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1908

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Eugene Wycliffe Kerr

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LOUISIANA BULLETIN NO. 107.

Agricultural Experiment Station

OF THE

LOUISIANA STATE UNIVERSITY and A. AND M. COLLEGE.

BATON ROUGE, LA.

Preliminary Tests of Sugar House Machinery.

BY

E. W. KERR, M. E.

BATON ROUGE:
THE DAILY STATE PUBLISHING COMPANY, STATE PRINTERS.
1908.

Louisiana State University and A. & M. College

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INTRODUCTION.

For the intelligent design and arrangement of the machinery of a power plant of any kind the designer should have at his command data regarding the capacity and the performance that may be expected of machines of different kinds and sizes. This data should be known, not only for the best operative condition, but for all conditions that are likely to occur in the operation of the machine. It is especially important to know something of the capacity under the least favorable conditions of practice as this largely determines the size of the machine which should be installed. For the machinery of ordinary steam power plants such as is used generally throughout the country, there is an abundance of data as regards both design and performance. Not only does such data exist, but it may be found in print, so that he, who will, may inform himself. For instance, the mean effective pressure, the steam consumption in pounds per horsepower per hour and the mechanical efficiency of steam engines of each particular type are accurately known and on record. In general, the same may be said of boilers, pumping machinery, hydraulic motors, electricity and perhaps to a smaller extent, gas and other internal combustion engines.

With reference to the machinery peculiar to sugar houses there seems to be little of such data. This fact has been forcibly brought to the attention of the writer who is responsible for a college course in sugar house engineering, a part of which course consists in designing and planning a complete sugar house outfit of a required capacity.

Being aware of the scarcity of printed information of the kind desired, it was decided that a series of tests, as complete as possible, should be made of sugar house machinery in order to get information as to the relations of capacity, energy consumed, and efficiency. Following is given the results of preliminary investigations made for the purposes explained above.

These tests were made with a view of using the results obtained in planning experiments along the same lines but more elaborate in character.

It was not originally intended that they should be printed in bulletin form which will account for what may seem to be their brief and more or less incomplete form. It is intended that more complete experiments be made during the coming grinding season and outlines for such work will be found on another page. The tests recorded in the following pages were made by the writer, assisted by students in the Engineering Courses at the Louisiana State University.

Power Required to Operate a Cane Mill.

Of the total energy supplied in turning a cane mill, part is utilized in the production of useful work and part in overcoming friction. The latter is probably very nearly constant even with varying quantities of cane fed, provided the lubrication of bearings does not vary. The writer has not had the opportunity to verify this last statement by direct experiment, but takes it for granted from the fact that such has been found to be the case with steam engines. The friction of the mill consists of that at the journals and in the sliding contact of the large gear teeth, of which there are many. In addition to this a large quantity of work is lost in the friction at the turn plate, this being proportional to the feed. The horsepower required to do the useful work of grinding will depend upon the weight of cane fed in a given time; the condition of the cane whether crushed or not; the percentage of fiber in the cane, and the proportion of the juice that is extracted, this latter depending upon the pressure between the rolls; an increase of any one of these causing an increase in power required for a given tonnage.

It is evident therefore that in order to make comparisons of different mills as to the power required to run them, the unit of measurement of work done should include factors representing each. This of course would be a difficult matter. For instance there would be no way of measuring the thoroughness of preparation by the crusher and no way of insuring that the cane would reach the mill in like condition for any two mills. This would suggest that a better way of measuring power would be to measure that required to run the crusher and mill taken as a whole.

Cane with a large per cent of fiber will require the application of more energy for a given extraction than will a cane of less fiber for a given tonnage, because of the greater volume of the crushing mass and the resulting high pressures required at the rolls.

