REPORT No. 48.

CARBURETING CONDITIONS CHARACTERISTIC OF AIRCRAFT ENGINES.[1]

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RÉSUMÉ.

Tests have been conducted at the altitude laboratory erected at the Bureau of Standards for the National Advisory Committee for Aeronautics to determine the changes in engine performance with changes in atmospheric temperature and pressure at various levels above the earth's surface, with special reference to (*a*) the variables affecting the functioning of the carburetor and (*b*) the changes in performance resulting from variables in the carburetor itself. This work has resulted in the following conclusions:

(1) Mixture ratio $\left(\frac{\text{air}}{\text{fuel}}\right)$ should be constant at all pressure levels, for maximum power at all levels.

(2) Change in viscosity of fuel with temperature change may be an important metering characteristic of the carburetor.

(3) Unwarranted waste of fuel is invariably involved in the use of carburetors not fully corrected for barometric changes.

(4) Heating of the mixture causes a loss in power output accompanied by an increase in the specific consumption of fuel (lb. gasoline/brake horsepower/hour), at least with such fuels as are available for war purposes.

CARBURETING CONDITIONS CHARACTERISTIC OF AIRCRAFT ENGINES.

The following results are offered as characteristic of the conditions surrounding the carbureting system of an aircraft engine. The whole is indicative of the changes experienced following those variations in barometric pressure encountered in the service operation of such engines.

Briefly, the purpose of this report is merely to summarize certain of the performance characteristics of an aircraft engine, to be followed later by a detailed investigation and report on the carburetion requirements and means for satisfying them in this service.

All of the tests from which the following material is taken were made in the altitude laboratory at the Bureau of Standards, employing a 150-horsepower Hispano-Suiza, type A engine, having eight cylinders in blocks of four, set at 90°:

Bore 120 mm. (4.73 inches).
Stroke=130 mm. (5.124 inches).
Compression ratio $\left(\frac{\text{Total volume}}{\text{Clearance volume}}\right)=5.3.$

A constant speed of 1,500 revolutions per minute (the speed of maximum mean effective pressures) was maintained throughout the runs.

It is known that the values of the air readings used in the following plottings are somewhat high; and, for this reason, it is pointed out that the results including air/fuel ratios for the mixtures should be employed qualitatively rather than quantitatively, though the results are in perfect agreement among themselves.

[1] This Report was confidentially circulated during the war as Bureau of Standards Aeronautic Power Plants Report No. 10.

The graphs used are described as follows:

Plot 1.—Curve a, altitude, in feet above sea level, versus barometric pressure; and curve b, temperature (mean annual) versus altitude in feet above sea level.

Plot 2.—Engine pumping capacity in pounds of air per hour per 100 cubic feet of piston displacement, with open throttle, versus barometric pressure. The points on this curve are means of a great many measurements using a carburetor capable of giving maximum output over the whole range of pressures; and while the readings are known to be high, as noted in the introduction, the characteristic is quite definitely established. It will be noted that the curve quite pronouncedly turns upward as the pressure becomes less. This follows from the fact that the pressure drop to cause air to flow at constant velocity is less with lesser density, thereby permitting the aspiration of proportionately greater volumes of air as the density value lowers. The graph, plot 3, showing manifold pressure drop plotted against barometric pressure, in this case carburetor inlet pressure, is characteristic of the variation in pressure drop to cause air to flow in the intake system with changes in atmospheric density.

Plot 4.—Pounds of gasoline (0.7350 sp. gr.) per hour per 100 cubic feet piston displacement, with open throttle, versus barometric pressure. The fuel used in these tests is described by the fractionation curve of plot 5. In plot 4 is shown the manner in which conventional carburetors, designed for compensation in the ordinary sense at ground level, cause enrichment of the mixture with lowered atmospheric pressure. Curve a is from tests of a device having a manual control reset to give greatest power output at each barometric level. Curves b, c, d, and e are results with several carburetors, some of which embody a measure of correction for enrichment with lowered density. Curve L is calculated from the equation:

$$Q_1 = Q\sqrt{\frac{P_1}{76}}$$

in which Q = the quantity of fuel discharged at sea level, Q_1 = the quantity of fuel discharged at any other level, corresponding to the pressure P_1. This equation assumes a constant value for the coefficient in the equation:

$$V = C\sqrt{2\,gh.}$$

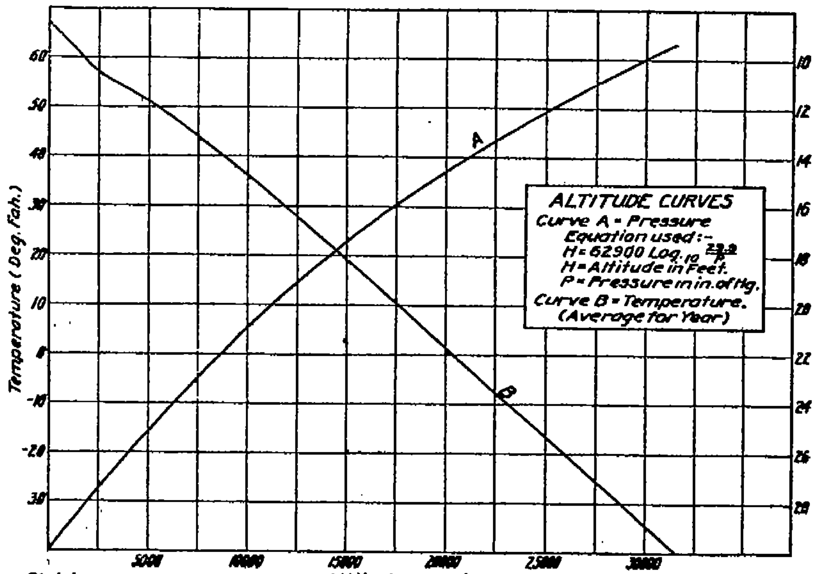
for the fuel metering passage. Curve g, plot 4, is that for carburetor (a), but with ground setting of the manual control at all barometric levels. The great waste of fuel resulting from the use of a carburetor uncompensated for wide barometric changes is obvious from the diagram, particularly when it is considered together with that of plot 7, wherein are given the brake mean effective pressures corresponding with the two rates of fuel consumption presented in curves a and d of plot 4.

The observed enrichments, expressed as per cent excess fuel in the mixture, for the several cases of plot 4, are plotted in plot 6, against barometric pressure.

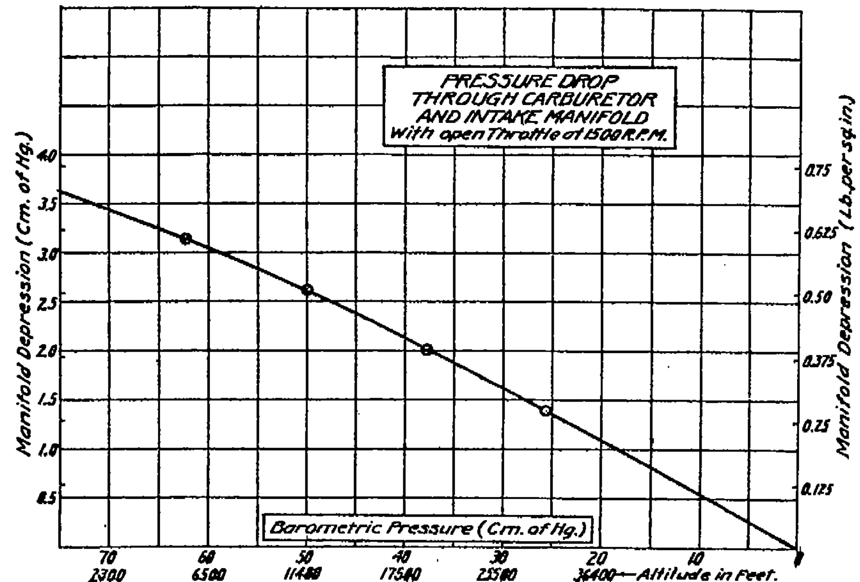
The considerable variations among the curves of plots 4 and 6 are largely the result of variations in the extent to which change in viscosity of the fuel with temperature enters the results. No two of the several carburetors used in these tests have identically proportioned fuel metering passages; hence it is to be expected that considerable differences will be apparent among the results, considering them from this viewpoint alone.

In plot 7—maximum brake m. e. p. versus barometric pressure—it is seen that no justification can be found for the fuel consumption rate of curve d, plot 4. Not only is fuel wasted at all levels and power lost above 14,000 feet altitude, but the mixtures are so rich at the greatest altitudes as to cause fouling of spark plugs and combustion chamber walls.

