REPORT No. 135

PERFORMANCE OF B. M. W. 185-HORSEPOWER AIRPLANE ENGINE

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By S. W. SPARROW.

This report deals with the results of a test made upon a B. M. W. engine in the altitude chamber of the Bureau of Standards, where controlled conditions of temperature and pressure can be made to similate those of the desired altitude.

A remarkably low value of fuel consumption - 0.41 pound per b.h.p. hour - is obtained at 1,200 r.p.m. at an air density of 0.064 pounds per cubic foot and a brake thermal efficiency of 33 per cent and an indicated efficiency of 37 per cent at the above speed and density. In spite of the fact that the carburetor adjustment does not permit the air-fuel ratio of maximum economy to be obtained at air densities lower than 0.064, the economy is superior to most engines tested thus far, even at a density (0.03) corresponding to an altitude of 25,000 feet.

The brake mean effective pressure even at full throttle is rather low. Since the weight of much of the engine is governed more by its piston displacement than by the power developed, a decreased mean effective pressure usually necessitates increased weight per horsepower. The altitude performance of this engine is, in general, excellent, and its low fuel consumption is the outstanding feature of merit.

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By S. W. SPARROW
Bureau of Standards

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INTRODUCTION.

This report, which was prepared for the Engineering Division of the Army Air Service and submitted to the National Advisory Committee for Aeronautics for publication, deals with a test made in the altitude chamber of the Bureau of Standards upon a B. M. W. (Bavarian Motor Works) engine. The engine was submitted by the Engineering Division of the Air Service for test according to their standard program of altitude tests. In preparing this program it was the purpose of the Engineering Division to subject engines to conditions sufficiently typical of those encountered in service to reveal any feature of superiority which would warrant further investigation.

TESTING OF ENGINE.

The engine has six vertical water-cooled cylinders with a bore of 5.90 inches, a stroke of 7.09 inches, and a compression ratio of 6.7. Report No. 1350 of the Engineering Division describes the engine. Descriptions have appeared also in some of the automotive journals.[1] The engine is not designed for full-throttle operation at ground-level densities. In fact, because of the high-compression ratio, such operation with ordinary aviation gasoline is likely to result in preignition. Throughout the ground-level tests made at the bureau the throttle was so adjusted as to give an absolute manifold pressure of 24 inches of mercury. McCook Field experiments had shown that no preignition would result under these conditions. The method of air-fuel ratio control is such that changes in charge quality are accompanied by changes in charge quantity. Both the quantity of charge received and its quality influence the amount of power developed. However, at all densities lower than 0.064 pounds per cubic foot, and even at this density at all speeds above 1,000 r. p. m., maximum power was obtained with the throttle wide open, the position which gave the leanest mixture the carburetor permitted. Hence, at these densities, the necessary compensation was secured only in so far as the carburetor gave inherent compensation for the changes in air fuel ratio which usually result from changes in air density.

Tests were made in the altitude chamber of the Bureau of Standards, where conditions of temperature and pressure can be so controlled as to simulate those of the desired altitude. Both the test chamber and the auxiliary apparatus have been described in detail in Report No. 44 of the National Advisory Committee for Aeronautics.

The fuel used in all tests was X gasoline.[2] Its higher heating value is 20,320 B. t. u. per pound and its lower value 18,940 B. t. u. per pound.

Runs were made at engine speeds of 1,000, 1,200, 1,400, and 1,600 r. p. m. at air densities corresponding to ground level and altitudes of 5,000, 10,000, 15,000, 20,000, and 25,000 feet. In addition to these runs which, with the exception of those at ground level, were all made at full power, propeller runs were made at speeds of 1,200 and 1,000 r. p. m. The load at these speeds is that which would be imposed by a propeller so proportioned as to absorb the full power of the engine at 1,400 r. p. m. In selecting these loads it is assumed that the power required to drive a propeller varies with the cube of the speed and hence b. h. p. at $1200 = \frac{1200^3}{1400^3} \times$ (b. h. p. at 1,400 r. p. m.). Friction horsepower determinations were made under

[1] "Aerial Age," September 13, 1920.

[2] X gasoline conforms to U. S. Government specifications for aviation gasoline.

all the conditions of speed and altitude at which full-load measurements were obtained. At air densities corresponding to ground level and altitudes of 15,000 and 25,000 feet a series of runs was made at various carburetor air temperatures. Such a series indicates, for a given engine, the amount of change in brake horsepower likely to result from a known change in temperature. Its chief purpose is to reveal any fault of engine operation that may exist only within a definite range of temperature.

