TEST OF A GASOLENE MOTOR CAR

BY

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June 1, 1903

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

JAMES THOMAS ATWOOD and LE ROY FITCH BEERS

ENTITLED TEST OF A GASOLENE MOTOR CAR

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering.

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering.

INDEX

The principal results of this work as shown by tables can be found on pages (46 to 48).

The principal results of this work as shown by curves can be found on pages (37 to 43).

All other pages give descriptive matter in detail.

PRELIMINARY REMARKS.

In the Fall of 1902 "Gas Engine Testing" was chosen by the undersigned as the subject for thesis work for the Degree of Bachelor of Science in Mechanical Engineering in the University of Illinois. Subsequently, however, this was modified, and tests on a gasolene automobile for horse-power and efficiency have occupied the larger part of the time consumed in the preparation of the following thesis. The work as finally accomplished consisted of the preparations for testing the Root and Vandervort engine upon which a small number of tests were made for the purpose of establishing a complete heat balance. The major part of the work was devoted to the testing of Packard Motor Car #242. On this an extended series of tests were made to determine indicated horse power, brake horse-power, efficiency, etc. The data and results of these tests are given in the following pages.

We desire to take this opportunity to thank the Root and Vandervort Engineering Co. of East Moline, Illinois, and the Packard Motor Car Co., of Warren, Ohio for the loan of the machines placed at our disposal. Also, we wish to express our appreciation of the services rendered by all those who helped us during these tests, and to express our thanks especially, to Mr. H.W. Day of the Class of 1904.

INTRODUCTORY REMARKS ON THE TEST OF PACKARD MOTOR CAR NO. 242.

The automobile industry has come so rapidly to the front, and the demand for machines has been so great, that probably few complete tests of this nature have ever been made. In most factories the facilities for testing, as well as the need or desire for such, have been lacking. This has been due to the effort to first turn out a good machine that would run satisfactorily and stand wear, leaving the less important questions of efficiency, economy, etc. till the more important part had been perfected. The most common method of automobile testing in use today is to mount the rear wheels on two pairs of loose pulleys, with or without a belt connecting each pair, and run the machine in that position. The necessary adjustments can be more easily seen and made than with the whole machine in motion. The apparatus used in the following tests, while it has shown some minor defects of design, has been on the whole very satisfactory. These defects were two in number and were as follows: the area of contact of the car wheel and the pulley of the jack-shaft was too small to transmit the maximum horse-power without excessive wear on the tires; next, rubber hose should have been replaced by iron pipe to transmit the oil pressure from the cylinder on the platform scales to the recording machine, the reasons for which are noted in the following matter.

FIG. 1.

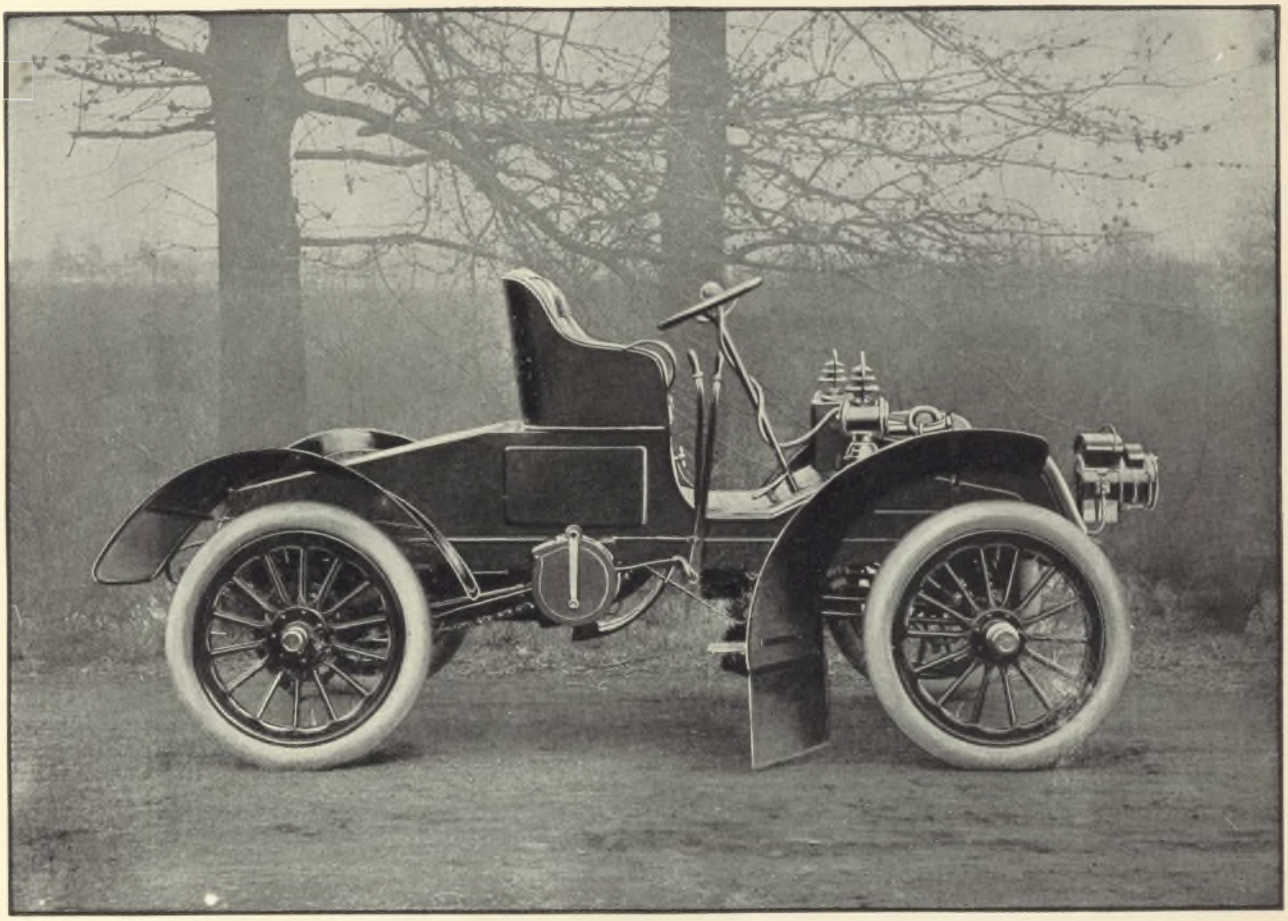


FIG. 2.

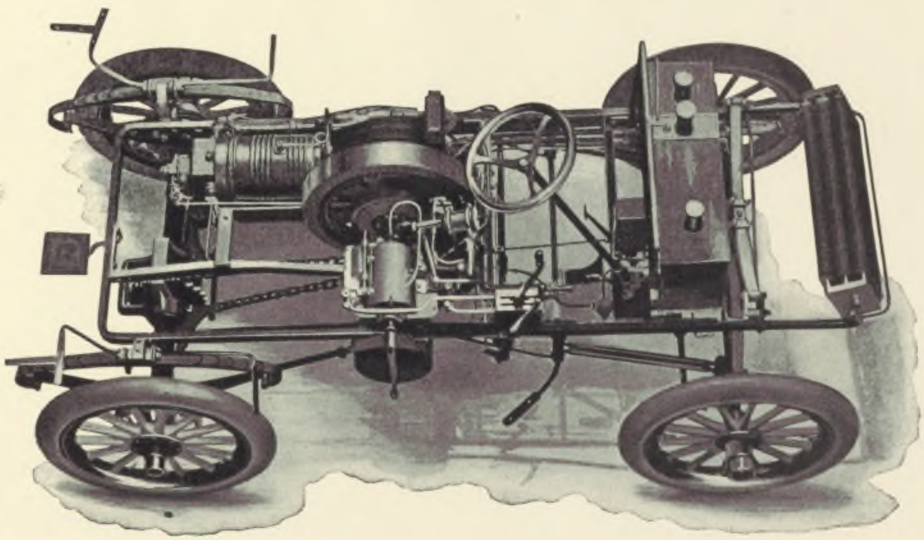


FIG. 3.

DESCRIPTION OF TOURING CAR,

MANUFACTURED BY THE PACKARD MOTOR CAR CO. OF WARREN, OHIO.

In general appearance this machine is much like many others on the market; it being built for four passengers; having the detachable tonneau, the so-called French front, heavy pneumatic tires, steering by wheel and using gasolene for the motive power, etc. (see cut of car, Figs. 1, 2, and 3). However, the distinctive parts are those which have made the Packard machine one of the most prominent in its class. These parts are: 1st, the carburetor, 2nd, the ignition governor with throttle control, 3rd, the copper water jacket, 4th, the transmission gear, and 5th, the spring construction in the flywheel.

Contrary to much of the present practice, the engine in this machine is of the horizontal single cylinder type, and located not over the front axle, but a little back of the center of the machine, and supported on cross arms of the frame. The frame is made of channel iron reinforced in the places of greatest strain.

The carburetor is of the float-feed type, and the gasolene is drawn through small grooves past a spraying cone, and then meets the air with which it forms the explosive mixture. The construction of the carburetor is such that the quality of the mixture is constant while the amount is under control from the foot throttle.

The ignition is obtained by the now almost universally adopted method of a jump spark and vibrator. The point in the stroke at which ignition takes place is varied by a centrifugal governor, which draws a spiral cam along the secondary shaft, and by this means changes the point of closing of the primary circuit. (see Figs. 4,and 5).

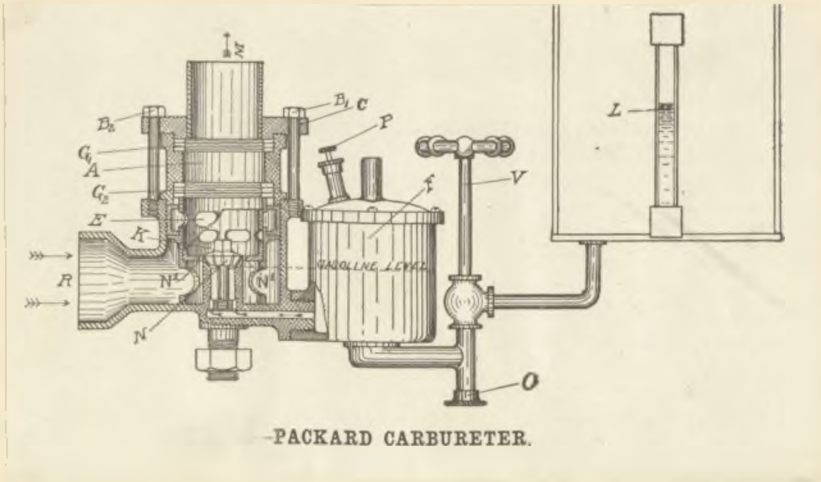


FIG. 4.

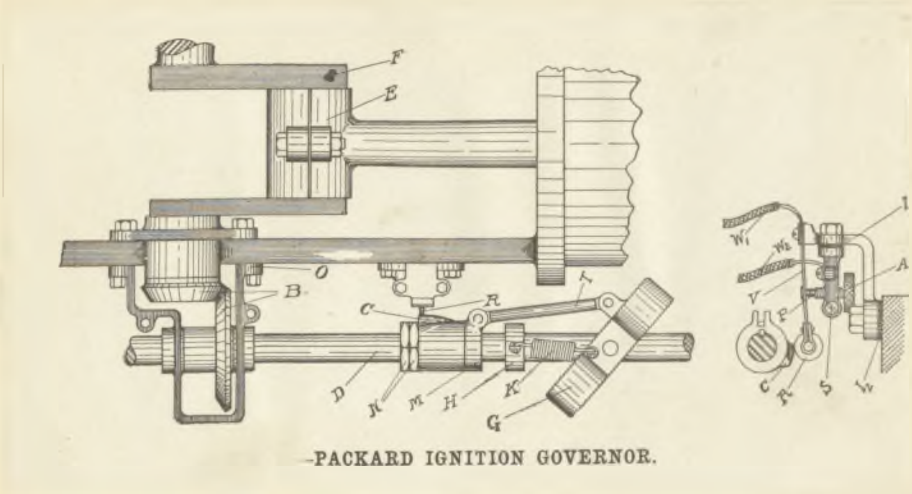


FIG. 5.

The speed of the engine is under control of a throttle worked by the driver's foot. When there is no pressure on the throttle, a spring holds it almost closed, and the engine can run slowly with no load. When pressure is applied to the throttle, the speed of the engine can be increased to any desired speed up to 850 revolutions per minute.

The cylinder is provided with a copper water jacket, and the water circulation is maintained by a positive rotary pump which keeps the water moving through the flanged copper cooling coils at the front of the car.

The transmission gear is carried in an aluminum case, to decrease weight, and permits of three speeds running forward and one speed running backward. These changes, in connection with the variable engine speed, provide a convenient range of speed and power. The following tests show what this range is. A locking device prevents the changing of gears while the friction clutch is thrown in, and thus avoids the stripping of gears which might otherwise result. From these gears the power is transmitted to the wheels by the usual chain and differential gear. (sketch of this transmission device is shown in Fig. 7). Two band brakes are provided - one on the transmission shaft and the other on the two rear wheels.

The flywheel is of a special design, which was resorted to in order to promote quietness of running and to reduce jar. This flywheel construction can be seen in the general view of the car, (Fig. 3). The flywheel consists essentially of two parts; 1st, an ordinary solid flywheel which may be considered to run loosely upon the shaft, and 2nd, a spider which is keyed to the engine shaft. Connection is made between the wheel and this spider by means of helical springs through which forces are transmitted from the engine to the gearing without shocks.

LOG RECORD AND DETERMINATION OF RESULTS.

The following is a list of the items given in the general table of results with the method of their determination.

1. Number of Reading, or test number.

2. Time Interval. Readings were taken every five minutes, and numbered consecutively under item (1).

3. Gear. -- Ratio of R.P.M. of motor to R.P.M. of drivers. This item is the number by which the revolutions of the engine can be multiplied to get the revolutions of the car wheel, and is obtained as follows:

Reverse Speed,	13/23 x 13/65 x 10/23 = .0492.	
Forward " #1,	13/65 x 10/23 = .087.	
" " #2,	27/51 x 10/23 = .230.	
" " #3,	33/45 x 10/23 = .319.	

In the above, the first ratio is that of the transmission gear teeth (see Fig. #7) and the second, 10/23 is that of the two sprocket wheels.

4. Mean R.P.M. of Motor. This item is the total number of revolutions as found from the recording machine record, divided by the number of minutes during which those revolutions were recorded. It was easy to ascertain this accurately, as the machine recorded both revolutions and time simultaneously.

