | 585 | ........ | 416 |
| 13 | Heating surface per boiler horsepower, square feet | 11.7 | 17.5 | 19.5 | 9.46 | 8.51 | ........ | 9.73 |
| 14 | Ratio of water evaporated from and at 212 °F to oil | 12.03 | 11.21 | 11.47 | 12.90 | 15.09 | ........ | 10.96 |
| 15 | Fuel oil per hour, barrels | [n] 1.01<br>[o] 1.09 | 5.1 | 2.3 | 1.25 | 4.27 | 1.12 | 4.18 |
| 16 | Fuel oil per minute, pounds | [n] 5.28<br>[o] 5.71 | 26.62 | 12.03 | 6.53 | 22.28 | 5.87 | 21.83 |
| 17 | Oil per indicated horsepower hour, pounds | [n] 2.04<br>[o] 2.20 | 2.38 | 3.14 | 3.22 | 2.06 | 2.56 | 2.6 |
| 18 | Oil per water horsepower hour, pounds | [n] 2.48<br>[o] 2.69 | 5.56 | 4.9 | 11.87 | 4.2 | 4.61 | 5.88 |
| 19 | Heat value per pound of oil, B. T. U. | 19,500 | 19,500 | 19,500 | 19,500 | 19,500 | 19,500 | 19,500 |
| 20 | Heat equivalent of oil per minute, B. T. U. | 111,300 | 519,300 | 234,500 | 127,300 | 434,500 | 114,500 | 425,700 |
| 21 | Total steam per minute, pounds | 58.4 | 276.0 | 119.3 | 72.4 | 310.5 | ........ | 216.8 |
| 22 | Heat per minute to produce total steam, B. T. U. [q] | 66,300 | 288,100 | 133,300 | 81,400 | 324,800 | ........ | 231,200 |
| 23 | Boiler efficiency, per cent | 59.6 | 55.5 | 56.8 | 64.0 | 74.8 | ........ | 54.3 |
| 24 | Heat equivalent of I. H. P. per minute, B. T. U. | 6,600 | 28,450 | 9,750 | 5,170 | 27,500 | 5,840 | 21,380 |
| 25 | Ratio of heat values of I. H. P. and of total steam, per cent | 9.96 | 9.88 | 7.3 | 6.34 | 8.46 | ........ | 9.25 |
| 26 | Ratio of heat values of I. H. P. and of oil, per cent | 5.93 | 5.48 | 4.15 | 4.05 | 6.33 | 5.1 | 5.02 |
| 27 | Heat equivalent of W. H. P. per minute, B. T. U. | 5,410 | 12,190 | 6,240 | 1,400 | 13,500 | 3,250 | 9,450 |
| 28 | Ratio of heat values of W. H. P. and of total steam, per cent | 8.16 | 4.23 | 4.68 | 1.72 | 4.16 | ........ | 4.09 |
| 29 | Ratio of heat values of W. H. P. and of oil, per cent | 4.85 | 2.35 | 2.66 | 1.1 | 3.11 | 2.84 | 2.22 |
| 30 | Duty in million foot-pounds per 1,000 pounds of steam | 72.1 | 34.3 | 40.7 | 15.0 | 33.8 | ........ | 33.9 |
| 31 | Duty in million foot-pounds per million B. T. U. in fuel | 37.8 | 18.3 | 20.7 | 8.5 | 24.2 | 22.1 | 17.3 |
| 32 | Cost of fuel oil per barrel of 42 gallons, cents | 23.5 | 35 | 35 | 35 | 35 | 35 | 35 |
| 33 | Cost of fuel oil per hour, cents | [n] 23.8<br>[o] 25.7 | 178.4 | 80.6 | 43.8 | 149.4 | 39.3 | 146.3 |
| 34 | Water pumped, gallons per minute | 32,560 | 70,290 | 51,830 | 27,660 | 41,820 | 32,030 | 30,820 |
| 35 | Cost of fuel for raising 1,000,000 gallons 1 foot, cents | [n] .78<br>[o] .85 | 2.61 | 2.31 | 5.57 | 1.97 | 2.16 | 2.76 |
| 36 | Cost of fuel to raise 1 acre-foot 1 foot, cents | [n] .26<br>[o] .28 | .85 | .75 | 1.82 | .64 | .70 | .90 |
| 37 | Cost of fuel to raise 2 acre-feet 20 feet, cents | [n] 10<br>[o] 11 | 34 | 30 | 73 | 26 | 28 | 36 |
| 38 | Cost of fuel to raise 2 acre-feet 20 feet, at 50 cents per barrel, cents | [n] 21.7<br>[o] 23.4 | 48.6 | 43 | 103.7 | 36.7 | 40.1 | 51.5 |
| 39 | Cost of fuel to raise 1 acre-foot of water to surface, cents | [n] 4<br>[o] 4.3 | 13.8 | 8.4 | 8.6 | 19.3 | 6.6 | 25.8 |

[a] Tandem compound condensing Corliss.
[b] Simple condensing Corliss.
[c] Simple noncondensing slide valve.
[d] Simple noncondensing Corliss.
[e] Triple-expansion condensing, vertical.
[f] Electrically driven.
[g] Three-cylinder vertical.
[h] Second test, see page 52.
[i] Cycloidal rotary.
[j] Horizontal fire tube.

