DETERMINATION OF AUTOMOBILE PERFORMANCE BY MEANS OF THE WIMPERIS ACCELEROMETER

A THESIS

PRESENTED BY

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C O N T E N T S.

Page.

LIST OF ILLUSTRATIONS.

--I N T R O D U C T I O N.--

The object of this thesis is the Determination of the Performance of Automobiles by means of Wimperis Accelerometer.

Various other methods of testing the performance of motor cars have been exploited but the results were decidedly discordant, due chiefly to the variation of resistances to motion.

Resistance to motion can be subdivided into three main divisions; rolling resistance, internal resistance of the mechanism and air resistance.

The total of these three resistances may very suitably be called the tractive resistance, since it represents the amount of tractive force which must be exerted by the engine.

Gravitational resistance affects the accelerometer readings only when the road is not level, and it is, of course, the same for all vehicles of the same weight upon the same road. This depends solely on the slope, so that a

gradient of 1 in 10 produces a gravitational resistance of one-tenth of a ton per ton, or 200# per ton. The total resistance is the sum of the tractive and gravitational resistances.

The rolling resistance is made up of two parts, one due to the road surface and one due to the tires. Part of the energy wasted goes into grinding up the road and part into heating the tires. The former part is usually assumed to be independent of the speed of the car. The resistance due to the rolling of rubber tires was shown by experiments of Ewing and of Bourlet, many years ago to be independent of the speed.

Frictional resistance depends entirely on the amount of mechanism there is attached to the road wheels. Thus a four-wheeled hand-cart having its wheels entirely free from all mechanism but their bearings would encounter practically none of this resistance at all. Whereas, in a steam road-roller which has its rear

road wheels coupled up to the flywheel and engine, the effort needed to haul it would always be much larger than if the engine were disconnected from the wheels. These are extreme cases of freedom and lack of freedom. The ordinary motor car comes between the two. The motor car engine can be engaged and disengaged, at will, from the road wheels, by use of the clutch; though even when disconnected in this way the rotation of rear wheels also require rotation of rear axle, the bevel or worm, the propeller shaft and the gears in the transmission.

If the effort to haul a motor car was being measured, it would be necessary for this reason to bear in mind that the requisite effort in pounds per ton would not be the effort needed at the road wheels but the effort needed at the clutch. The resistance of the mechanism is largely independent of the load, though somewhat dependent upon speed, but the

loss in transmission, due to the churning of the lubricant, increases rapidly with the speed, in fact, the resistance due to this churning action is almost proportioned to the square of the speed, and the energy loss to the speed cubed.

The air resistance, an unimportant factor at low speeds, is the most important one at high speeds. If a flat surface is exposed to a wind blowing perpendicular to it, the pressure on the area will be given by the equation

$$F = 0.0003V^2A$$

where F is the force in pounds. V is the velocity in miles per hour, and A the area in square feet. Although a motor car presents some wind resisting area it does not present flat surfaced areas. Its line is very much broken, so that the total force due to air resistance is sometimes far greater than that given by putting A as equalling the projected

area of the car. Since body shapes vary so much, it is best to make actual measurements whenever it is possible to do so.

The sum of the components gives the tractive resistance in pounds per ton. This statement might seem to imply that all three components rise and fall with the load, which is not true of the air resistance, since in a closed-in motor car it would be the same, regardless of the load on the inside; so that, although it is convenient to measure tractive resistance in pounds per ton, it must be remembered that the air resistance will depend not on the weight of the load but upon the shape of the body carrying it. The effect of wheel diameter upon tractive effort is not large.

The tractive resistance R. expressed in pounds per ton is usually calculated from an equation of the following type:-

$$R. = A + bv + cv^2$$

where A is the resistance due to the components independent of V; b is the item added by road hammering, but is usually so small that the term is omitted; and cv^2 is the component due chiefly to the air resistance but increased also by lubricant churning in the gear box, and probably by mud churning by the wheels when running on very heavy roads.

From the preceeding it is obvious that the variables in the various equations would be very difficult to determine.

This led up to some form of testing motor vehicles on the road.

The first form of indicating apparatus used to measure the tractive effort, consisted of a spring draw-bar. The tractive effort was measured by hauling the vehicle with a spring draw-bar attached to another vehicle. This was found to be a difficult measurement to make, particularly at high speeds and the least hill slope affected the readings seriously.

With the purpose of eliminating these errors, the leading Automobile Engineers of that time attempted to design and perfect an instrument that would indicate correctly the resistances to traction of a motor vehicle. This instrument they called an accelerometer.

The leaders in this work were Desduits, Lanchester and Trotter, who developed their accelerometer prior to 19o9. These types of accelerometers in spite of their high state of mechanical perfection, were not applicable to road transport work.

In 1909 H.E.Wimperis, with the skilful aid of Elliot Bros., constructed an accelerometer on a new method altogether, which would easily be able to endure hard usage on the road, while loosing nothing in accuracy. The description of instrument and theory of operation is described in the next chapter.

Acknowledgement is made of the help obtained from the papers and experimental data of Messers H. E. Wimperis, W.C. Marshall and C. L. Sheppy.

P A R T I.

DESCRIPTION AND THEORY OF OPERATION.

The Wimperis Accelerometer is an instrument so designed that it is applicable to the study of the resistances and power requirements of moving vehicles. The construction is such that it records acceleration and decceleration in feet per second per second.

The problem of investigating the merits of motor cars, may be divided into two main factors, namely a study of the resistances offered to the propulsion of motor cars and the determination of their power requirements. The factor of resistance can be subdivided into three branches; a quantity due to rolling resistance which is constant; a quantity due to the friction of the internal mechanism of the car; and a quantity due to air resistance which is variable.

The factor of power requirement can be divided into two facts namely the horsepower necessary to accelerate and also to drive the vehicle.

PLATE I.

Suppose for example that having determined the acceleration (a) and the decceleration (a') for a car of mass m moving at a velocity of v feet per second that an equation for horse power be derived. Then using the equation,

$$F = ma \qquad (1)$$

the value of a and m can be substrituted in order to determine the value of F when the car is accelerating. The determination of the value of F when the car is deccelerating is an exact duplicate of the previous calculation so the equation

$$F = ma' \qquad (1')$$

holds true.

Having determined the values of F in pounds, we know that a horse power is equivalent to 550 foot pounds per second or

$$H.P. = \frac{F.v}{550} \qquad (2)$$

where v is the velocity in feet per second.

Using the equation (2) the horse power necessary to accelerate and to drive the car

can be determined. The sum of these two horse powers will be the total horse power developed by the motor.

This method of calculation may be simplified as follows:-

$$F = ma = \frac{Wa}{32.2} \quad \text{in pounds.}$$

v = 5280 X M.P.H. in feet per hour.

One horse power hour is equivalent to 1,980,000 foot pounds.

