6-1922

Investigation of the Effect of the Temperature of Intake Air on the Economy and Torque of a Gasoline Engine

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Investigation of the Effect of the Temperature of Intake Air on the Economy and Torque of a Gasoline Engine

Abstract

The object of this investigation is to make a study of the effect, on the economy and torque of a gasoline motor, of heating the air going to the carburetor.

The knowledge gained from such an investigation is of considerable importance and might be used in determining the temperature at which to supply air to the carburetor of a motor in order to get the best results under its working conditions. General practice indicates that a motor will run more smoothly and first regularly when the temperature of the intake air is 150 degrees or more. The theory is that up to a certain point, the economy becomes better with increasing air temperatures. The brake horsepower, however, falls off as the temperature is raised.

Assuming then that we have an unlimited heating source, it is our purpose to find the best temperature to use in order to obtain the highest economy without seriously reducing the torque. Also the effects at various loads and speeds will be considered. With the poor grade of gasoline now being supplied, this investigation should be of the utmost value.

Disciplines
Automotive Engineering | Heat Transfer, Combustion | Mechanical Engineering

INVESTIGATION OF THE EFFECT OF THE TEMPERATURE

OF INTAKE AIR ON THE ECONOMY AND TORQUE

OF A GASOLINE ENGINE.

A Thesis Submitted to the Faculty of The

Towne Scientific School of

The University of Pennsylvania

for the

Degree of Bachelor of Science

in

Mechanical Engineering

by

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and

John H. Carter

June, 1922.

CONTENTS.

INTRODUCTION.

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DESCRIPTION OF APPARATUS.

The motor used was a 4" x 5", four cylinder teeter engine: rating - 30 H.P. at 1200 R.P.M.

A Sprague electric dynamometer was used to load the engine and to measure its output.

The motor was set up on adjustable test blocks and a connection made to a main for cooling water. A thermometer was placed at the outlet of the water-jacket so that the temperature of the water leaving could be noted. The fuel tank was mounted on a scales and connected with the motor by a flexible tube. A pipe was attached to the air intake of the carbureter and carried over a row of bunsen burners. The temperature of the air passing thru the pipe could then be adjusted at will by lighting the required number of burners. A thermometer inserted in the air line at the entrance of the carbureter enabled the temperature at this point to be observed. The dynamometer field was so mounted on trunnions, that a scales attachment enabled data to be taken from which the torque could be calculated.

The accompanying photographs show the general arrangement of the apparatus.

A. Gasoline tank on scales.

B. Stove to heat intake air.

C. Thermometer at entrance to carbureter.

D. Dynamometer.

E. Scales for measuring torque.

F. Automatic revolution counter.

G. Automatic stop-watch.

H. Rheostat for varying load on engine.

CONDUCT OF THE TEST.

In making runs to obtain the actual data, it was first necessary to decide what quantities were to be maintained constant, and what quantities were to be varied. The temperature of the cooling water was maintained throughout as nearly as possible at 150° Fahrenheit. Runs were made for five different temperatures of the air entering the carbureter, ranging in equal steps, from 90° to 170° Fahrenheit. For each temperature of the air, runs were made at four different positions of the throttle. With values assigned to the two above variables, runs were made at three or four speeds, and data were recorded of fuel consumption, torque, and speed. The speed was varied by changing the load. The carbureter was adjusted to the point which gave the best running conditions for the engine for each different temperature of intake air.

The effect of opening the throttle of a carbureter is to increase the suction and thus draw more gas through the jet. For this reason, the percentage of suction at any position, based on the suction for wide open throttle, is a better measure of the throttle opening than the position of the throttle lever. Moreover, a change of speed has a slight effect on the suction and the throttle should be changed to bring

back the suction to the assigned value. This effect
would not be visible if the throttle opening were ad-
justed placing the lever in different positions.

FORMULAE.

H.P. (output of motor) $= \dfrac{R.P.M. \times W^{lb.}}{4,000}$

in which $\qquad W$ = load on dynamometer

scales in lbs.

and 4,000 is a constant for the dynamo-

meter and is equal to $\dfrac{33,000\#}{2\pi R}$

Fuel lb./B.H.P.-hr. $= \dfrac{(W_2 - W_1) \times 60}{T \times B.H.P.}$

where $\quad T.$ = the time in minutes in which

$W_2 - W_1$ pounds of fuel are used.

Torque ft.lb. $= W^{lb.} \times 1.314$

where 1.314 ft. is a constant for the machine

and is the effective radius at which the force

W is applied.