*Summary of results of tests.*

| Plant number. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 17 | No. |
| Grand Canal, new plant | Abbott Bros., lower farm. | Wesson's plant. | Saxby's plant. | Crowley Farming Co.'s plant. | South Side drainage wheel. | Algiers drainage plant. | New Orleans drainage station No. 3. | New Orleans drainage station No. 7. | Main plant, Neches Canal. | Main plant, Neches Canal. | |
| (a) | (c) | (c) | (c) | (c) | (c) | (e) | (f) | (g) | (a) | (h) | 1 |
| 452.3 | 122.2 | 71.6 | 30.7 | 28.7 | 9.68 | 193.6 | ........ | 90.6 | 657.7 | ........ | 2 |
| Cent. | Cent. | Cent. | Cent. | Rotary | Wheel. | Cent. | ........ | Cent. | (i) | (i) | 3 |
| 31.65 | 15.4 | 14.2 | 15.3 | 15.7 | 2.7 | 6.8 | 14.31 | 13.4 | 31.62 | 32.01 | 4 |
| 85.65 | 29.0 | 2.16 | 3.66 | 4.84 | 14.3 | 130.5 | ........ | 30.5 | 152.9 | 291.6 | 5 |
| 306.8 | 50.2 | 3.48 | 6.33 | 8.63 | 4.20 | 98.8 | ........ | 46.2 | 547.9 | 1,055.7 | 6 |
| 67.89 | 41.9 | 5.0 | 20.8 | 30.1 | 43.4 | 51.0 | ........ | 51.0 | 83.3 | ........ | 7 |
| Open. | Closed. | None. | None. | None. | None. | Closed. | ........ | ........ | Open. | Open. | 8 |
| (k) | j2 | (l) | (l) | (l) | ........ | (k) | ........ | ........ | (k) | ........ | 9 |
| 153.4 | 75.1 | 84.0 | 98.0 | 79.3 | ........ | 140.6 | ........ | ........ | 140.0 | 140 | 10 |
| 188.5 | 189.0 | 88.0 | 73.5 | 82.0 | ........ | 190.2 | ........ | ........ | 199 | ........ | 11 |
| 242.2 | 194 | 87 | 62 | 51 | ........ | 191 | ........ | ........ | 434 | ........ | 12 |
| 18.58 | 11.5 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | 8.32 | ........ | 13 |
| 12.56 | 13.91 | 12.87 | 12.36 | 12.61 | ........ | 11.03 | ........ | ........ | 13.14 | ........ | 14 |
| 2.11 | 1.54 | .74 | .55 | .52 | ........ | 1.91 | ........ | ........ | 3.62 | 6.33 | 15 |
| 11.1 | 8.04 | 3.90 | 2.88 | 2.74 | ........ | 10.0 | ........ | ........ | 19.04 | 33.23 | 16 |
| 1.47 | 3.95 | 3.27 | 5.62 | 5.73 | ........ | 3.1 | ........ | p.85 lb. | 1.74 | ........ | 17 |
| 2.14 | 9.61 | 67.2 | 27.27 | 19.02 | ........ | 6.07 | ........ | 1.67 lb. | 2.09 | 1.89 | 18 |
| 17,834 | 19,500 | 19,500 | 19,500 | 19,500 | ........ | 19,500 | ........ | 14,374 | 18,790 | 18,790 | 19 |
| 197,970 | 156,800 | 76,000 | 56,240 | 53,400 | ........ | 195,000 | ........ | 18,500 | 357,780 | 624,400 | 20 |
| 129.6 | 105.6 | 43.0 | 30.0 | 29.6 | ........ | 103.7 | ........ | ........ | 241.4 | ........ | 21 |
| 134,200 | 108,000 | 48,400 | 34,300 | 33,500 | ........ | 106,500 | ........ | ........ | 241,500 | ........ | 22 |
| 67.9 | 68.9 | 63.7 | 61.0 | 62.8 | ........ | 54.6 | ........ | ........ | 67.5 | ........ | 23 |
| 19,185 | ........ | 3,040 | 1,300 | 1,210 | ........ | 8,200 | ........ | 3,840 | 27,900 | ........ | 24 |
| 14.3 | ........ | 6.27 | 3.80 | 3.61 | ........ | 7.68 | ........ | ........ | 11.55 | ........ | 25 |
| 9.7 | ........ | 4.0 | 2.32 | 2.27 | ........ | 4.21 | ........ | 20.75 | 7.8 | ........ | 26 |
| 13,013 | ........ | 148 | 268 | 366 | ........ | 4,190 | ........ | 1,960 | 23,200 | 44,772 | 27 |
| 9.70 | ........ | .31 | .78 | 1.10 | ........ | 3.93 | ........ | ........ | 9.61 | ........ | 28 |
| 6.57 | ........ | .19 | .48 | .69 | ........ | 2.15 | ........ | 10.6 | 6.5 | 7.16 | 29 |
| 78.16 | ........ | 2.67 | 6.96 | 9.65 | ........ | 31.4 | ........ | ........ | 75.4 | ........ | 30 |
| 51.14 | ........ | 1.51 | 3.73 | 5.34 | ........ | 16.7 | ........ | 82.4 | 50.05 | 55.8 | 31 |
| 45 | 35 | 52.5 | 52.5 | 40 | ........ | 78 | ........ | 80 | 65 | 65 | 32 |
| 95.1 | 53.9 | 39.1 | 28.9 | 21 | ........ | 149.2 | ........ | 30.9 | 236 | 412 | 33 |
| 38,445 | 13,000 | 967 | 1,642 | 2,172 | ........ | 58,600 | ........ | 13,700 | 68,620 | 131,220 | 34 |
| 1.30 | 4.52 | 47.4 | 19.2 | 10.21 | ........ | 6.35 | ........ | 2.8 | 1.81 | 1.63 | 35 |
| .424 | 1.48 | 15.45 | 6.27 | 3.34 | ........ | 2.08 | 2.18 | .859 | .556 | .50 | 36 |
| 16.96 | 59 | 618 | 251 | 134 | ........ | 83 | ........ | 34 | 22.24 | 20.05 | 37 |
| 18.84 | 83.5 | 589 | 225 | 156 | ........ | 43.4 | ........ | 11.6 | 17.11 | 16.4 | 38 |
| 13.43 | 22.8 | 219.4 | 95.9 | 52.4 | ........ | 14.1 | ........ | ........ | ........ | ........ | 39 |

k Water tube.
l Locomotive type.
m Basis 34.5 pounds from and at 212 °F.
n Heater in use.
o Heater not in use.
p Coal, prices based on ton.
q Reckoned from temperature of feed.