Results are presented in the accompanying curves. In examining the full-load curves it must be remembered that the runs at ground-level density were at partly closed throttle. This accounts for the fact that the powers and mean effective pressures at an air density of 0.064 pound per cubic foot are higher than those at a density of 0.072. In figures 3, 4, and 8 it will be noted that mean effective pressures and horsepower vary almost linearly with changes of air density from about 0.055 to 0.030, but that the power at an air density of 0.065 is less than would be expected from this linear relation. In spite of this low power, or more likely because of it, the fuel consumption in pounds of fuel per horsepower hour (shown in figs. 10 and 11) is very low. A probable explanation is that the mixture at this density was considerably leaner

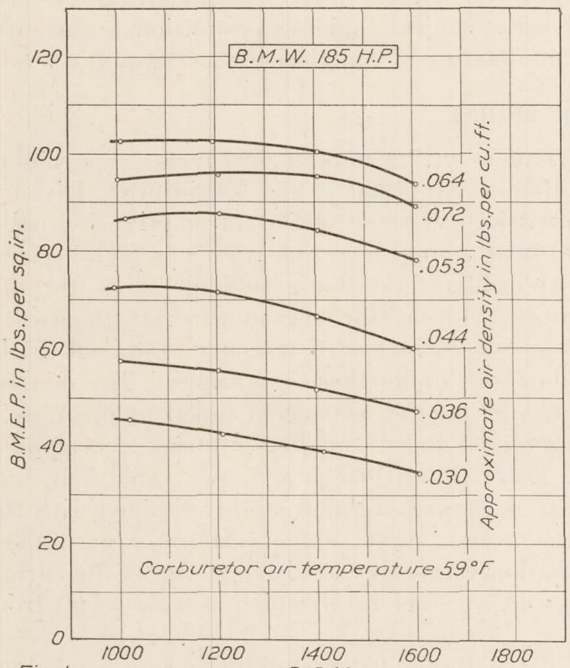

Fig. 1

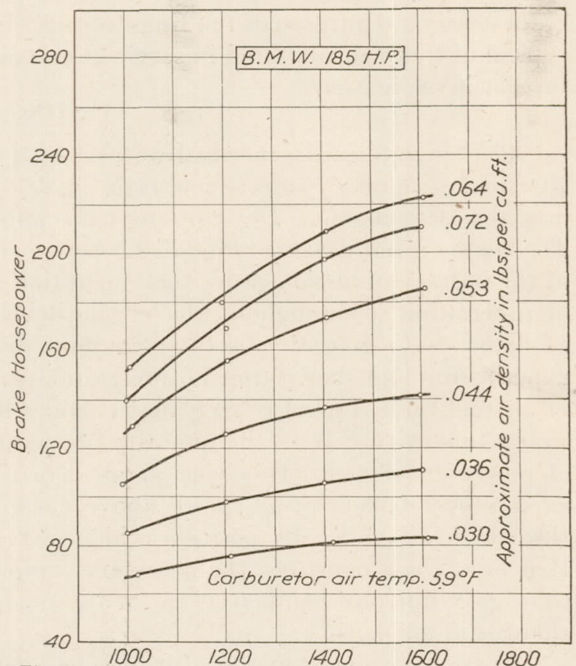

Fig. 2

than that which would give maximum power were it possible to change the air-fuel ratio without changing the quantity of charge supplied to the engine. It is well known that maximum engine efficiency, minimum specific fuel consumption, is obtained with air-fuel ratios considerably greater than those which give maximum power. With this engine maximum power was obtained at this air-fuel ratio because a lower ratio could have been attained only by decreasing the amount of charge furnished the engine so much as to overbalance the gain from the higher power-producing ability of the richer mixture.

In addition to the full throttle friction runs of figure 5 two series of runs were made at part throttle at ground-level density. From these the lower curves of figure 6 were obtained, showing the relation of friction to manifold depression. Since the power runs at ground-level density were all made at reduced throttle, the friction horsepower corresponding to the measured manifold suction is selected from this lower set of curves of figure 6.

Figs. 10 and 11, giving the fuel consumption in pounds per brake horsepower hour and per indicated horsepower hour, both indicate a mixture giving high efficiency at an air density of 0.064 and mixtures increasing in richness with decrease in air density. A remarkably low value of fuel consumption—0.41 pound per b. h. p. hour—is obtained at 1,200 r. p. m. at an air density of 0.064 pound per cubic foot. The thermal efficiency based on the lower heating value of this fuel may be obtained by dividing 13.45 by the specific fuel consumption. This gives a brake thermal efficiency of 33 per cent and an indicated efficiency of 37 per cent at the above speed and density. In spite of the fact that the carburetor adjustment does not permit the air-fuel ratio of maximum economy to be obtained at air densities lower than 0.064, the economy is superior to most engines tested thus far, even at a density (0.03) corresponding to an altitude of 25,000 feet.

Air flow as measured gave volumetric efficiencies ranging from 67 to 80 per cent at full throttle, the higher efficiencies occurring at the lower speeds. In general, the air measurements showed a rather erratic behavior. The fact that this erratic behavior was not paralleled by similar variations in engine power indicates faulty air measurements rather than real peculiarities of air flow. The arrangement of piping for measuring air flow included a considerably greater number of joints than is ordinarily necessary, and it is likely that leakage at some of these joints accounts for whatever errors may exist. Since the air flow data do not appear to merit the confidence that can be placed in the other measurements, it should be noted that the only other plotted values that are affected by errors from this source are the air-fuel ratios.