$\dfrac{33,000}{2\pi \times 4,000} = r = 1.314$ ft.

SAMPLE COMPUTATIONS.

$$H.P. = \frac{1400 \times 27.5}{4,000} = 9.61 \quad B.H.P.$$

$$\text{Fuel lb/B.H.P.-hr.} = \frac{(35.1 - 33.9) \times 60}{.603 \times 9.61} = 2.07 \text{ lb.}$$

$$\text{Torque - Foot - pounds} = 27.5 \times 1.314$$

$$\text{Torque} = 36.2 \text{ Foot-pounds.}$$

EXPLANATION OF CURVES.

Having obtained sufficient data, the first step was to plot B.H.P. against speed as shown in Fig. (3). A separate sheet was used to show the results at each temperature. By plotting values for each of the throttle positions, we have a method of obtaining four values of B.H.P. at any desired speed. It was found that 1,000 R.P.M. gave the best results for this engine.

In the same way as for the B.H.P. the Fuel consumption curve was plotted as shown in Fig. (4). Having chosen 1,000 R.P.M. values for fuel consumption were plotted against the corresponding values of B.H.P. and the five curves shown in Figure (5) were obtained.

The next step was to choose any desired H.P. from the curve in Figure (5) and find the pounds per hour of fuel corresponding to the different temperatures. Dividing these values by the chosen B.H.P. converts to pounds per B.H.P.-hour. Figure (6) shows the curves obtained by plotting these values of fuel rate of consumption against the corresponding temperatures for three values of B.H.P.

Figure 7 shows a specimen of the preliminary curves of torque against speed and were drawn in the same manner as for the B.H.P. and the fuel curves.

Figure 8 is the same curve as Figure 7 but it shows the curves at one throttle position for

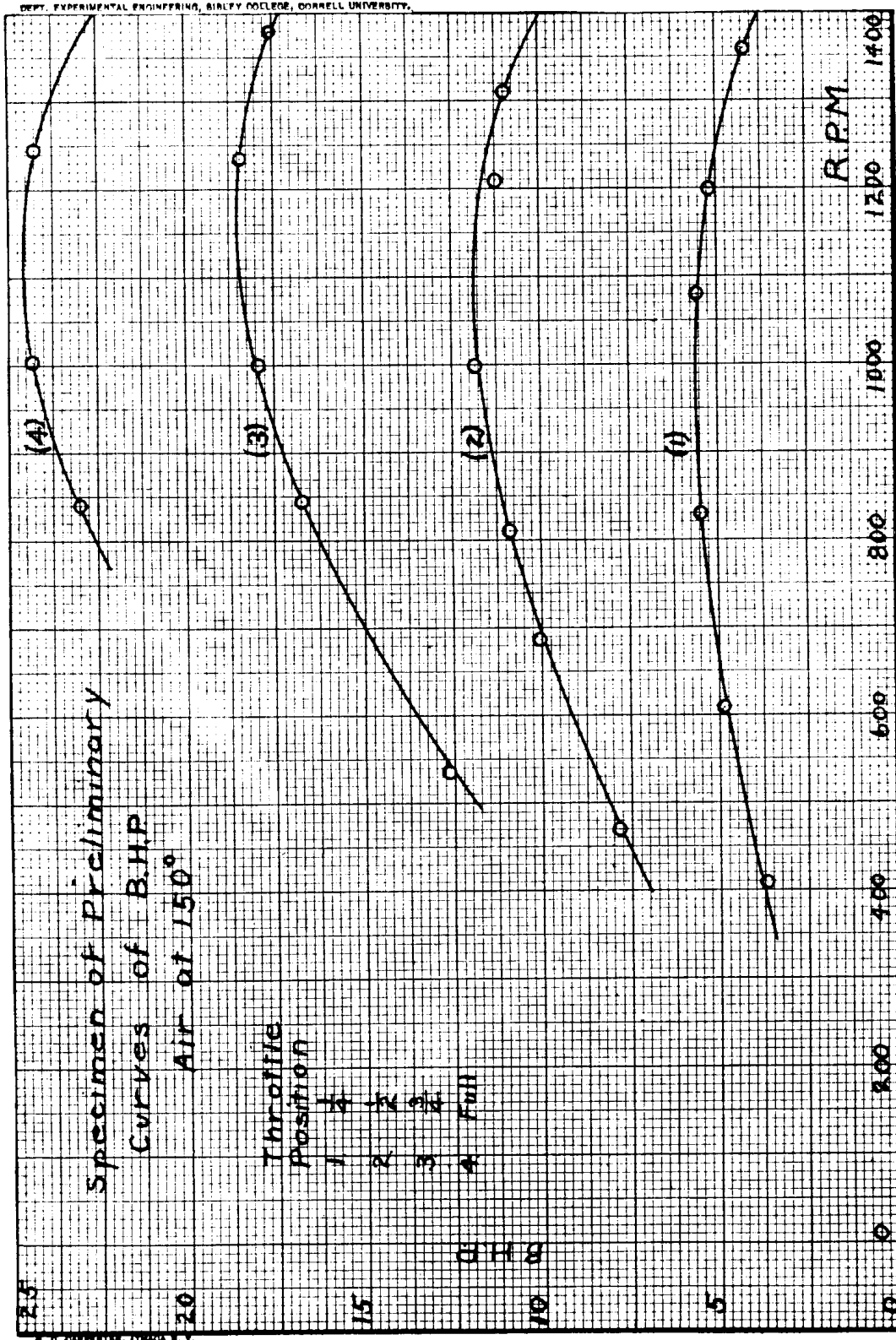temperatures on the same sheet.