These factors being known they can be combined into an equation representing horse power.

$$H.P. = \frac{Wa \times 5280 \times M.P.H.}{32.2 \times 1,980,000.}$$

Simplifying

$$H.P. = \frac{W. \times a \times M.P.H.}{12075} \qquad (3)$$

which is equivalent to the horse power to accelerate or when deccelerating the H.P. to drive vehicle is

$$H.P. = \frac{W. \times a' \times M.P.H.}{12075.} \qquad (3')$$

PLATE II.

The terms in equation (3) and (3') are of such a nature that they can be obtained directly from test data and the determination of the horse power becomes a simple mathematical calculation.

There are two forms of Wimperis Accelerometers, the indicating and recording types. The recording accelerometer which is to be described in this chapter was the model used to obtain the data for this thesis.

A general view of the recording accelerometer is shown in Plates I and II. In order to simplify the description of the instrument it was necessary to consider the two units of the mechanism individually, that it to describe the accelerometer proper and the recording mechanism separately.

The accelerometer proper as illustrated in Plate III consists of a circular aluminum disk mounted on a vertical shaft which is geared to an auxilliary vertical shaft mount-

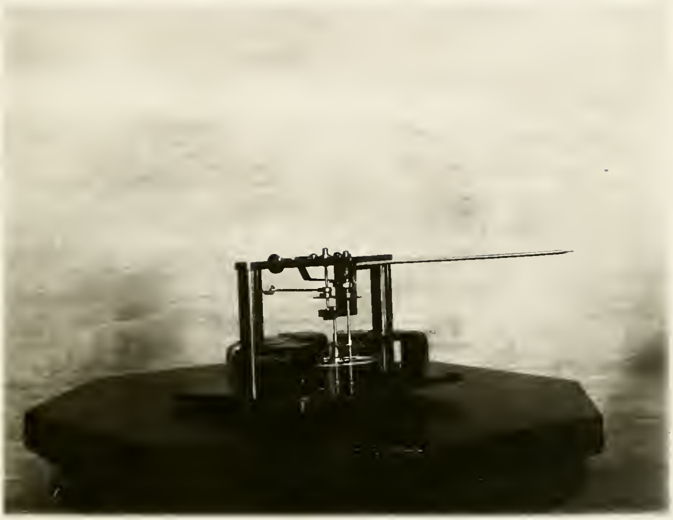


PLATE III.

ing the needle and a small hair spring rigidly attached to the frame on one end and the auxilliary shaft on the other.

Six permanent magnets are set around the periphery of the disk and the magnetic field acting at right angles to the plane of the disk, serves as a brake to dampen the movement of the rotating element. This method of braking is steady and has none of the sticking qualities of frictional braking.

Any acceleration in the direction of motion tends to make the disk lag. This lag rotates the mechanism and winds up the hair spring. The greater the lag of the disk the greater will be the amount that the spring is wound up and hence the acceleration is measured by the degree to which the spring is wound up.

The needle is not affected by any changes of gradient, because the downward acceleration is neutralized.

This can be explained mathematically as

follows:-

To prove this let the slope of the hill be s and the weight of the moving parts of the accelerometer w. Also let g be the gravitational constant, x the distance travelled by the car, and f the resistance.

Then the acceleration of the car is

$$\frac{d^2 x}{d t^2}$$

while the forces acting on the car in the direction of motion are

$$-(w \sin s + f)$$

assuming that the hill slope is against the car. But force is equal to mass times acceleration.

$$\therefore -(w \sin s + f) = \frac{w}{g} \times \frac{d^2x}{dt^2}$$

$$\frac{d^2x}{dt^2} = - \frac{g}{w} (w \sin s + f)$$

the minus sign meaning, of course, a retardation.

But owing to the slope of the car the needle tends to rest not at the zero but at a reading equal to the slope, namely, g sin s.

So that the needle has to move thru this amount before it shows any reading on the other side of the zero. The actual retardation will therefore be

$$\frac{g}{w}\ (w \sin s + f) - g \sin s.$$

which reduces to

$$\frac{f \times g}{w} \text{ feet per second per second.}$$

If the value of F in pounds per ton is desired then multiply the acceleration in feet per second per second by $\frac{w}{g}$ or by $\frac{2000}{32.2}$ which is equal to 62.11.

In order to have the instrument record correctly when traveling around curves a compensating balance is fitted to a stub shaft which is geared to the auxilliary vertical shaft mounting the needle and hair spring.

If the disk is deflected by an acceleration in the direction of motion of the car and by a second acceleration like that given by a slope in the road, it would act at right angles to the first and tend to add or sub-

tract from the force, causing the hair spring to be wound up, which of course would give a false record of the acceleration. This error is most noticeable in the pendulum form of instrument where the complicating vertical acceleration often far exceeds that of gravity.

The purpose of the gear wheels connected to the compensating balance is in effect, the same as that of the disk. In Figure I is shown a diagramatic outline of the mechanism.

The moments of mass of these disks about the axes A and B are equal and have their centers of gravity eccentric to the same extent. It can be seen from Figure I that a force in the direction of the arrow P will cause the two disks to roll together. A force acting in the direction of the arrow R. will produce no effect upon the disks. Forces perpendicular to the plane of the page will have no tendency to cause or produce rotation. Therefore the only acceleration recorded will be that which

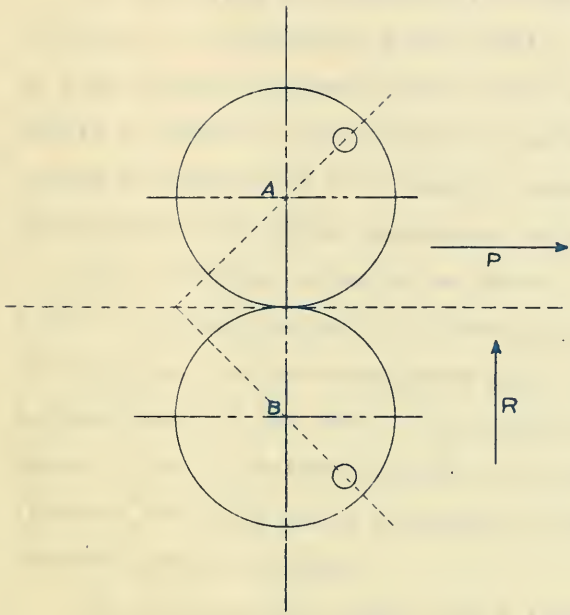


FIGURE I.

is produced by a force acting in the direction indicated by the arrow P or opposite to it.

In recording the acceleration readings no effect is produced by a down grade. This is true because the gravitation effect on the needle on account of the slope is neutralized by the acceleration due to gravity acting upon the car when the latter descends a slope.

The recording mechanism as shown in Plates I and II consists mainly of a clock mechanism which drives the recording chart paper thru a toothed wheel at the rate of six inches per minute. The space between each of the curved lines on the chart paper represents two and one-half seconds of time.

The chart paper travels over a horizontal table, upon which the recording needle of the accelerometer plots its indications. A pneumatic operated pen on the front edge of the table is found to be useful for a variety of purposes, such as recording the speed of a vehicle as

observed from the speedometer.

On the outside of the case of the instrument is attached a knurled brass nut which is used to adjust the height of the recording pen.

