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EFFECT OF CARBURETOR-MIXTURE-CONTROL AND SUPERCHARGER CHARACTERISTICS ON FUEL KNOCK UNDER SIMULATED SEA-LEVEL FLIGHT CONDITIONS

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SUMMARY

Knock-limit data were recorded for a current 100-octane-number aviation gasoline in a full-scale single-cylinder test engine. Inlet-air temperatures were the temperatures estimated from a consideration of the temperature increase through an aircraft-engine supercharger. Low-speed and high-speed superchargers were considered in making these estimates. A carburetor-mixture-control curve was assumed from which, in conjunction with the knock-limit data, estimates were made of those conditions under which the engine would knock with a current 100-octane fuel at sea level.

The data indicate that the relation of the carburetor-mixture-control characteristics to the knock characteristics of the fuel is an important factor in determining knock-free operation. The data further indicate that for the estimated conditions knock is more apt to occur at cruising than at take-off power. It will be necessary to provide a manual device for leaning the mixture to fuel-air ratios of 0.060 or less if knock-free operation is to be insured at the other operating fuel-air ratios. A method is outlined for presenting data considering the knocking characteristics of the fuel, the inlet-air temperatures resulting from the compression of the air in the supercharger, and the carburetor-mixture-control characteristics.

INTRODUCTION

In most single-cylinder determinations of the knock limit of aviation gasolines, tests have been conducted under conditions in which the effect of engine speed on the heating of the inlet air during the supercharging process has not been considered; nor has consideration been given to the relation between the knocking characteristics of the fuel and the metering characteristics of the carburetor.

In the present report data will be discussed in which the inlet-air temperatures at three different engine speeds were the temperatures estimated from a consideration of the characteristics of the supercharger (fig. 1). These data were computed from the conventional supercharger equations given in the appendix; an inlet-air temperature of 100° F and a supercharger adiabatic efficiency of 72 percent were assumed.

The solid line of figure 1 represents a high-speed supercharger giving a maximum pressure ratio of 2.35; the dashed line represents a low-speed supercharger for which the speed is 0.75 times that of the high-speed blower and the maximum pressure ratio is 1.65. These values are in line with current supercharging practice. The scale of engine speed shows a maximum value of 2500 rpm.

The tests under the high-speed-supercharger conditions were run with a current aviation gasoline that had an octane number of 100 by the CFR Aviation (1-C) Method and an octane number of S-1 + 1.0 milliliter of tetraethyl lead by the Supercharged Knock Test (3-C) Method (rich rating). The data under the low-speed-supercharger conditions were run with a similar fuel except that the rich mixture 3-C rating was not determined. Check points indicated that both fuels had about the same 3-C rating and, for the purpose of this comparison, they can be considered to be the same fuel. The tests were made at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics.

APPARATUS AND METHODS

The tests were conducted on a Wright 1820-G-200 cylinder mounted on a CUE crankcase. The following conditions were held constant:

Spark advance, degrees B.T.C.. 20

Cooling-air pressure drop
  across cowling, inches water 20

Cooling-air temperature, °F 125

Oil-in temperature, °F 170-180

Compression ratio 7.0

Tests were run at engine speeds of 2500, 2100, and 1700 rpm. The fuel was injected into the inlet manifold approximately 9 inches upstream from the inlet valve. Injection took place during the inlet stroke.

Under each condition a run was made in which the relation between the fuel-air ratio and the maximum permissible inlet pressure as limited by knock was recorded. Indicated mean effective pressures, indicated specific fuel consumptions, and indicated air consumptions were also determined. A flat-plate orifice installed according to the A.S.T.M. standards was used to indicate the rate of air flow to the engine. Details of the setup have been given in reference 1. The inlet-air temperatures were measured previous to the injection of the fuel. At the three speeds, the following inlet-air temperatures were tested (fig. 1):

Engine speed (rpm)	High-speed supercharger (°F)	Low-speed supercharger (°F)
1700	200	160
2100	250	180
2500	310	220

In the computations to determine the appropriate inlet-air temperatures, no consideration was given to the effect of fuel vaporization during the supercharging process. The final estimated mixture temperature is probably not appreciably affected by neglecting this effect of fuel vaporization. Either of two conditions might be assumed: (1) Vaporization is completed before the air enters the supercharger, or (2) vaporization is completed after the air has passed through the supercharger. The correct final mixture temperature will lie somewhere between these two extremes.

Estimates of the effect of the two conditions assumed for the high-speed supercharger operating at an engine speed of 2500 rpm are that the final mixture temperature under condition (1) for complete vaporization of the fuel is approximately 230° F. Estimates made of the final mixture temperature with complete vaporization of the fuel under condition (2) give a value of approximately 260° F.

Actually, the time of complete vaporization of the fuel is unknown. The data as presented in the present report probably represent mixture temperatures somewhat low for the assumed supercharger conditions; that is, in comparison with service conditions the data are representative of a supercharger efficiency somewhat higher than the 72 percent assumed. This fact will not affect the conclusions based on the test results. For the other supercharger conditions assumed, the temperature differential between conditions (1) and (2) will, of course, be less.