Figure 3.

Figure 4.

13.

Figure 5.

Figure 6.

DEPT. EXPERIMENTAL ENGINEERING, SIBLEY COLLEGE, CORNELL UNIVERSITY

Specimen of Torque Curves
against Speed
Air at 150°

Throttle
Position

1. ¼
2. ½
3. ¾
4. Full

(4)
(3)
(2)
(1)

Torque — Foot — Pounds

140
120
100
80
60
40
20
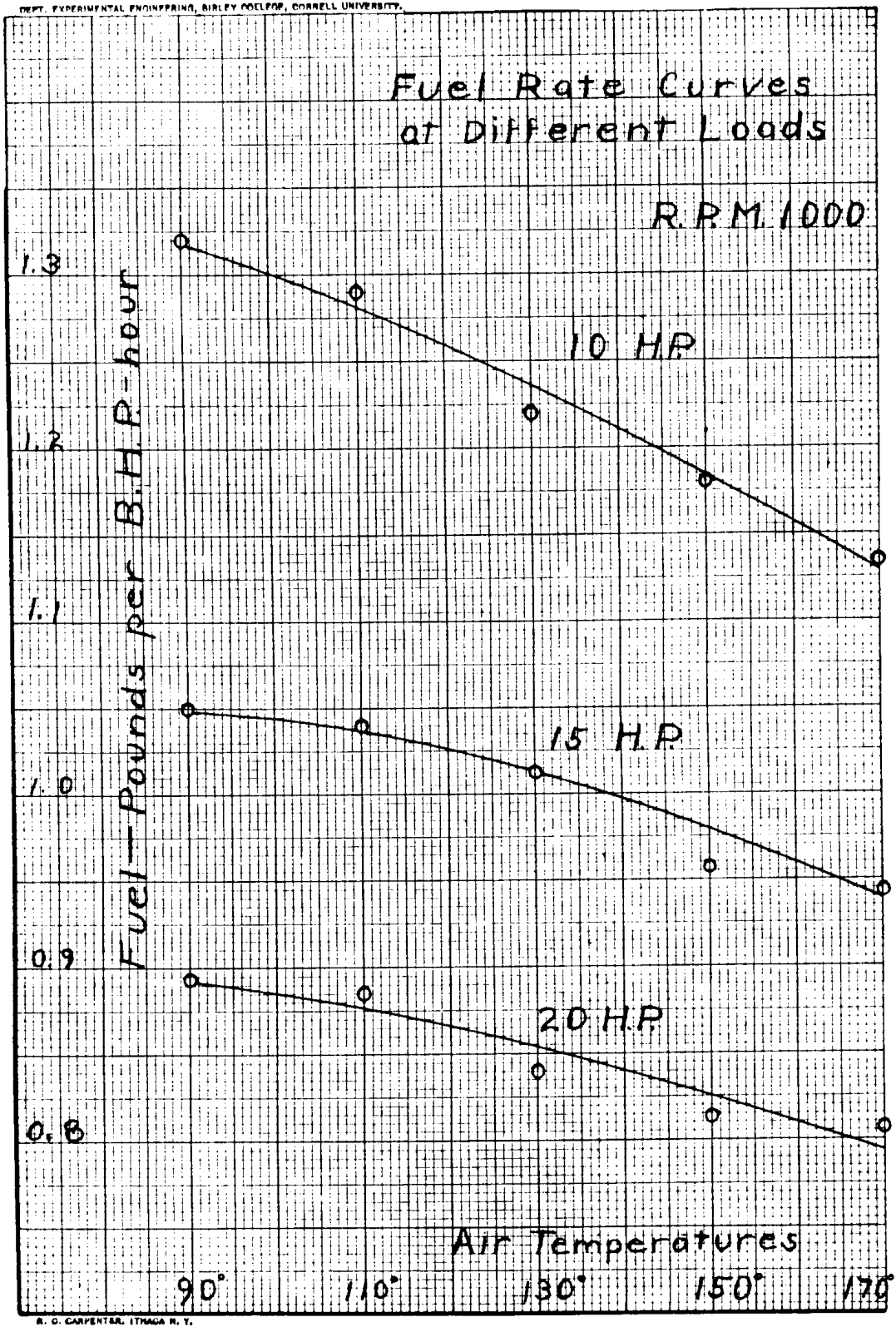0

R.P.M.