## DISCUSSION OF RESULTS.

In the summary of results given herewith, besides the quantities usually stated in reports of this kind, it has been thought best to compute the results, in most cases, on a heat basis. This was made possible by the fact that the fuel was crude oil. The heat value of oil from the Jennings field was obtained from experiments with a Parr calorimeter at Tulane University. The results were confirmed by information obtained from many sources, and as a result the heat value of 19,500 British thermal units per pound of oil was used where not otherwise stated. Attention has already been called to the presence of water in some of the oil used and to the uncertainty as to its amount. It is important that the water in crude oil be allowed sufficient time to settle and to be drawn off from the bottom of supply tanks. The loss due to water intimately mixed with the oil may be enormous, even when no trouble is experienced by having the fires put out. Low boiler efficiency may be due to several causes, among which may be named: (1) Kind of burner used; (2) arrangement of fire-brick checkerwork to receive the impact of the flame; (3) proportions of boiler, particularly the heating surface per boiler horsepower; (4) water intimately mixed with the fuel oil, and (5) too great an excess of air.

The amount of steam used by burners to spray the oil varies from 3 to 8 per cent, while in exceptional cases it may run as high as 12 or possibly 15 per cent. The average burner will probably use 6 per cent of the total steam in this way. The small pipes used to conduct steam to burners present considerable condensing surface, so that the steam entering burners must contain a large percentage of moisture. Latent heat is required to convert the water into steam and more heat to raise the steam to the furnace temperature, while the steam enters the flue at the temperature of the gases formed by combustion. The more steam used by the burners, the less the amount to give up its energy as indicated horsepower and the greater the amount of heat lost in the furnace. Extensive tests conducted elsewhere have shown conclusively that the arrangement of the fire-brick checkerwork in a furnace where fuel oil is burned has a marked effect on efficiency. Attention has already been called to the fact that the boiler which showed the best efficiency had the smallest amount of heating surface per boiler horsepower. The fact has also been noted that two boilers of the same type, those of the Acadia plant and of Grand Canal, and of nearly the same size, gave widely varying efficiencies. The difference is chiefly accounted for by the amount of water in the oil.

The efficiencies of the boilers tested were remarkably low; in only one case did the efficiency exceed 70 per cent. The Acadia plant gave nearly 75 per cent, but in this respect it stands alone, as the next highest was less than 70, and in a few cases efficiencies approximating 55 per cent were obtained. Many of the boilers tested were designed for using wood as fuel, while the others were intended for coal. It seems probable that in many cases the heating surface is too large for using oil economically. Another source of loss is in too liberal a supply of draft area. A large supply of oxygen is absolutely necessary, but the draft which corresponds to highest economy, other things being equal, is that which is just sufficient to prevent smoke. It is a very simple process to cut down draft area until smoke appears, and then to increase it until the point is reached where smoke disappears. However, this loss is too often overlooked.

The heat to produce the steam is reckoned from the temperature of feed, assuming dry and saturated steam. The error involved is small; this error is certainly less than that involved in measuring the discharge from the pumps.

Indicated horsepower and water horsepower were both reduced to the heat basis. By multiplying horsepower per minute by 42.42 the equivalent British thermal units are obtained.

Having computed these quantities, it is possible to locate losses in the plant. In this way boiler efficiency, the percentage of heat in total steam, appearing as indicated horsepower, and the percentage of heat equivalent of water horsepower to that in the oil, to that in total steam, and to the indicated horsepower, all become known.

The mechanical efficiencies of engine, transmission, and pump vary within wide limits. It is impossible to compute the efficiencies of pumps without assuming the mechanical efficiencies of the engines, which will probably range from 90 to 93 per cent. Where pumps are not directly connected, as in every case except the Abbeville plant, the Algiers drainage plant, and the Neches plant, the efficiency of transmission must also be assumed; the probable value will range from 90 to 95 per cent.

The final comparison of pumping plants must be made on a financial basis. In designing a pumping plant for a certain set of conditions, not only the cost of oil must be considered, but also interest on the investment, depreciation, repairs, and wages. In order to put the comparison on a practical basis, the cost of plants of different types was obtained from many sources as well as the cost of operating plants and distributing water.

Much information regarding the amount of fuel required in various plants, in addition to that obtained from the tests, was secured. It was found that in general the plants tested were typical of their class with the exception of plant No. 10.

The best plant for a particular case must possess two qualities—reliability and maximum financial economy. The first is absolutely essential, while the second becomes more and more important as the margin of profits becomes smaller.

To operate economically a plant must be run at its full capacity—that is to say, the maximum number of acres that can safely be watered should be irrigated annually. Keeping these conditions in mind, the problem of designing a large pumping plant will be considered. To make the discussion concrete the plant will be supposed to have a capacity sufficient to water 9,000 acres when operated eighteen hours out of each twenty-four during the irrigation season, which is assumed to be of eighty days' duration.

For the actual hours of operation we will assume that the amount of water needed is 7.5 gallons per minute per acre irrigated, or $7.5 \times 9{,}000 = 67{,}500$ gallons per minute. While it is intended to run the plant eighteen hours per day, it may, in case of excessive drought, be operated continuously for several days; operated eighteen hours per day for eighty days the water pumped would amount to a depth of 24 inches over 9,000 acres.

Our entire outfit will consist of two units so arranged that either engine may be furnished steam from any of the boilers and either or both units operated at will.