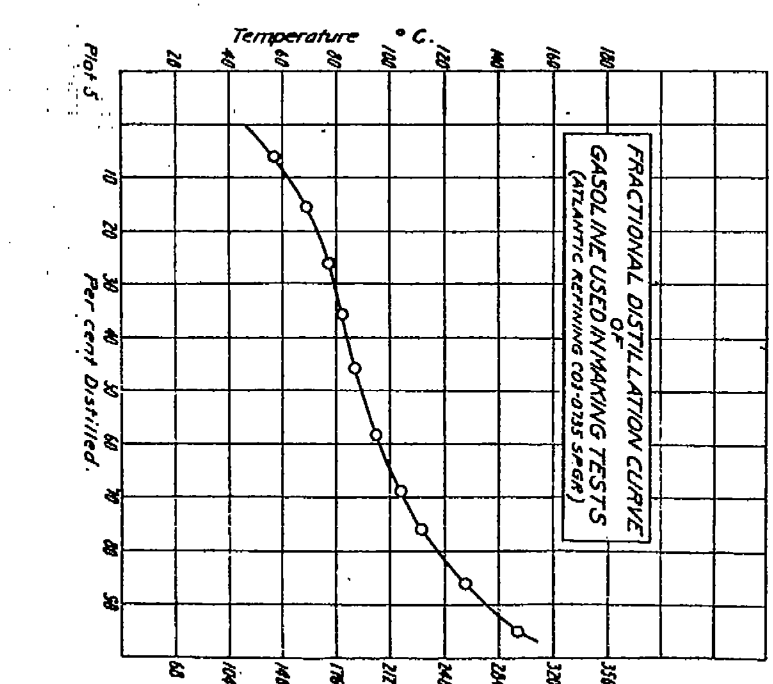
In plot 8 are presented the relationships between brake m. e. p. and mixture ratio, with the latter varied through wide limits at each pressure level. The important conclusion to be reached from this diagram is that maximum power output at each pressure level (operating at the rated speed of the engine), is secured with the same ratio of air to fuel in the mixture. Further, the mean cylinder pressures decrease more rapidly with a given change in the air-fuel ratio the lower the atmospheric pressure. This points to the need for much closer regulation of the mixture with lowered pressures as compared with the higher. (Note that the mixture ratio for maximum brake m. e. p.'s should have a somewhat lower value than indicated in this diagram, because of the too high air readings previously noted.)