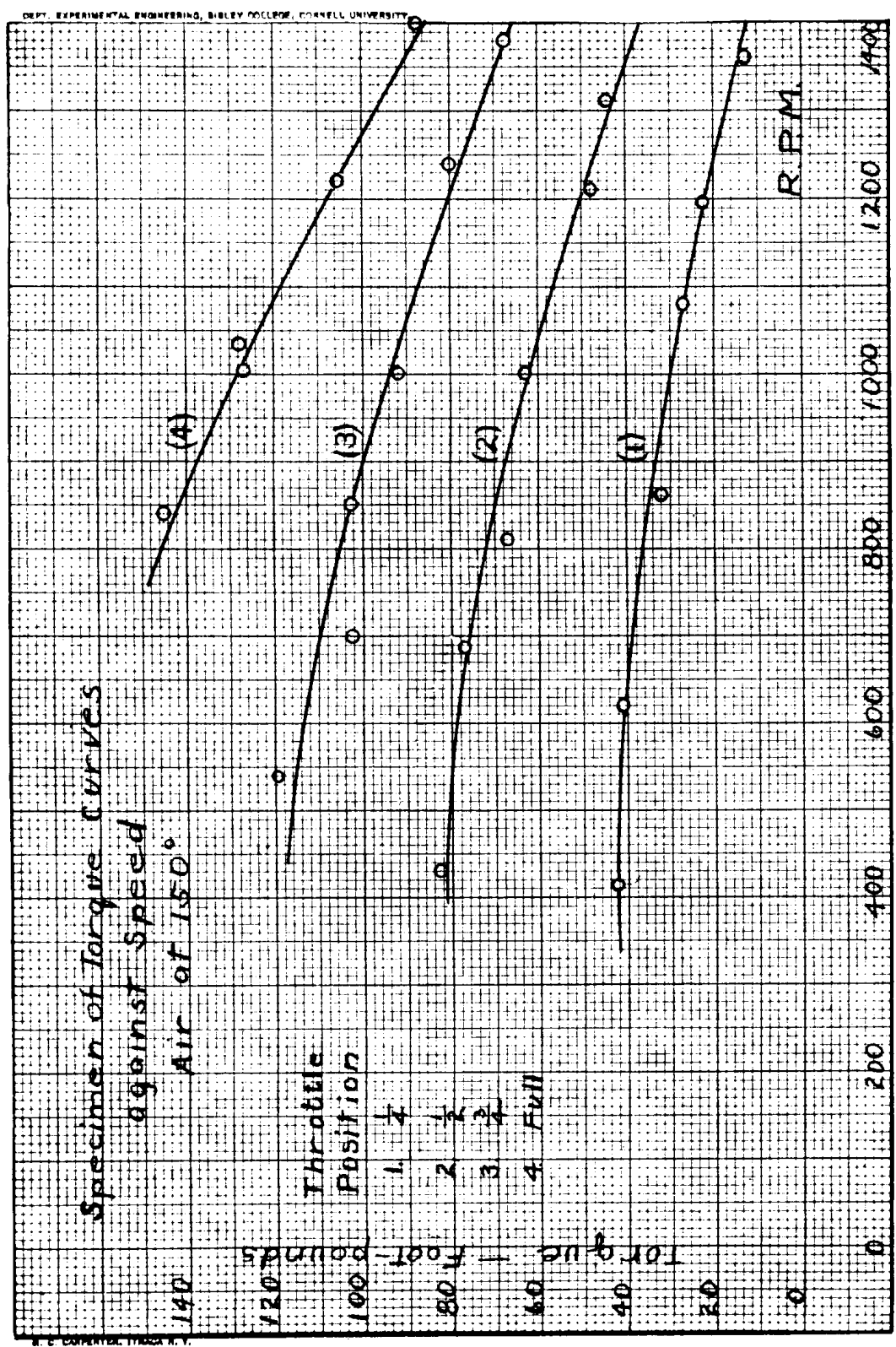0   200   400   