The plant is to be erected on the banks of some stream conveniently located and where the water supply is known to be ample. The actual lift is to be 20 feet as a maximum.

It is assumed that the building will cost the same in any case. The type of boilers, engines, accessories, and pumps may vary. Prices and estimates have been obtained from as many sources as possible and specifications carefully studied and compared. It would manifestly be unfair to state, specifically, the sources of this information, as nearly all was confidential. The discussion will, therefore, be confined to a general statement, giving average results of this inquiry. In making comparisons reliability, running expenses—which include depreciation and repair, interest on investment, wages, and cost of fuel—will be considered. A part of the running expenses are constant—that is, they do not vary from year to year, as they are prorated on the investment; they will be larger as the investment is larger.

The quantity most liable to fluctuation is the fuel bill. This is a function of several variables: (1) The price of oil per barrel; all calculations have been based on the use of fuel oil, as it has been found most economical at present prices in this section. If in the future the cost of fuel oil should advance from any cause to more than $1 per barrel, many will return to coal as a fuel, if its present price is maintained. It has been found that a fair comparison between the two fuels is on the basis of 3½ barrels of oil per ton of average soft coal. Of course, it costs more for wages to burn coal than it does for crude oil. (2) The amount of water pumped, which will vary considerably in different seasons. (3) The head pumped against, the amount of the variation of level of the water supply in some places being as great as 10 to 15 feet. (4) The type of plant.

The first of these variables depends on the market and on proximity of the oil field. The second and third vary according to the amount of rainfall during the irrigating season. The fourth will affect the amount of the fuel bill according to economy of operating.

To the above plant charges, as they may be called, must be added the canal expenses. It has been found by examining a great deal of reliable data that on the average the first cost of right of way, canals, flumes, and laterals is about $10 per acre irrigated. This would mean an investment of $90,000 for an acreage of 9,000. Now, capital when once invested in canals and flumes is no longer convertible into money, and the rate of interest would therefore have to be larger than on the plant investment. Six per cent is assumed as a fair basis for canals and flumes and 5 per cent for the plant. The canal charges are therefore as follows:

| | |
|---|---|
| Interest at 6 per cent on $90,000 | $5,400 |
| Depreciation, maintenance, repairs, and cost of distributing water | 8,000 |
| Total expenses | 13,400 |

Expenses per acre, 13,400÷9,000=$1.49, say $1.50.

These figures agree with many actual average cases.

For the purpose of comparison five types of plants have been taken:

Plant No. I, consisting of water-tube boilers, compound condensing engine, and high-grade centrifugal pump.

Plant No. II, consisting of water-tube boilers, compound condensing engines, and rotary pumps.

Plant No. III, consisting of water-tube boilers, simple condensing Corliss engine, and centrifugal pumps.

Plant No. IV, comprising what would ordinarily be called a "cheap outfit"—horizontal return tubular boilers, slide-valve noncondensing engines, and cheap centrifugal pumps.

Plant No. V, which is a small well plant, with locomotive type of boiler, small slide-valve engine, and vertical-shaft centrifugal pump. Area to be watered by Plant No. V, 150 acres.

Each of the above plants is to be equipped with suitable accessories, such as feed-water heaters, boiler-feed pump, and, in the case of condensing plants, with vacuum pumps.

Let us now examine the cost and performance of each in turn, assuming the price of oil at 50 cents per barrel.

Plant No. V is often run by an inexperienced man without regard for economy. The depreciation should be figured higher than for good machinery. Ten per cent is assumed for depreciation and repairs.

The figures below are those of an actual plant now in operation:

| | | |
|---|---|---|
| Cost of plant | | $2,000 |
| Area irrigated | acres | 150 |
| Fuel per season | barrels of oil | 725 |
| Fixed charges as follows: | | |
| Repairs and depreciation at 10 per cent | | $200.00 |
| Interest at 5 per cent | | 100.00 |
| Wages at $75 per month for three months | | 225.00 |
| Total fixed charges | | 525.00 |
| Fixed charges per acre | | 3.50 |
| Cost of fuel per acre | | 2.42 |
| Cost of irrigating per acre | | 5.92 |

There are no canal charges, as the plant belongs to the farm.

This plant corresponds in cost and expense of operating, including cost of fuel, to that tested as plant No. 11.

It is typical of its class and rather above the average. The well is said to be one of the best in that part of the country. In order to supply 2 acre-feet per acre for 150 acres, the well plant will need to be operated ninety days eighteen hours per day. With the large pump the plants are operated eighty days eighteen hours per day in each case to furnish 2 acre-feet for the 9,000 acres irrigated.

Next consider plant No. IV. This plant has been designed to meet the demand stated for our big canal plant. It is made up of cheap centrifugal pumps, rope driven from slide-valve engines; the steam is supplied by horizontal return tubular boilers. Many of this type were installed in the early years of rice irrigation in Louisiana. Strange as it may seem, actual figures from estimates show the cost of installing this plant to be as much as 10 per cent more than the cost of installing a plant of the same capacity but having high-grade machinery. This is easily explained when we consider that a slide-valve engine uses from 30 to 40 pounds of steam per indicated horsepower-hour as against 15 to 20 for the compound condensing. The pump will not have a high efficiency, and this will increase the engine horsepower and the size of boilers needed. It takes very little more fuel to generate steam at 160 to 200 pounds pressure for the compound engine than at 100 for the slide-valve engine; leaving the pumps and accessories out of consideration, the boiler capacity in the two plants must bear approximately the ratio of 2 to 1. The foundations and settings are also much more expensive for the wasteful plant.

Taking the average of a number of high-grade plants the total cost per water horsepower is just about $100, perhaps a trifle less in some instances. Now, 67,500 gallons per minute pumped against 20 feet of actual elevation is about 340 water horsepower, so that one proposed plant with high-grade machinery would cost about $34,000. The slide-valve plant which has been under discussion would cost 10 per cent more, or $37,400, and the fuel consumption for the season of eighty days would be about 14,000 barrels of oil.