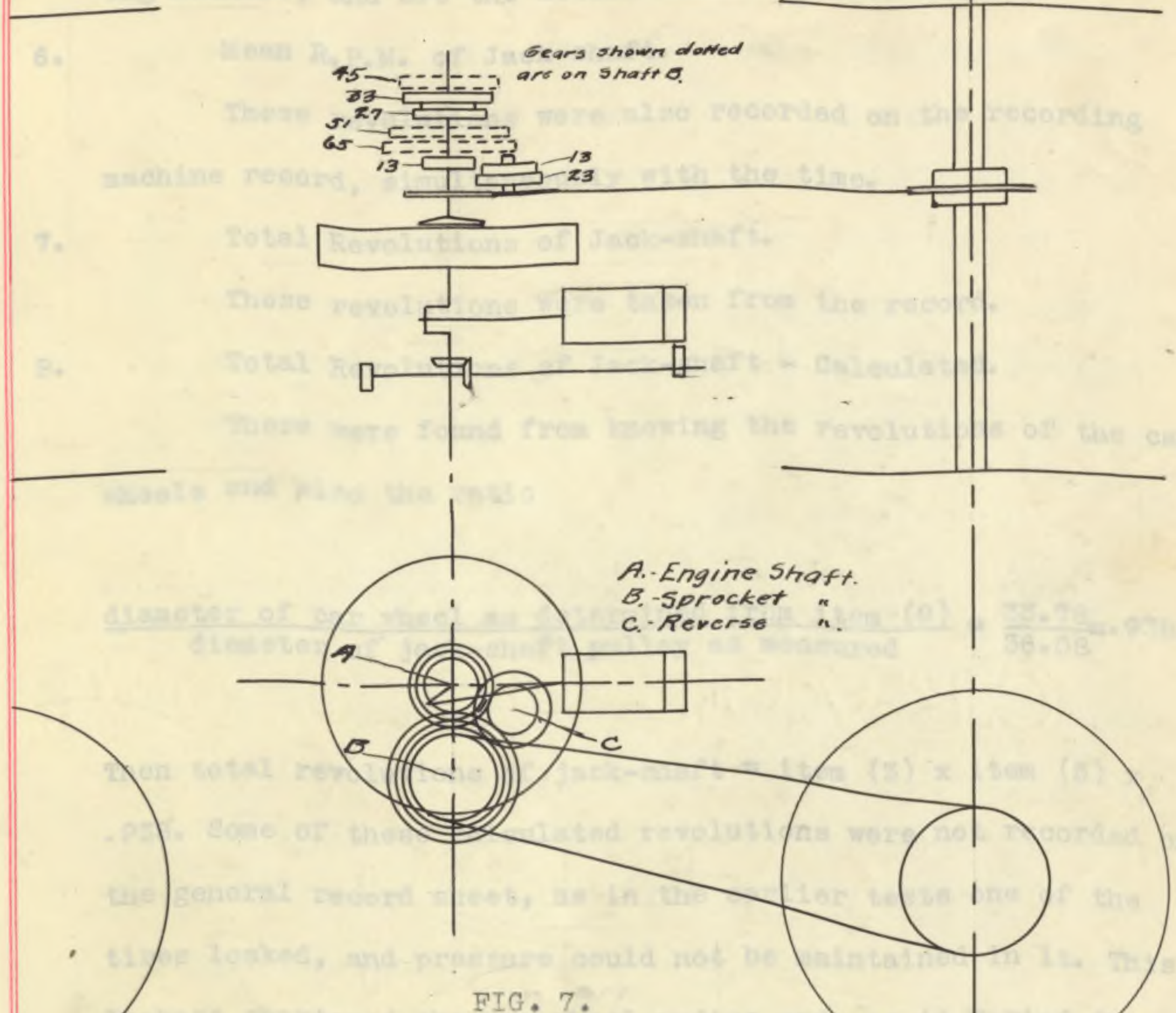


FIG. 7.

Test of Packard Motor Car. #292
Mech. Eng. Dept. University of Illinois.
Thesis Atwood & Beers.

Diagramatical Sketch of Engine and Transmission Gear.

The numbers shown on gears indicate no. of teeth on that gear.
The gear combinations for various speeds are as follows.

	A.	B.	C.	Chain Sprockets	Ratio of rev. of driver to rev. of motor.
Reverse	13	65	23-13	10 - 23	
1st. gear. Forward.	13	65		10 - 23	.0492
2nd. " "	27	51		10 - 23	.087
3rd. " "	33	45		10 - 23	.230
					.319

5. Total Revolutions of Motor.

These were taken directly from the record of the recording machine, and are the actual number of revolutions.

6. Mean R.P.M. of Jack-shaft.

These revolutions were also recorded on the recording machine record, simultaneously with the time.

7. Total Revolutions of Jack-shaft.

These revolutions were taken from the record.

8. Total Revolutions of Jack-shaft - Calculated.

These were found from knowing the revolutions of the car wheels and also the ratio

$$\frac{\text{diameter of car wheel as determined from item (9)}}{\text{diameter of jack-shaft pulley as measured}} = \frac{33.78}{36.08} = .938.$$

Then total revolutions of jack-shaft = item (3) x item (5) x .938. Some of these calculated revolutions were not recorded on the general record sheet, as in the earlier tests one of the tires leaked, and pressure could not be maintained in it. This leakage shortened the car wheel radius and, as it varied from day to day before the tire was changed, the above calculated results were omitted as being inaccurate.

9. Slip - Percent.

In the use of rubber tires it is impossible to prevent a certain amount of creep or slip due to the stretching of the rubber on the face of the tire.

In order to find the slip the actual diameter of the car wheels had to be determined, and this was done as follows. The motor was run on gear #1 at slow speed - about 200 R.P.M. - and no load. In this test it was assumed that under these conditions there would be no slip. A record was taken under these conditions and it showed 261 revolutions of the jack-shaft to 3200 revolutions of the motor, or a ratio of $\frac{261}{3200}$ = .0816. Now if this be divided by item (3) for gear #1, it gives .938 as a constant multiplier for any of the gears; or, this is the ratio

$$\frac{\text{carriage wheel diameter}}{\text{jack-shaft pulley diameter}}.$$

This is all that is necessary, to compute jack-shaft R.P.M., but to find the actual car wheel diameter we have $\frac{x}{36.08} = .938$. Where x equals diameter of car wheel, and 36.08 equals the measured diameter of pulley. x = 33.78. The decimal .938 is used to find item (8). The slip in percent can now be determined, and is equivalent to $\frac{\text{item (8)} - \text{item (7)}}{\text{item (8)}} \times 100$.

10. Miles Run.

This item is equal to the circumference of the jack-shaft pulley multiplied by the revolutions of the jack-shaft and divided by 5280 (feet per mile), = .00178 x item (7).

11. Miles per Hour of the Machine.

This item is obtained from items (2) and (10) as follows - $\frac{60}{\text{item (2)}}$ x item (10).

12. Weight in Pounds of Jacket Water.

This item is a record of the jacket water as weighed in the discharge tank.

13. Temperature Range.

This range is the average difference in temperature between that of the water entering the water jacket and that of the water leaving, as measured by thermometers in mercury wells.

14. Heat Absorbed in B.T.U. per Hour.

This item is the product of items (12) and (13).

15. Air Temperature.

This temperature was measured near the car.

16, 17, 18, and 20. These items were all taken directly from light or heavy spring cards. (see page 44).

19. Back Pressure during Exhaust - Mean.

This item was found by measuring, with a planimeter, the area under the back pressure line on the light spring cards and dividing by item (22).

21. Mean Effective Pressure.

This pressure was obtained in the usual way by dividing the average card area by the average card length, and then multiplying by the scale of the spring = $\frac{\text{item (23)}}{\text{item (22)}}$ x 160 x 2.

22. Card Length.

This item is the average of the lengths of all cards taken in each test.

23. Average Area of all Cards.

This item is self explanatory.

24. Indicated Horse-power,- I.H.P.

$$I.H.P. = \frac{P\ L\ A\ N}{33000}$$

P = Mean effective pressure - - item (21)

L = Length of stroke in feet - - - .542'

A = Piston area in sq. in. - - - - 28.25

N = Number of explosions - - - $\frac{\text{item (4)}}{2}$

I.H.P. = item (4) x item (21) x constant .00232.

25. Brake Horse-power,- B.H.P.

This item was the brake horse-power delivered at the circumference of the wheels, as determined from the speed of the jack-shaft and the pressure of the brake on the platform scales. No account is taken of the horse-power absorbed in friction by the jack-shaft bearings, but as these were roller bearings running in oil this loss would be very small. B.H.P. = R.P.M. of jack-shaft x the circumference at the brake arm radius in feet x the pressure on the scales ÷ 33000. The R.P.M. of the jack-shaft is given by item (6). The brake arm length = 62.5" = 5.21'. The pressure on the scales - as observed during the run.

$$\text{B.H.P.} = \frac{\text{item (6)} \times \frac{62.5 \times 2\pi}{12} \times \text{pressure}}{33000}$$

The oil system used to give a continuous record of the pressure on the scales was not sensitive or accurate enough to be relied upon for true results. Backlash and stretch of the rubber tubing connections were the chief causes of error and they, notably the latter, should be avoided in future where this method is used. The record of the brake pressure, obtained by means of the oil cylinder mentioned above was, on account of the inaccuracy previously noted, not used in making calculations of brake horse-power; but, giving as it did, a continuous record of pressure, it served to show variations and permitted conclusions to be drawn concerning the uniformity of the brake load.

26. I.H.P. - B.H.P.

Item (24) - item (25). This shows the horse-power absorbed by the engine and transmission gear in friction.

27. Tractive Effort - Observed.

This item was not included in the results, as the recording machine record did not show it accurately. This was due to the overlooking of the necessity of having the car axle directly above the jack-shaft, i.e. to have the wheel rest on the highest part of the pulley. This is necessary, for if the wheel were a little ahead or behind the center, it would give an effect of descending or climbing a grade, which would correspondingly give a greater or less tractive effort. This record too, however, serves as a comparative record, of the performance, but where sufficient care was taken an accurate reliable record was obtained. After each run the heavy spring, which took the tractive effort (see #8 in sketch of testing apparatus, page 30), was calibrated, and from this calibration a scale was made by which the tractive effort in pounds could be measured for any point on the record (see also sample record).

28. Tractive Effort - Calculated.

This was obtained by considering the moment of the couple acting about the point of contact of the pulley, and then measuring the force of this couple. In this sketch (Fig. 6) is shown the wheel, pulley, and the brake arm with the forces acting on them. The wheel tends to turn as shown by the arrow, and creates a tension or force E in the restraining wire, also an equal and opposite force E' acts at point A. Now if A be considered as a point of the pulley, the force E' can be measured by the pressure on the scales at D.

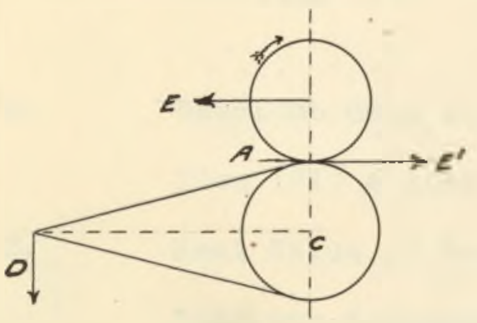


FIG. 6.

That is, $\frac{E'(force)}{D\ (force)} = \frac{DC\ (distance)}{CA\ (distance)} = \frac{62.5}{18.04} = \frac{62.5}{18.04} \times D =$

3.465 x pressure on the scales = the tractive effort.

29. Gasolene Used in Pounds.

This is the observed weight as recorded during the test.

30. Gasolene Weight per Gallon in Pounds.

By hydrometer test the specific weight of the gasolene used was .72 (Baume) at 21° C. (72° F.) or as reduced to the ordinary standard,.78 at 60° F. The weight of one gallon of water at 21° C. = 8.33 pounds. Then the weight per gallon of gasolene is 8.33 x .72 = 6.00 pounds.

31. Gasolene Used in Gallons per Hour.

This is found by dividing the total weight of gasolene used by the product of the time and the weight per pound -

$$\frac{\text{item (29)}}{6.00 \times \frac{\text{item (2)}}{60}}$$

32. Gasolene Used per Mile.

Item (31) ÷ item (10) gives the gasolene used per mile.

33. Heat Value of Gasolene Used.

This was determined by Prof. S.W. Parr and Mr. C.H. Bean at the Chemical Laboratory of the University and is found to be 19,120 B.T.U. per pound.

34. Gasolene Used per I.H.P. per Hour in Gallons.

This is item (31) ÷ item (24).

35. Gasolene Used per B.H.P. per Hour - Gallons.

Similar to the above item, this is item (31) divided by item (25).

36. Cost per Car Mile in Cents. (Gasolene at 15¢ per Gal.)

This item is simply the product of the cost per gallon of gasolene and the gasolene used per mile. - item (32) x item (15).

37. B.T.U. Equivalent to I.H.P.

The foot pounds of work per minute equivalent to one B.T.U. is $\frac{33000}{778} = 42.4$. Now multiplying this number by the number of minutes (item 2) and by the I.H.P. (item 24) we have this item. - 42.4 x item (2) x item (24).

38. B.T.U. Converted into Work in Cylinder (I.H.P.) - %.

This is item (37) divided by item (43).

39. B.T.U. Equivalent to B.H.P.

Similarly obtained as item (37), this item is equal to 42.4 x item (25) x item (2).

40. B.T.U. Converted into Useful Work. (B.H.P.) - %.

This is item (39) divided by item (43).

41. Heat Lost in Jacket Water. - %.

This item is the heat lost in the jacket water divided by the total heat in the gasolene used. - $\frac{\text{item (12) x item (13)}}{\text{item (43)}}$

42. Heat Lost in Exhaust and by Radiation. - %.

This item is the ratio of the heat lost in the exhaust and by radiation to the total heat in the gasolene used, and is represented thus; $\frac{\text{item (43) - item (38) item (41)}}{\text{item (43)}}$

43. Heat Available in Gasolene Used in B.T.U. - 100%.

This is simply the gasolene used in pounds multiplied by the constant 19120. (see item (33).

44. Mechanical Efficiency.

This is the efficiency of the total machinery from the piston to the tires and not of the engine alone, which would ofcourse be much higher. - $\frac{\text{item (25)}}{\text{item (24)}}$.

45. Thermal Efficiency for I.H.P.

This gives a basis for comparison with the thermal efficiency of other motive powers. - $\frac{\text{item (37)}}{\text{item (43)}}$.

46. Thermal Efficiency for B.H.P.

This item gives a basis for comparison of the thermal efficiency of this machine with that of other machines for power delivered at the wheels. - $\frac{\text{item (39)}}{\text{item (43)}}$.

GAS ANALYSIS.

By Prof. Parr and C. H. Bean.

Analysis of samples of gas taken at full load is given below.

Carbon dioxide - - - -	3.%
Oxygen - - - - - - - - -	6.%
Nitrogen - - - - - - - -	91.%
	100.%

EXPLANATION REGARDING CONDUCT AND PURPOSE OF TESTS.

All tests up to and including #25 except #5, #6, #17 and #18 were run for maximum horse-power with the throttle wide open, and the speed was regulated by means of the Prony brake. However, the brake pressure on the platform scales was kept as nearly uniform as possible, and in general it remained remarkably constant. During the above named tests the throttle was partly closed so as to give the correct speed for comparison with other tests on other gears, and the brake load was kept constant as before.

Besides the above mentioned tests others were run as follows;

1. A test to determine effect of muffler.

2. A test to determine the point of ignition for various speeds.

3. A test to determine effect of spring construction of flywheel.

Indicator cards taken from the engine at the first of the series of tests seemed to indicate a tardy opening of the exhaust valve and this was remedied by advancing the exhaust cam. The distances from the end of the stroke at which the exhaust began to open are as follows:

Tests #1, #2, #3 - - - - 5/16".

Test #4, - - - - - - - 7/16".

All other tests - - - - 1 5/16".

Before running test #7 a liner 3/16" in thickness was placed behind the crank pin brasses to increase the compression by decreasing the clearance. The effect of this is not very apparent see item (16) until the speeds of the motor are taken into consideration.