In calculating the heat distribution given by figure 17, the higher heating value of the fuel is used, since in the calorimetric measurement of exhaust heat the water vapor resulting from combustion is condensed. The power developed by the combustion of the lubricating oil is not included, because no information is available as to the proportion of the oil consumed that is actually burned on the power stroke.

At the lowest density—0.029—the engine would not operate well at reduced load, but elsewhere the propeller load operation was satisfactory. The runs at an air density of 0.074 are shown in dash lines, because they could not be obtained with the same propeller as the other curves, but necessitated a propeller operating at 1,400 r. p. m. when the throttle was in the arbitrarily chosen position used in the runs at ground-level density.

The brake mean effective pressure even at full throttle is rather low. Since the weight of much of the engine is governed more by its piston displacement than by the power developed, a decreased mean effective pressure usually necessitates increased weight per horsepower. The altitude performance of this engine is, in general, excellent, and its low fuel consumption is the outstanding feature of merit.

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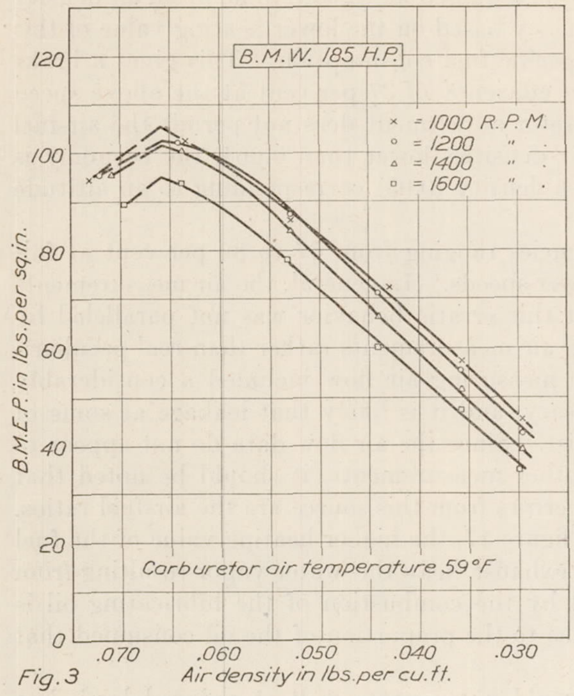