With the slide-valve engine a greater allowance must be made for depreciation than for the compound engines. The following assumptions are therefore made:

| | |
|---|---|
| Repairs and depreciation, at 10 per cent | $3,740.00 |
| Interest, at 5 per cent | 1,870.00 |
| Wages of employees | 1,000.00 |
| Total fixed charges | 6,610.00 |
| Fixed charges per acre | .734 |
| Fuel per acre | .78 |
| Canal charges per acre | 1.50 |
| Total cost of irrigating per acre | 3.01 |

Plant No. III is now to be considered. This plant has water-tube boilers, simple condensing Corliss engines, and good centrifugal pumps. The cost is about $34,000, the same as the compound condensing plant. It is a good, reliable, easy running plant, but the fuel consumption is high, as 8,100 barrels of oil are needed. The bill of cost is as follows:

| | |
|---|---|
| Repairs and depreciation, at 8 per cent | $2,720.00 |
| Interest, at 5 per cent | 1,700.00 |
| Wages of employees | 1,000.00 |
| Total fixed charges | 5,420.00 |
| Fixed charges per acre | .602 |
| Fuel per acre | .45 |
| Canal charges per acre | 1.50 |
| Total cost of irrigating per acre | 2.55 |

Plant No. II is in actual operation. The cost assumed is the price for the machinery at the present time. The cost is 20 per cent greater than for Plant No. I. The outfit is made up of water-tube boilers and high-grade rotary pumps, driven by compound condensing engines. The increase in cost is due to the rotary pumps. It will be seen later that under the conditions assumed this increase in cost is not justified by the returns, although the cost of fuel per acre is less with the more expensive plant.

| | |
|---|---|
| Cost of plant | $42,000.00 |
| Fuel consumed, barrels of oil | 3,860 |
| Running expenses: | |
| Repairs and depreciation, at 8 per cent | $3,360.00 |
| Interest, at 5 per cent | 2,100.00 |
| Wages of employees | 1,000.00 |
| Total fixed charges | 6,460.00 |
| Fixed charges per acre | .72 |
| Fuel cost per acre | .21 |
| Canal charges | 1.50 |
| Total cost of irrigation per acre | 2.43 |

Plant No. I is now to be considered. It is made up of water-tube boilers carrying 160 to 200 pounds; high-pressure compound condensing engines, having a steam economy of 15 pounds or less per indicated horsepower hour. These engines are direct-connected to well-designed centrifugal pumps having a guaranteed efficiency of 70 per cent at full load and proper speed. A fuel consumption of 4,500 barrels of oil is assumed for a season when the plant is to be operated eighteen hours each day for eighty days.

As already stated, the cost of this plant erected and ready for operation is $34,000. The running expenses would be as follows:

| | |
|---|---|
| Repairs and depreciation at 8 per cent | $2,720.00 |
| Interest at 5 per cent | 1,700.00 |
| Wages of employees | 1,000.00 |
| Total fixed charges | 5,420.00 |
| Fixed charges per acre | .60 |
| Fuel per acre | .25 |
| Canal charges | 1.50 |
| Total cost of irrigating per acre | 2.35 |

There are two other types of plants to be mentioned, neither of which, so far as the writer knows, has been used for rice irrigation. The first of these consists of an outfit having centrifugal pumps direct-connected to steam turbines, the steam to be supplied by water-tube boilers. The guaranteed duty is 78,000,000 foot-pounds of work per 1,000 pounds of dry steam supplied at the turbine throttle, which is about the same as for the compound engine-centrifugal pump plant. The price of this outfit is, however, 20 per cent in excess of that of Plant No. I, or about equal to that of Plant No. II with no better economy than Plant No. I. This consideration alone would suffice to exclude using a turbine plant. There are other considerations which will confirm this decision. In order to operate a centrifugal pump economically against a head fluctuating between 10 and 20 feet it would be necessary to vary the speed. The steam turbine is essentially a high-speed machine, and the pumps suitable for high lifts. Slow speeds can only be had at a great sacrifice of economy. It might be possible to gear down a steam turbine to drive a rotary pump, but the transmission losses would probably be so large as to make the plan impracticable.

The engineers of the rice district are altogether unacquainted with the operation of turbines; for this reason it would be unwise to intrust the operation of a turbine plant to any but the very best of stationary engineers. This would probably result in an increase in wages for plant operation.

The other type to be mentioned is the producer gas-engine outfit. This engine is the latest development in the science of power generation. Plants are being installed under a guarantee of furnishing a brake horsepower hour on 1.25 pounds of anthracite coal. The total efficiency, or ratio of heat equivalent of developed horsepower to the heat energy of the coal for this outfit will range from 14 to 20 per cent, while the compound condensing engine will give about 10 per cent, disregarding steam used by burners and accessories. The cost of the producer plant would be nearly twice as great as the cost of Plant No. I. The price of fuel oil would have to advance considerably above present rates before the comparison of this plant with those of the better types already considered would be of interest. Furthermore, the gas engine is likely to be less reliable in operation than is the steam engine, and it is less familiar to the men who would have to run the plants. For intermittent operation, with the plant laid by for three-fourths of the year, the producer gas plant is not well suited. For these reasons this plant will not be further considered.

It will now be of interest to compare the cost of irrigating per acre with these various plants.

The first case to be examined is the cost of irrigating a farm of 150 acres by means of a well plant and by taking water from a canal company. In many sections the two alternatives are offered, while in other places water must be obtained from wells. In the latter case the only question of interest is whether the farmer can afford to raise rice at the cost of installing and operating a well plant. Assume an 8-barrel crop and that the average price of rice is \$3 per barrel. In case water is taken from a canal system, the charges of the canal company will be $\frac{1}{5} \times 8 \times \$3 = \$4.80$ per acre. With rice selling at \$2.50 per barrel the amount paid the canal company would amount to $\frac{1}{5} \times 8 \times \$2.50 = \$4$.