600   800   1000   1200   1400
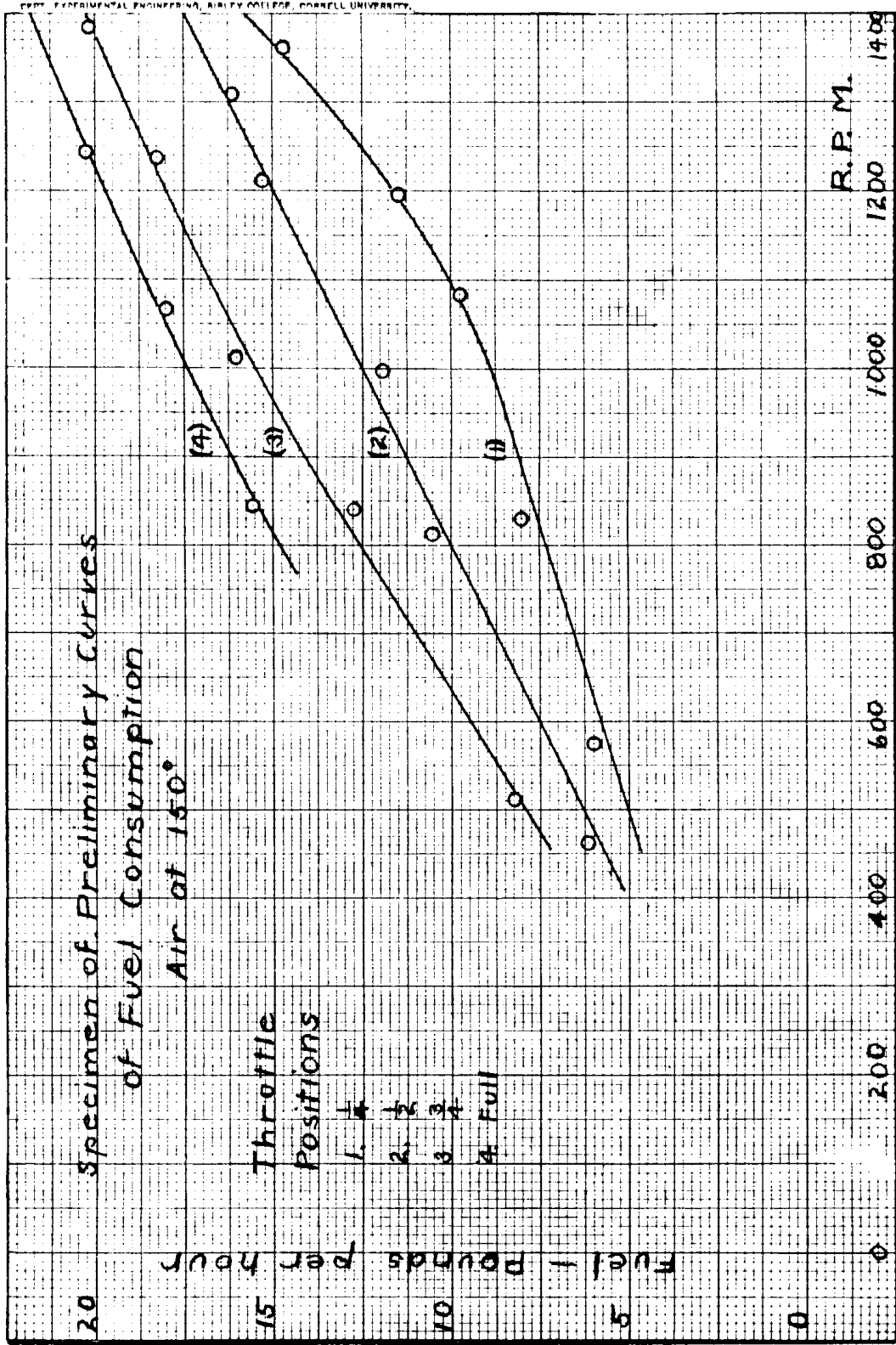