Fig. 3

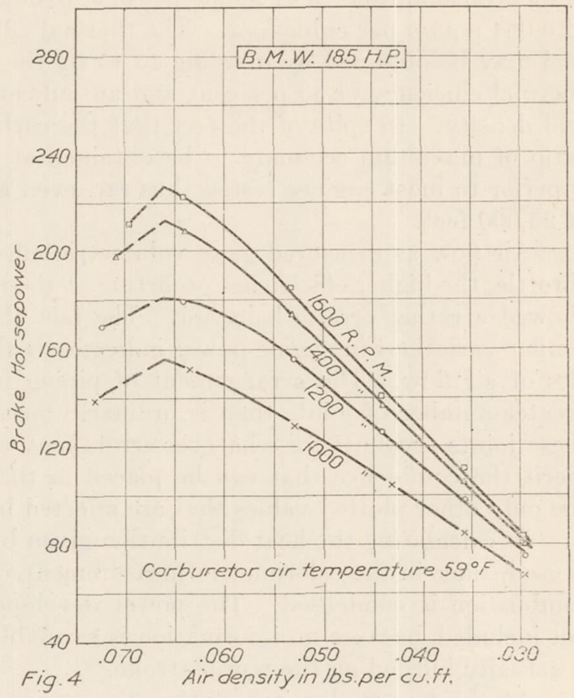

Fig. 4

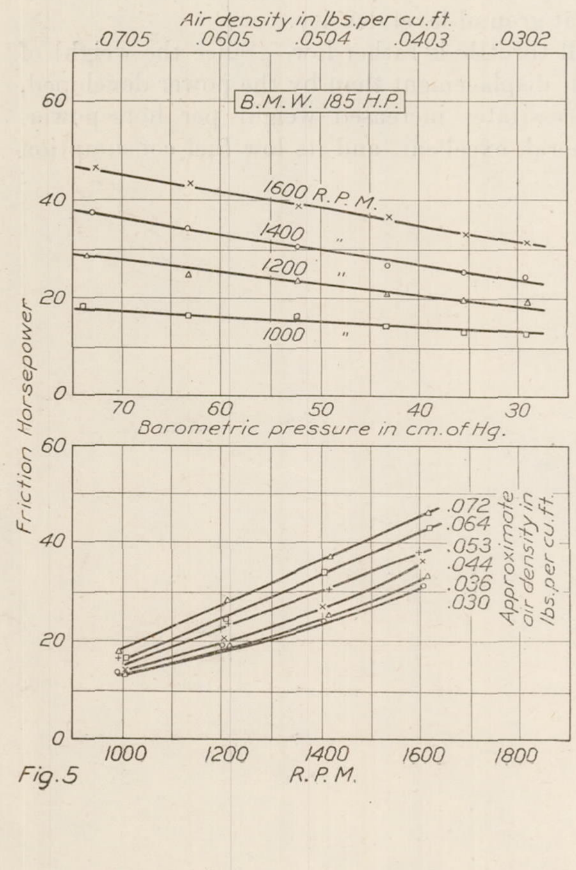

Fig. 5

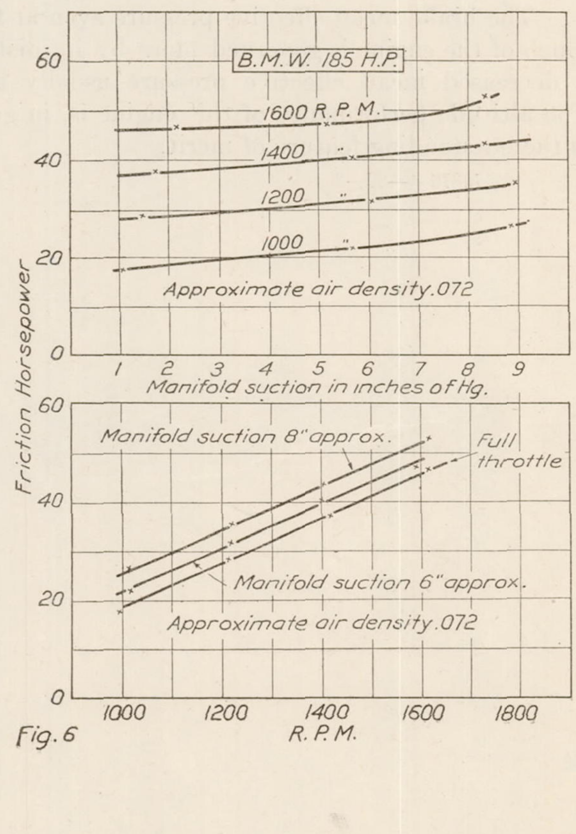

Fig. 6

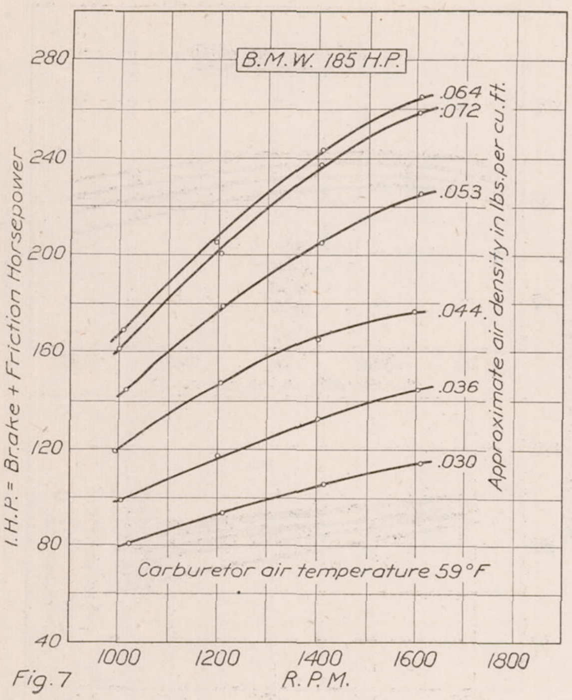

Fig. 7