The clearance volume was determined by water displacement, all air being removed from the chamber. The clearance volume of all tests up to #7 was 59.88 cubic inches. (24.6%). After the 3/16" liner was placed at the end of the connecting rod, the volume was decreased by 5.28 cubic inched, leaving a clearance of 54.6 cubic inches (22.9%) for all tests from #7 to #28 inclusive.

DESCRIPTION AND EXPLANATION OF METHODS OF OPERATION OF TESTING APPARATUS.

The testing apparatus consisted in general of the following parts.

1. A platform and a pair of flat faced wood pulleys on which ran the driving wheels.

2. A device for putting resistance upon the driving wheels, and for measuring this resistance.

3. A device for holding the machine in place, and for measuring the tractive force.

4. The apparatus for supplying and weighing the gasolene used.

5. The apparatus for supplying the jacket cooling water, and for determining the heat removed in the jacket water.

6. The indicator and reducing rig.

7. The Oliver recording machine, with its cord, oil and electrical connections.

As a matter of convenience and to promote clearness, the description and explanation of methods of operation of apparatus will be taken up under these heads. In the following discussion, reference is made to the two photographs (Figs. 8 and 9), and the diagrammatical sketch (Fig. 10) showing the arrangement, found on pages 30, 31 and 32.

1. It was found desirable to place the car upon a platform of ample size and high enough to allow the pulleys upon which the car

ran to clear the floor. The rear wheels of the car rested upon the upper part of the rims of the pulleys, and were kept in this position by the apparatus described under (3). These pulleys, 36" in diameter with a 10" face, were mounted upon a 2" jack shaft which turned in roller bearings, the friction of which was negligible.

2. Upon this jack shaft midway between the two pulleys was mounted a Prony brake, which in operation gave any desired resistance to the jack shaft's turning, resulting in giving resistance to the drivers of the car. The arm of the Prony brake was 62.5" long, and the groove in its end rested upon the edged end of a plunger, the cylinder for which rested directly upon a platform scales. The operation of this cylinder when filled with oil will be described under (7).

3. Attached to the rear end of the frame of the car, and running backward, was a horizontal wire fastened to the upper end of the vertical arm of a right angled bell-crank. The right angled vertex of this triangle was securely fixed to the wall so as to turn easily, and the end of the horizontal arm rested, through a spring, upon a platform scales. The two arms of this bell-crank were made equal in length. By means of a turnbuckle in the horizontal wire, its length was easily adjusted so as to bring the axle of the car directly over the jack shaft. The spring above mentioned was used in connection with the recording machine to give a continuous record of the tractive force, and will be

taken up under(7). As a guard against danger in case of accident to this apparatus, a heavy chain was attached to both ends of the rear axle and, with necessary slack to prevent its taking any of the forward pull of the car, was securely fastened to the floor. Likewise, the front end of the car was secured by means of ropes, which hung loosely while the tests were being run.

In order to facilitate the weighing of the gasolene used, the connection to the gasolene tank on the machine was removed and the carburetor connected, through iron pipe and flexible rubber tubing, to a tank resting upon a platform scales. These scales read to hundredths of pounds, and were placed upon a small platform entirely free from the main platform, to avoid all jar and vibration. In order that the float valve in the carburetor might act practically the same as in practice, the level of the gasolene was kept at the same level as is usual in the operation of the car.

5. The jacket water system of the car was disconnected, and the jacket supplied directly from the mains. The water leaving the jacket emptied into a tank having a capacity of 400 pounds, and resting upon a platform scales. In the pipes, just before entering and leaving the jacket were placed mercury wells, fitted with slotted iron pipe guards for two thermometers. The range of temperature between the water entering and leaving the cooling jacket was so regulated as to be the same as in the usual operation of the car. Consequently, the change made in the cooling

system in no way affected the operation of the motor.

6. The indicator used was a Crosby gas engine indicator, having a piston area of 1/4 square inch and a reinforced pencil motion. This pencil motion gave no trouble as to bending or breaking, and was adjusted but once for wear at the joints. The 1/2" gas pipe leading to the indicator from the combustion space in the cylinder was 9" long including one 90° elbow, and allowed room for a 5" tin water jacket placed around this pipe below the indicator. Ordinarily a very small amount of water flowed through this jacket, but even when water was allowed simply to evaporate from it, all the troubles from a heated indicator were entirely done away with. At no time in the tests did the indicator become too hot to be comfortably handled with the hands. This feature was found very convenient when changing the heavy spring for a light one, for taking the light spring cards at the end of a run.

The question of a reducing rig for speeds as high as 800 and 900 revolutions per minute, presented itself at first as a rather difficult one. After using a Crosby geared reducing wheel, which worked satisfactorily for speeds up to 300 revolutions per minute, a simple reducing arm was tried and found to work satisfactorily for all speeds. This rig consisted of the following parts as shown in sketch. (Fig. 11). A short pin (a) screwed into the wrist pin boss of the piston, and connected with the link (b). Link (c) turned about the point (c_1), tak-

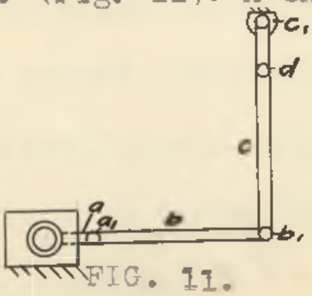


FIG. 11.

ing practically the motion of the piston at the point (b_1), and giving this motion reduced at (d). From (d) a cord passed horizontally over a pulley and off to the indicator drum. Point (b_1) was placed a little below the line of piston motion passing through (a), in order to make the error from rotation about (c_1) as small as possible. The point (d) was adjustable to three positions, for low, medium and high speeds; it being necessary to have a very short drum travel for high speeds. The three card lengths obtained were approximately, 2.4", 1.8" and 1.3". Links (b) and (c) were made as light as consistent with strength, and pins at points (a), (b) and (c) were made extra large to avoid excessive wear.

7. A description of the Oliver recording machine may be found in the American Machinist for Feb. 27, 1903. See accompanying cuts from that article. (Figs. 12, 13 and 14). This machine, as it was used, consisted of two essential parts.

A. A set of rolls, driven by the secondary shaft of the motor, and giving to a roll of paper a positive travel proportional to the speed of the motor.

B. A set of marking pens connected to record data as follows. See Fig. 15 and sample record.

a. Single and 100 jack shaft revolutions.

b. 280 revolutions of the motor. - A constant.

c. 5 second intervals.

d. Miscellaneous data, such as readings, cards, etc.

e. Tractive force. Measured from base line (e_1).

f. Pressure of Prony brake upon scales. Measured from base line (f_1).

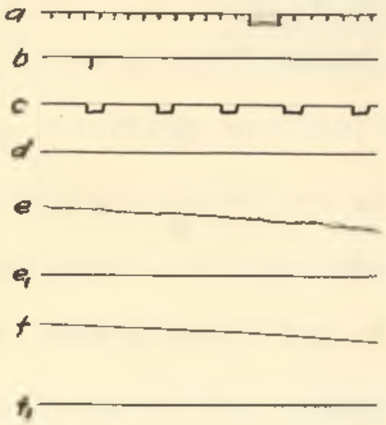


FIG. 15.

On the recording machine were four magnets which operated pens (a), (b), (c) and (d), electrically.

Circuit (a) was closed by a contact device on the jack shaft every revolution, and again every 100 revolutions. This latter was accomplished by a small worm and worm-wheel working in the ratio of 1 to 100.

Circuit (b) was closed and the corresponding record made every 200 revolutions of the motor by a contact on the paper drum of the machine, and in this way there was made a record at equal intervals of paper travel.

Circuit (c) was closed and the corresponding record made every 5 seconds by a Newman clock.

Circuit (d) was closed by a push button for general data, such as starts, readings, etc., and also by a switch on the indicator, which operated when taking a card. Base lines (e) and (f) were made by pens which were movable on a rod and adjustable in a line perpendicular to the line of paper travel.

Line (e) gave a continuous record of the tractive force by means of a cord connection to the bell-crank referred to in (3).

The end of the horizontal arm of this bell-crank was attached to the lower end of a long helical spring, which was supported from a stand placed upon a platform scales. From the end of this horizontal arm a cord passed directly downward, over a pulley, and off to the recording machine and was held taut by a light spring. Now when resistance was placed upon the drivers and the car tended to move ahead, the arm pressed downward, extended the helical spring, and allowed the cord to be drawn in toward the machine. A light cord of the recording machine, which was a continuation of this heavy cord, held taut by another spring, gave to the pen which it operated, the corresponding motion. By mounting this heavy spring upon a platform scales, the actual pull could be read directly.

Line (f) was obtained by the use of an oil cylinder, mentioned in (2). A flexible pipe line ran from this cylinder to a large especially made indicator cylinder on the recording machine. This system was filled with oil, care being taken to displace all the air. By this system any pressure of the brake arm upon the plunger, gave to the piston in the indicator a corresponding pressure, and a movement of the pencil motion. From the end of the pencil arm, the pen was operated by a cord in the same manner as the pen giving line (e).

For all except the muffler test, the muffler was removed and the exhaust was carried out of the building through 10' of 1 1/2" pipe, including no extra bends except two 45° elbows. The air was drawn through a 2" pipe from beneath the platform and thus insuring a pure supply. Some trouble was experienced from the heating and wearing of the tires. An air blast was tried and found to have some effect toward keeping them cool, but later, upon using powdered soap stone, it alone kept the tires from heating to an objectionable degree, and also stopped practically all the wearing. The tires in this condition, however, were found to slip seriously before stalling the motor upon the first gear.

Top View.

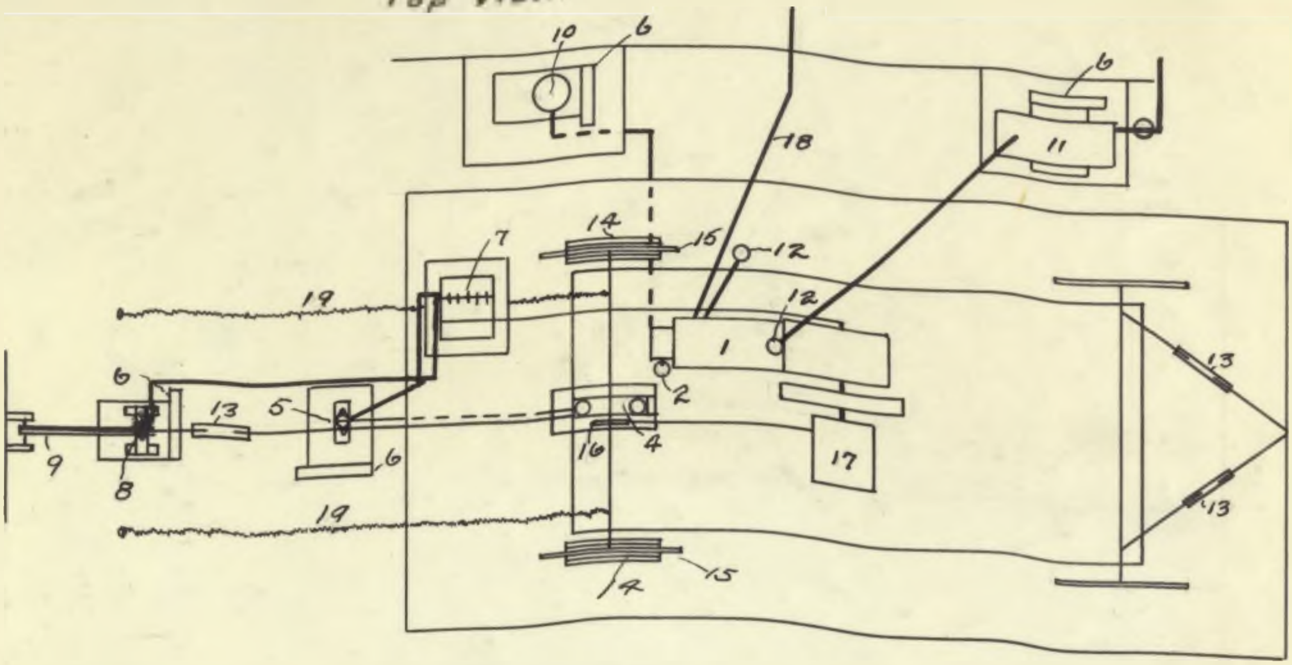
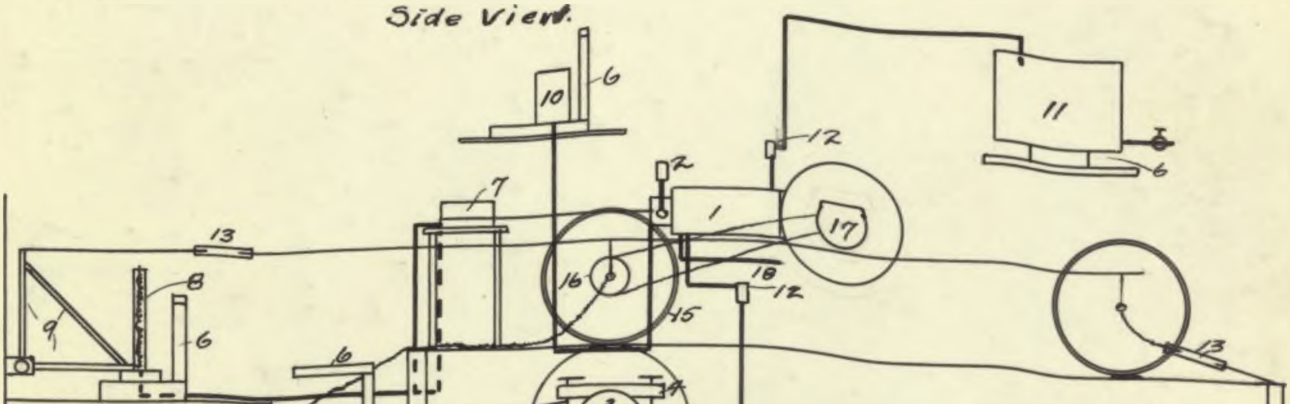


FIG. 10.

Side View.



Test of Packard Motor Car #242.

Mech. Eng. Dept. University of Illinois.

Thesis Atwood & Beers.

Diagrammatical Sketch Showing Arrangement of Apparatus.

1-Cylinder.	6-Scale	11.-Jacket Water Tank.	16.-Chain Sprocket.
2-Indicator.	7-Recorder.	12-Mercury Well.	17.-Transmission Gears
3-Roller Bearing	8-Spring	13-Turn buckle.	18-Exhaust Pipe.
4-Prony Brake.	9-Bellcrank.	14-J.S. Pulley	19-Heavy Chain.
5-Oil Cylinder.	10-Gasolene Tank.	15-Driver.	20.