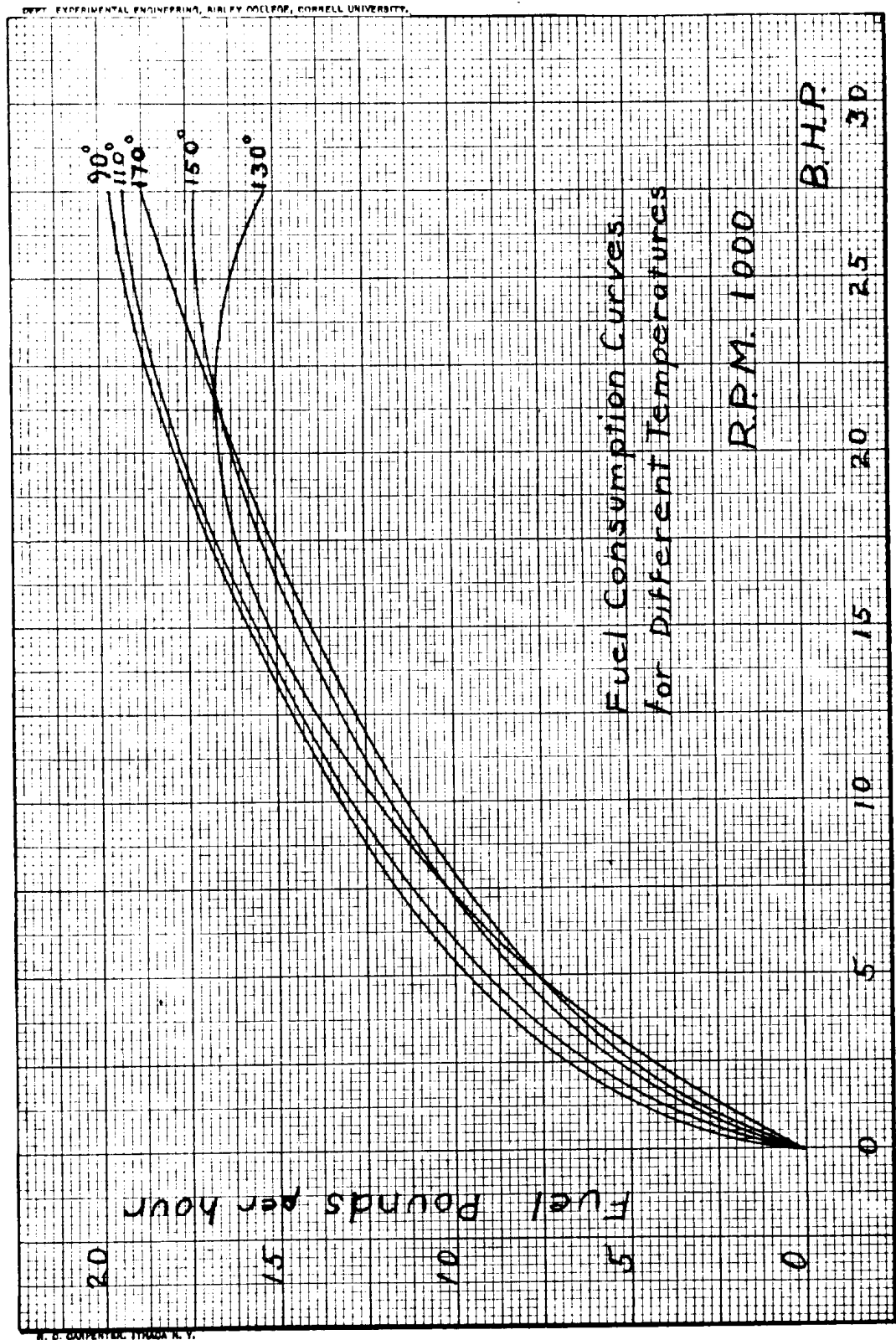