TEST RESULTS

Curves showing the relation between fuel flow in pounds per hour and the maximum permissible air flow in pounds per hour are presented in figures 2 and 3. This method of presenting the data has been discussed in reference 2. Analysis at this laboratory has shown that data presented in this manner introduce fewer possible errors than data presented in the conventional form of fuel-air ratio against maximum permissible indicated mean effective pressure. The indicated-mean-effective-pressure data will be presented later in the report.

Under the low-speed-supercharger conditions, as the engine speed is increased the maximum permissible air quantity inducted at any given fuel flow increases for fuel-air ratios in excess of about 0.064 and decreases for fuel-air ratios below this value. The curves are presented by a series of straight lines. For the high-speed-supercharger conditions, a single straight line represents the data for the three speeds at fuel-air ratios less than 0.065. At larger fuel-air ratios the points separate and give, in general, curves of increasing slope as the engine speed is increased. Check points are shown for the run at 2100 rpm.

Figures 4 and 5 show the relation between the inlet pressure and the air quantity inducted. For each speed a single straight line can be drawn through the points regardless of the fuel-air ratio.

The data for indicated specific fuel consumption are presented in figure 6. A single curve has been drawn to represent all the experimental points. At 1700 rpm, particularly in the lean region, the experimental data show higher fuel consumptions than that expressed by the curve. The average curve for indicated specific fuel consumption, together with the average curve for indicated specific air consumption, is presented in figure 7.

Based on the data in figure 7 the performance chart in figure 8 is constructed to show the relation between fuel flow, air flow, fuel-air ratio, and indicated horsepower. A superimposition of the curves in figures 2 and 3 on the curves in figure 8 determines figures 9 and 10. These figures represent the performance of the current 100-octane-number aviation gasolines under the assumed supercharged conditions.

Reference to figure 9 shows that the maximum indicated horsepower (point Y) is 152. In the present analysis this value will be considered as the take-off horsepower for the cylinder with either the high-speed or the low-speed supercharger. The rated horsepower is considered to be 87.5 percent of this value, or 133 indicated horsepower. The knock-limit curve at 2500 rpm intersects the curve for 133 indicated horsepower at point W. Point X represents the estimated knock limit for the rated horsepower at 2300 rpm. It is noted that at 2100 rpm the knock-limit curve never reaches the value of 133 indicated horsepower. Cruising horsepower is considered to be 55 percent of the take-off value, or 84 horsepower. The knock-limit curves for the three speeds intersect the 84-horsepower line at points Q, R, and S, respectively, at fuel-air ratios greater than 0.065. In the lean region the knock-limit curve for the three speeds again intersects the horsepower curve at point T, U, V. The performance data for the points discussed are given in table I.

Throughout this analysis, all points designated by letters of the alphabet from point G through point Y will represent the same set of conditions, regardless of the figure on which the points appear.

With the same values for take-off, rated, and cruising horsepower, it is seen that, for the low-speed supercharger, take-off power is reached at point P (fig. 10) and rated power is reached at points M, N, and O for speeds of 2500, 2300, and 2100 rpm, respectively. The cruising horsepower is below the knock-limit curves except for the vertex of the curve at 1700 rpm. Two cruising conditions will be considered: one at a fuel-air ratio of 0.060 (point G,H,I) and the other at a fuel-air ratio of 0.051 (point J,K,L). It is appreciated that a fuel-air ratio of 0.051 is not practical because of uneven distribution in a multicylinder engine, which results in one or more cylinders cutting out; but it is included for the sake of comparison with the previous figure.

The data for the foregoing points are also tabulated in table I. A comparison of the low-speed and the high-speed supercharger conditions shows that, cruising at a fuel-air ratio of not less than 0.060 at 1700 rpm, the limiting fuel consumption with a high-speed supercharger is 0.42 pound per indicated horsepower-hour as against 0.36 pound per indicated horsepower-hour for the low-speed supercharger. It is also seen that there is no advantage from the standpoint of fuel consumption in cruising below a fuel-air ratio of 0.060. There is a disadvantage in that for lower fuel-air ratios a higher manifold pressure is required, as is shown by comparing the inlet pressures for point J,K,L with those for point G,H,I.

For rated power at 2300 rpm with a high-speed supercharger, a fuel-air ratio of 0.106 is required; whereas, with the low-speed supercharger, the fuel-air ratio may be decreased to 0.08 with a corresponding decrease in the specific fuel consumption. With the high-speed supercharger, take-off requires a fuel-air ratio of 0.112; whereas, with the low-speed supercharger, this ratio is decreased to 0.083. It is also noted that the maximum permissible indicated horsepower with a low-speed supercharger is 174 (point Z, fig. 10).

Figures 11 and 12 present the maximum permissible indicated mean effective pressure expressed as a function of the fuel-air ratio. The curves in the left-hand half of the figure are constructed from the previous performance charts. On the right-hand side the same curves are shown in comparison with the experimental data. At 1700 rpm with the low-speed supercharger, the curves are above the experimental points in the lean region. At a fuel-air ratio of 0.060 the curve is approximately 5 percent high. With the high-speed supercharger the curve of indicated mean effective pressure at 1700 rpm lies above the experimental points in both the lean and rich regions. The deviation is probably allowable for the present analysis, and the assumption that the curves represent the actual conditions is justified by the simplification of the experimental data.