When the farmer raises a 10-barrel crop, and the price is \$3 per barrel, the cost will amount to \$6, while if the price of rice is \$2.50, the 10-barrel crop will cost \$5 to irrigate from a canal.

Now, the cost of irrigating 150 acres, by means of a well plant, was computed at $5.92, a figure nearly as great as the cost of taking water from a canal when a 10-barrel crop, selling at $3 per barrel, is assumed. In general, it may be said that 8 barrels is nearer the average yield than is 10 barrels. Wells are uncertain, and in many cases their lives are short. With the conditions as assumed, the desirability of using one method or the other would be dependent on the yield, the price of rice, and the amount of flood water needed. It must be remembered that this comparison is based on approximately 2 acre-feet of water to be supplied per acre. During a season of plentiful rain the amount of water pumped would be considerably less than this amount; in this case the well plant would not need to be operated for the full ninety days, and therefore the cost of irrigating would be reduced, while if water is taken from a canal the cost is independent of the amount used. During the last two seasons the rainfall has been so plentiful that the amount of flood water required has been much less than for the average season. The result has been that the farmers having good well plants have saved money by operating their own plants. The conditions assumed in the problem must be clearly kept in mind, for the conclusions apply only for these assumptions. The method is applicable to any set of conditions, and each separate problem may be solved in this way.

Next the canal plants to irrigate 9,000 acres will be considered. In order to bring the results together so that comparisons can easily be made, the following table, which is based on an average crop of 8 barrels per acre, has been prepared:

*Cost and profits for pumping water for rice irrigation, with an average crop of 8 barrels per acre.*

| Number of plant. | Total investment. | Fixed charges per acre, including canal charges. | Cost of fuel per acre. | Total cost per acre. | Rice at $2.50 per barrel. | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Amount received per acre. | Profit per acre. | Profit on 9,000 acres. | Per cent profit on investment. |
| 1 | $124,000 | $2.10 | $0.25 | $2.35 | $4.00 | $1.65 | $14,850 | 12.0 |
| 2 | 132,000 | 2.22 | .21 | 2.43 | 4.00 | 1.57 | 14,120 | 10.7 |
| 3 | 124,000 | 2.10 | .45 | 2.55 | 4.00 | 1.45 | 13,050 | 10.5 |
| 4 | 127,400 | 2.24 | .78 | 3.01 | 4.00 | .99 | 8,910 | 7.0 |
| 5 | ........... | 3.50 | 2.42 | 5.92 | ........... | ........... | ........... | ........... |

| Number of plant. | Rice at $3 per barrel. | | | | |
|---|---|---|---|---|---|
| | Amount received per acre. | Profit per acre. | Profit on 9,000 acres. | Per cent profit on investment. | Minimum price for rice, to make plant just pay expenses. |
| 1 | $4.80 | $2.45 | $22,050 | 17.8 | $1.47 |
| 2 | 4.80 | 2.37 | 21,330 | 16.25 | 1.52 |
| 3 | 4.80 | 2.25 | 20,250 | 16.3 | 1.59 |
| 4 | 4.80 | 1.79 | 16,110 | 12.6 | 1.88 |

From the above discussion it is evident that under the assumed conditions Plant No. I would be the best investment. It should be noted, however, that Plants Nos. I and II will be equally good investments when fuel oil costs about $1.50 per barrel, as the cost of irrigating an acre with either will be $2.85. With fuel oil at $1 per barrel the total cost per acre of irrigating with Plant No. I will be $2.60, while with Plant No. II it will be $2.64. The cost of this plant is $34,000 and the cost of the right of way, canals, flumes, and laterals would be $90,000, making a total investment of $124,000 for Plants Nos. I and III, $132,000 for Plant No. II, and $127,400 for Plant No. IV. Total acreage to be irrigated, 9,000.

In order to cover conditions too wide to be included in the above discussion without hopeless entanglement in details, curves have been platted showing, besides the quantities already discussed, the following varying conditions (figs. 3 and 4):

(1) Cost of fuel oil per barrel;
(2) Inches in depth of water supplied to irrigated lands;
(3) Head pumped against;
(4) Type of plant; and
(5) Acres irrigated.

The first three of these variables are almost entirely beyond our control. We may select by means of this diagram the type of plant most suited to a given set of requirements. The plants are all assumed to be equally reliable in operation. The conditions are not wide enough to cover all possible cases; for instance, the head pumped against may be considerably in excess of 20 feet. There are plants in Texas which lift the water 60 feet or more. The cost of canals and flumes will be a minimum in a level country having just the desirable slope to the land to make the distribution of water a simple problem, while the cost will be a maximum where the country is rolling and numerous flumes and high canal embankments are required.

While all deductions are based on the average conditions found in the plants tested, the methods can be applied to any set of conditions.

The second plat shows the profits and losses of canal companies under the following varying conditions:

(1) The market price of rice per barrel;
(2) Total cost of irrigation per acre; and
(3) Yield in sacks per acre.

The first of the above variables is beyond our control. The other plat shows the conditions determining the cost of irrigating. The yield depends on (1) the climatic conditions of the season, (2) the quality of the land, (3) the energy and skill of the farmer cultivating the rice crop, and (4) the reliability of water supply.

In this plat the profit or loss per acre is shown and, assuming a crop of 9,000 acres and an investment of $124,000 by the canal company, total gain or loss and the percentage on investment have been laid off on separate scales.

Briefly summarizing, it is evident that a canal company can not afford to have any but economical engines, preferably of the compound condensing type. The pumps may be high-grade centrifugals or rotary pumps, according to the conditions of the special case.