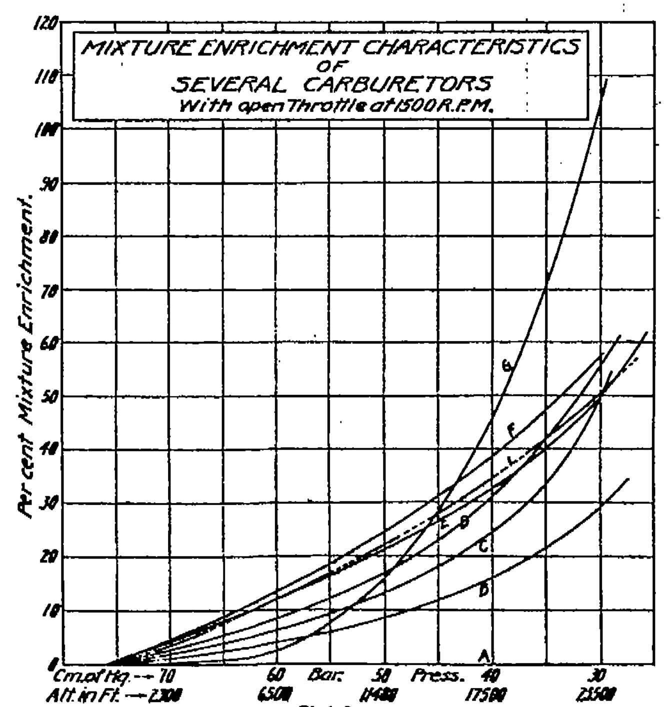
Plot 1



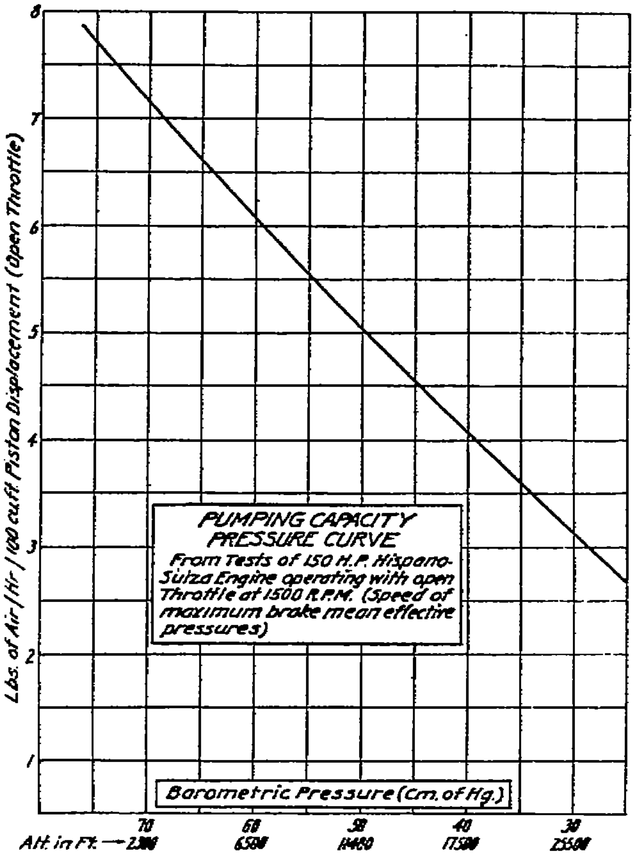
Plot 3.