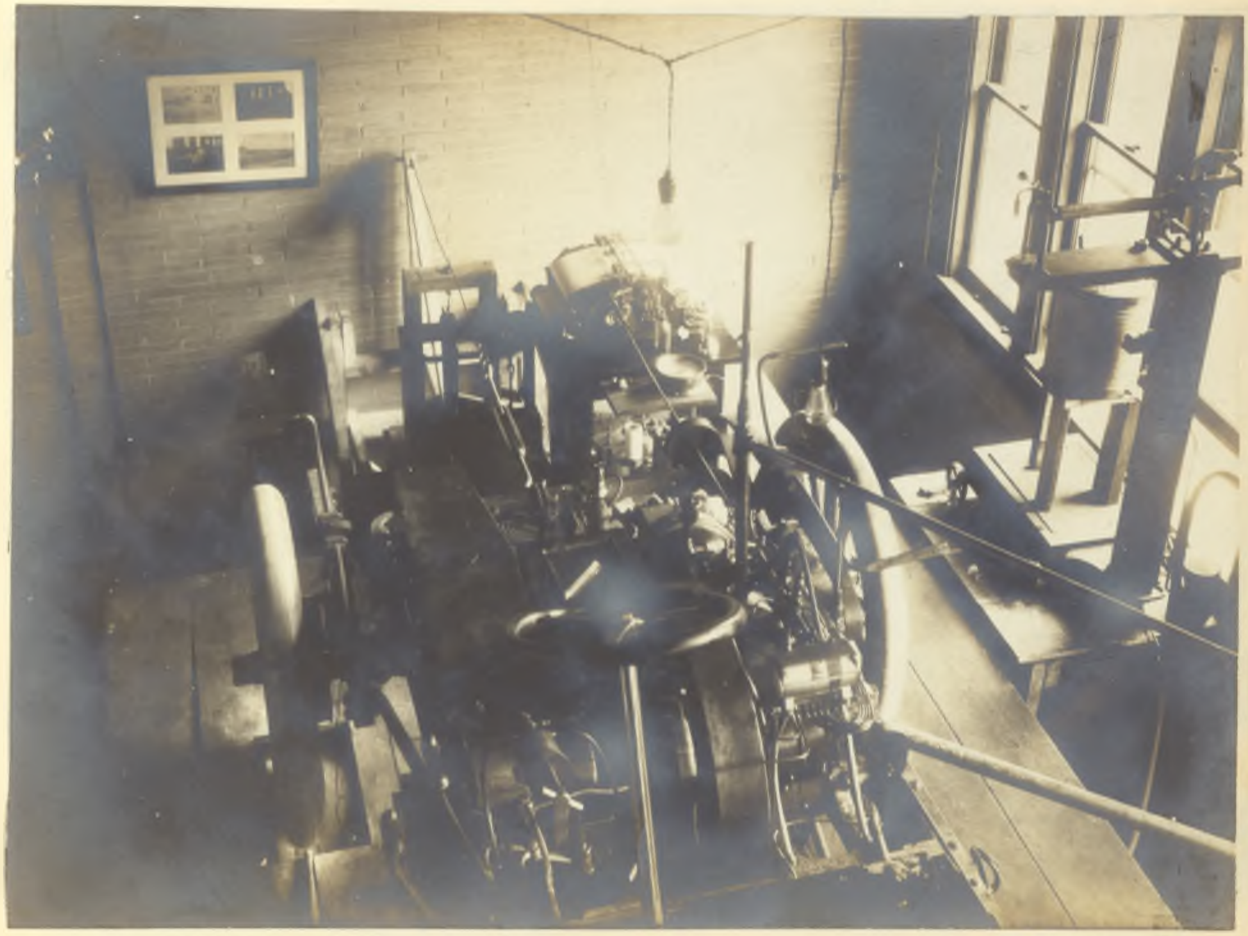


Fig. 8.

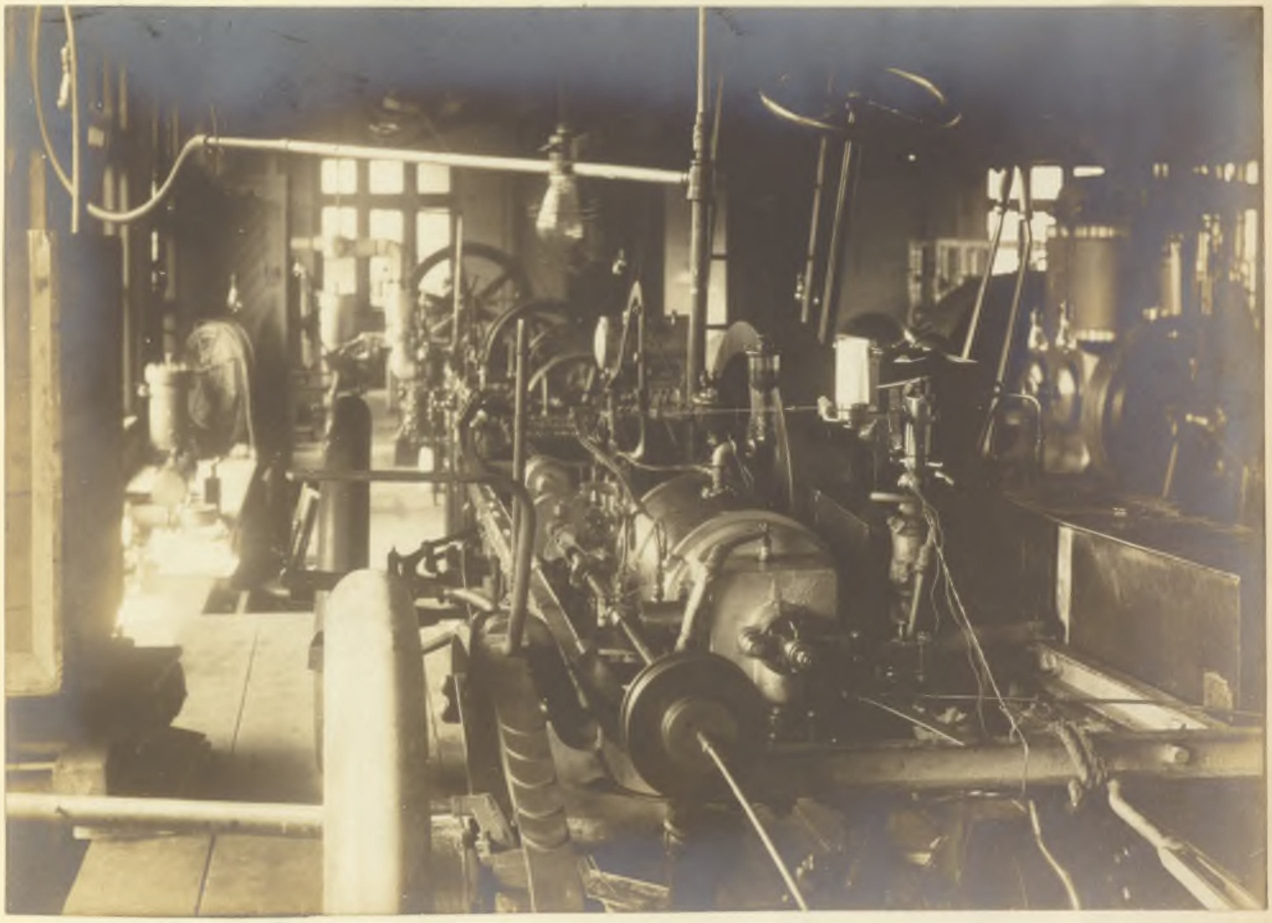


Fig. 9.

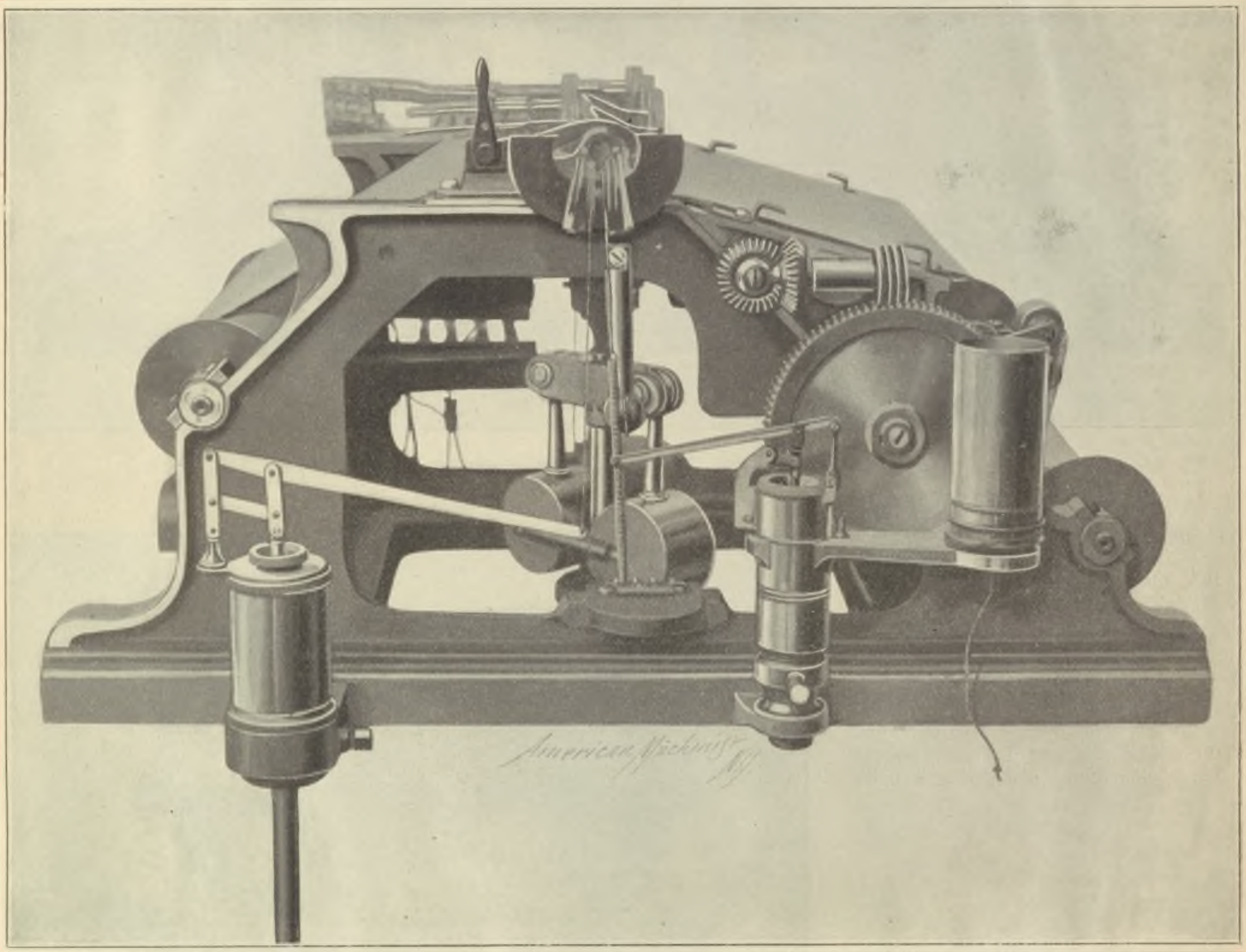


Fig. 12.

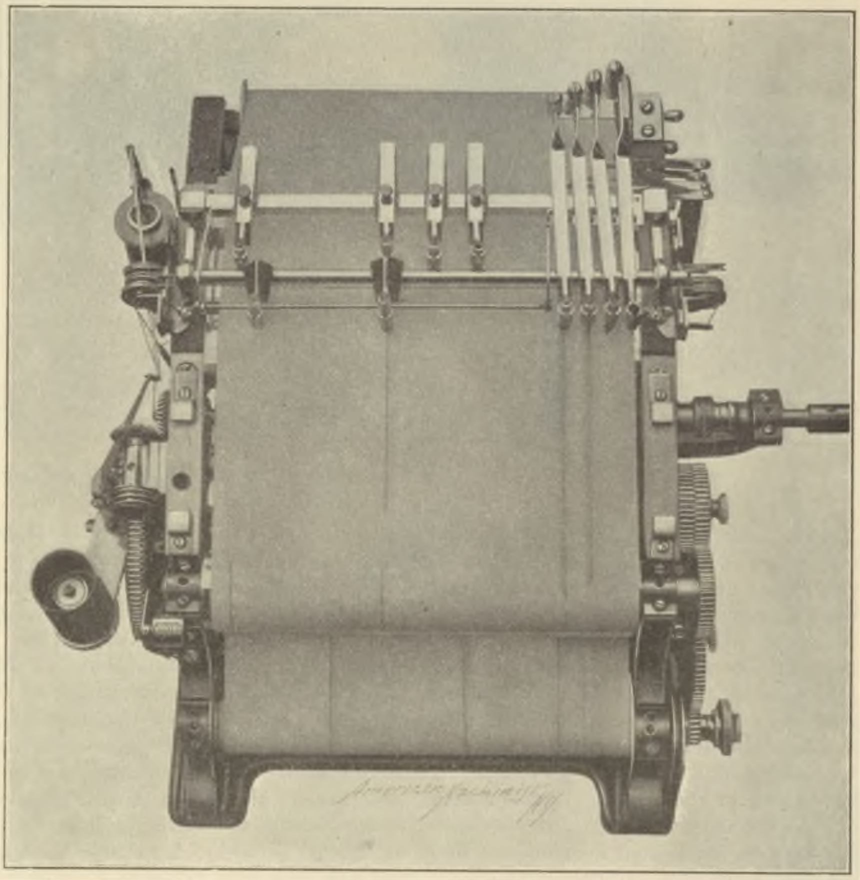
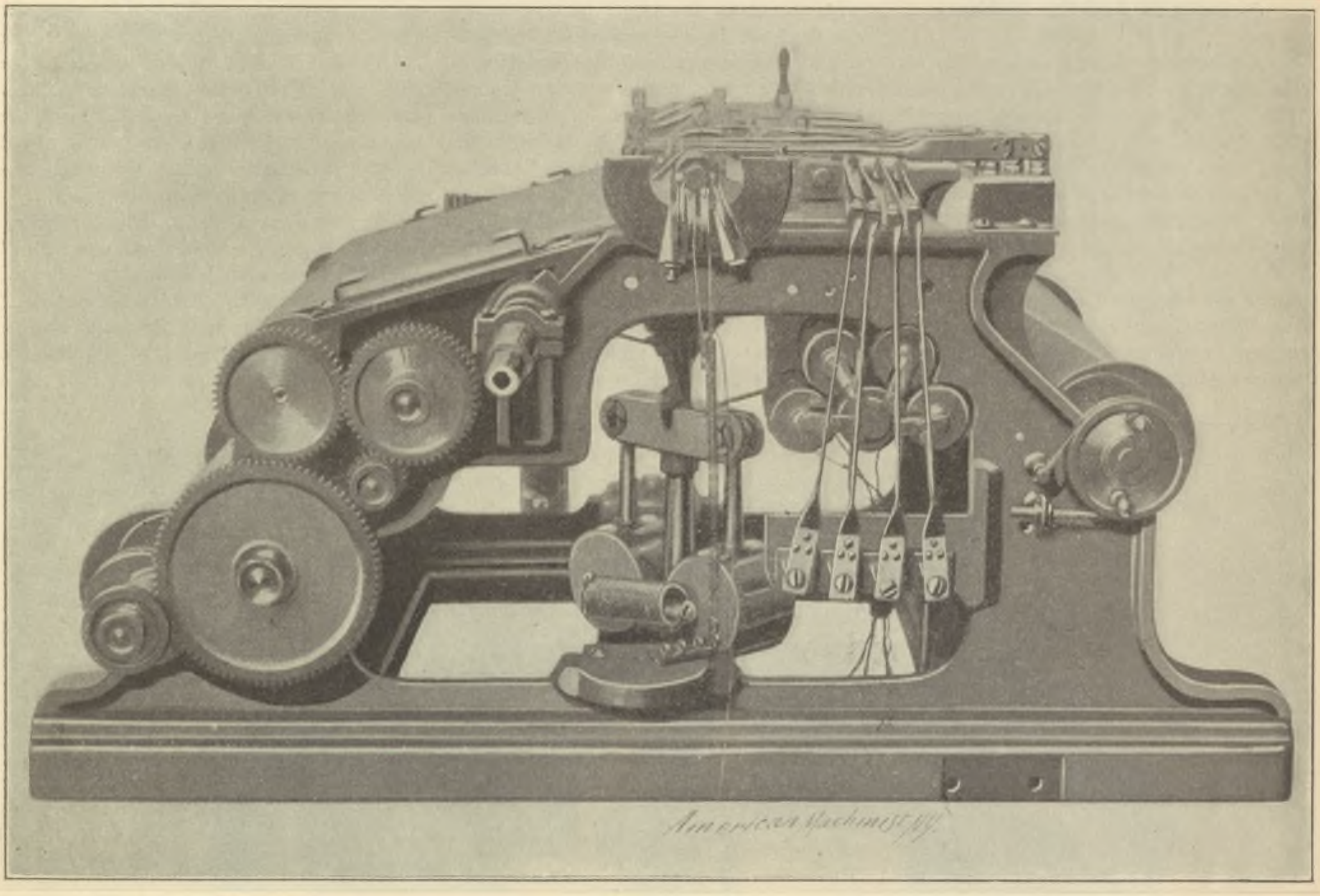


Fig. 13.