The purpose of the milled brass thumb screw on the top of the supporting frame, is to adjust the recording needle so that it will read zero acceleration when the vehicle is at rest.

P A R T II

APPLICATION TO THE TESTING OF MOTOR CARS.

The total resistance interposed to the progress of a motor driven vehicle, consists mainly of two factors:- A fixed quantity due to the rolling resistance and a variable quantity due to the air resistance.

The fixed quantity alone gives the resistance to traction.

Besides the rolling resistance and the wind resistance there are three other factors which enter into the total resistance. These are, the friction in the vehicle itself, grades, and curves.

If we propel a vehicle at a certain speed over a level road and suddenly stop the propelling force, the speed will decrease with the retardation proportional to the total resistance. If the latter is small the retardation will be small and the time required to change the speed will be longer than if the resistance were large as it would be, for example, if the brakes were applied or a strong wind

blowing.

Considering a car weighing two tons traveling at a rate of 30 miles per hour against a steady resistance of 119#, this resistance on analysis is found to be composed of 47 X 2 + 25 = 119#. The rolling resistance is 47# per ton. The wind resistance against the exposed surface of the car at 30 miles per hour, considering 12 square feet exposed, is 25#

With the accelerometer even this small calculation which is based on emperical formulae, would not have to be made. The indicator on the instrument immediately shows the decceleration of the car in feet per second per second.

A study of the recording mechanism of the instrument will show that it records in two directions from the zero mark. On one side of zero is acceleration and on the other side decceleration. When measuring the pick-up of the

motor, the needle is first set to zero with the leveling screw when the car is on a level piece of road. The motor is started with the readings recorded directly by the instrument when speeding up. It will be noted that the acceleration is recorded in feet per second per second. After any desired speed has been attained and it is desired to determine the resistance to progress, the clutch is thrown out and the car allowed to coast. The retarding force will then be read on the deceleration side of the chart directly in feet per second per second.

The practical value of the instrument is readily explained. Suppose in a car of two tons which we have considered, the resistance instead of being 119#, the normal amount, should suddenly show to be 200#, the driver would immediately realize that something was wrong. The car would be using 60 per cent more power than required before.

Dragging brakes, bearings which are too tight, badly alligned wheels and other faults which go to increase the power necessary to pull the car over the road, can increase operating costs enormously.

When the operator sees by the accelerometer that the resistance has increased to a noticeable extent the car is inspected and a large amount of damage checked before it occurs. The instance of badly alligned wheels will illustrate this. The wear on the tires of the front wheels when they are out of allignment is so great that a new pair of tires may be worn through in 500 miles of travel. If this misallignment occured on a car equipped with an accelerometer it would be detected immediately.

The accelerometer must be handled very carefully to obtain accurate results on the road.

It was found to give greater accuracy

if the readings were taken on a slight down-grade, because it allows the car to coast longer.

When the road is not level the instrument reading shows the acceleration or deceleration due directly to the motor, brakes, road resistance or a combination of them, and a knowledge of the slope is unnecessary as proven by previous theory.

Plate IV shows the accelerometer set up for operation in test car #I.

In setting up for test the instrument should be set so that the pointer is perpendicular to the direction of motion, and then the pointer should first be released from the holding clip, when it will swing to the center of the chart paper. If the case is quite level the pen should come to rest on the zero line of paper when the paper is running; if this is not so the pointer can readily be adjusted by means of the zero adjusting device,

PLATE IV.

which will be found attached to the brass bridge piece underneath the removable glass cover.

The pen should be washed in methylated spirits, and then filled with ink which is supplied with the instrument. The methylated spirits washes off any dirt or grease that may be on the pen and allows the ink to flow freely.

The pen should now be carefully set to bear very gently on the paper, no more pressure being put on than just sufficient to cause the pen to mark properly across the scale. This adjustment can be made very simply by means of the brass screw, which will be found at the top end of the case, and is marked "Raise" and "Lower".

The paper chart upon which the instrument records, is fitted as follows:- First pull the hinged spring lever on left hand side of clock over to an angle of 90 degrees, where

it will rest on a stop. The roll of paper can then be placed on the pin on the opposite side of the bracket and the lever put back again into original position. The paper should then be threaded under the three blued steel springs on the paper table and make to engage with teeth on pin-wheel, then it will be ready for use.

The paper will pay out through the slot in the bottom of the case at the rate of 6 inches per minute.

A pneumatic marking pen will be found fitted on one side of the instrument for marking on the margin of paper. A mark is placed by means of this on the margin of chart at every increment of speed, in accelerating and retarding.

Having the instrument adjusted the following method is used in taking diagrams.

The driver sets the car in motion in first speed and brings the car up to a speed

of 5 miles per hour, which the driver holds until receiving the signal from the instrument operator to accelerate. At this signal the operator marks a reference mark on margin of paper with the pneumatic market, which represents 5 miles per hour, and at the same time releases the clock mechanism which pays out the paper chart.

The driver then throws throttle wide open and accelerates to a maximum speed in first speed, changes gears to second speed, accelerates to a maximum, changes to third speed, accelerates to a maximum, and if a fourth speed, changes to fourth speed and accelerates to a maximum. When the maximum acceleration is attained the accelerometer reads zero.

After attaining maximum acceleration in direct drive, there are three alternatives in determining the decceleration.

First the motor is declutched from the

driving gear, and the car allowed to coast until it comes to rest. At each decrement of speed the operator marks the paper chart as previously explained. With this determination of the decceleration of the vehicle, the rolling resistance can be determined directly. This is the method that is most generally used, as the resistance to motion includes the frictional resistance of all moving parts back of the motor.

Secondly after attaining maximum acceleration in direct drive, the driver shifts the speeds to neutral position. This allows the clutch and jack-shaft in transmission to come to speed of motor, which decreases the resistance to motion, and does not give a true value on the frictional resistance of the driving mechanism, for considerable work is required to revolve the jack-shaft in the transmission, especially if heavy grease is used as lubricant.

Thirdly, after attaining maximum speed in direct drive, the ignition is switched off and the car allowed to coast as before. The results from this diagram give the total resistance to motion of the car, including the frictional horsepower of the motor.

This form of diagram is very valuable for a study of the friction horse power of the motor. Having the resistance of driving mechanism from method one, the friction horse power can be determined direct by subtracting resistance of method number one from resistance of method number three and reducing to horse power.

Having the test finished the pointer should be raised from paper by brass screw and be swung to one side of instrument where it is placed in holding clip.

The pen should be carefully taken off of pointer and washed in methylated spirits until free from ink, which leaves the pen in

good condition for next test.

It may appear at first sight that the accelerator is open to objection for road testing of motor vehicles, as the measuring instrument is carried on the moving vehicle, it is subjected to a good deal of vibration, and possibly to zero error should the floor of the car change appreciably in its upward or downward tilt relative to the road. Vibration, however is actually useful in that it helps to overcome any statical friction there may be in the mechanism, and although difficulty due to change of tilt cannot be avoided by any attention to the mechanism of the accelerometer, nevertheless its amount has been the subject of careful study on a variety of cars, and been found to be less than can be measured in practice.