In figures 13 and 14 the curves of air quantity inducted as a function of inlet-air pressure are reproduced with the performance points previously presented. Curves are also constructed representing the supercharger limits at sea level. It is seen that at low speed, points I, L, and O lie outside the supercharger limit and consequently could not be obtained. Point Z is also considerably outside the supercharger limit. For the high-speed supercharger all the experimental points lie within the supercharger limit.

Figure 15 presents a carburetor-mixture-control curve of fuel-air ratio against specific air quantity in pounds per hour per cubic inch of engine displacement. The data from which this curve is estimated were obtained by the Bureau of Aeronautics, Navy Department, with a PD-12B Stromberg metering unit on the R-1830-66 engine. For application to the present report, the Navy data were scaled down for the G200 single cylinder and adjusted until the fuel-air ratio of 0.10 in automatic rich was reached at approximately the assumed take-off power of 0.752 indicated horsepower per cubic inch.

It is recognized that in service the fuel-air ratio at any specific air flow does not remain constant because the carburetor does not fully compensate for changes in both inlet-air temperature and inlet-air pressure. In the present analysis the use of a single curve to represent automatic rich or automatic lean is justified, however, because the principles to be studied are dependent upon the general relation of the carburetor-control curve to the knock-limit curve of the fuel. Although other carburetor and engine combinations may give mixture-control curves of somewhat different shapes from that given in figure 15, the general shape of the mixture-control curve based on power output, to be shown later, will not be changed.

Figure 16 sums up all the data presented thus far for the low-speed supercharger. Horizontal lines represent take-off, rated, and cruising horsepower. Solid curves present the knock-limit data. The full-throttle-power curves represent the power realized for the maximum air flow from the supercharger; that is, they represent the intersection of the supercharger limit curve in figure 13 with the curves of air quantity inducted against inlet pressure for the three speeds. The carburetor automatic rich and automatic lean curves are constructed from information based on the curves of indicated specific air consumption of figure 7 and the curve of figure 15.

Full throttle on the engine results in the power developed at point E or point F. Both points are below the knock-limit curve at 2500 rpm and are at approximately the assumed take-off power. Consequently, take-off can be made with the carburetor set for either automatic rich or automatic lean.

For rated horsepower a fuel-air ratio of 0.074 is required at 2500 rpm (point M) or 0.08 at 2300 rpm (point N). The mixture ratio in either automatic lean or automatic rich at rated power lies to the right of these knock points at rated power.

Cruising horsepower at 1700 rpm (point I) is slightly below the knock curve. Full-throttle operation at this speed would give incipient knock at 1700 rpm with the carburetor in automatic lean (point A), but the engine would not knock if the carburetor were in automatic rich (point B). Full-throttle operation at 2100 rpm will result in light knock with the carburetor in automatic lean (point C) and in no knock with the carburetor in automatic rich (point D). If sufficient air were available to reach the fuel-air ratio for maximum permissible power at 2500 rpm, a fuel-air ratio of 0.107, the accompanying inlet pressure (point F') would be 4 inches of mercury below the permissible inlet pressure (point Z). The carburetor-flow curve intersects the knock-limit curve at a fuel-air ratio of 0.122 and an inlet pressure of 61 inches of mercury (point E').

Figure 17 shows similar data for the high-speed supercharger. Under these conditions the assumed carburetor characteristics are unsatisfactory. For instance, take-off power is reached in full rich at point A, which is 5 inches in excess of the permissible knock-free boost at this fuel-air ratio, point B. This mixture ratio at point A, 0.101, is compared with the required mixture ratio of 0.112 (point Y) for suppression of knock at take-off. Rated horsepower occurs at a fuel-air ratio of 0.089 with the carburetor in automatic rich; whereas, the fuel-air ratios required to suppress knock are 0.098 and 0.106 at 2500 and 2300 rpm, respectively (points W and X). The automatic-rich carburetor curve intersects cruise horsepower at a fuel-air ratio of 0.073, which is in excess of the required mixture ratio at 2500 rpm (point Q) but is too lean to suppress knock at either 2100 or 1700 rpm (points R and S).

If the carburetor were set for automatic lean for cruising at 1700 rpm (point D), the inlet pressure would be 8 inches above the maximum permissible inlet pressure for knock-free operation at 1700 rpm (point E). If the carburetor were leaned manually to point V, knock would be suppressed and cruising horsepower would be maintained. Again, it is emphasized that this lean mixture ratio of 0.51 cannot be used in present-day engines. Knock at point D could also be suppressed by leaning manually to point D' and maintaining the air throttle constant or by closing the throttle to point F at 31 inches of mercury. Both of these processes would cause a decrease in the cruise horsepower.

It is seen that under these simulated conditions of operation with a high-speed supercharger the engine is nearly always operating under knocking conditions. These knocking conditions would probably be severe enough to damage the engine.

Comparisons of figures 16 and 17 emphasize the importance of increasing the supercharger efficiency, of using a two-speed supercharger, or of installing intercoolers to decrease the temperature of the supercharged air. Data such as are presented in this report, although they do not present the knock ratings of the fuels, do present a method of estimating the suitability of a given fuel for flight under service conditions. Knocking characteristics of the fuel should be considered as unsatisfactory unless, for the operating range, the knock-limit curves always lie above the carburetor-mixture-characteristics curve.