Fig. 14.



SUMMARY OF RESULTS.

Some of the interesting results of the work should be noted, and are as follows.

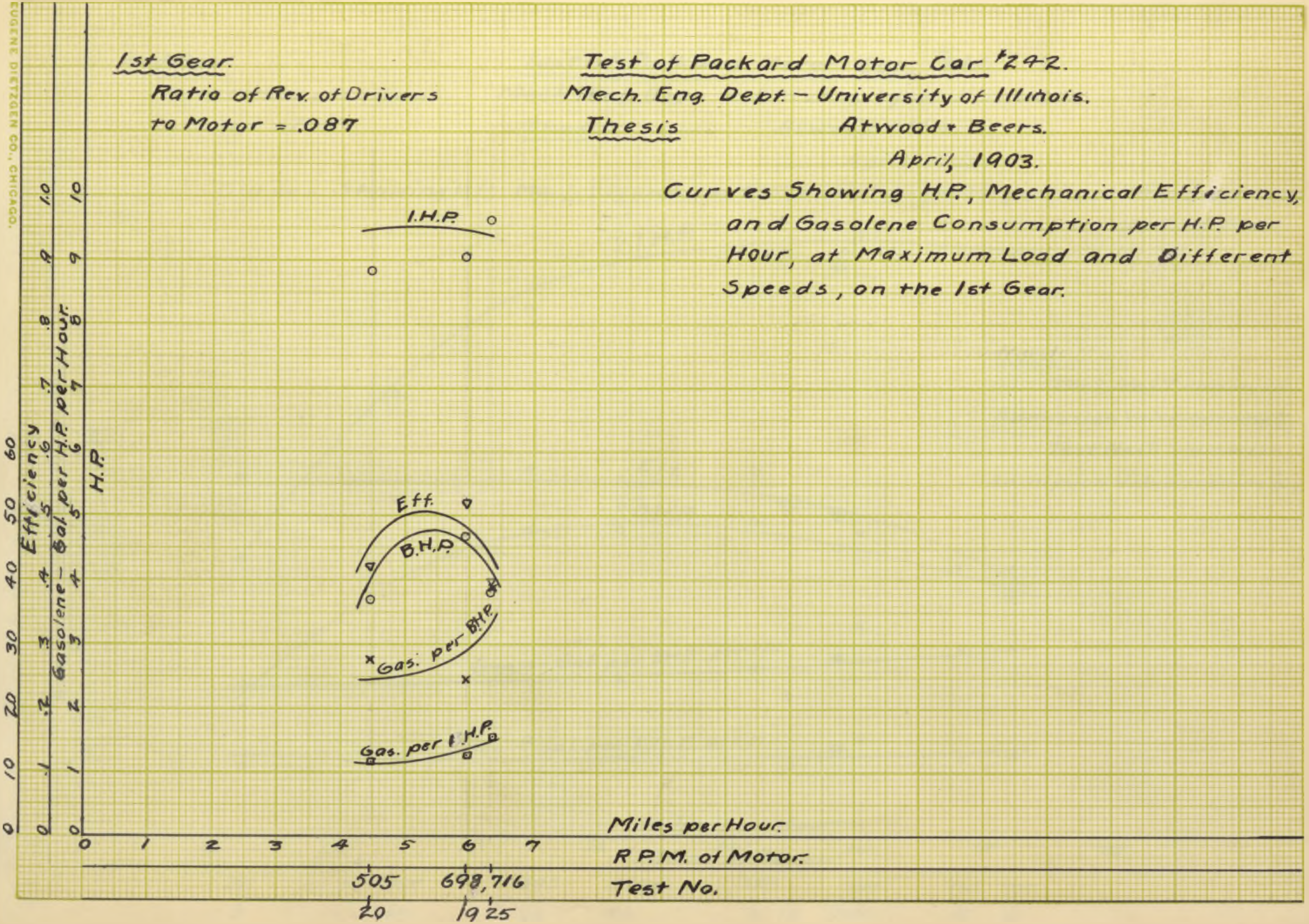
1. The curves show that the maximum horse-power developed at different speeds, varies with reference to the speed, with remarkable uniformity. These curves show also that practically the same amount of horse-power - a little over 4 3/4 - was delivered on the three gears. They show also, that there is a great decrease in the power delivered between the maximum speed on the first gear and a low speed on the second gear; while the second and third gears give much the same performance over a range in speed of from ten to eighteen miles per hour. During this range, except for a small difference in power delivered, there is, however, an advantage gained with the third gear, both in efficiency and mechanical running.

2. The effect of partial throttling seemed to show an ample inlet valve opening. As will be noticed on curves for second gear, the restriction of the opening to 1/8" and 1/16" had little effect in lowering the power developed below the maximum.

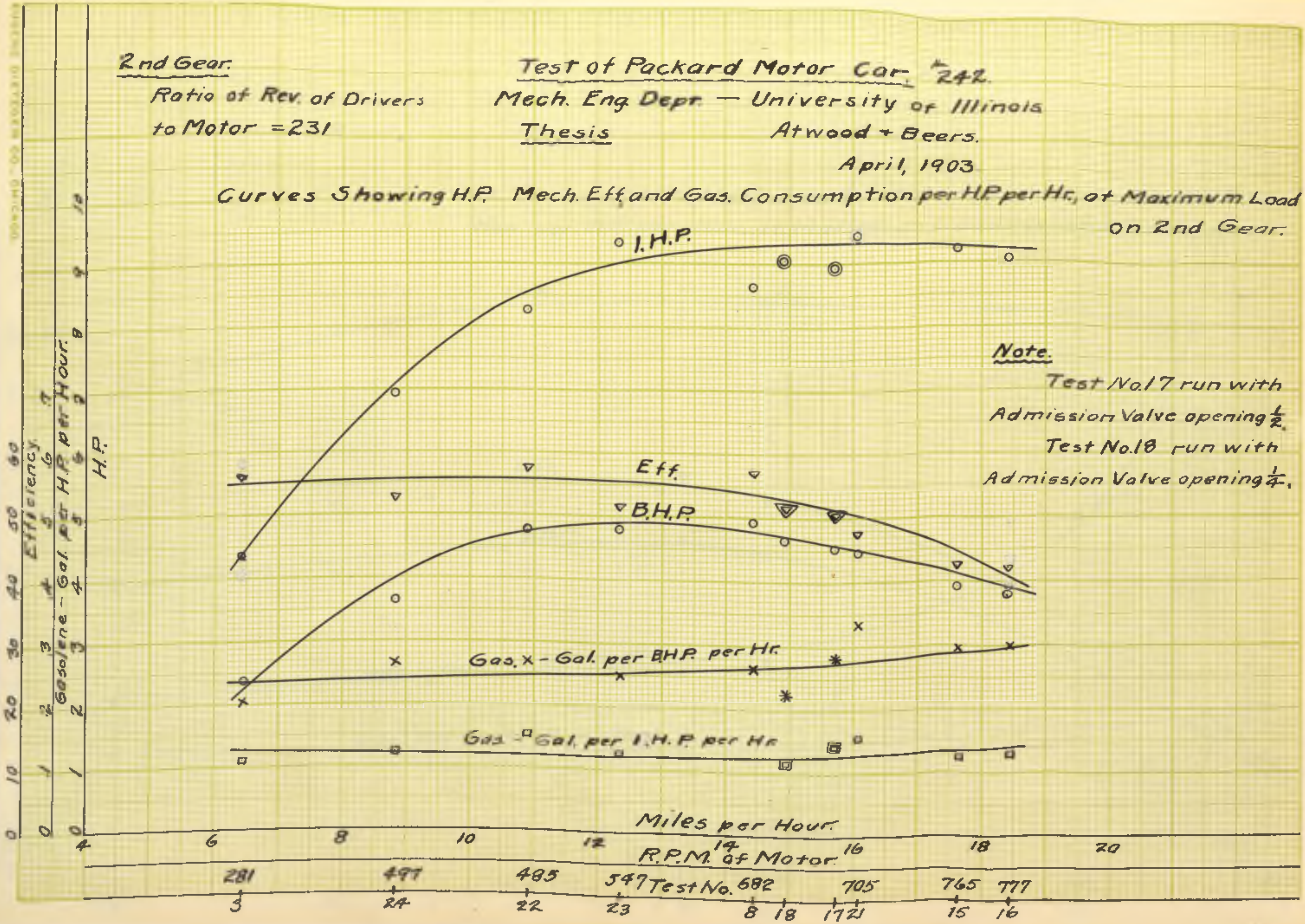
3. In regard to the spring construction in the flywheel, the record obtained with the wheel blocked to the spider, did not show any appreciable difference in the uniformity of tractive force, over that shown with the flywheel in its usual condition, this, however, would not disprove what is claimed for the construction in regard to steadiness of running and freedom of the car from vibration.

Attention should be called to the good performance of the muffler. The noise from explosions was practically done away with at the expense of a very slight back pressure.

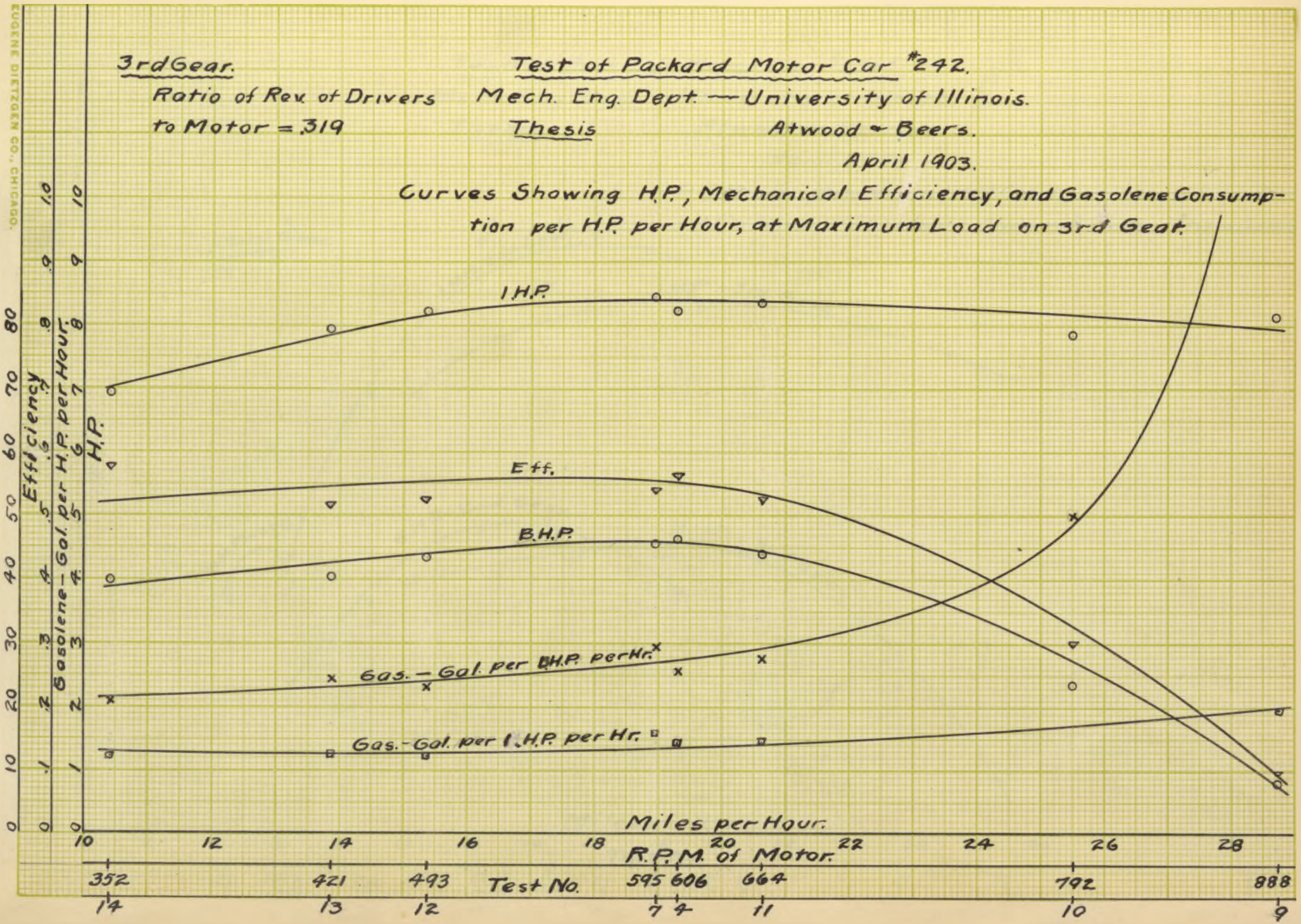
Many other interesting and instructive facts, such as, the cost of operation on different gears giving the same performance, the speed giving maximum efficiency and horse-power, etc., can be learned by a study of the accompanying curves and tables.