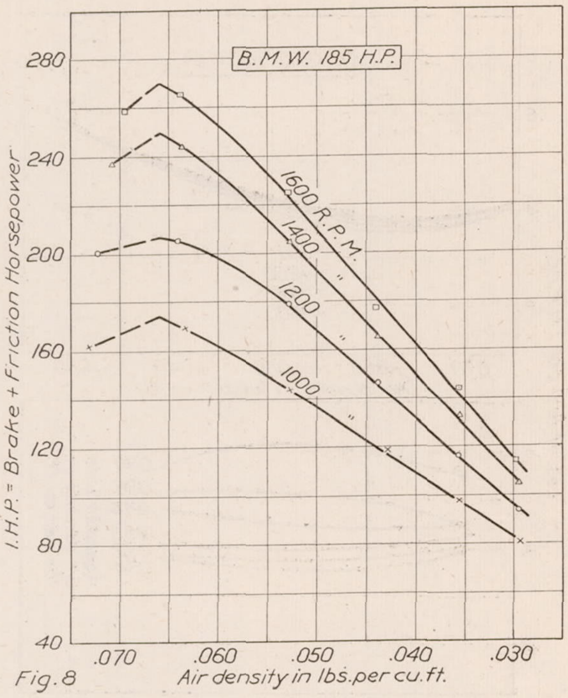

Fig. 8

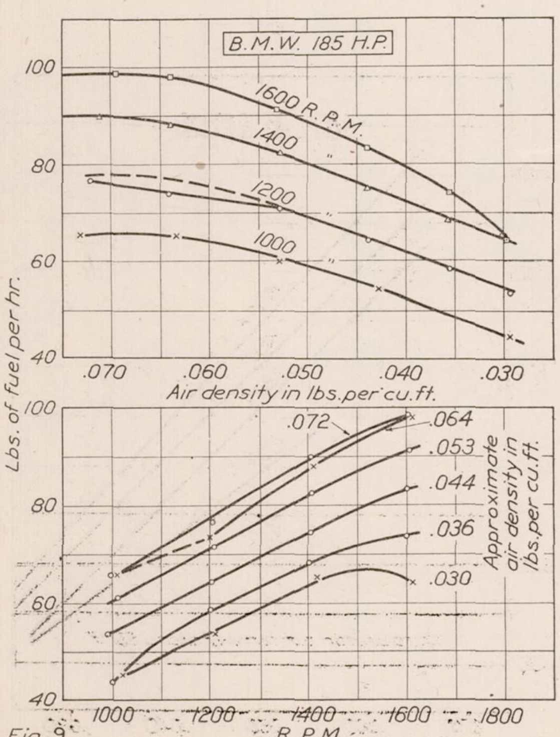

Fig. 9

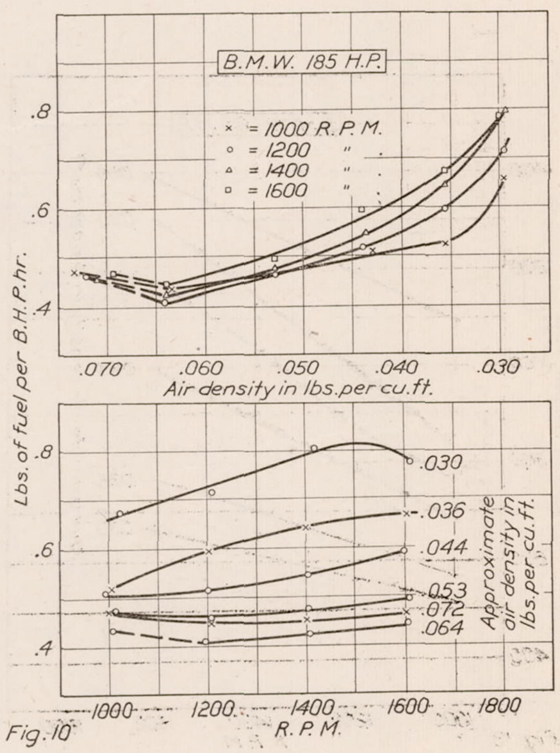

Fig. 10

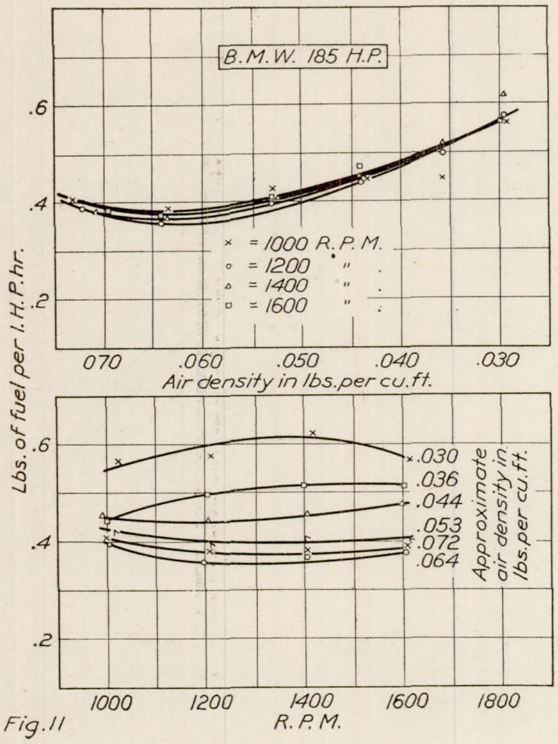

Fig. 11