It is noted that, if the automatic carburetor is to permit operation at fuel-air ratios as lean as 0.060 at about 50 percent of take-off power, knock under some conditions of operation will be very difficult to eliminate because of the negative slope of the knock-limit curve at this fuel-air ratio. It is probable that, for long-distance cruising, the most efficient means of operation will be to permit manual leaning of the carburetor to obtain reasonably high cruising horsepower at the minimum specific fuel consumption.

Throughout this analysis all data have been considered on an indicated basis. It is recognized that the mechanical efficiency of the complete engine is not a constant and that in applying this method of analysis to full-scale engines, suitable corrections for this mechanical efficiency have to be made.

The analysis considered thus far has been based on sea-level conditions. In figure 18 are presented atmospheric temperatures and pressures as a function of altitude for Army standard air. There are also presented corresponding supercharging-outlet temperatures and pressures for the high-speed supercharger. Curve 2 shows that, for the high-speed supercharger, the temperatures assumed for the low-speed supercharger apply at altitudes of 18,400, 15,100, and 10,200 feet at engine speeds of 2500, 2100, and 1700 rpm, respectively. In these data, consideration of the effects of compression of the air in the inlet scoop as a result of the airplane velocity are not considered. In the application of the low-speed supercharger knock-limit curves to the high-speed supercharger for the altitudes just given, the effect of the decreased back pressure on the knock limit is neglected.

CONCLUSIONS

1. The data presented in this report show that with current aviation fuels knock may be a more serious factor under cruise than under take-off conditions if the engine is to be operated at fuel-air ratios of 0.060 or less and at speeds of approximately 70 percent of take-off speed.

2. The data also indicate that in engines which employ a single-stage high-speed supercharger without aftercooler, knock may become serious at sea-level conditions and at altitude conditions up to several thousand feet. This knock, particularly at altitude, can be eliminated through lowering of the charge temperature or increasing the antiknock properties of the fuel.

3. The data indicate that, because of the relation of the carburetor-mixture-control curve to the knock-limit curves, it will be very difficult to cruise at fuel-air ratios of 0.060 or less without knock unless a manual control is supplied on the carburetor to permit leaning to the above-mentioned fuel-air ratio.

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APPENDIX

ESTIMATION OF SUPERCHARGER OUTLET

TEMPERATURES AND PRESSURES

From the conventional centrifugal supercharger equations:

$$\frac{c_p T_1}{\eta}\left[\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] = c_p \left(T_2 - T_1\right) \qquad (1)$$

$$c_p \left(T_2 - T_1\right) \propto U^2 \qquad (2)$$

in which

c_p specific heat of air at constant pressure, 0.241 Btu per pound per $^{\circ}$F

c_v specific heat of air at constant volume

γ ratio of specific heats, $c_p/c_v = 1.394$

T_1 temperature of inlet air to supercharger, $^{\circ}$F absolute

T_2 temperature of outlet air from supercharger, $^{\circ}$F absolute

p_1 pressure of inlet air to supercharger, inches of mercury absolute

p_2 pressure of outlet air from supercharger, inches of mercury absolute

η supercharger adiabatic efficiency, assumed to be 0.72

U factor proportional to supercharger or engine speed, U = 1.0 at maximum engine speed

$$\frac{p_2}{p_1} = 2.35$$

$$T_1 = 560^\circ \text{ F abs. } (100^\circ \text{ F})$$

Substitution in equation (1) gives:

$$T_2 - T_1 = 211^\circ \text{ F}$$

$$T_2 = 771^\circ \text{ F abs. } (311^\circ \text{ F})$$

Values of $T_2 - T_1$ at engine speeds from 1500 to 2500 rpm are computed from proportionality (2) with $(T_2 - T_1) = 211^\circ$ F and $U = 1.0$ at 2500 engine rpm. Substitution of the estimated values of $T_2 - T_1$ at each engine speed in equation (1) determines the pressure ratio at each engine speed.

The low-speed supercharger is assumed to turn at 0.75 the speed of the high-speed supercharger. At $U = 0.75$ for the high-speed supercharger, $T_2 - T_1 = 220^\circ$ F and $\frac{p_2}{p_1} = 1.65$, which are the values for the low-speed supercharger at $U = 1.0$.

REFERENCES

1. Rothrock, Addison M., Biermann, Arnold E., and Corrington, Lester C.: Maximum Permissible Engine Performance of Eight Representative Fuels of 100-Octane Number. NACA ARR, Jan. 1942.

2. Sanders, Newell D.: Effect of Fuel Vaporization, Inlet-Air Temperature, and Fuel-Air Ratio on Knock Limit of Isooctane. NACA ARR, Nov. 1942.