P A R T   III

INTERPRETATION OF RESULTS.

The following data was obtained from a series of tests on cars #1 and #2, and recorded as described in method of testing. These tests were made over good asphalt roads, the results being tabulated in tables I,2,3, and 4 and the curves corresponding to these are shown in curves 1 to 7, calculations being made directly from diagrams 1 and 2.

Test car No. 1 was a 1912 model, standard 6 cylinder touring car, having a motor of 3 3/8 inch bore by 4 1/2 inch stroke. Total weight of car was 3300 pounds equipped for the test.

The rolling resistance tractive pull, as determined experimentally over the roads which accelerometer tests were made, averaged 54 pounds total, or 32 pounds per ton of car weight.

After the completion of test, car #1 was taken back to laboratory, and there the speedometer was calibrated for range used

in the testing. Curve #4 shows the calibration curve for speedometer used.

The gearatios on this car were as follows:-

First	speed-	18.5---1
Second	"	12.0---1
Third	"	7.1---1
Fourth	"	4.62--1

From diagram #1 can be obtained the maximum acceleration or decceleration at any car speed. With this data available the horse power to drive or rolling resistance of the motor car can be determined by a simple calculation.

From the following equation which was developed earlier in the thesis, the horse power necessary to accelerate can be calculated

$$\frac{W \text{ X } a \text{ X } M.P.H.}{12075} = H.P. \qquad (3)$$

Obtaining from diagram #1 the decceleration at various car speeds, the resistance to rolling then can be calculated

as follows. From equation (1'),

$$F = ma' \qquad (1')$$

knowing the mass of the car and the deceleration in feet per second per second, the value of F can then be found.

Then from equation (3') the horse power due to decceleration, is

$$H.P. = \frac{W \times a' \times M.P.H.}{12075} \qquad (3')$$

The total horse power developed by the motor is equal to the sum of the values obtained from equations (3) and (3').

To obtain the friction horse power of the motor, the car is allowed to coast with ignition shut off, after having obtained a maximum acceleration in direct drive. Knowing the decceleration in feet per second per second from previous diagram, taken while motor was declutched, and the decceleration taken from car coasting with ignition off, the friction horse power can easily be determined.

TABLE No. 1.

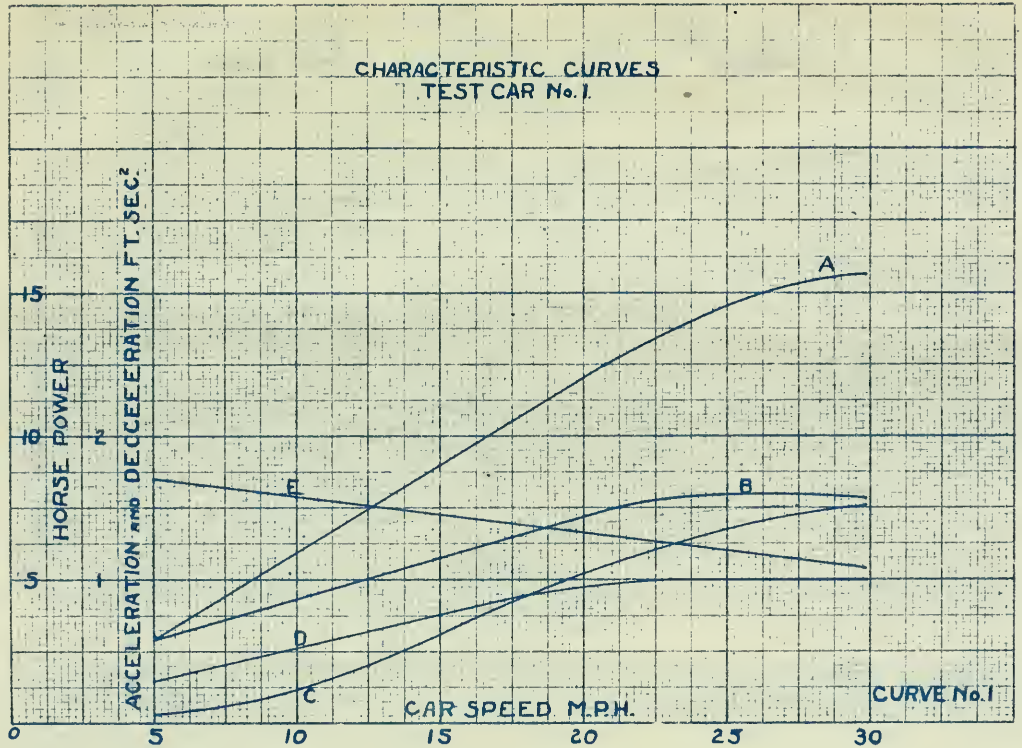
TEST CAR No. 1.

REG. M.P.H.	ACTUAL M.P.H.	ACC. FT SEC^2	DECC. FT. SEC.^{2}	H.P. TO ACC.	H.P. TO DRIVE
5	7.25	1.60	0.40	3.70	0.79
10	12.5	1.50	0.60	5.20	2.05
15	17.7	1.30	0.90	6.29	4.36
20	23.0	1.25	1.00	7.85	6.28
25	28.6	1.00	1.00	7.82	7.82

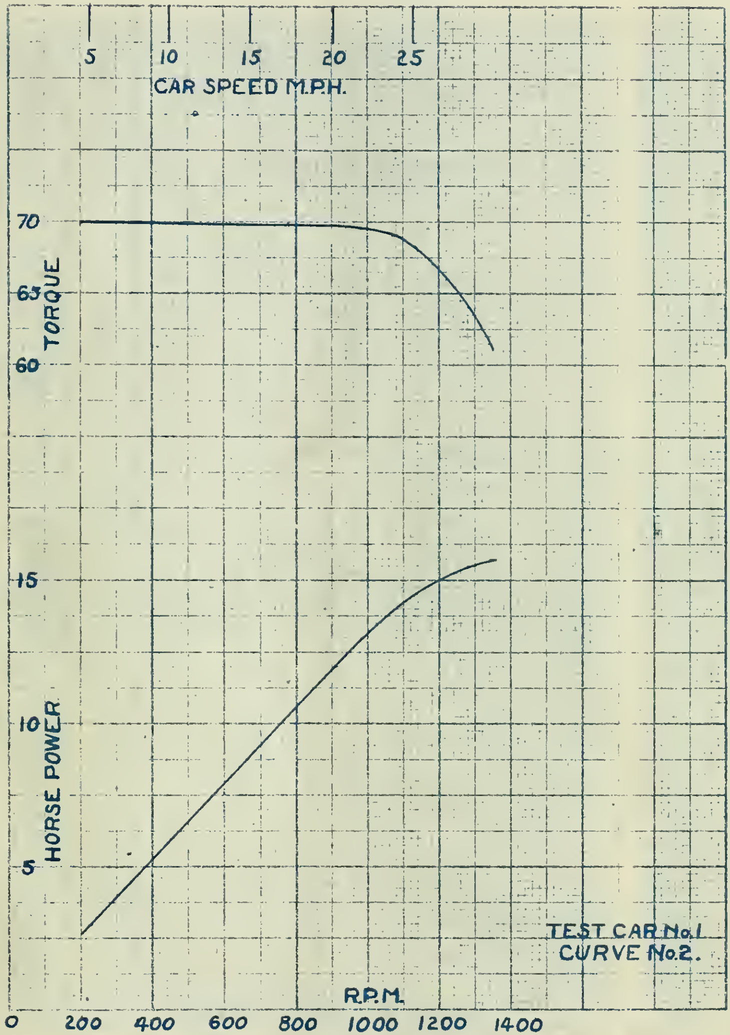
TABLE No. 2.