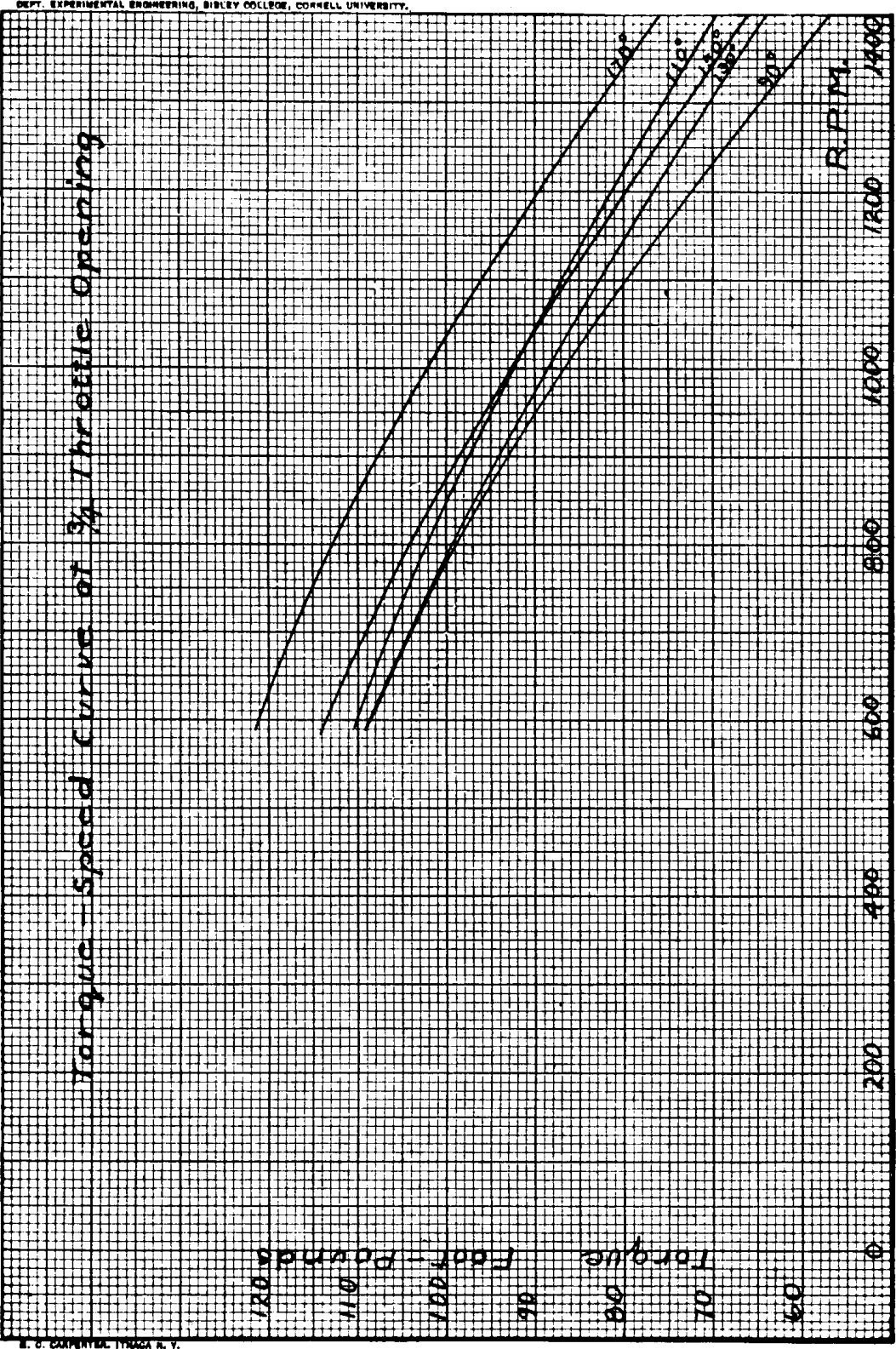
Figure 7.