TABLE I

RELATION BETWEEN ENGINE SPEED AND OPERATING CONDITIONS AS LIMITED BY KNOCK

Engine speed (rpm)	imep (lb/sq in.)	High-speed supercharger					Low-speed supercharger				
		Symbol	$\frac{\rho}{\rho_o}$	F/A	isfc (lb/hp-hr)	Inlet pressure (in.Hg abs.)	Symbol	$\frac{\rho}{\rho_o}$	F/A	isfc (lb/hp-hr)	Inlet pressure (in.Hg abs.)
Cruising 84 ihp; 0.415 ihp/cu in.											
2500	132	Q	0.73	0.070	0.39	30.0	G	0.82	[b]0.060	0.36	30.0
2100	157	R	.86	.074	.41	32.5	H	.94	[b].060	.36	32.5
1700	194	S	1.07	.076	.42	37.5	I	1.16	[b].060	.36	38.5
2500	132	T	.87	.051	.36	37.0	J	.95	[b].051	.36	34.5
2100	157	U	1.03	.051	.36	39.0	K	1.09	[b].051	.36	37.0
1700	194	V	1.26	.051	.36	44.5	L	1.29	[b].051	.36	43.0
Rated 133 ihp; 0.658 ihp/cu in.											
2500	209	W	1.13	0.098	0.56	46.5	M	1.15	0.075	0.42	42.0
2300	227	X	[a]1.24	[a].106	.65	[a]49.0	N	[a]1.23	[a].080	.45	[a]43.5
2100							O	1.36	.084	.47	46.5
Take-off 152 ihp; 0.752 ihp/cu in.											
2500	238	Y	1.35	0.112	0.71	56.0	P	1.30	0.086	0.48	47.5

[a]Estimated.
[b]Below knock limit.

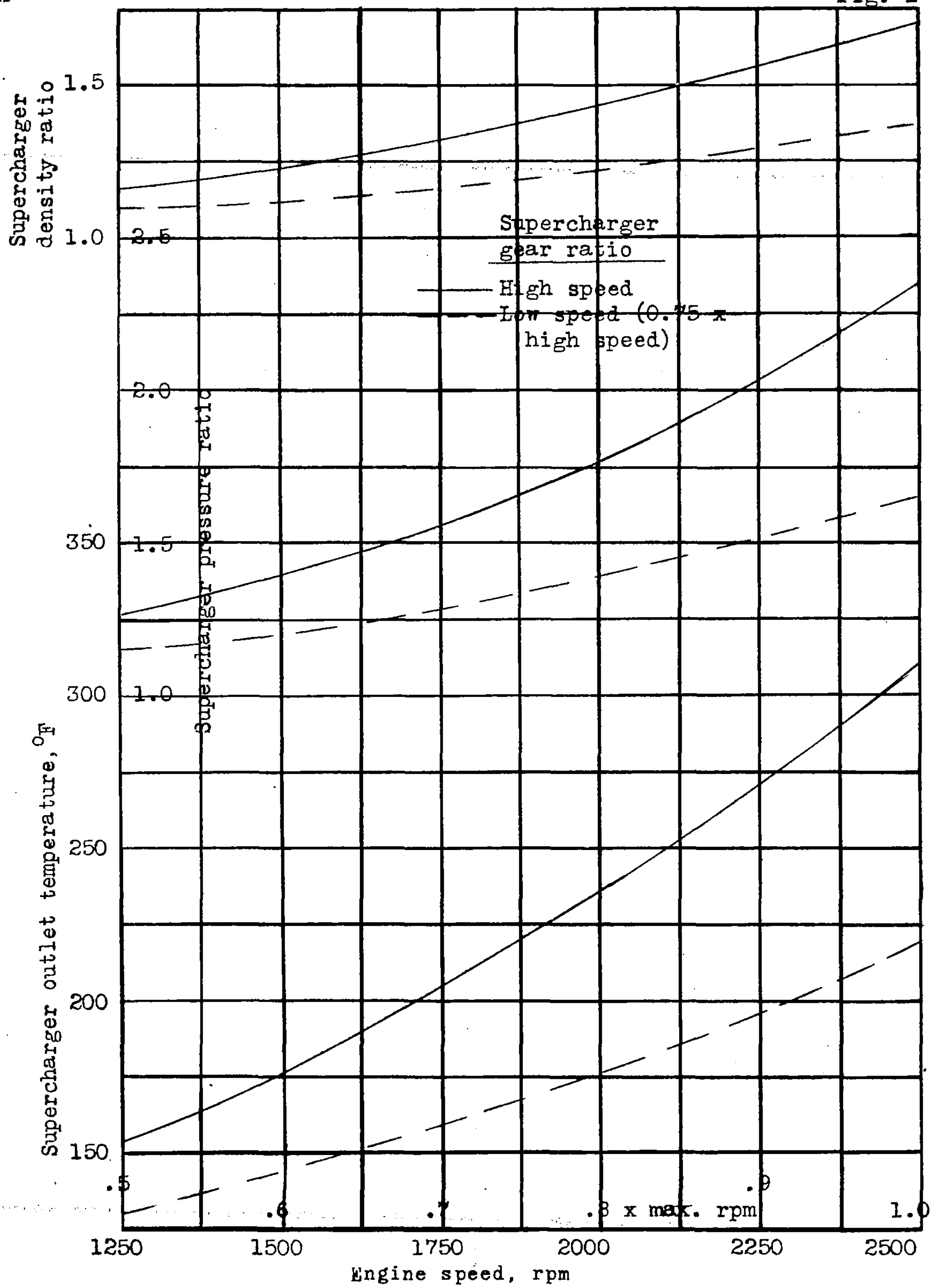


Figure 1. - Relation between engine speed and estimated supercharger performance characteristics. Assumed inlet-air temperature to supercharger, 100° F; assumed supercharger adiabatic efficiency, 0.72; effect of fuel vaporization on supercharger performance is neglected.