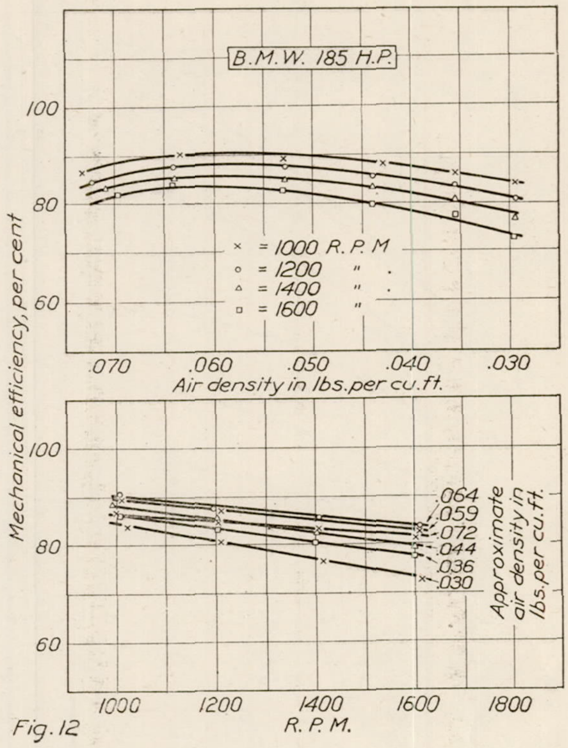

Fig. 12

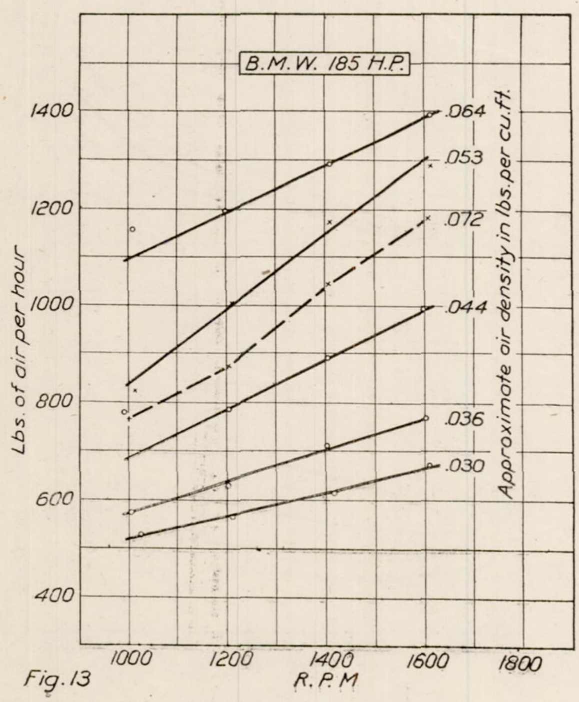

Fig. 13

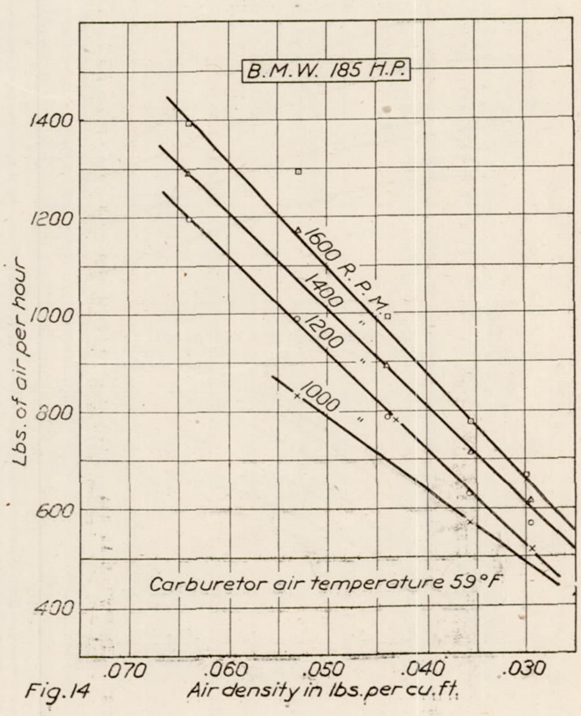

Fig. 14

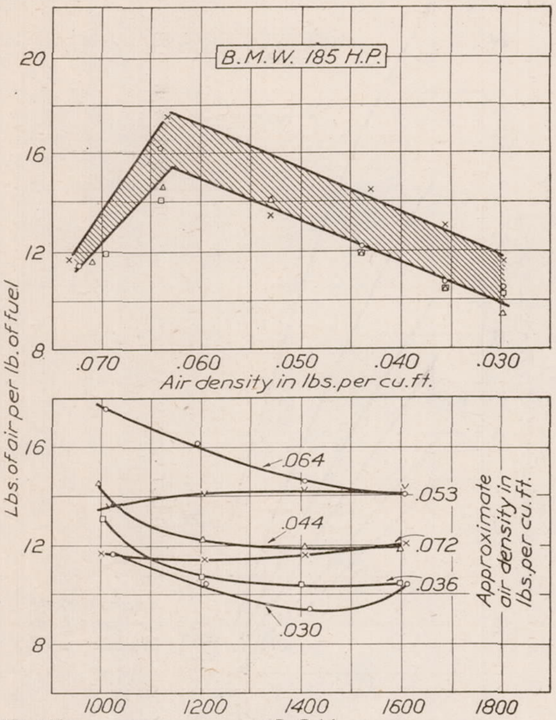

Fig. 15