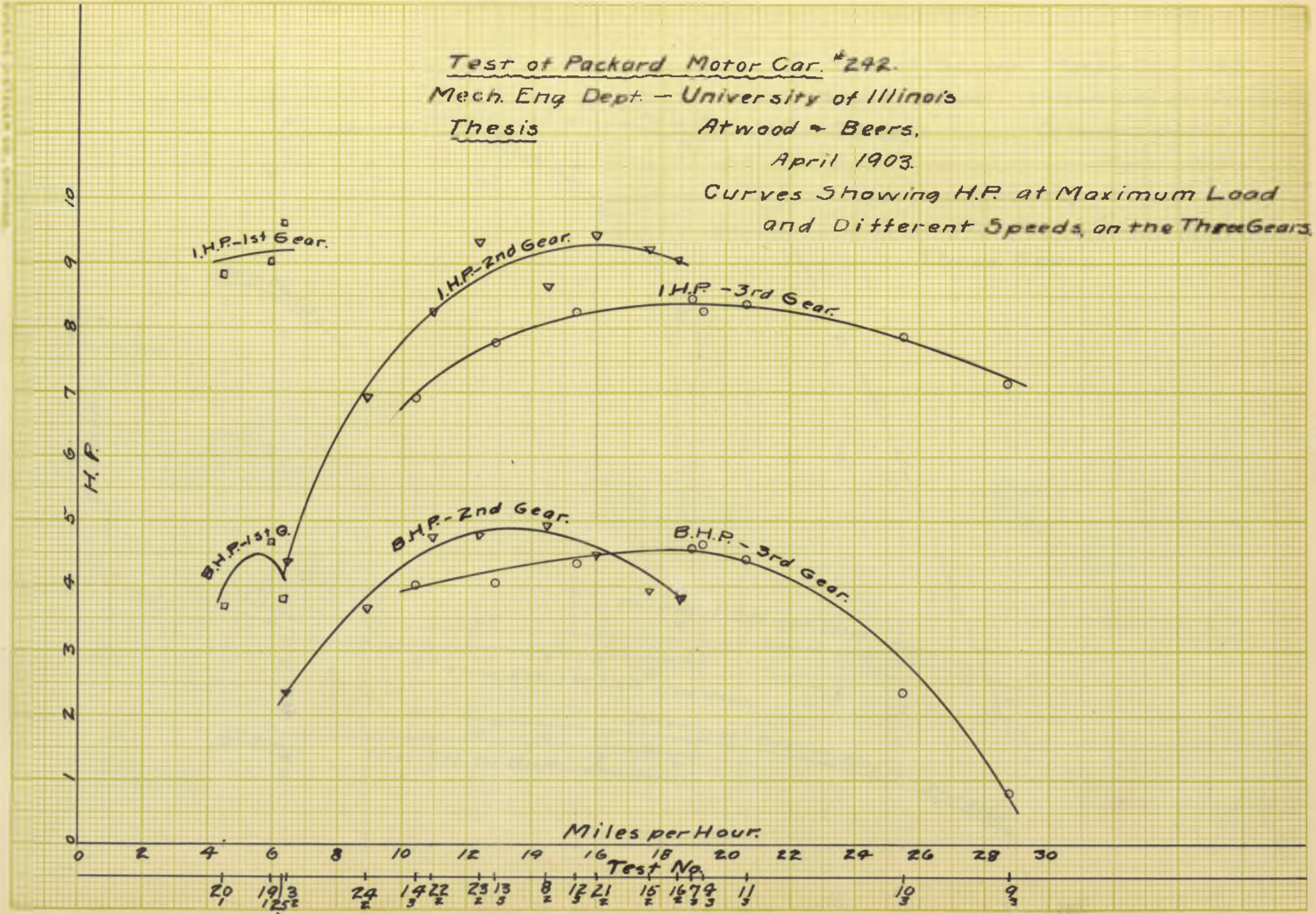


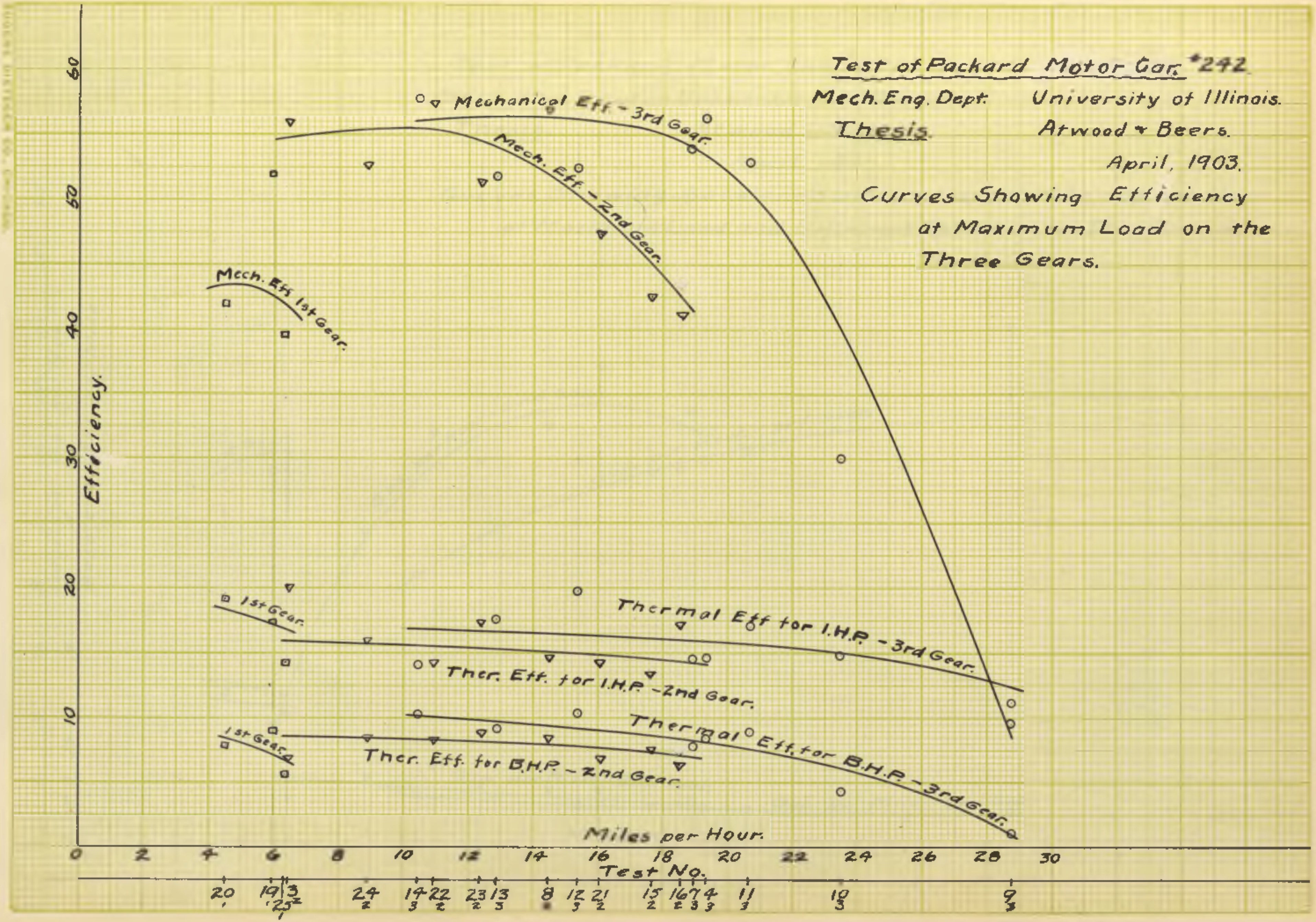
EUGENE DIETZGEN CO., CHICAGO.
1st Gear.
Ratio of Rev. of Drivers to Motor = .087
Test of Packard Motor Car #242.
Mech. Eng. Dept. - University of Illinois.
Thesis
Atwood & Beers.
April, 1903.
Curves Showing H.P., Mechanical Efficiency, and Gasolene Consumption per H.P. per Hour, at Maximum Load and Different Speeds, on the 1st Gear.
I.H.P.
Eff.
B.H.P.
Gas. per B.H.P.
Gas. per I.H.P.
Efficiency
Gasolene - Gal. per H.P. per Hour.
H.P.
Miles per Hour.
R.P.M. of Motor.
Test No.
505
698, 716
20
19 25

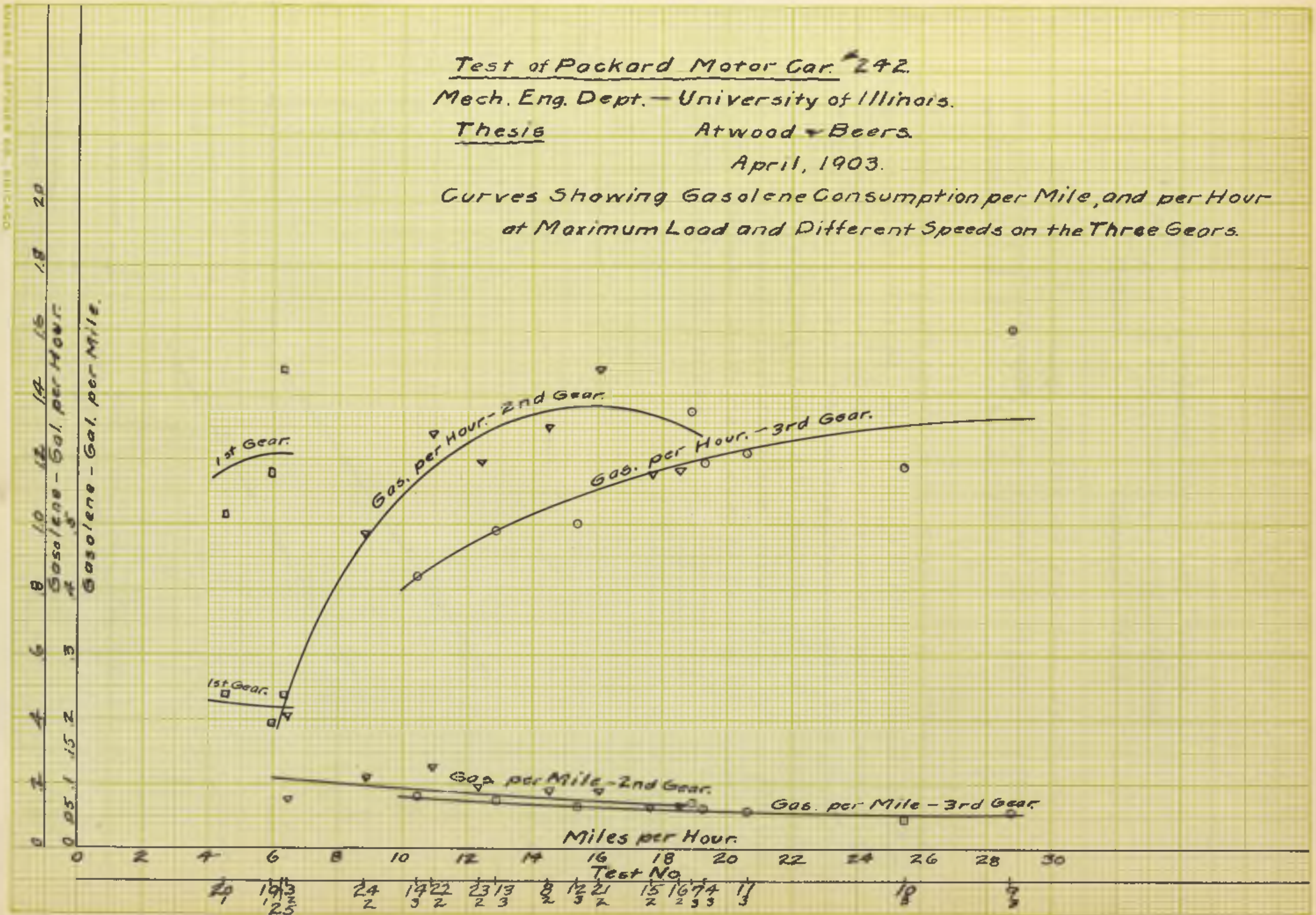


2nd Gear.
Ratio of Rev. of Drivers to Motor = 231
Test of Packard Motor Car #242.
Mech. Eng. Dept. — University of Illinois
Thesis
Atwood + Beers.
April, 1903
Curves Showing H.P. Mech. Eff. and Gas. Consumption per H.P. per Hr., at Maximum Load on 2nd Gear.
I.H.P.
Eff.
B.H.P.
Gas. x - Gal. per B.H.P. per Hr.
Gas. - Gal. per I.H.P. per Hr.
Note.
Test No.17 run with Admission Valve opening 1/2.
Test No.18 run with Admission Valve opening 1/4.
Efficiency
Gasolene - Gal. per H.P. per Hour.
H.P.
Miles per Hour.
R.P.M. of Motor
Test No.
281 497 485 547 682 705 765 777
3 24 22 23 8 18 17 21 15 16
4 6 8 10 12 14 16 18 20


3rd Gear.
Ratio of Rev. of Drivers to Motor = .319
Test of Packard Motor Car #242.
Mech. Eng. Dept. — University of Illinois.
Thesis
Atwood & Beers.
April 1903.
Curves Showing H.P., Mechanical Efficiency, and Gasolene Consumption per H.P. per Hour, at Maximum Load on 3rd Gear.
I.H.P.
Eff.
B.H.P.
Gas. — Gal. per B.H.P. per Hr.
Gas. - Gal. per I.H.P. per Hr.
Efficiency
Gasolene - Gal. per H.P. per Hour
H.P.
0 10 20 30 40 50 60 70 80
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
0 1 2 3 4 5 6 7 8 9 10
Miles per Hour.
10 12 14 16 18 20 22 24 26 28
R.P.M. of Motor.
352 421 493 595 606 664 792 888
Test No.
14 13 12 7 4 11 10 9
EUGENE DIETZGEN CO., CHICAGO.


Test of Packard Motor Car. #242.
Mech. Eng. Dept. – University of Illinois
Thesis
Atwood & Beers,
April 1903.
Curves Showing H.P. at Maximum Load and Different Speeds, on the Three Gears.
I.H.P.–1st Gear.
I.H.P.–2nd Gear.
I.H.P. –3rd Gear.
B.H.P.–1st G.
B.H.P.–2nd Gear.
B.H.P. – 3rd Gear.
H.P.
Miles per Hour.
Test No.

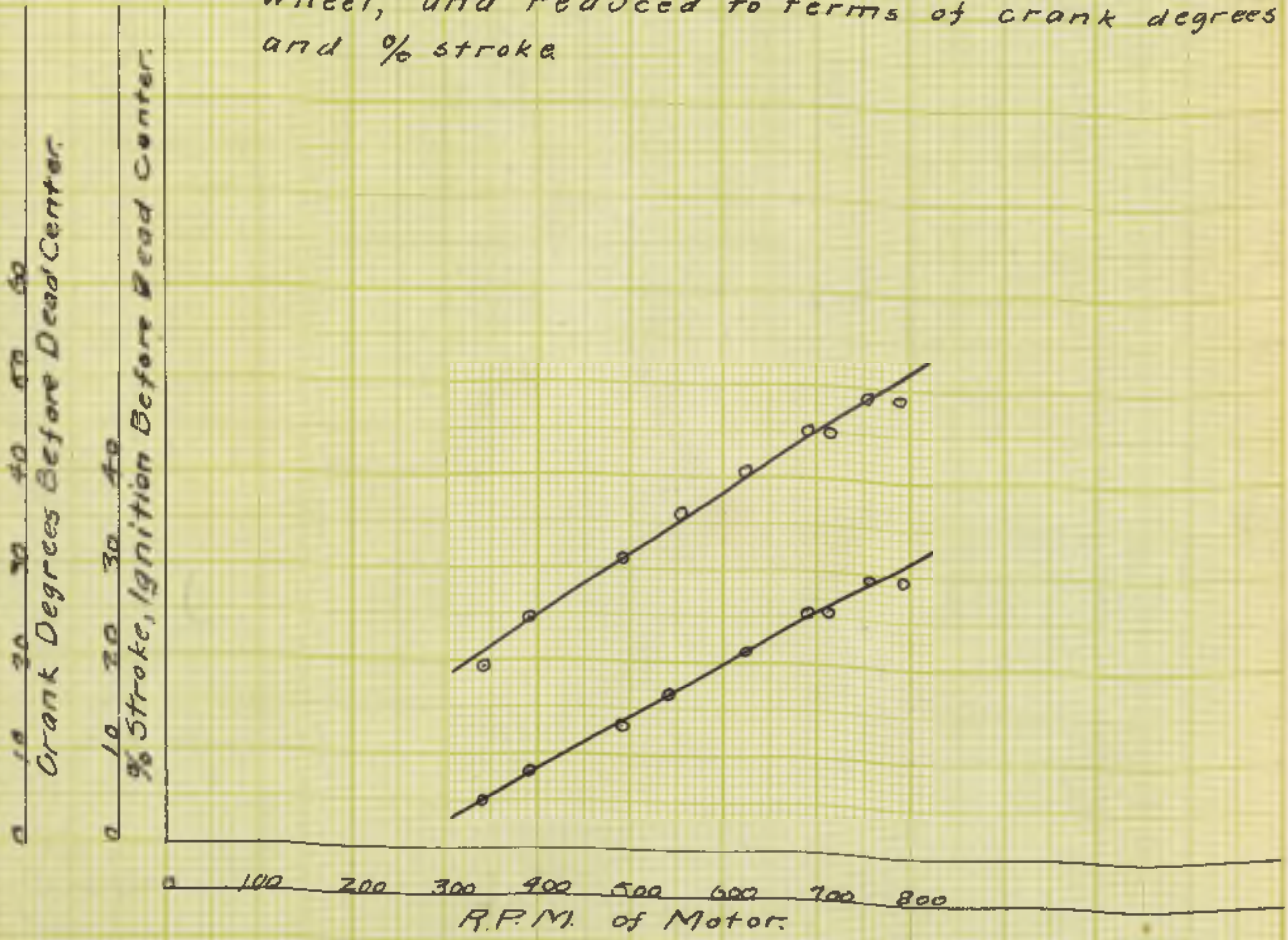

Test of Packard Motor Car. #242
Mech. Eng. Dept.
University of Illinois.
Thesis.
Atwood + Beers.
April, 1903.
Curves Showing Efficiency at Maximum Load on the Three Gears.
Mechanical Eff. - 3rd Gear.
Mech. Eff. - 2nd Gear.
Mech. Eff. 1st Gear.
1st Gear.
Thermal Eff for I.H.P. - 3rd Gear.
Ther. Eff. for I.H.P. - 2nd Gear.
Thermal Eff. for B.H.P. - 3rd Gear.
Ther. Eff. for B.H.P. - 2nd Gear.
1st Gear.
Efficiency.
Miles per Hour.
Test No.
10
20
30
40
50
60
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30