TEST CAR No. 1.

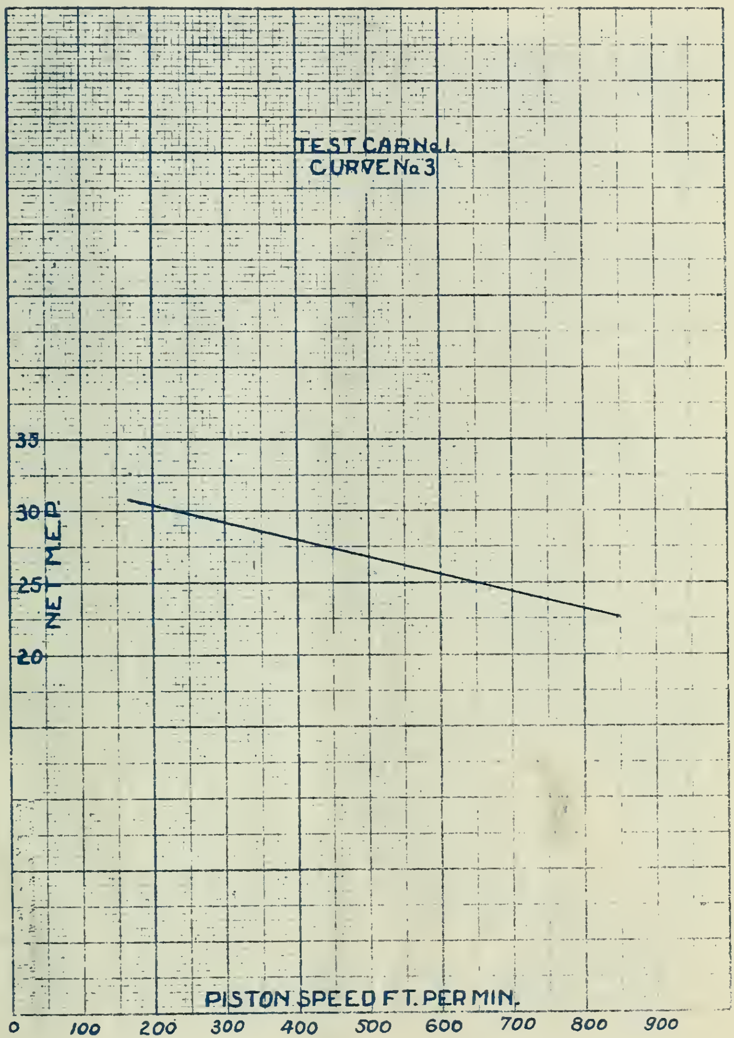
REG. M.P.H.	TOTAL H.P.	R.P.M.	TORQUE	PIS. SP. FT-MIN	NET M.E.P.
5	449	226	69.75	169.5	32.60
10	7.25	452	69.80	339.0	26.43
15	10.65	678	69.60	508.0	25.78
20	14.13	904	69.60	678.0	25.68
25	15.64	1130	68.25	847.0	22.70

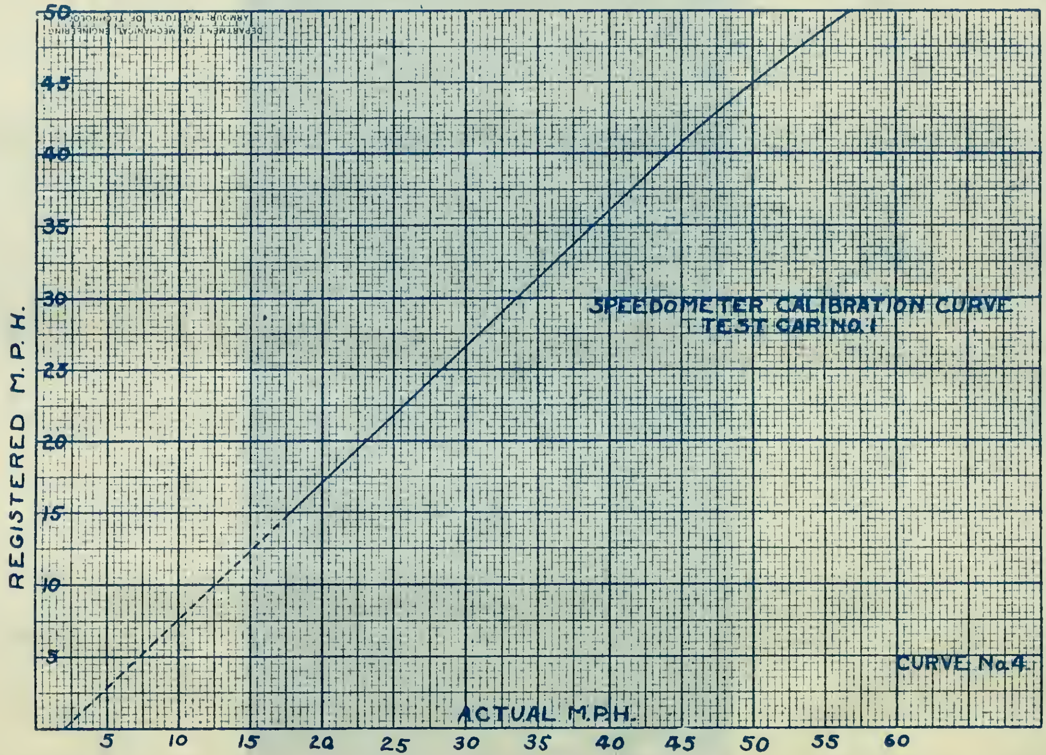


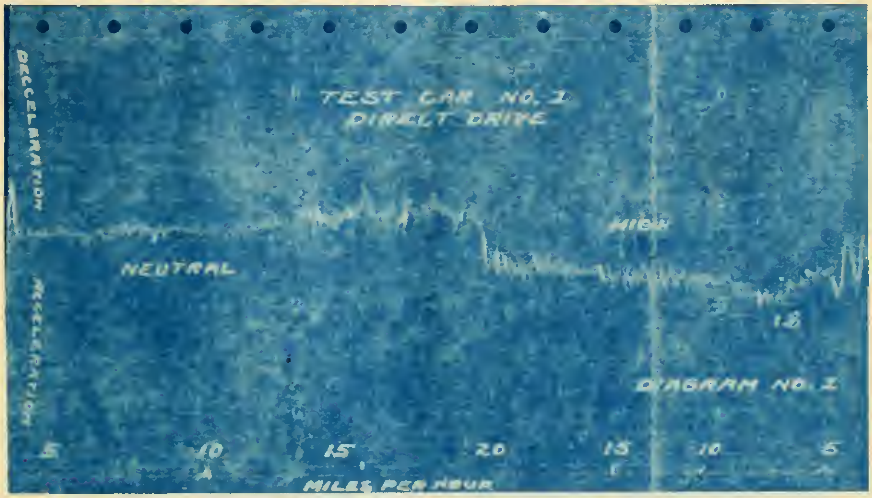
CHARACTERISTIC CURVES
TEST CAR No. 1.
HORSE POWER
ACCELERATION AND DECCEEERATION F.T. SEC.²
CAR SPEED M.P.H.
CURVE No. 1
A
B
C
D
E
0
5
10
15
20
25
30
1
2