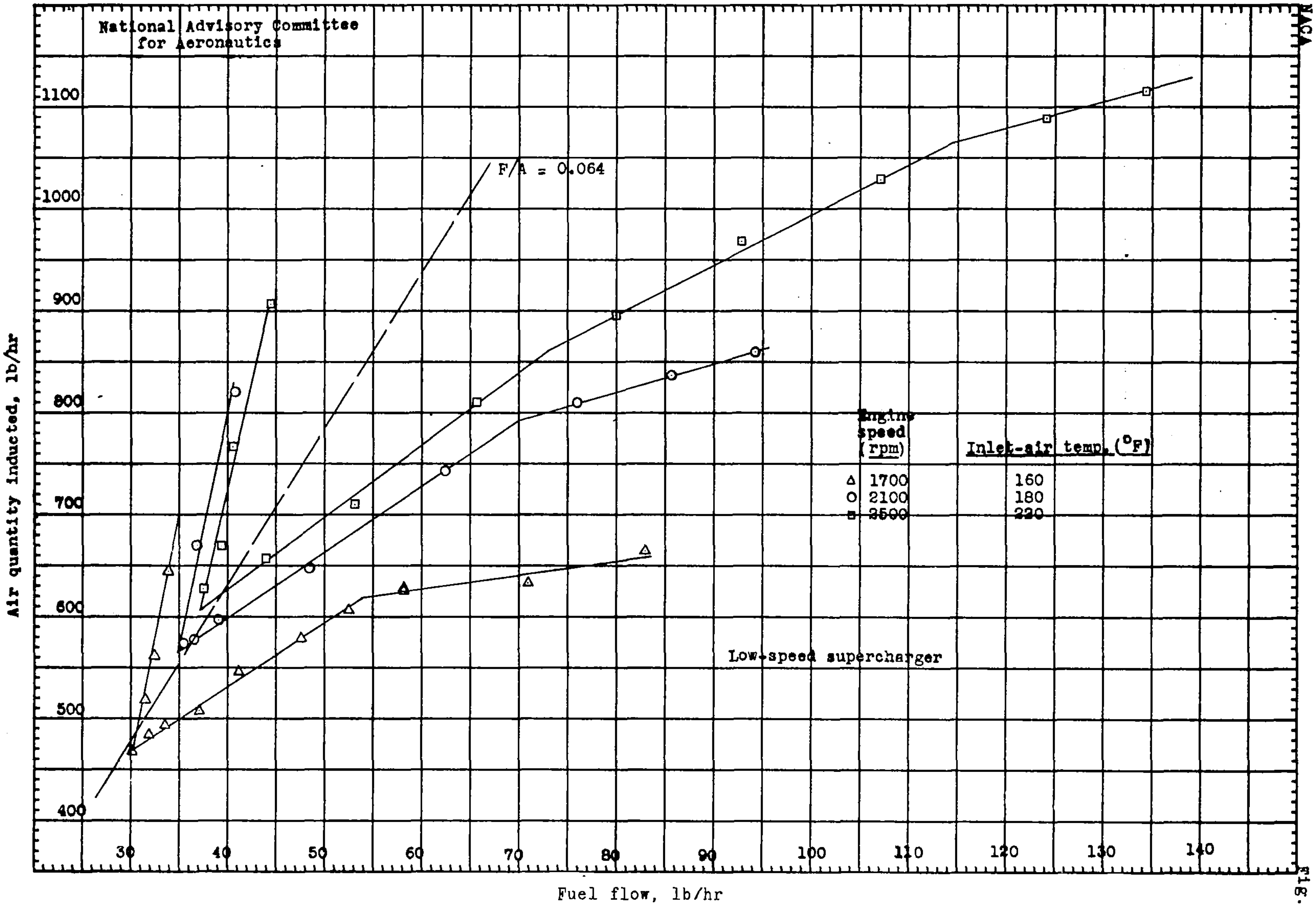


Figure 2. - Knock-limit curves for current 100-octane-number aviation gasoline. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 180° F; compression ratio, 7.0.