The two prime requisites of any plant are reliability and financial economy. These are in no way opposed to each other, but, on the

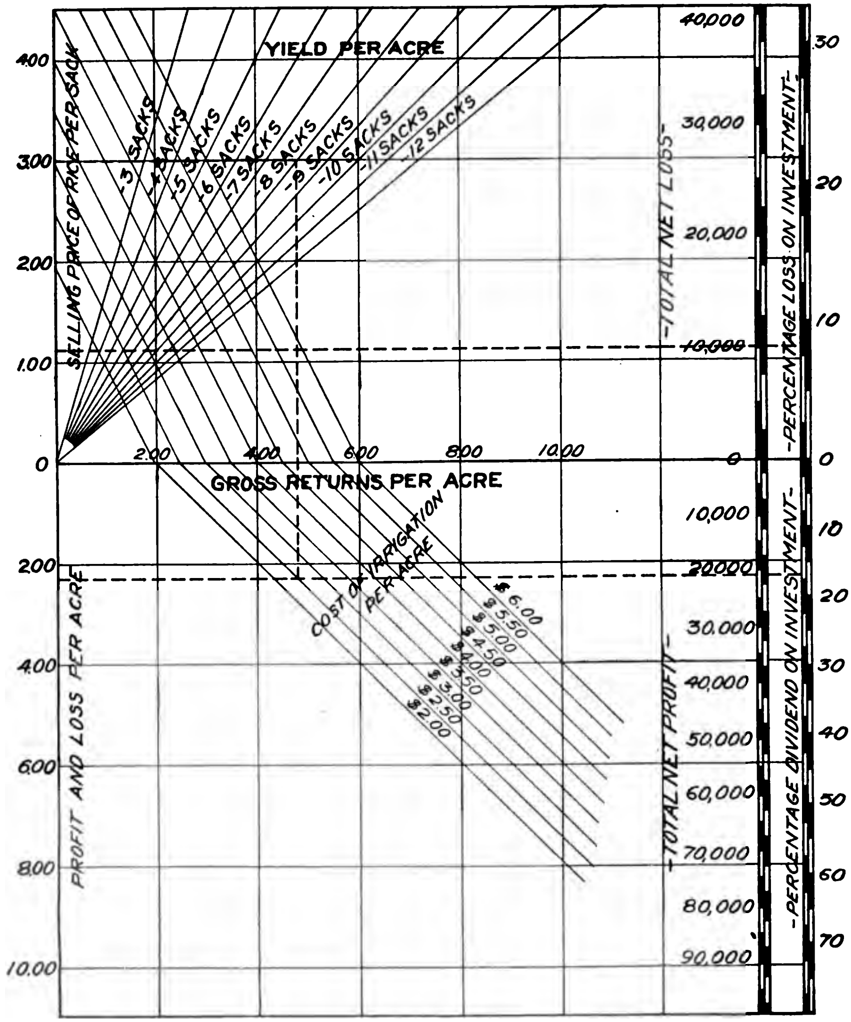


FIG. 3.—Diagram showing profits and losses from Plant No. I.

contrary, are both attributes of high-grade machinery. The proportions must be such that an accident to a portion of the machinery will not paralyze the entire plant. There should be at least two units, and the figures given in this discussion have all been based on this assumption.