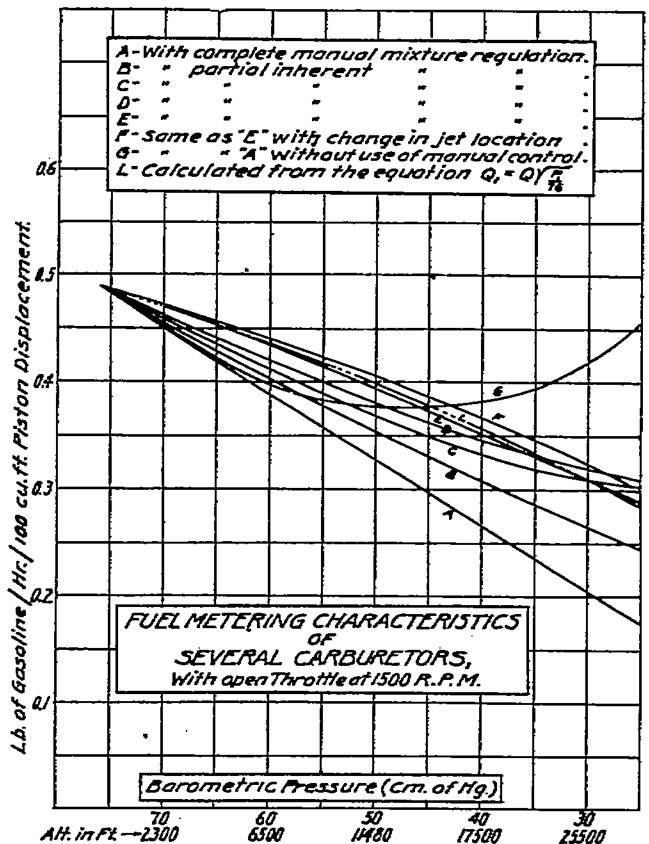
Plot 5



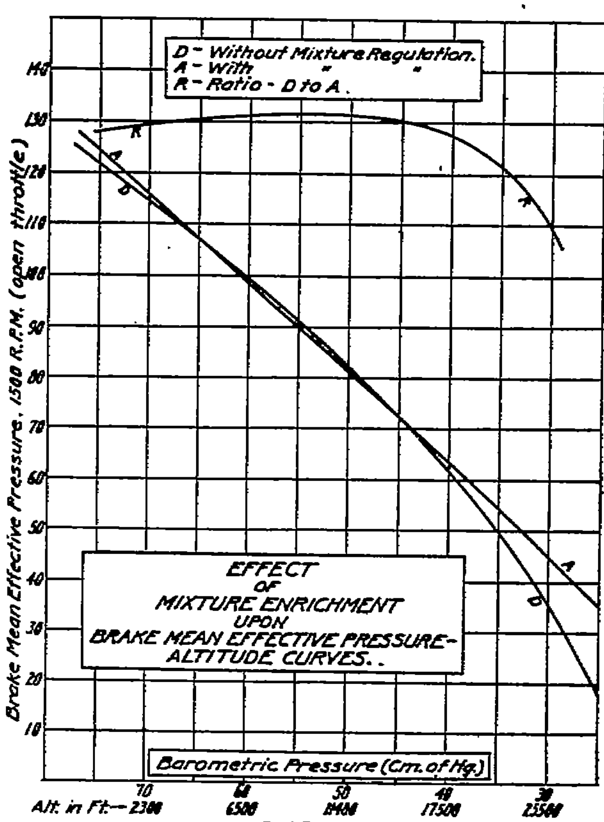
Plot 6.



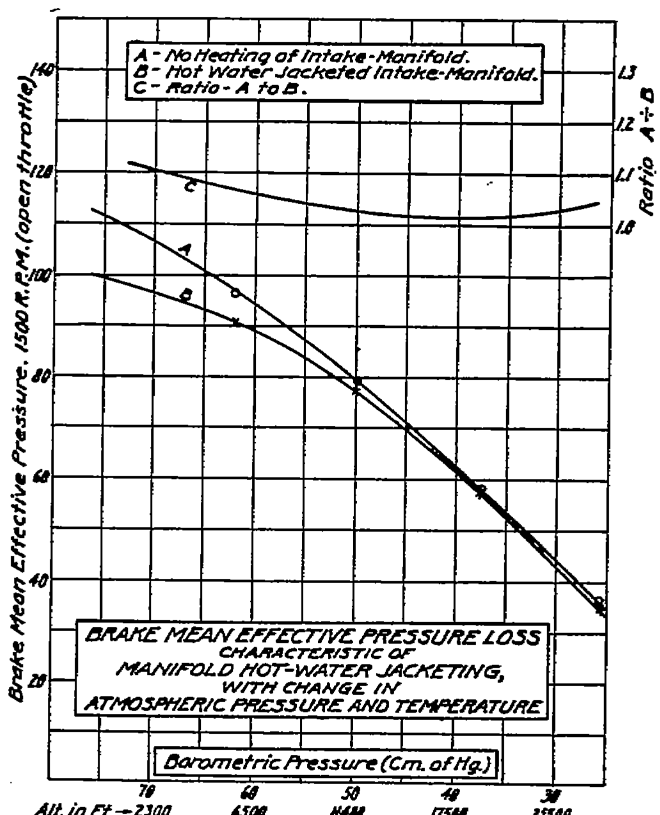
Plot 2.



Plot 4.



Plot 7.