Fig. 2

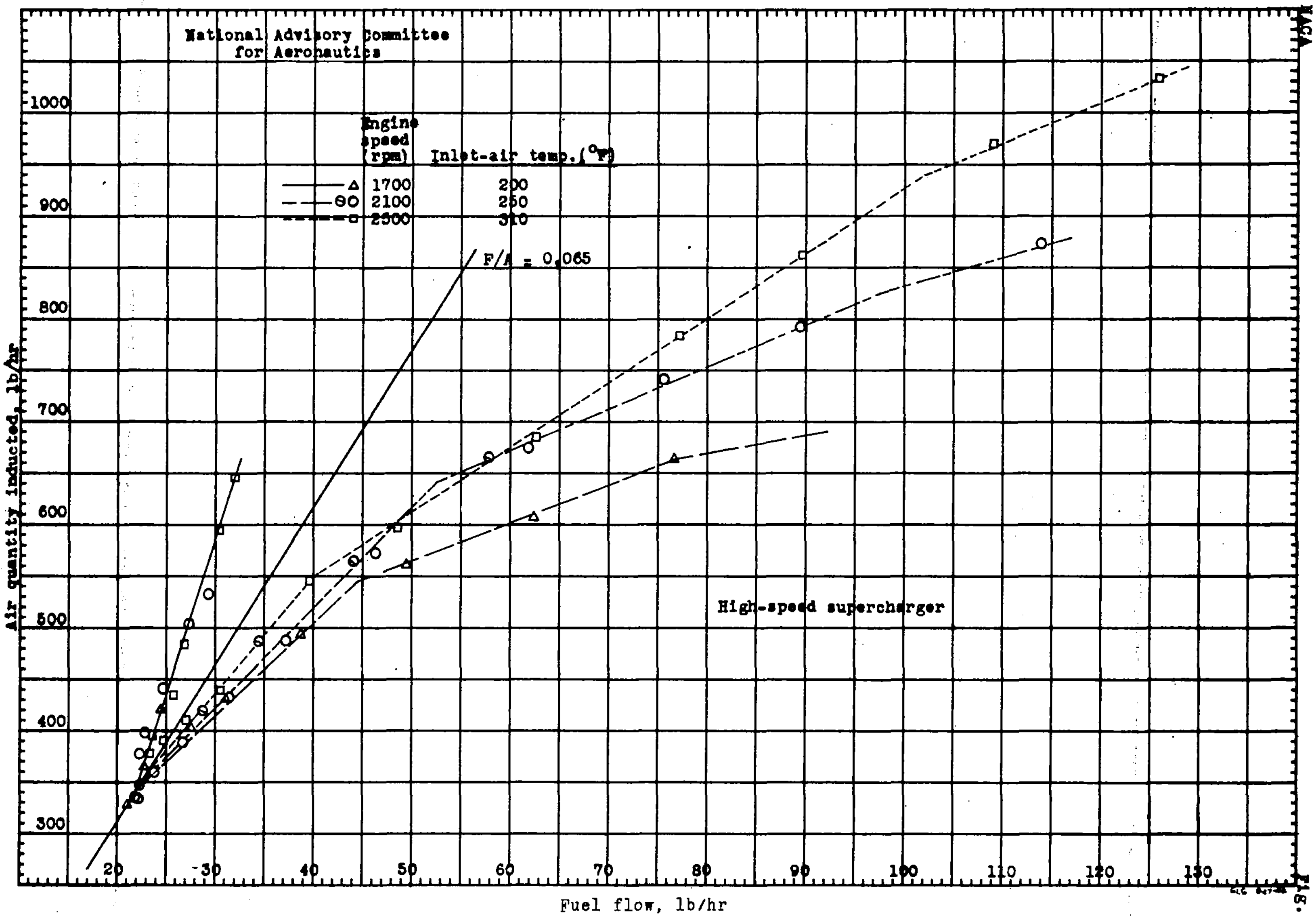


Figure 3. - Knock-limit curves for current 100-octane-number aviation gasoline. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 180 - 185° F; compression ratio, 7.0.