With reference to the question of extraction there are three methods of testing mill work; first the juice expressed, in per cent of the weight of the cane, usually termed "extraction." This is not a satisfactory basis of comparison because the "extraction" will depend entirely upon the original amount of juice in the cane. Second, the per cent, by weight, of moisture in the bagasse which is a better mode of comparison than "the extraction," but is misleading for the reason that it does not take into account the effect of maceration in varying the density of the juice left in the bagasse; third, "the volume of juice in the bagasse per unit weight of fiber in the bagasse." This last which is due to Mr. Noel Deerr is undoubtedly the only real test of mill work. For this determination in practice it would be necessary to obtain from samples of bagasse, the weight of juice, weight of fiber in a unit weight of bagasse, also the density of the juice in the bagasse. For example, suppose a sample of 100 parts of bagasse is found to contain 58 parts of juice and 42 parts of fiber, all by weight, the density of the juice being 1.38. Then $\frac{58}{42 \times 1.38} = 1.0007$ is the volume of juice in the bagasse per unit weight of fiber in the bagasse as stated above. The principal difficulty in applying this method would be in determining the density of the juice, so that the second method as stated above should be accurate enough for practical purposes. In the test recorded below no attempt was made to secure the data necessary for this determination, the principal object of the test being to get a general idea of the power required of the engine to operate a mill in a Louisiana plant, as well as the variation of the power with ordinary conditions of feed. The test consisted in taking the data necessary for determining the horse-power of the mill engine by means of an indicator, the formula for which is $H.P. = \frac{PLAN}{33000}$ in which P is the mean effective pressure, L the length of the stroke in feet, A the area of the piston in square inches, and N the number of strokes per minute. The observations taken during the test were, revolutions per minute, boiler pressure and indicator cards at regular intervals. These observations are recorded in columns 1 to 4 in table I.

The mill is of the six roller type manufactured by the Reading Iron Company and served by a Krajewski crusher. The mill rolls are 34x84 inches, geared so that with an engine speed of 50 R. P. M. the front mill rolls have a peripheral speed of 23.7 feet per minute and those of the back mill 25.5 feet per minute. A pressure of 330 tons on the front mill and 390 tons on the back mill is supplied by the hydraulics.

The top rolls were separated from the other rolls in the front mill so as not to touch, but those of the back mill were set "iron to iron." The cane is brought to the crusher by a carrier operated by the direct current motor, the speed of which may be varied by hand so as to regulate the feed to the crusher.

The mill engine is a 26x60 inch Corliss with a normal speed of about 50 R. P. M., and having a piston rod 5 inches in diameter. Indicator cards were taken every 15 minutes, or as nearly so as possible, with simultaneous readings of R. P. M., boiler pressure and time. The first four columns of table I contain this data. Column 5 of the same table gives the horse-power as calculated from the indicator cards by use of the formula explained above. During the test a carrier slat was broken, stopping the feed. Cards 5 and 6 were taken with the mill in motion, but with no cane feed, except for a few stalks passing when No. 5 was taken. Figure 1 is a sample head end card taken while the mill was feeding and Figure 2 with no feed.

TABLE I.

1 Time	2 Number of Card	3 R. P. M.	4 Boiler Pressure	5 H. P.
2:20 P. M.	1	50	100	238.7
2:25 P. M.	2	50	100	200.9
2:30 P. M.	3	50	98	181.0
2:45 P. M.	4	49	97.5	215.2
2:52 P. M.	5	35	101	37.2
3:00 P. M.	6	35	100	25.4
3:30 P. M.	7	50	101	201.1
3:45 P. M.	8	50	102.5	184.1
4:00 P. M.	9	50	102	239.9
4:15 P. M.	10	49	101	214.1
4:30 P. M.	11	50	101	211.2
4:45 P. M.	12	50	101	220.8
5:25 P. M.	13	50	98	169.8
5:45 P. M.	14	50	102	174.5
6:00 P. M.	15	50	100	184.9

FIGURE 1.

FIGURE 2.

From records of the mill for the day on which the test was made, the following data was obtained: Maceration, 5.04 per cent; fiber, 10.23 per cent; extraction, 76.63 per cent; cane mixed; density of juice, 13.9 Brix. On account of a breakage during the night the mill ran 18 1-3 hours during the 24 hours, the mill record showing a grinding of 901.53 tons during this time. This would be at the rate of 49.26 tons per hour or 1,180 tons per day of 24 hours.

RESULTS OF TESTS.

By reference to column 5 of Table I it will be seen that the power of the engine varies from a maximum of about 240 H. P. to a minimum of about 170 H. P. This gives a maximum of 34.3 H. P. per foot length of roll, or 29.0 H. P. per foot length per 1000 tons. The variation in power is caused by irregular feed due to the fact that the cane was unloaded from cars by mechanical means in such large quantities that it fell upon the carrier in bunches, the variable speed of the carrier being insufficient to correct it entirely. With steam at 100 pounds pressure this engine should develop about 320 H. P. It is, therefore, working considerably below its full capacity at this speed. It will be noticed that the speed was only 35 R. P. M. when card No. 6 was taken, the horse-power being 25.4. Since there was no cane passing this must represent the combined friction of the engine and mill. The mill friction consists of that of the main journals and the gear teeth, as well as that of the bagasse carrier which is run from the back mill.