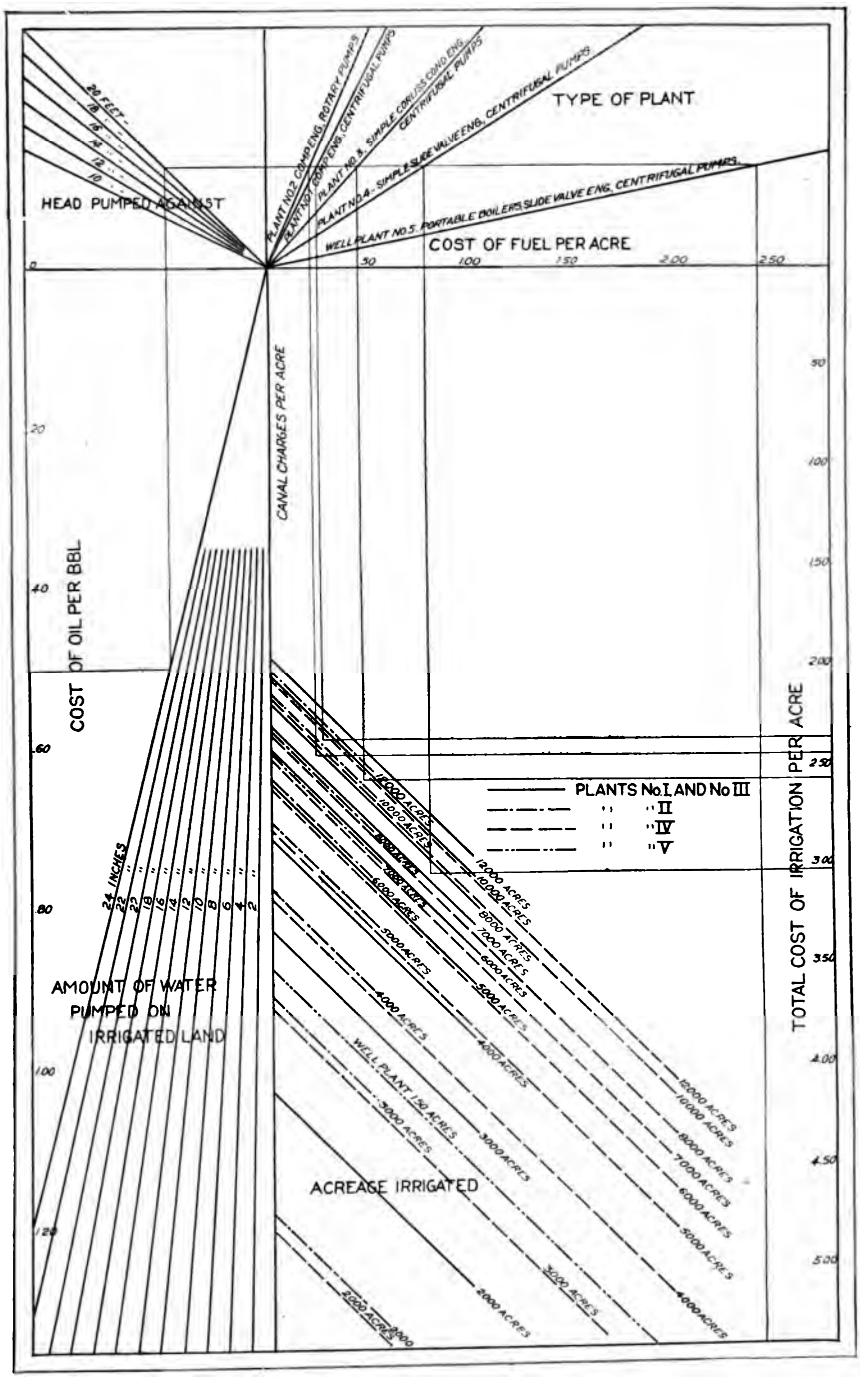


FIG. 4.—Diagram showing cost of fuel and total cost of irrigation per acre under varying conditions.

## DRAINAGE PLANTS.

It is estimated that nearly one-half of the area of Louisiana is of alluvial formation, having been deposited in recent geological ages by the great river. Like all alluvial soil it is of great fertility, and the semitropical climate makes this land, when properly drained, very productive. Sugar cane, cotton, and rice are the staple crops. Along the Mississippi the elevation of the land is sufficiently great to make natural drainage practicable. The land slopes back from the river to the swamps. The strip of land on both sides that is drained by natural slope and cultivated varies in width from 1 to 2 miles. In many places the strip has been widened by artificial drainage, and nearly every plantation could be increased in area by one-third in this way. These conditions obtain not only along the Mississippi, but also along many of its tributaries and outlets.

In the southern part of the State are vast tracts of the richest lands, too low to be successfully cultivated without the aid of artificial drainage except in seasons of unusually small rainfall. Colonies have already started to reclaim this land in some sections and numerous projects are now under consideration having for their object the reclamation and settlement of these lands, the level of which is nearly the same as the Gulf of Mexico. The general plan is to build a protection levee around a tract of land and by means of open ditches to drain the water to a pumping plant where it is pumped out over the levee. It is essential that the levees protecting reclaimed land be of sufficient height to keep out the backwater due to storms on the Gulf. A strong wind from the south often raises the water level several feet so that tracts near the coast require levees of considerable size.

The problem is similar to that of reclaiming the low lands of Holland, with the exception that in Louisiana the lands already reclaimed and those to receive attention in the near future are relatively much higher than some of the lands reclaimed in Holland. The reason is obvious. Lands in general in this section have not yet advanced in value sufficiently to make it desirable to reclaim any but the highest and most favorably located. However, the movement is well started, and the next few years will witness great progress along these lines. A pumping plant to remove drainage water is of the greatest importance in these undertakings.

Louisiana produces more sugar cane than any other State in the Union. The alluvial lands along the Mississippi and in the southern part of the State are extensively planted to sugar cane, and nowhere is drainage of greater importance. Rainfalls of from 5 to 7 inches are not at all uncommon, and such a downpour flooding the fields of cane, even temporarily, may inflict an injury on the soil that will reduce the yield, even if the cane is not directly injured. Open ditches are used and the drainage pumped over the levee protecting the rear of the plantation into the swamp.

A great variety of pumps are used. The height through which the water has to be elevated is small and the volumes large. The average lift varies from 3 or less to 10 feet, but is usually nearer the lower figure than the higher. Some of the pumping plants are extensive in size and have thoroughly modern machinery.

The prime requisites for these plants are (1) reliability and (2) economy of operation.

The first is absolutely essential; the second is desirable, but under the conditions is not easy of attainment.

The pumping plants used to drain plantations are operated intermittently; when a rain comes steam is raised and the pump started. The run may be for a few hours or, in exceptional cases, for several days, depending on the precipitation and consequent run-off. With the low lifts these pumps are not expected to be very efficient. Among the types used for drainage may be mentioned the centrifugal, rotary, and centrifugal with a wooden casing, the Dutch drainage wheel, and occasionally a wheel with blades that scoop up the water and discharge it near the shaft.

The centrifugal pump with a wooden casing is particularly suited to elevating large volumes of water through small heights. The only metal parts are the pulley, shaft, bearings, and impeller. It is cheaper than all-metal pumps, and has been extensively used on sugar plantations. A test of one of these pumps used for irrigating is given under the head of plant No. 4. It is believed that the efficiency found in that test is unusually low on account of the inefficiency of the rope drive.

Another type of pump that has long been justly popular for drainage work is the Dutch drainage wheel. It is probably the most efficient pump built for low lifts, and is capable of moving large volumes of water. A test of one of these wheels is described as plant No. 12. The efficiency for lifts of less than 3 feet was between 35 and 50 per cent. This form of drainage wheel is successfully used for lifts up to one-fourth of the diameter of the wheel. The diameter usually ranges from 25 to 30 feet.

As these plants are operated at very irregular intervals, it is not necessary that the boilers and engines be of the highest grade, as it would be impossible to get a high efficiency even from the best and most economical outfit under the circumstances. The machinery for such plants must be good and reliable, and not at all complicated, so that it may be safely intrusted to men who are not skilled engineers, as only on a few of the largest plantations is the drainage