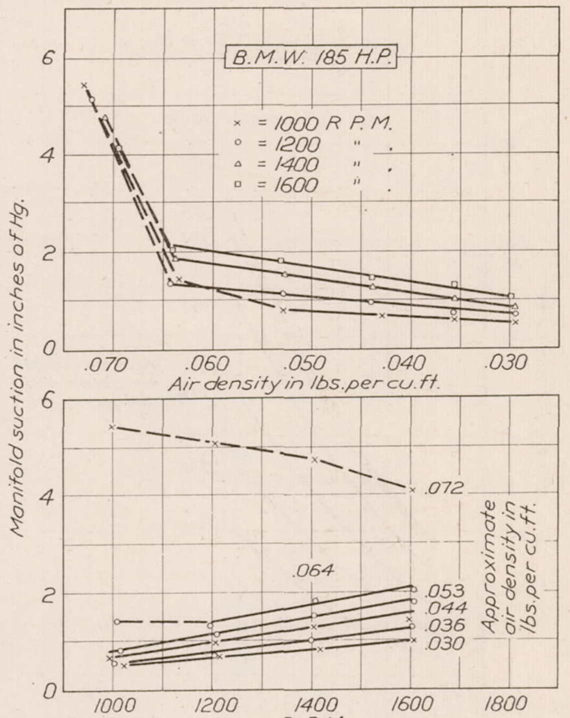

Fig. 16

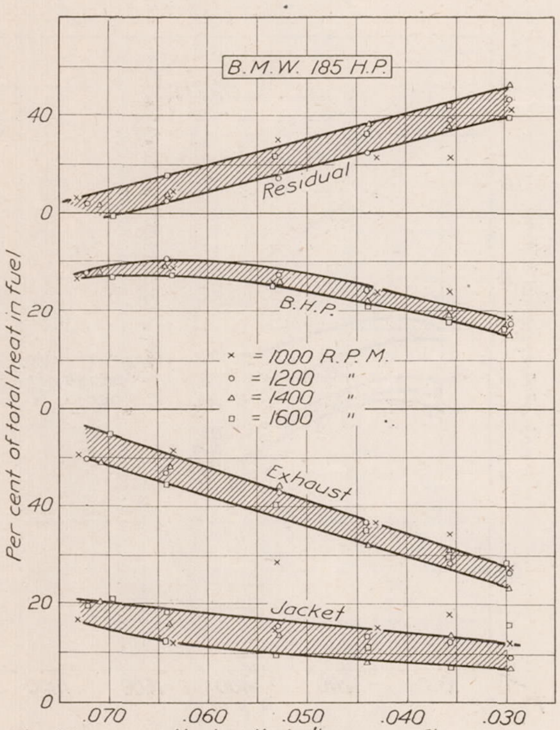

Fig. 17 Air density in lbs. per cu. ft.

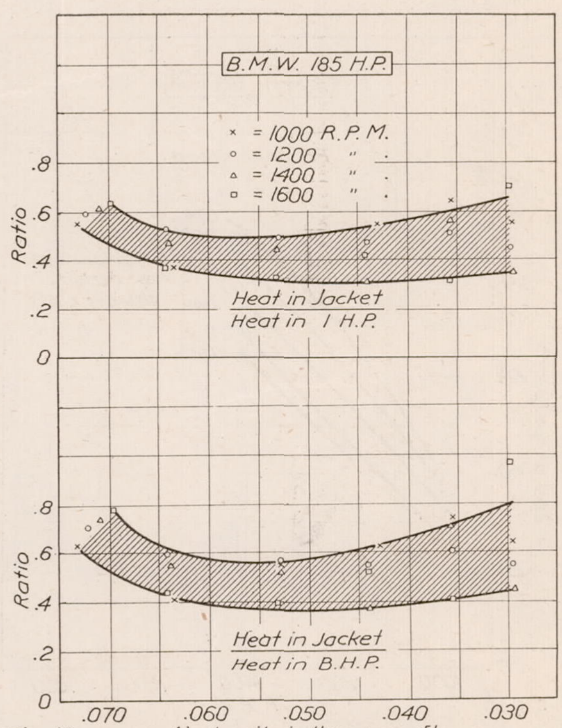

Fig. 18 Air density in lbs. per cu. ft.