It is reasonable to suppose that had the engine been making the normal 50 R. P. M. at this time that the power would have been increased in the ratio of 50÷35, which would run the friction up to about 36 horse-power. The friction of steam engines has been found by experiment to be practically constant for all loads, and it may be reasonably expected that the same would be true of a mill except for turn-plate friction, especially as the pressure of the hydraulics is removed only from the journals of the two lower rolls of the front mill when the feed is stopped. Taking 240, the maximum horse-power as the basis, the friction of both engine and mill amounts to only 15 per cent of the total. The friction of an engine of this type may be taken at about 10 per cent, which would leave only 5 per cent of the total indicated horse-power lost in mill friction. This is, of course, only approximate, but it shows that the friction of the mill is very small. It, however, takes no account of the friction at the turn plate, which is, in fact, a large source of power loss.

MAIN CANE CARRIER.

The object of this test was to get information as to the power required to drive a cane carrier operated by an electric motor of the direct current type. The power was measured by the use of volt meter and ammeter readings taken with instruments supplied from the electrical department of the Louisiana State University. The carrier supplies cane to the mill upon which the test recorded in preceding pages was made. The total length is 600 feet, and the vertical distance through which the cane is lifted is 27 feet, the cane being carried on the day of the test at the rate of 1180 tons per 24 hours or 49.26 tons per hour.

As already explained this motor is supplied with a starting box by means of which an attendant may vary the speed of the carrier so as to regulate the feed to the crusher; in other words, when a large bunch of cane is approaching the crusher the carrier's speed is reduced and vice versa. Readings of voltage and current were taken at intervals of one minute as shown in columns 1, 2 and 3 of Table II. The horse-power, column 4, was obtained by the well-known formula, $\text{H. P.} = \frac{\text{Volts} \times \text{Amperes}}{746}$

TABLE II.

MAIN CARRIER.

1 Time	2 Volts	3 Amp.	4 H. P.
1:30 P. M.	110	105	15.5
1:31 P. M.	111	62	9.2
1:32 P. M.	112	65	9.7
1:33 P. M.	112	66	9.9
1:35 P. M.	114	40	6.1
1:36 P. M.	110	70	11.0
1:38 P. M.	111	52	7.7
1:39 P. M.	109	68	9.9
1:40 P. M.	113	62	9.4
Average	111	65.5	9.8

Reference to Table II shows a maximum of 15.5 horse power and an average of 9.8 horse power, the former figure being that which would determine the necessary capacity of motor and the latter the average energy required to operate it. The average energy supplied to the carrier, therefore, is $9.8 \times 33{,}000 = 323{,}400$ foot pounds per minute. The useful work done in lifting the cane is $49.26 \times 2{,}000 \times 27$ foot pounds per hour, or $\frac{2660040}{60} =$ 44338 foot pounds per minute. The efficiency, therefore, is $\frac{\text{Useful work}}{\text{Supplied work}} = \frac{44338}{323400} = .137$. In other words, 86.3 per cent of the work is used in overcoming friction.

CENTRIFUGALS.

Tests were made upon a set of four 30″ centrifugals of the '97 model Weston type, used for drying second sugars and a set of five 40″ Weston centrifugals used for drying first sugars, in order to obtain information as to the power required both for running and for starting. Both sets were of the belt driven type, the power for the centrifugals for seconds being supplied by a direct current electric motor through a main belt to a jack shaft, from which the individual centrifugals were driven by belts. The 40″ centrifugals were arranged in exactly the same manner except that the source of power was an automatic high speed engine.

The power required to run the motor driven set was obtained from current and voltage readings of the motor, as in the tests of the cane carrier. The power of a motor for running centrifugals is determined by that required in starting, due to the inertia of the heavy mass of sugar and basket. After the machine has reached its running speed no further energy is required except for overcoming the friction of the bearings and the resistance of the air. Both of these being very small in quantity. the power required to run the machine at normal speed is small. The power required to run the centrifugals alone was determined by getting the power required to run the main belt and jack shaft and subtracting the same from the total power to run the same with the centrifugals connected. In order to make the experiment as comprehensive as possible, both empty and loaded centrifugals were tested, both starting and running, the operating conditions being the same as for regular work.