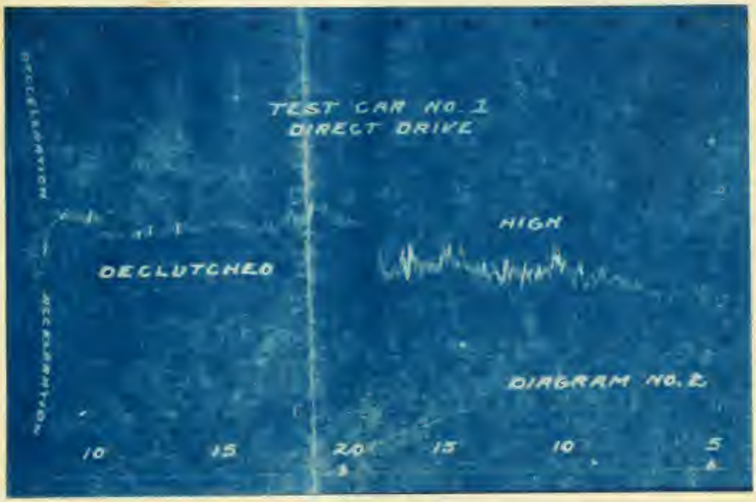


5
10
15
20
25
CAR SPEED M.P.H.
70
65
60
TORQUE
15
10
5
HORSE POWER
TEST CAR No.1
CURVE No.2.
R.P.M.
0
200
400
600
800
1000
1200
1400


TEST CAR No. 1.
CURVE No. 3
NET M.E.P.
35
30
25
20
PISTON SPEED FT. PER MIN.
0
100
200
300
400
500
600
700
800
900


SPEEDOMETER CALIBRATION CURVE
TEST CAR NO. 1
CURVE No. 4
REGISTERED M. P. H.
ACTUAL M.P.H.
5
10
15
20
25
30
35
40
45
50
55
60


TEST CAR NO. 1
DIRECT DRIVE
DECELERATION
ACCELERATION
NEUTRAL
HIGH
DIAGRAM NO. 1
5
10
15
20
15
10
5
MILES PER HOUR



TEST CAR NO. 1
DIRECT DRIVE
DECELERATION
ACCELERATION
HIGH
DECLUTCHED
DIAGRAM NO. 2
10
15
20
15
10
5

The difference between these two deccelerations gives the decceleration due to friction in the motor. From the diagram we can obtain the speed of the car in M.P.H. corresponding to any decceleration, then from equation (3') the friction horse power can be calculated.

Test car No. 2 was a standard make, 7 passenger touring car, having a 6 cylinder Tee head motor, of 5 inch bore by 7 inch stroke. The car weighed equipped for test , 6000 pounds.

The gear ratio of this car on direct drive was 2.7 to 1.

Table 3 shows the acceleration and retardation in pounds of this car for every 10 mile increment of speed.

Referring to curve #5 curve A shows the total horse power developed by the motor and is determined by the algebraic sum of curves C and B.

Curve B. shows the horse power required to produce acceleration, while curve C gives the horse power to drive the car.

Curve D gives the pounds retardation as taken from the accelerometer, also curve E gives the acceleration in feet per second per second as recorded.

The above data on test car #2 was kindly submitted for use in this thesis.

TABLE No.3.

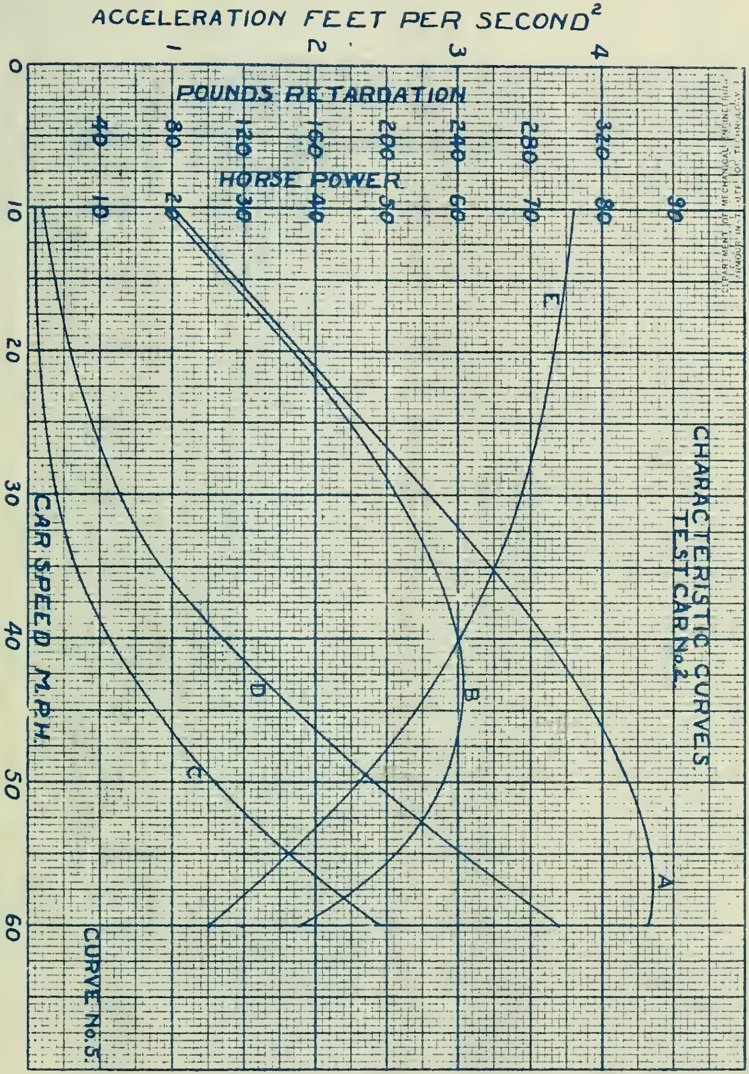
TEST CAR No.2.