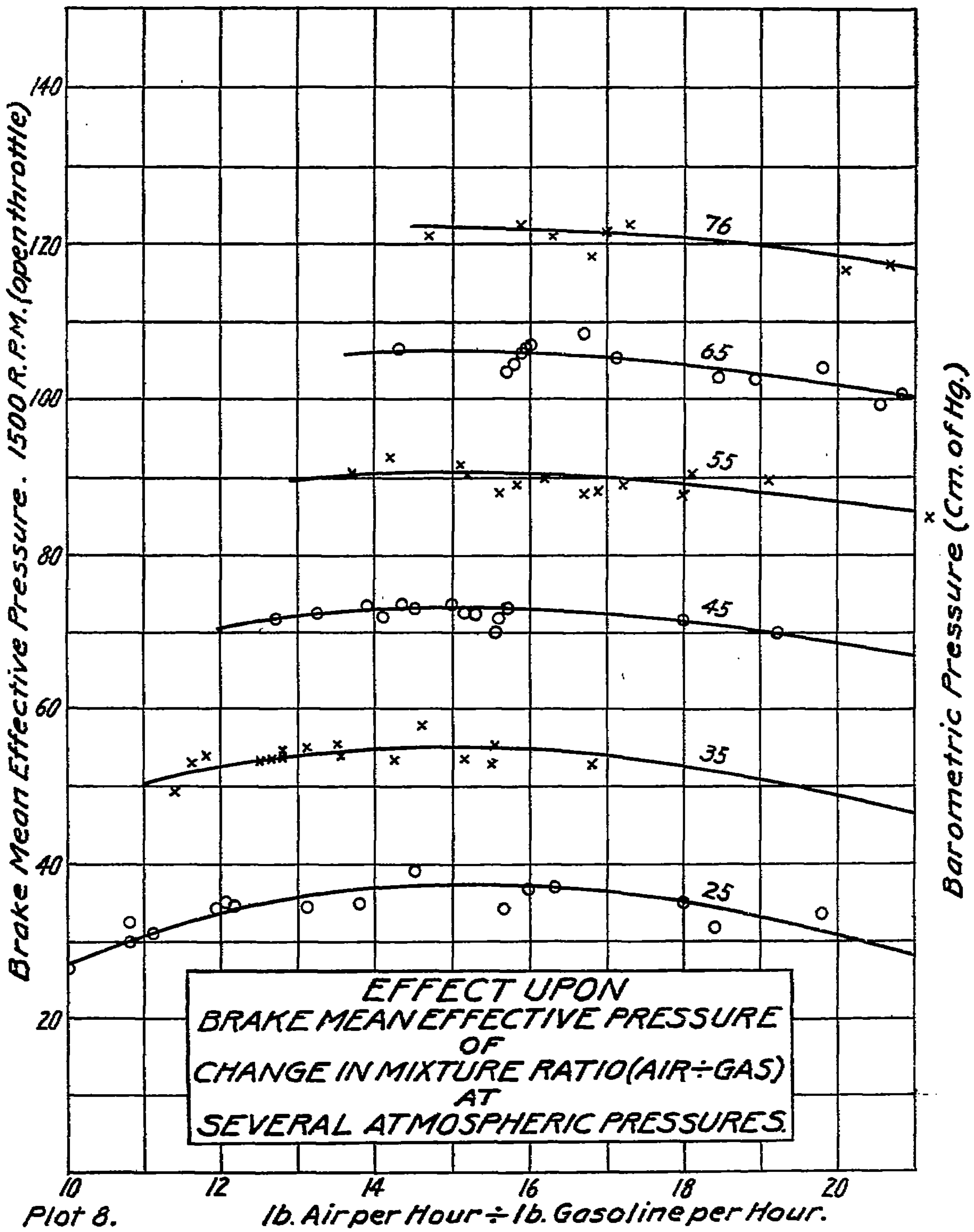
Plot 9.

The effect of hot-water jacketing of the intake manifold in the engine used (Hispano 150-horsepower) is shown for two sets of test runs in diagram plot 9, these two tests being fairly representative of the results found in other tests that have been made with this engine. The loss following jacketing of the manifold branching immediately above the carburetor is greatest at the greatest atmospheric pressure, which latter is accompanied by the highest atmospheric temperature, and becomes of relatively less importance, up to 17,000 feet altitude (note curve c, plot 9), as the atmospheric pressures and temperatures become lower.

In these tests a constant intake manifold water jacket temperature of 37° C. = 96.8° F. was maintained. In such a case the pumping loss in the engine following heating of the mixture will vary directly with the temperature difference between mixture and jacket and in an inverse manner with the mixture density.

This assumes that the whole of the heat given up by the constant temperature water jacket appears as sensible heat in the mixture. Of course, this is not realized, since some of the heat taken up by the mixture is used to evaporate the fuel and becomes latent. The proportion of the total heat received which is so used depends upon so many variables, considering different fuels and different carbureting methods, that it is impossible to state the two results in general terms. In any case, the net result only is of importance and its characteristic, as found in these tests, is shown clearly by the curves of plot 9.

It is noteworthy also that, in general, loss in output resulting from manifold hot-water jacketing is accompanied by greater fuel consumption values, regardless of carburetor design and method of control, and with fixed adjustment carburetor designs the economy loss following heating in this way may attain quite serious proportions.


Brake Mean Effective Pressure. 1500 R.P.M. (open throttle)
Barometric Pressure (Cm. of Hg.)
140
120
100
80
60
40
20
76
65
55
45
35
25
EFFECT UPON
BRAKE MEAN EFFECTIVE PRESSURE
OF
CHANGE IN MIXTURE RATIO (AIR÷GAS)
AT
SEVERAL ATMOSPHERIC PRESSURES.
10
12
14
16
18
20
lb. Air per Hour ÷ lb. Gasoline per Hour.

Plot 8.