Columns 1, 2, 3, 5 and 6 of Table III, contained the data taken during the test. As shown in column 1, there were several combinations of loading. The first horizontal line of the table contains the data taken with the jack shaft and conveyer running, the latter being belted to the shaft so that it could not be conveniently disconnected. This conveyer (empty) was therefore running during all the tests.

The second line, likewise, contained the data for one empty centrifugal, columns 2 and 3 giving voltmeter and ammeter readings for starting, and columns 5 and 6 for running at normal speed. To get these readings, the motor being in motion, the centrifugal was thrown in and the maximum reading of the ammeter needle noted, this reading and the corresponding voltmeter reading being taken as the data necessary for finding the power of starting and recorded in columns 2 and 3. The start having been made, the centrifugal was allowed to run until the ammeter needle came to a rest; this and the corresponding voltmeter reading being recorded in columns 5 and 6.

With one centrifugal in motion, the test for two empty centrifugals was made by simply starting centrifugal number 2, noting the maximum ammeter reading, etc., as before, and recording in columns 2 and 3, and 5 and 6. This gives the data, for both starting and running, for two empty centrifugals, one of which is running and the other starting. The next test was for three empty centrifugals, two of which were running and one starting, the other tests following in like manner.

The values given in column 4 were obtained by multiplying the values in columns 2 and 3 and dividing by 746.

The values in column 7 were obtained in a like manner from columns 5 and 6. The values in column 8 were obtained by subtracting 6.38, the horse power required to run the jack shaft and conveyor, from the corresponding values in column 4. The values in column 9 were obtained in the same manner from column 7.

RESULTS OF TESTS.

A comparison of columns 8 and 9 shows that the running power was very much less than the starting power, for instance, in the case of the single centrifugal, both empty and loaded, the running power was about 25 per cent of the starting power. The latter determines the capacity of the source of power though as it acts for a few seconds only, it does not represent the energy which has to be supplied by the boiler. The values in column 9, however, represent very nearly the average energy supplied. It will be noticed that the results are not altogether logical, though the irregularities are not greater than should be expected under operating conditions with varying tightness of belts and lubrication of bearings.

There is also a liability of a brake being accidentally thrown on, in fact, the large value of the next to the last item in column 8 was probably due to something of this kind.

CENTRIFUGALS DRIVEN BY A STEAM ENGINE.

The test mentioned on a preceding page of the set of 40″ Weston centrifugals was planned to include the same scope as that of the motor driven set, the scheme for which is shown in Table III. The power was measured in this case by means of a steam engine indicator, using a No. 50 spring. The speed of the engine in revolutions per minute was obtained with a Starrett speed counter applied to the end of the engine shaft. A complete table similar in every respect to Table III was made out, but it was deemed inadvisable to include it here because of the fact that the results appeared to be so irregular as to be of little value. This irregularity was due to the fact that the speed counter could not be depended upon to indicate, accurately, the speed at the moment of starting. In other words, the instrument required several seconds time to get a reading, in which length of time there was a considerable variation of speed. The errors in speed caused corresponding errors in horse power. A tachometer will be procured for future tests.

Figures 2 to 5, inclusive, are head end indicator cards taken during the test. These may be taken as fairly accurate with respect to speed, and will give a good comparison of the power required to run one centrifugal under different conditions of operation, the horse power being proportional to the area of the card.

The engine was a 10″x20″ automatic high speed, the speed being 140 R. P. M. for cards 3, 4 and 5, and 136 R. P. M. for number 6.

The card, figure 3, represents the power required to run the jack shaft with a screw conveyer 14″ in diameter and 32 feet long, connected to it by belt. The power in this case figures 10.92 horse power. Figure 4 was taken with one empty centrifugal running, the power being 7.42 horse power. Figure 5 with one loaded centrifugal running, the power being 7.0 horse power; and figure 6 with one loaded centrifugal, starting, the power for which is 57.4 horse power.

It should be understood that the conveyor was running only when card No. 3 was taken. Unfortunatelly, the power required to run the jack shaft alone was not accurately deter-


FIGURE 3.