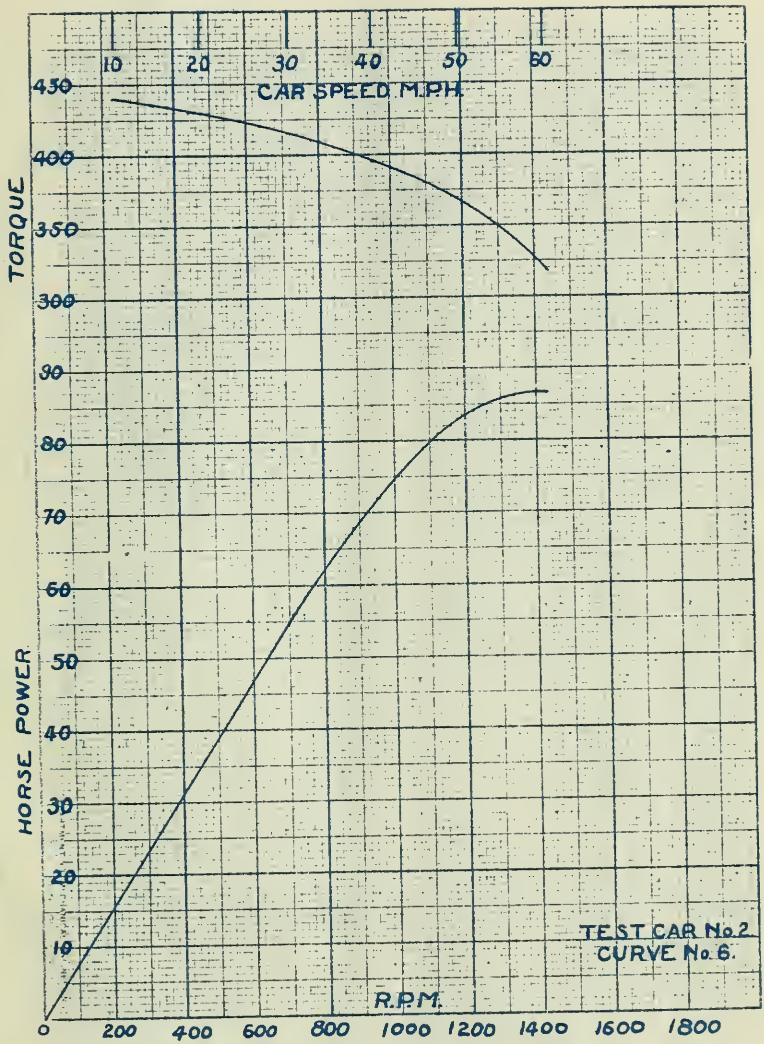
M.P.H.	ACC FT SEC²	POUNDS RET.	H.P. TO ACC.	H.P. TO DRIVE	D.H.P.
10	3.80	8	19.5	0.5	20.
20	3.65	24	37.0	1.0	38.
30	3.45	52	51.0	4.0	55.
40	3.00	122	60.0	12.5	72.5
50	2.80	192	58.0	26.0	84.
60	1.25	292	37.5	49.0	86.5

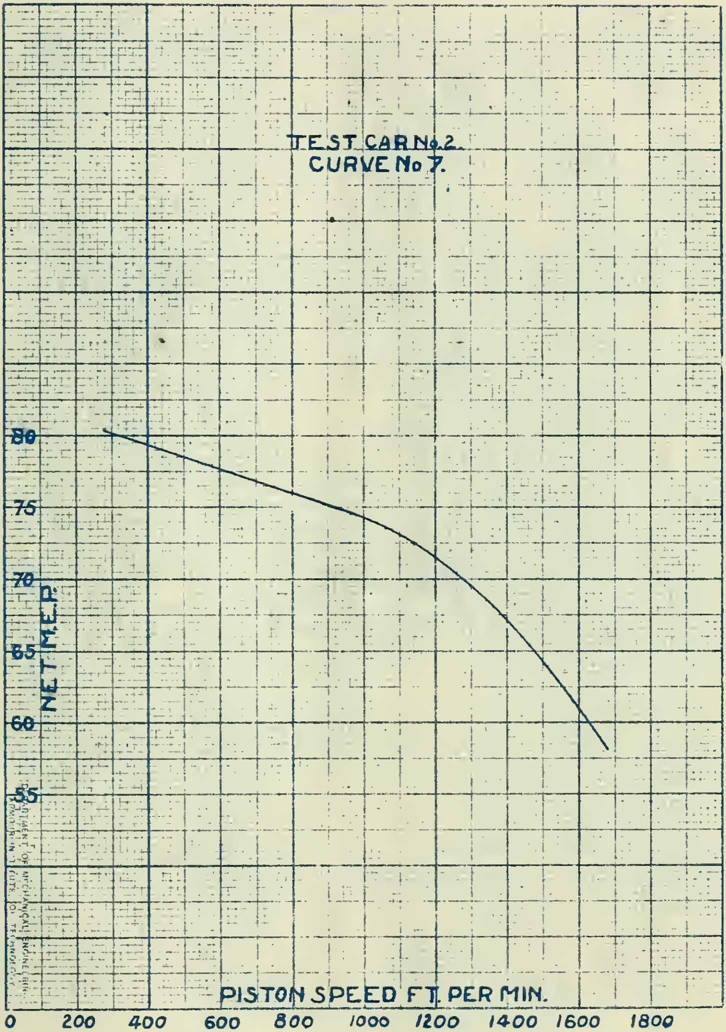
TABLE No. 4.

TEST CAR No. 2.

M.P.H.	D.H.P.	R.P.M.	TORQUE	PIS. SP. FT. MIN.	NET M.E.P.
10	20.	238.5	440	278	80.5
20	38.	477.	418	556	76.0
30	55.	716.	411	836	75.0
40	72.5	955	397	1140	72.5
50	84.	1190	369	1388	67.9
60	86.5	1430	318	1668	58.1


ACCELERATION FEET PER SECOND²
1
2
3
4
POUNDS RETARDATION
40
80
120
160
200
240
280
320
HORSE POWER
10
20
30
40
50
60
70
80
90
0
10
20
30
40
50
60
CAR SPEED M.P.H.
CHARACTERISTIC CURVES
TEST CAR No. 2
A
B
C
D
E
CURVE No. 5
DEPARTMENT OF MECHANICAL ENGINEERING


10
20
30
40
50
60
CAR SPEED M.P.H.
TORQUE
450
400
350
300
90
80
70
60
50
40
30
20
10
HORSE POWER
TEST CAR No. 2
CURVE No. 6.
R.P.M.
0
200
400
600
800
1000
1200
1400
1600
1800


TEST CAR No. 2.
CURVE No 7.
NET M.E.P.
80
75
70
65
60
55
PISTON SPEED FT. PER MIN.
0
200
400
600
800
1000
1200
1400
1600
1800
DEPARTMENT OF MECHANICAL ENGINEERING
ARMOUR INSTITUTE OF TECHNOLOGY

P A R T IV.

CONCLUSION.

During this investigation of the performance of motor cars with the accelerometer, many factors arose that could not be given a separate chapter in this thesis.