Test of Packard Motor Car #242.
Mech. Eng. Dept. — University of Illinois.
Thesis
Atwood & Beers.
April, 1903.
Curves Showing Gasolene Consumption per Mile, and per Hour
at Maximum Load and Different Speeds on the Three Gears.
Gasolene - Gal. per Hour.
Gasolene - Gal. per Mile.
1st Gear.
Gas. per Hour. - 2nd Gear.
Gas. per Hour. - 3rd Gear.
1st Gear.
Gas per Mile - 2nd Gear.
Gas. per Mile - 3rd Gear.
Miles per Hour.
Test No.

Test of Packard Motor Car #242.
Mech. Eng. Dept. University of Illinois.
Thesis - Atwood & Beers.

Curves Showing Point of Ignition of Motor at Different Speeds, Expressed in Crank Degrees and % Stroke Before Dead-Center.

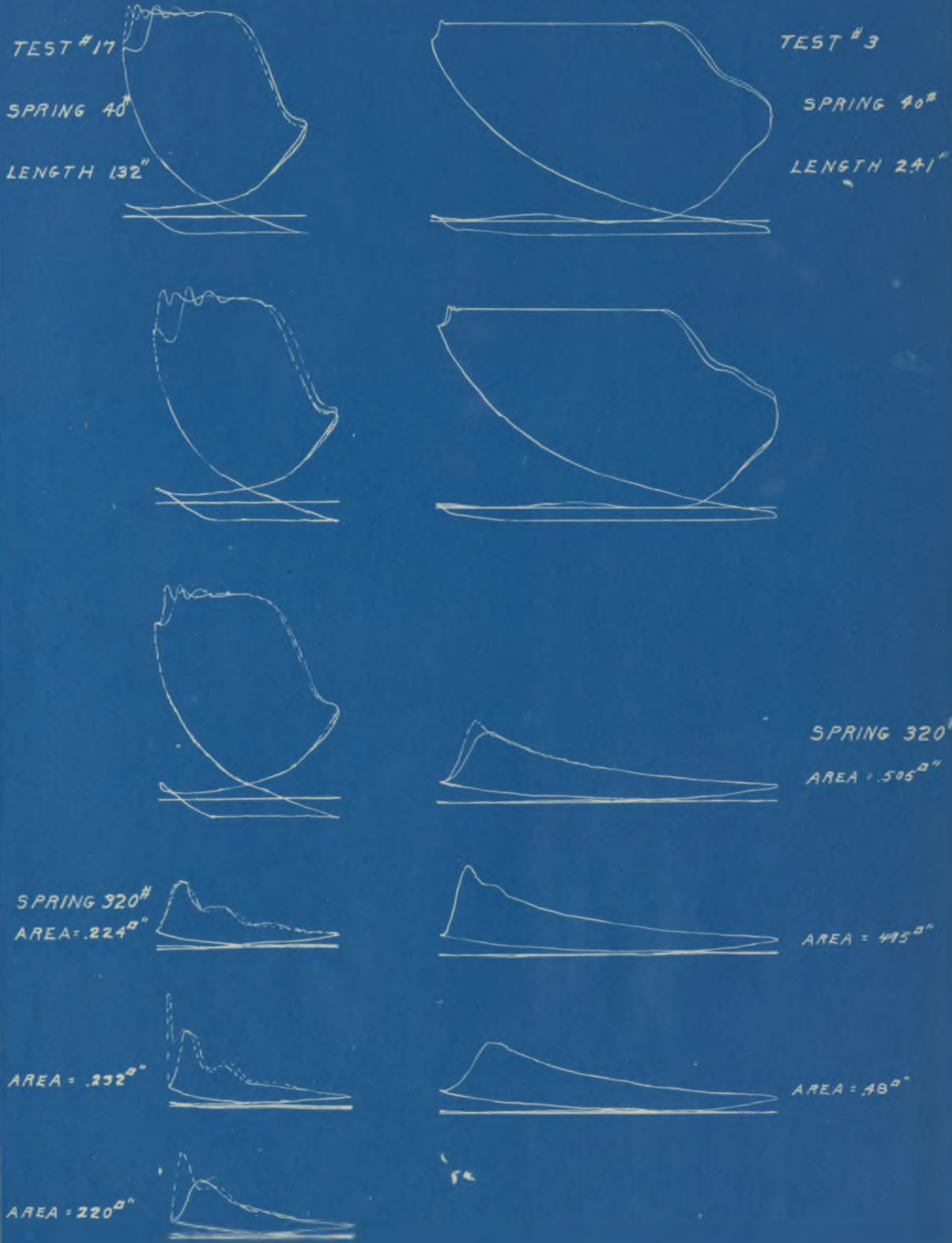
In determining points for these curves, the lateral position of the ignition cam was recorded upon the record, for different speeds. Later, with the motor stopped, and the cam held in these positions, the points of ignition for different speeds were measured off on the fly-wheel, and reduced to terms of crank degrees and % stroke.

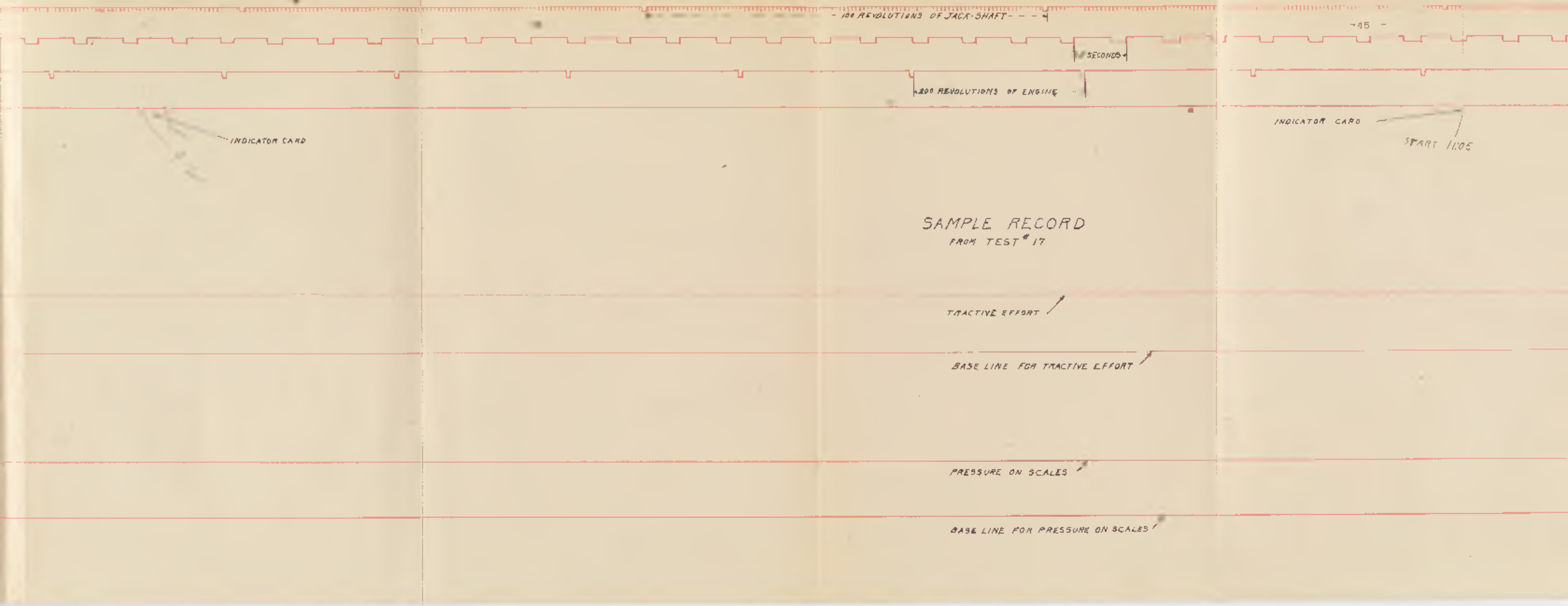


THESIS - Atwood & Beers.

SAMPLE INDICATOR CARDS SHOWING 1ST. AND 3D. LENGTHS OF DRUM TRAVEL.

FOR HIGHEST SPEEDS. FOR LOWEST SPEEDS.




100 REVOLUTIONS OF JACK-SHAFT
SECONDS
200 REVOLUTIONS OF ENGINE
INDICATOR CARD
INDICATOR CARD
START 11:05
SAMPLE RECORD
FROM TEST # 17
TRACTIVE EFFORT
BASE LINE FOR TRACTIVE EFFORT
PRESSURE ON SCALES
BASE LINE FOR PRESSURE ON SCALES

TEST of PACKARD MOTOR CAR No 242

MECH. ENG. DEPT — UNIVERSITY of ILLINOIS.

THESIS — ATWOOD & BEEMS – 1905.

GENERAL TABLE OF RESULTS

NOTE— TESTS #5 AND #6 WERE RUN ON GEAR #1 FOR COMPARISON WITH TEST #3 RUN ON GEAR #2 AND PRACTICALLY SAME LOAD AND CARRIAGE SPEED.
TESTS #17 AND #18 WERE RUN ON GEAR #2 FOR COMPARISON WITH TESTS #12 AND #13, RESPY. RUN ON GEAR #3 – AT SAME LOADS AND SPEEDS.
ALL OTHER TESTS WERE RUN FOR MAXIMUM HORSE POWER

1		TEST NO	1	2	3	4	5	6	7	8	9	10	11	12	13
2		TIME INTERVAL – MINUTES	15	15.25	30	15	15	20	15	20	10	15	20	20	20
3	REVOLUTIONS	GEAR – RATIO OF R.P.M. OF MOTOR TO R.P.M. OF DRIVERS	.230	.230	.230	.319	.077	.077	.319	.230	.319	.319	.319	.319	.319
4		MEAN R.P.M. OF MOTOR	2736	2590	2810	6060	6840	7983	5960	6322	7774	7916	6640	4928	4205
5		TOTAL REV. OF MOTOR	3960	4252	8430	9070	10262	15966	8926	12644	7774	11874	13280	9856	8410
6		MEAN R.P.M. OF JACK SHAFT – BY COUNT	52	552	599	1800	553	526	1771	1347	2681	2380	1927	1437	1207
7		TOTAL REV. OF JACK SHAFT BY COUNT	780	840	1798	2709	829	1052	2657	2694	2681	3568	3853	2873	2403
8		TOTAL REV. OF JACK SHAFT CALCULATED													
9		SLIP – %													
10		MILES RUN	134	1.50	322	483	148	1.88	4.747	482	479	6375	6.88	513	429
11		MILES PER HR OF MACHINE	556	590	644	1932	592	5.64	1798	1446	2874	25.50	2064	1539	1287
12	[illegible]	WT. IN LBS.	61	63	171	148	147	151	142	177	85	137	196	136	180
13		TEMPERATURE RANGE	102	108	77	82	61	62	58	67	66	71	[illegible]	88	70
14		HEAT ABSORBED IN B.T.U. PER HR	24880	26750	25180	47480	35880	28050	33300	33300	33600	38400	34500	36000	37800
15		AIR TEMPERATURE	69	69	78	86	85	83	93	69	68	71	76	76	76
16	[illegible]	PRESSURE AT END OF COMPRESSION	50	50	50	46	42	45	50	55	42	40	45	546	55
17		MAX. PRESSURE AT BEGINNING OF EXPANSION	237	220	184	200	70	98	190	230	140	200	240	257	275
18		PRESSURE AT END OF STROKE	35	35	35	30	20	28	28	24	22	22	26	33	35
19		BACK PRESSURE DURING EXHAUST – MEAN	6.5	6.6	3.7	7.3	6.6	8.3	5.0	6.5	4.9	8.1	8.3	6.6	4.5
20		PARTIAL VACUUM DURING ADMISSION	4	4	4	2	[illegible]	5	3	6	5	4	3	3.5	3
21		MEAN EFFECTIVE PRESSURE	716	717	673	686	308	342	613	590	399	430	595	722	800
22		CARD LENGTH	245	242	241	1.26	130	130	128	130	134	133	130	18	179
23		CARD AREA – AVE.	567	549	505	230	126	139	[illegible]	239	.66	179	222	407	449
[illegible]		[illegible]		737							772				
25	ENERGY	BRAKE H.P.	257	278	237	463	221	208	458	493	80	236	440	433	403
26		I.H.P. – B.H.P.	214	1.58	201	360	268	425	389	372	732	553	398	392	376
27		TRACTIVE EFFORT OBSERVED													
28		" " CALCULATED	174	174	1385	90	140	137	906	128	104	348	86	1067	118
29	FUEL CONSUMPTION	GASOLINE USED – LBS.	84	84	195	179	142	158	2.03	261	160	177	244	201	196
30		WT. PER GAL. – LBS.	6.00	—	—	—	—	—	—	—	—	—	—	—	—
31		GASOLINE USED – GALS. PER HR.	560	.565	485	1.190	.950	.792	1.352	1.305	1.603	1.180	1.220	1.006	990
32		" " PER MILE – GALS.	.101	.096	.076	.062	.160	.141	.071	.090	.056	.046	.059	.064	.076
33		HEAT VALUE OF GASOLINE – B.T.U.	19120	—	—	—	—	—	—	—	—	—	—	—	—
34		GASOLINE USED PER I.H.P. PER HR – GALS.			1105	.145	.194	.125	.160	.151	.197	.150	.145	.122	.126
35		GASOLINE USED PER B.H.P. PER HR – GALS.			.203	.257	.430	.371	.296	.265	.200	.500	.278	.292	.243
36		COST OF RUNNING PER MILE IN CENTS (GASOLINE @ 15¢ PER GAL)	1.56	1.43	1.13	.925	2.4	2.12	1.07	1.35	.84	.690	.885	.96	1.15
37	HEAT BALANCE	B.T.U. EQUIVALENT TO I.H.P.			5561	5230	3100	5970	5640	7345	3446	5010	7110	7660	6610
38		B.T.U. CONVERTED INTO WORK IN CYLINDER – I.H.P. – %			20.1	15.4	11.4	17.8	14.6	14.7	11.2	14.8	17.1	19.8	17.6
39		B.T.U. EQUIVALENT TO B.H.P.			3012	3083	1400	1760	3630	4180	339	1500	3730	3667	3420
40		B.T.U. CONVERTED INTO USEFUL WORK – B.H.P. – %			10.9	8.65	5.17	5.84	7.84	8.90	1.11	4.44	8.96	10.4	9.13
41		HEAT LOST IN JACKET WATER – %			45.4	35.7	33.1	31.0	21.3	22.3	18.3	28.4	27.5	32.5	33.6
42		HEAT LOST IN EXHAUST AND BY RADIATION – %			34.6	49.9	55.5	61.2	69.1	63	70.6	56.8	55.2	47.7	49.8
43		HEAT AVAILABLE IN GASOLINE	16000	16660	27700	34000	27100	30200	38700	49800	30600	33800	41600	36880	37500
44	EFFICIENCY	MECHANICAL EFF. – %	56.7	63.4	65.9	56.2	46.2	32.8	54.0	57.0	9.86	30.0	52.8	52.5	51.8
45		THERMAL EFF. FOR I.H.P.			20.1	15.4	11.4	17.8	14.6	14.7	11.2	14.8	17.1	14.8	17.6
46		" " B.H.P.			10.9	8.65	6.17	5.84	7.84	[illegible]		4.44	7.76	10.4	9.13