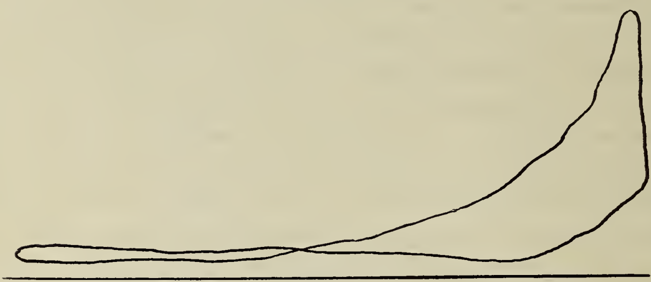
FIGURE 4.


FIGURE 5.

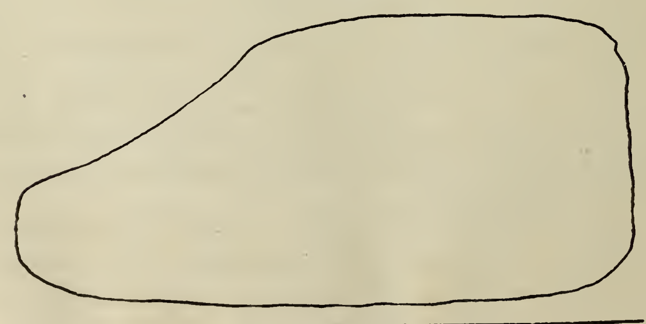
FIGURE 6.

mined, but as the friction of engines of this type is usually about 8 per cent of the rated capacity, it may be legitimately assumed that the friction of the engine, belt and jack shaft is about 8 plus 5, or 13 per cent of the rated power of the engine, which in this case is about 50 horse power. This will give 6.5 horse power, which is subtracted from 57.4, leaves 50.9 horse power, required to start the 40″ centrifugal.

TABLE III.

1	2	3	4	5	6	7	8	9
LOAD	One starting, with counter shaft and conveyor.		H. P., one starting, with counter shaft and conveyor.	Running, with counter shaft and conveyor.		H. P., running, with counter shaft and conveyor.	H. P., one starting, centrifugals only.	H. P., running, centrifugals only.
	Volts	Amperes		Volts	Amperes			
Counter shaft and conveyor..	....	....	....	119	40	6.28	.....	.....
One empty centrifugal	112	160	24	117	70	10.98	17.62	4.60
Two empty centrifugals	113	150	22.7	116.5	80	12.45	16.32	6.07
Three empty centrifugals....	111	180	26.8	116	90	14.00	20.52	7.62
Four empty centrifugals	110	170	25.8	114	100	15.3	19.52	8.92
One loaded centrifugal	112	140	21	117	65	10.2	14.62	3.82
Two loaded centrifugals.....	111	150	22.3	116	95	14.7	15.92	8.32
Three loaded centrifugals...	107	250	35.9	115	120	18.5	29.52	12.12
Four loaded centrifugals....	110	180	26.5	115	122	18.8	20.12	12.42

FUTURE EXPERIMENTS.

Other and more extensive tests will be made to determine the power required to operate crushers of different kinds, also the effect of turn-plate setting upon the power required to run the mill, using some such standard as that outlined on page 5, that will afford a means for just comparison of the work done by different mills. It is desirable also to make experiments that will throw further light upon the question of roll velocity and thickness of blanket and their effect upon the efficiency of crushing.

Centrifugals of the belt driven, water driven, and direct motor driven types will also be tested carefullly for the purpose of making comparisons as to the energy required to dry first, second and third sugars with each of these methods of driving. Investigations will also be carried on, as soon as practicable, to determine the relative capacities and efficiencies of different types of evaporators under different steam pressures. In this connection tests will be made to determine the actual increase of capacity due to increasing the pressure toward the end of the week's run, to overcome the effect of fouled heating surface. This has to be done at the expense of increased back pressure on all the engines of the house and the increase in capacity should be considerable to make its practice of actual profit.

Another ripe field for investigation is along the line of bagasse burning, including such questions as, bagasse burners, types and proportions of boilers, composition and temperature of chimney gases, heat value of bagasse, etc. In general it may be said that as rapidly as is practicable, this department will make more or less thorough experimental investigations into all the machinery of sugar houses.