. Figure 8.

DISCUSSION AND CONCLUSIONS.

ACCURACY OF THE TESTS AND RESULTS.

Little can be said in favor of this investigation from the standpoint of accuracy. The variation in the economy and torque due to the change in the temperature of the intake air may be expected to be very small at best. In order to detect this accurately, it is essential that the operating conditions be as nearly constant as possible. Unfortunately the apparatus in the laboratory is so arranged that a number of internal combustion engines exhaust into a common main with a single exhaust head. The result is that the back pressure in the exhaust main varies with the number and speed of other engines running at that time. As an illustration of how pronounced is the effect of this variable back pressure - the engine used in this test was racing under a medium load and was then made to stall by simply speeding up another engine exhausting into the common line. This back pressure varied thruout all our runs and is sufficient, in my estimation, to account for almost any discrepancy in our findings and to make our results anything but reliable.

Another source of error was the violent vibration in the apparatus. The motor used was in extremely bad condition. The bearings and bushings were loose

and occasionally the engine knocked violently. The spark had to be fully retarded at all times, During the test, one of the connecting rods bearings was actually pounded to pieces and had to be replaced. Needless to say, this engine had a much more than average vibration. The test block should have been on a concrete foundation. Instead, it was resting on rubber pads on a pavement, which in turn, had a very poor foundation itself. The result of this was that everything in the vicinity of the motor had a most pronounced vibration transmitted to it. The greatest error caused by this was in the matter of weighing the fuel. The fuel scales were mounted on one of the supporting columns of the building in an unsuccessful effort to avoid vibration. A certain amount of vibration was also transmitted thru the gasoline pipe, in spite of a section of rubber tubing inserted in the line. The effect of this vibration was that frequently the scale beam instead of coming smoothly to the horizontal position, would bob up and down and touch off the electrical devices for timing the runs and counting the revolutions, at random. Thus the weight of fuel $W_2 - W_1$ was not always the quantity actually used during the time indicated on the stop-watch and for which the revolutions were counted.

Still another major source of error was the

condition of the gasoline and the fuel line. The gaso-
line was very dirty and at times had a large percentage
water in it. It seemed to be impossible to keep a
certain amount of this from getting into the fuel tank.
The gasoline pipe itself had a heavy scale on the in-
side that would break loose and be washed down into the
fuel. This caused a lot of trouble by making the engine
backfire and occasionally stall. At times it was nec-
essary to stop and clean out the carbureter as many as
three or four times during the course of a day. It
goes without saying that the runs made just before the
carbureter was cleaned would be under different condi-
tions in regard to richness of mixture, from those made
just after.

The above mentioned and many other differences
in the conditions under which the tests were made, have
all helped to make the results inaccurate.

CONCLUSIONS TO BE DRAWN FROM

THE RESULTS.

As regards the saving of fuel obtained by
heating the intake air the results show conclusively
that the rate of fuel consumption in pounds per brake-
horse power hour, decreases rapidly with the increasing
air temperature. A study of Figure 6 shows that at
20 H.P., the saving in the short range from 90° to
170° amounts to 11.1% and at lesser loads amounts to
over 25%. The question now arises, why not heat the
air to still higher temperatures? The curves seem to
indicate that the fuel saving will continue to in-
crease, the hotter the air. This, however, is not the
case. Although, we have no results to prove it, the
curve would probably rise soon after 180° is reached.
Experiments at Purdue University show that temperatures
higher than 180° have no further beneficial effect on
the fuel and this would cause the curve to flatten out.
But since the volumetric efficiency is reduced by
heating the charge, this would cause the brake-horse
power to decrease and hence the curve would rise again.

However, in ordinary automobile service, the
method used to heat the air is usually to use the ex-
haust heat of the engine. With this method it would
be hardly possible to obtain higher temperatures than

170°. Any other plan for burning fuel solely to heat the air would not give any total gain in efficiency.

Thus the curves in Figure 6 show that the effect of the temperature was greater in reducing the fuel consumption than in reducing the brake-horse power. But, as explained in the introduction, it was the intention to find the effect on the torque independent of the effect on the fuel.

Figure 7 shows the preliminary curves for one of the temperatures, a typical torque-speed curve. In Figure 8 we have all the curves at one throttle opening for the different temperatures, drawn on the same sheet. The reason for choosing one throttle opening originally was to have the same amount of gas drawn into the charge at any one speed. However, it was found necessary to make different adjustments on the carbureter at the different temperatures, hence the weight of charge drawn in was not affected by the temperature of the mixture alone. For this reason consistent results were not likely and the curves shown in Figure 8 do not bear out the theory when plotted in this way. Data should have been taken on the quality of the mixture and by choosing a constant ratio of air to gas, the desired results would have been obtained in a study of the torque.

In spite of the failures in some lines, the

results should convince the owner of a gasoline engine
of the importance of supplying hot air to the carbure-
ter.

COMPLETENESS OF THE INVESTIGATION AND
RECOMMENDATIONS FOR FURTHER RESEARCH.

As stated above, this test was conducted between the temperature limits of 90° and 170° F. To be really complete, the air temperature should have been carried up to about 300° and down to about 60°F. This would make it possible to draw more accurate curves showing variations with temperature, because there would be more points and any one incorrect point would introduce a smaller percentage of error. Also the variation in the fuel consumption per degree is greater in the vicinity of 90* than with the higher temperatures. Therefore, it would be interesting to carry the air temperatures down to the low figure suggested above. In this test temperature limits were used that would be easily obtainable if the engine were in operation in an automobile. For a complete investigation, however, the increased limits would give much more definite conclusions.

In regard to recommendations for further research, we have to suggest·in addition to the increased temperature limits, only that the defects in the arrangement of the apparatus mentioned under "Accuracy of Tests, etc." be remedied. The dynamometer equipment itself is excellent and if this were used with a motor in good repair and operating under stabilized conditions,

there is no doubt that authoritative results could be obtained.