1	TEST NO	14	15	16	17	18	19	20	21	22	23	24	25
2	TIME INTERVAL – MINUTES	20	10	20	20	20	15	20	20	12.5	15	15	14
3	GEAR – RATIO OF R.P.M. OF MOTOR TO R.P.M. OF DRIVERS	.319	.230	.230	.230	.230	.077	.077	.230	.230	.230	.230	.087
4	MEAN R.P.M. OF MOTOR	3615	7646	7767	6769	6632	6979	5052	7050	4747	6467	3967	7157
5	TOTAL REV. OF MOTOR	7030	7646	15534	13738	13064	10468	10104	14100	6056	8200	5950	10736
6	MEAN R.P.M. OF JACK SHAFT – BY COUNT	971	1645	1670	1468	1393	558	3905	1505	1020	1164	819	592
7	TOTAL REV. OF JACK SHAFT BY COUNT	1942	1645	3340	2937	2785	837	781	3009	1274	1732	1229	829
8	TOTAL REV. OF JACK SHAFT CALCULATED				2972	2826	859	824	3050	1310	1776	1288	875
9	SLIP – %				1.20	1.40	2.00	5.20	1.35	2.75	2.40	4.60	5.75
10	MILES RUN	347	294	6150	5240	4980	1494	1473	5365	2275	3.079	2195	1480
11	MILES PER HR OF MACHINE	1041	1764	1845	1572	1494	598	448	1610	1091	1236	877	635
12	WT. IN LBS.	285	100	146	152	142	157	134	153	99	114	91	92
13	TEMPERATURE RANGE	50	56	79	80	70	59	92	80	79	65	65	86
14	HEAT ABSORBED IN B.T.U. PER HR	[illegible]	33000	34500	36000	30000	26990	36900	37800	36650	29700	33670	[illegible]
15	AIR TEMPERATURE	68	68	72	72	72	69	72	75	87	89	[illegible]	[illegible]
16	PRESSURE AT END OF COMPRESSION	585	45	45	50	48	46	58	50	55	60	60	50
17	MAX. PRESSURE AT BEGINNING OF EXPANSION	258	200	230	210	200	200	270	210	226	270	230	220
18	PRESSURE AT END OF STROKE	27	30	30	27	22	35	32	30	32	28	33	25
19	BACK PRESSURE DURING EXHAUST – MEAN	4	7		7	7	9.7	9.5	9.2	7.1	7.2	7.5	8.4
20	PARTIAL VACUUM DURING ADMISSION	2.5		4	4.5	5	4	3.5	4	4	26	3	3
21	MEAN EFFECTIVE PRESSURE	836	518	502	560	597	557	753	577	738	737	765	580
22	CARD LENGTH	179	135	135	132	128	132	128	191	180	18	179	190
23	CARD AREA – AVE.	468	217	212	231	239	230	30	341	416	416	423	34-
25	BRAKE H.P.	400	391	380	451	465	469	370	447	476	470	366	38[illegible]
26	I.H.P. – B.H.P.	293	529	523	442	439	433	513	496	354	453	329	581
27	TRACTIVE EFFORT OBSERVED												
28	" " CALCULATED	144	83	797	108	117	293	[illegible]	104	163	144	115	226
29	GASOLINE USED – LBS.	168	116	234	265	212	174	206	296	160	179	146	207
30	WT. PER GAL. – LBS.	—	—	—	—	—	—	—	—	—	—	—	—
31	GASOLINE USED – GALS. PER HR.	840	1160	1170	1275	1055	1166	1.030	1470	1280	1195	974	1471
32	" " PER MILE – GALS.	.081	.066	.064	.081	.071	.195	.230	.092	.127	.097	.110	.236
33	HEAT VALUE OF GASOLINE – B.T.U.	—	—	—	—	—	—	—	—	—	—	—	—
34	GASOLINE USED PER I.H.P. PER HR – GALS.	.121	.126	.130	.143	.116	.129	.117	.157	.154	.128	.112	.154
35	GASOLINE USED PER B.H.P. PER HR – GALS.	.210	.298	.308	.273	.226	.247	.279	.332	.270	.249	.267	.388
36	COST OF RUNNING PER MILE IN CENTS (GASOLINE @ 15¢ PER GAL)	1.21	.99	.95	1.21	1.05	2.92	3.45	1.38	1.90	1.45	1.66	3.45
37	B.T.U. EQUIVALENT TO I.H.P.	6150	3950	7660	7990	7670	5730	7570	8000	4390	5430	4410	5710
38	B.T.U. CONVERTED INTO WORK IN CYLINDER – I.H.P. – %	14.2	13.3	17.2	16.4	17.9	17.3	14.2	14.2	14.3	17.4	15.9	14.4
39	B.T.U. EQUIVALENT TO B.H.P.	3341	1666	3230	3730	3950	2985	3160	3790	2620	3060	2320	2200
40	B.T.U. CONVERTED INTO USEFUL WORK – B.H.P. – %	10.4	7.35	7.23	7.88	9.70	9.00	7.98	6.71	8.25	8.95	8.35	5.56
41	HEAT LOST IN JACKET WATER – %	49.3	29.3	25.7	[illegible]	24.7	27.9	31.2	22.3	25	21.8	21.3	20
42	HEAT LOST IN EXHAUST AND BY RADIATION – %	41.5	57.4	67.3	58.7	62.4	59.8	49.6	60.35	60.7	60.8	62.9	65.6
43	HEAT AVAILABLE IN GASOLINE	32100	29200	44700	49700	40000	33200	34900	56600	30600	34200	27800	39600
44	MECHANICAL EFF. – %	57.8	42.5	42.1	50.5	51.6	52.0	42.0	47.4	67.4	51.4	[illegible]	47.6
45	THERMAL EFF. FOR I.H.P.	19.2	13.3	17.2	16.4	17.9	17.3	19.2	14.1	14.3	17.4	15.9	14.4
46	" " B.H.P.	10.4	7.35	7.23	7.88	9.70	9.00	7.97	6.71	8.26	7.95	8.36	5.56

TEST – PACKARD MOTOR CAR No 242.

MECH. ENG DEPT. UNIVERSITY – ILLINOIS.

THESIS of ATWOOD & BEEMS – 1903

TEST No 3 – By 5 minute intervals.

1	NO. OF READING		1	2	3	4	5	6	TOTAL	MEAN
2	TIME INTERVAL – MINUTES		5	5	5	5	5	5	30	5
4	REVOLUTIONS	MEAN RPM OF MOTOR	261.6	277.6	307.6	276.9	277.6	284.9	1686	281
3		GEAR – RATIO OF RPM OF MOTOR TO RPM OF DRIVERS	.230	—	—	—	—	—		—
5		TOTAL REV OF MOTOR	1306	1379	1535	1384	1387	1424	8430	1405
6		MEAN RPM OF JACK SHAFT – BY COUNT	55.6	59.6	66.4	58.6	59.4	60.6	359.6	59.9
7		TOTAL REV. OF JACKSHAFT BY COUNT	278.	298	327.	293.	297.	303.	1798	299.
8		TOTAL REV OF JACK SHAFT CALCULATED								
9		SLIP – PERCENT								
10		MILES RUN	.479	.530	.585	.523	.530	.549	3.22	.531
11		MILES PER HR OF MACHINE	5.96	6.37	7.01	6.27	6.37	6.50	38.48	6.44
12	JACKET WATER	WT. IN LBS.	26	14	25	43.5	20	32.5	170.5	28.4
13		TEMPERATURE RANGE	79	88	92	83	68	68	462	77
14		HEAT ABSORBED IN B.T.U. PER HR.	23150	14850	27600	43200	16330	26400		25180
15		AIR TEMPERATURE	87	86	88	88	88	89		88
16	DATA FROM INDICATOR CARDS	PRESSURE AT END OF COMPRESSION	50	—	—	—	—	—		—
17		MAX. PRESSURE AT BEGINNING OF EXPANSION	200	180	185	170	190	180	1105	184
18		PRESSURE AT END OF STROKE	37	37	37	35	35	30	211	35
19		BACK PRESSURE DURING EXHAUST – MEAN	3.7	—	—	—	—	—		—
20		PARTIAL VACUUM DURING ADMISSION	4.0	—	—	—	—	—	—	—
21		MEAN EFFECTIVE PRESSURE	71.5	67.7	66.5	64.3	67.7	66.2	403.9	67.3
22		CARD LENGTH	2.41	—	—	—	—	—	14.46	2.41
23		CARD AREA – AVE.	.540	.490	.502	.485	.500	.498	3.015	.505
24	ENERGY	INDICATED H.P.	4.32	4.35	4.73	4.14	4.34	4.36	26.29	4.38
25		BRAKE H.P.	2.22	2.36	2.59	2.32	2.35	2.40	55.61	2.37
26		I.H.P. – B.H.P.	2.10	1.99	2.14	1.82	1.99	1.96	20.66	2.01
27		TRACTIVE EFFORT OBSERVED								
28		" " CALCULATED	130	138	151	135.5	137	140	831.0	138.5
29	FUEL CONSUMPTION	GASOLINE USED – LBS.	.18	.25	.26	.28	.24	.24	1.45	.2416
30		WT. PER GAL – LBS.	6.0	—	—	—	—	—		—
31		GASOLINE USED – GALS. PER HR.	.36	.5	.521	.56	.48	.48	2.41	.485
32		" " PER MILE – GALS	.060	.078	.074	.089	.075	.074	.452	.0753
33		HEAT VALUE OF GASOLINE – B.T.U	19120	—	—	—	—	—		—
34		GASOLINE USED PER IHP PER HR. GALS	.0834	.115	.11	.135	.1105	.11	.663	.1105
35		GASOLINE USED PER BHP PER HR. GALS.	.164	.213	.200	.242	.203	.20	1.218	.203
36		COST OF RUNNING PER MILE IN CENTS [GASOLINE @ 16¢ PER GAL]	.906	1.17	1.11	1.34	1.19	1.11	6.78	1.13
37	HEAT BALANCE	B.T.U. EQUIVALENT TO I.H.P.	915	922	1000	877	920	924	5561	927
38		BTU CONVERTED INTO WORK IN CYLINDER – I.H.P. – PERCENT	26.6	19.3	20.6	16.4	20.0	20.8	120.6	20.1
39		BTU EQUIVALENT TO BHP	470	500	548	492	498	508	3012	502
40		B.T.U. CONVERTED INTO USEFUL WORK – BHP – PERCENT	13.7	10.4	11.0	9.2	10.8	11.1	65.4	10.9
41		HEAT LOST IN JACKET WATER – %	56	26	46.4	67	29.7	48.	272.4	45.4
42		HEAT LOST IN EXHAUST AND BY RADIATION – %	17.4	54.7	33.1	16.6	50.3	31.2	207.0	34.5
43		HEAT AVAILABLE IN GASOLINE USED IN BTU – 100%	3440	4780	4470	5350	4590	4590	27700	4616
44	EFFICIENCY	MECHANICAL EFF. – BHP/IHP	.516	.544	.547	.56	.542	.55	3.357	.559
45		THERMAL EFF. FOR IHP	26.6	19.3	20.5	16.4	20.0	20.8	120.6	20.1
46		" " " B.H.P.	13.7	10.4	11.0	9.2	10.8	11.1	65.4	10.9

TEST of PACKARD MOTOR CAR No. 242.

MECH. ENG. DEPT. UNIVERSITY of ILLINOIS.

THESIS of ATWOOD & BEERS – 1903.

TEST of MUFFLER For backpressure loss

TEST #28A – EXHAUST LED THROUGH 16 FEET OF 1½" PIPE
" #28B – " FREE ENTIRELY
" #28C – " LED INTO MUFFLER

	TEST	28A			28B			28C			
3	GEAR --- RATIO OF MOTOR RPM TO R.P.M. OF DRIVERS	.319			.319	.319	.319	.319	.319	.319	.319
4	MEAN R.P.M. OF MOTOR	576	600	625	650	660	670	380	400	620	700
11	MILES PER HR. OF MACHINE	18.4	19.2	19.8	20.8	21.1	21.4	11.5	12.8	19.8	22.4
16	PRESSURE AT END OF COMPRESSION	56	56	56	57	57	57	59	59	59	59
17	MAX. PRESSURE AT BEGINNING OF EXPANSION	240	240	240	240	240	240	210	210	210	210
18	PRESSURE AT END OF STROKE	28	28	28	24	24	24	28	28	28	28
19	BACK PRESSURE DURING EXHAUST	5.95	6.05	7.0	5.2	6.5	7.1	4.0	4.3	7.8	8.4
20	PARTIAL VACUUM DURING ADMISSION	5.	5.	5.	6.0	6.0	6.0	5.5	5.5	5.5	5.5
21	MEAN EFFECTIVE PRESSURE	65.5	65.5	65.6	63	63	63	62.5	62.5	62.6	62.5
22	CARD LENGTH	1.83	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
23	CARD AREA - AVE.	.375	.375	.375	.364	.364	.364	.362	.362	.362	.362
24	INDICATED H.P. — TAKEN FROM 3rd GEAR CURVES AT THESE R.P.M.	8.4	8.4	8.4	8.4	8.4	8.4	7.3	7.7	8.4	8.3
25	BRAKE H.P. — TAKEN FROM 3rd GEAR CURVES AT THESE R.P.M.	4.6	4.6	4.5	4.5	4.45	4.4	4.0	4.2	4.6	4.