In the test work it was found that if the instrument was placed parallel to the direction of motion, the deflection shown by needle would indicate the amount of acceleration of the car or car body in a direction perpendicular to the direction of motion. This will be designated as body swaying.

If a comparison is wanted between different cars, in regard to body swaying or the same car equipped with different types of spring suspension, the accelerometer will be found to be very useful, in that it records directly the amount of side swaying.

In order to show the application of the accelerometer to fields other than that

of the motor car, diagrams were taken from electrically operated railway trains. These diagrams will be found enclosed in the envelope at the rear of this thesis.

Diagram #3 shows a complete graph from 55th street to 12th street, taken from a South Side Elevated Railway train. This train consisted of four cars, each of which was motor driven with unit multiple control.

From such a diagram can be obtained the accelerating power of trains, also the braking rate. The time required for station stops, and the time required for run between stops.

Diagram #4 was taken from surface car #3036 of the Chicago Surface Lines. The applications as mentioned above applies also to use of the accelerometer for surface railway work.

In addition to above, the accelerometer is useful to determine the correct rate of

acceleration and braking rate of the car for the comfort of the passengers, also to determine the time of stop per passenger loaded or unloaded.

Only a description of a few of the tests that have been made during the study of the accelerometer are found within this thesis; but the general conclusions which have so far been reached may be sumed up as follows:-

1. By the use of the accelerometer the road resistance of different kinds of roads or tracks, under various weather conditions can be measured and compared.

2. The amount of air resistance due to various forms of vehicles can be at once determined.

3. The mechanical and thermal efficiency of the engine at various speeds can be obtained under actual working conditions.

4. The brake horse power exerted by the engine when running at various speeds can be

obtained under actual working conditions.

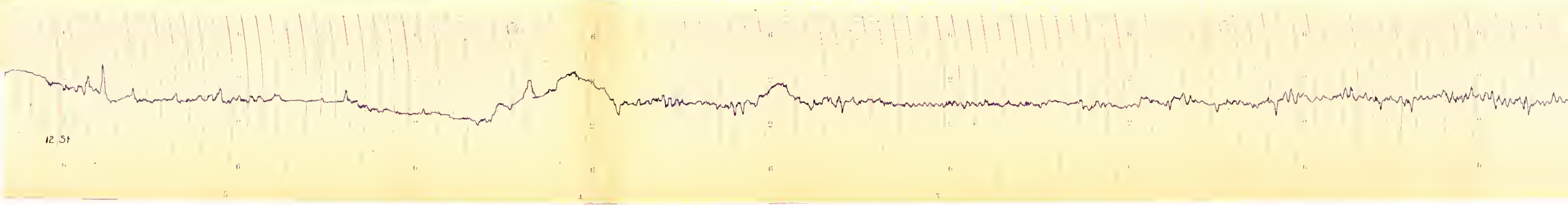
5. It is possible to trace step by step the losses of power in transmission.

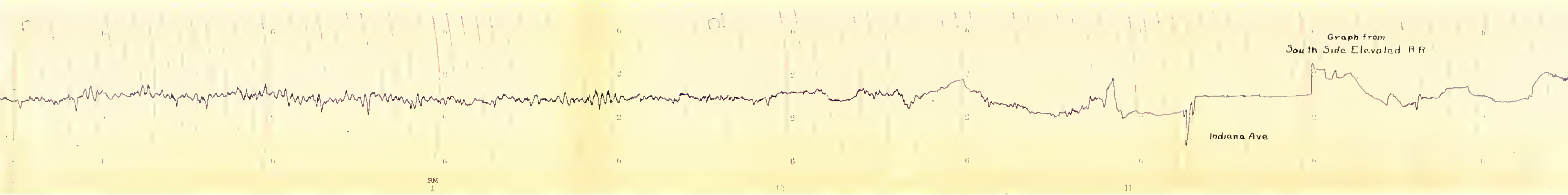
6. It is possible to make a definite allowance for motor vehicles which are specified to show a given fuel economy, and which may have to run their tests on exceptionally heavy roads.

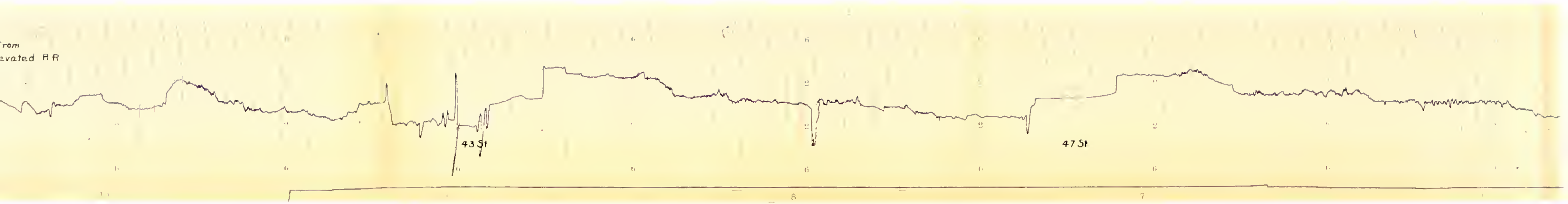
7. Finally the use of the accelerometer enables a useful interpretation to be given to speed and efficiency tests, which are carried out on specially prepared motor tracks, having characteristics different from those of the ordinary highway, at unrestricted speeds.

B I B L I O G R A P H Y.

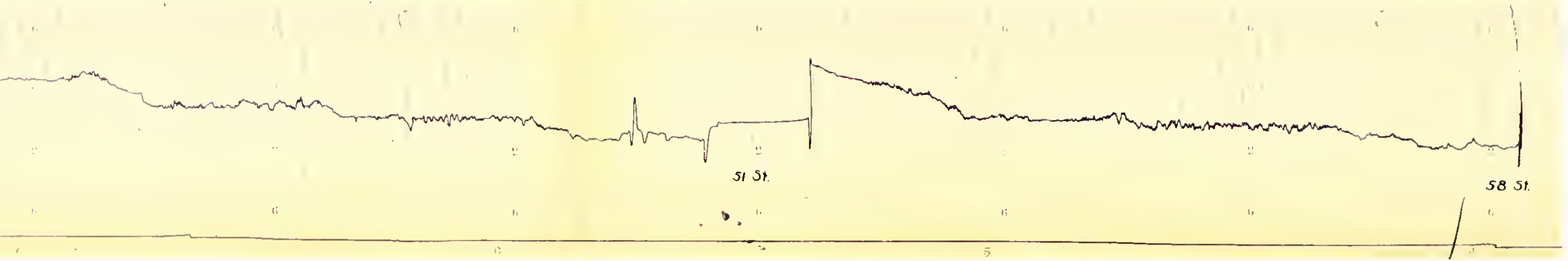
58 St.


12 St


Graph from
South Side Elevated R R
Indiana Ave
RM



From
Elevated R R
43 St
47 St


51 St.
58 St.


Graph from
Chicago Surface Lines
Car No. 3036
S. State Street