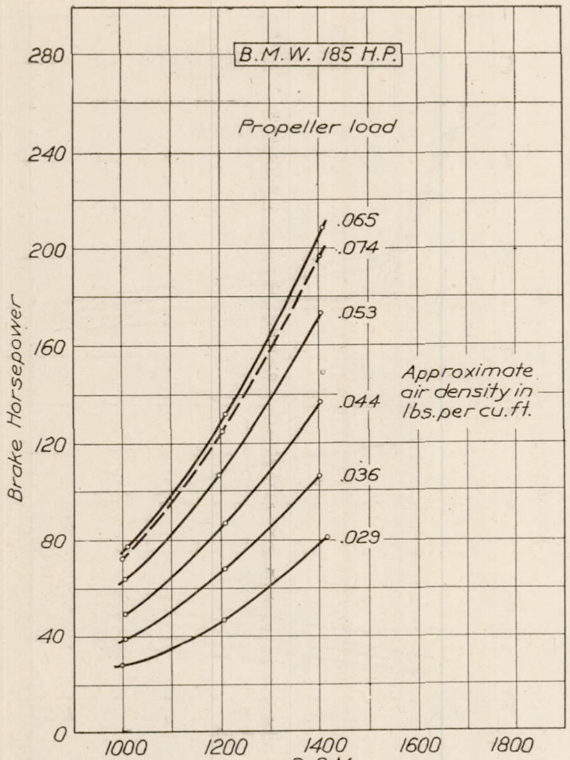

Fig. 19

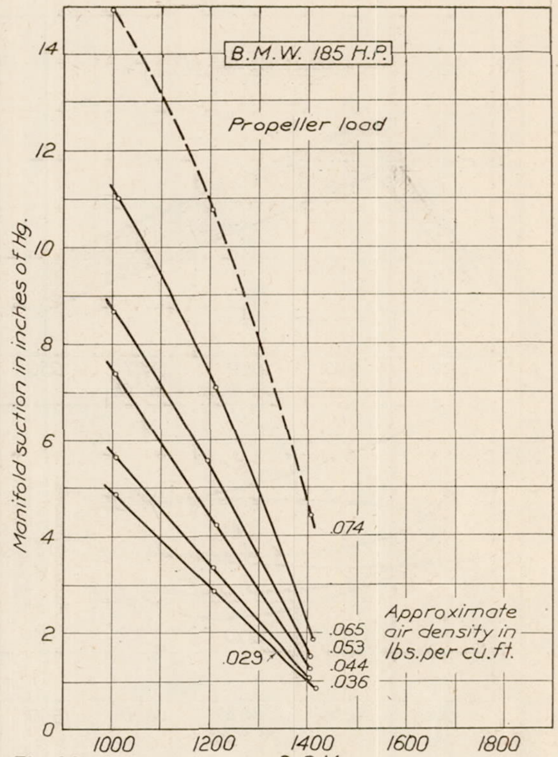

Fig. 20

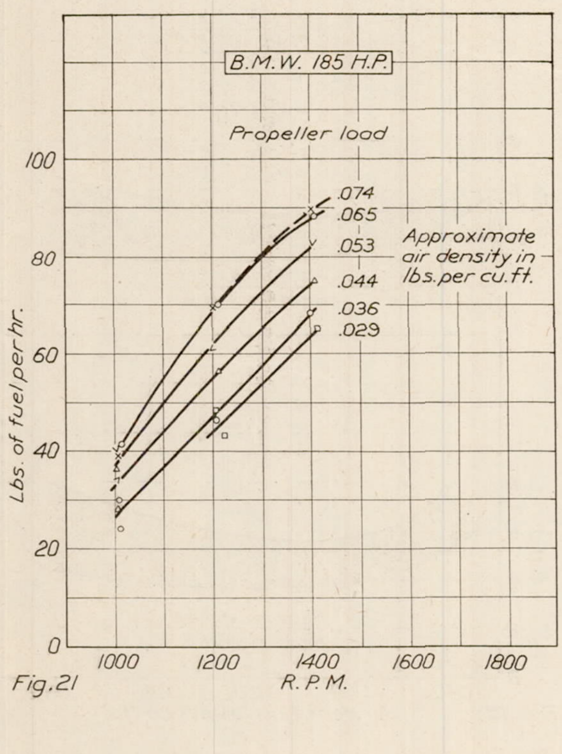

Fig. 21

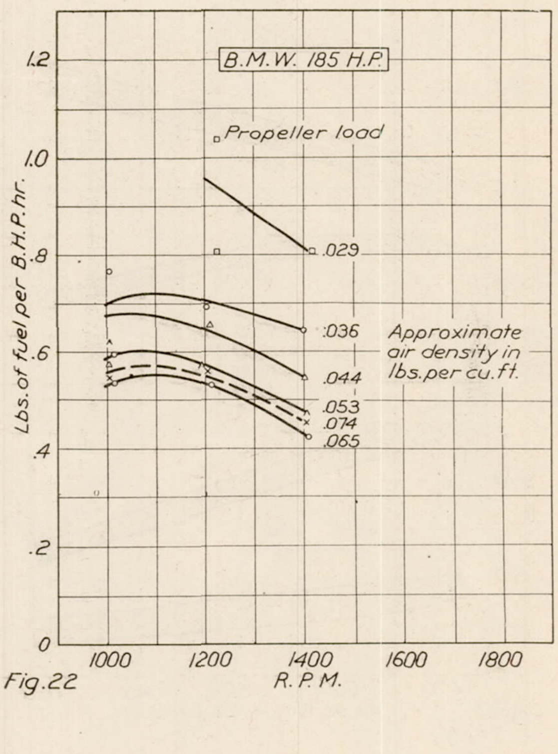

Fig. 22