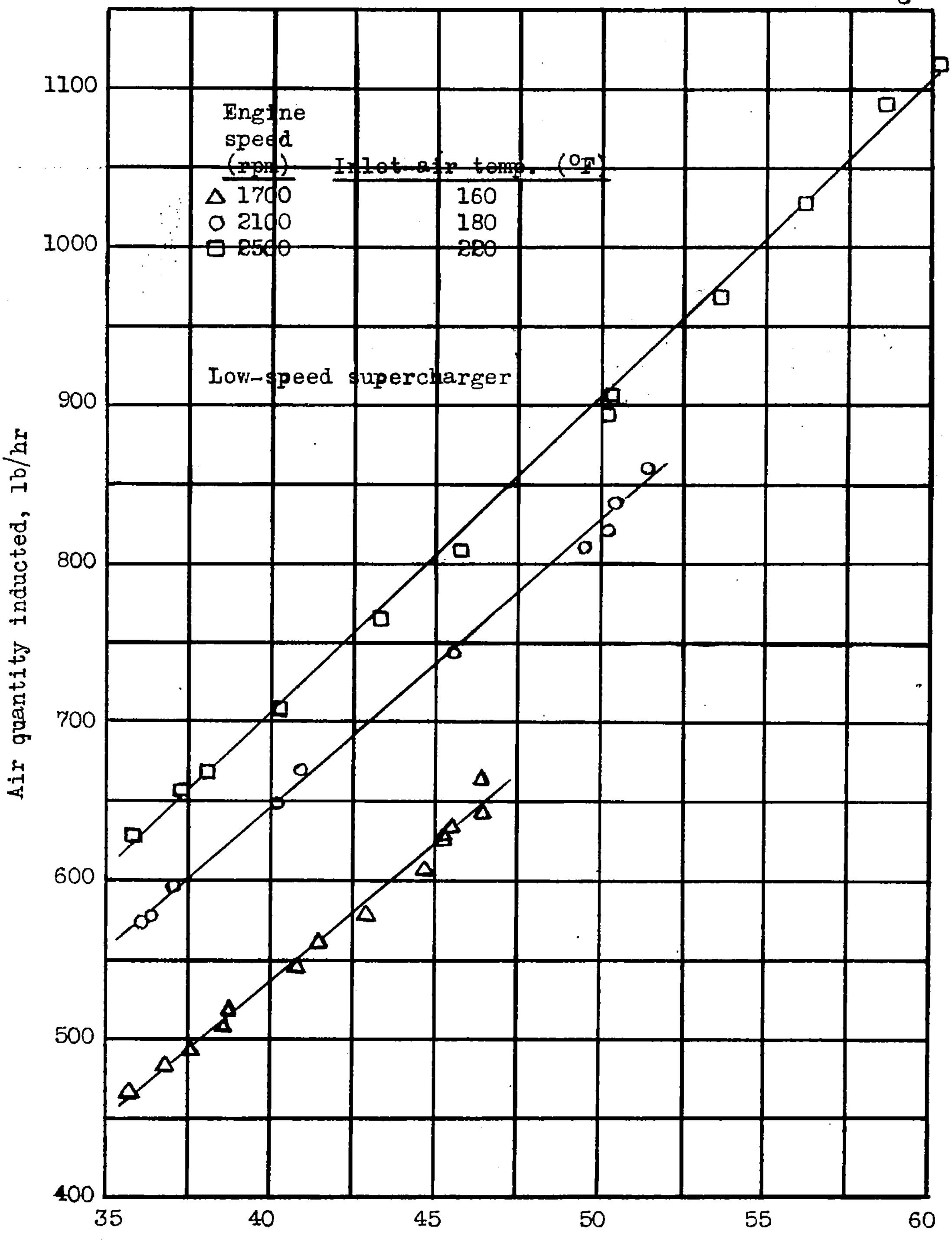
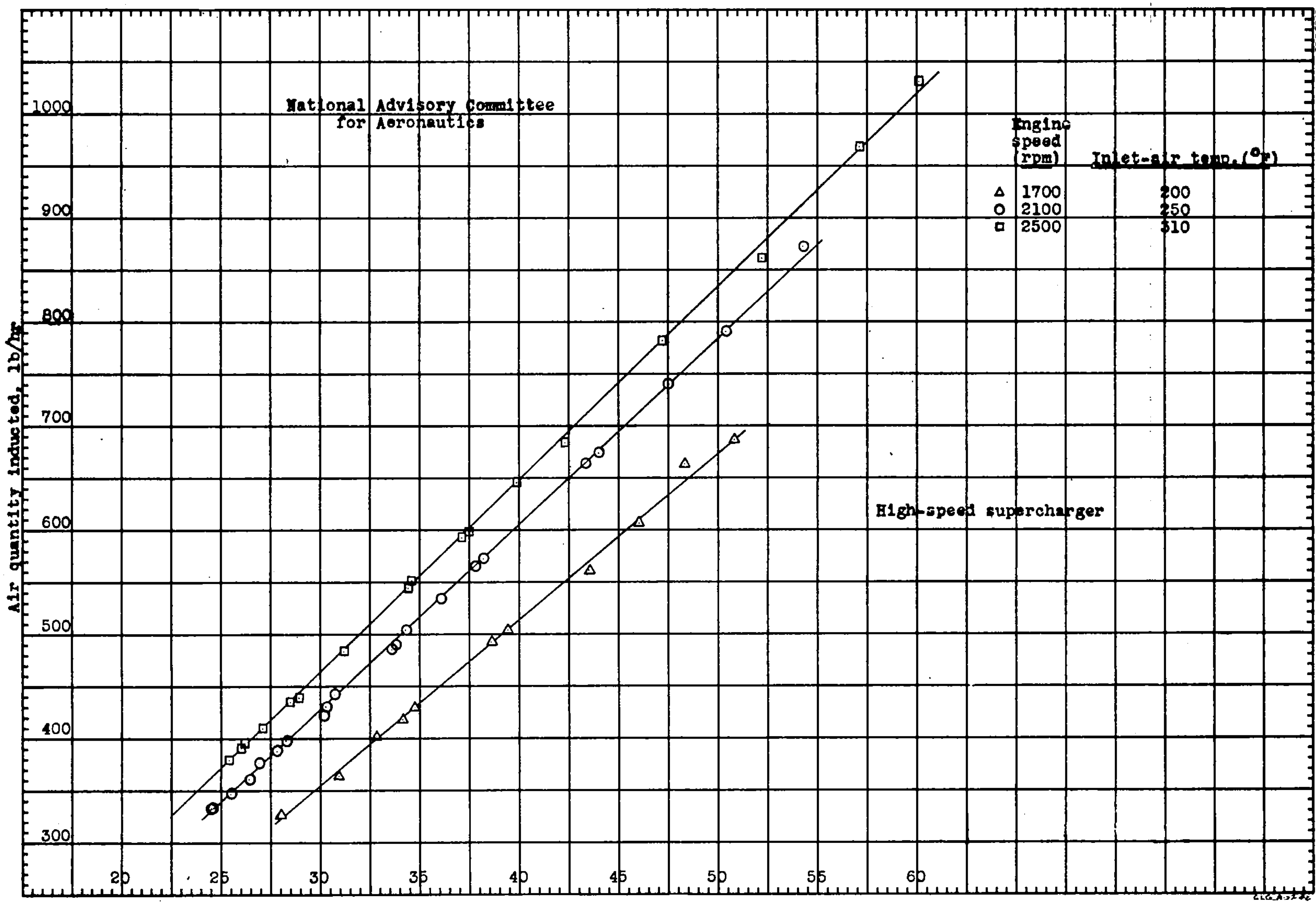


Figure 4. - Relation between inlet-air pressure and air quantity inducted. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 180° F; compression ratio, 7.0.



Inlet-air pressure, in. Hg abs.

Figure 5. - Relation between inlet-air pressure and air quantity inducted. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 180 - 185° F; compression ratio, 7.0.

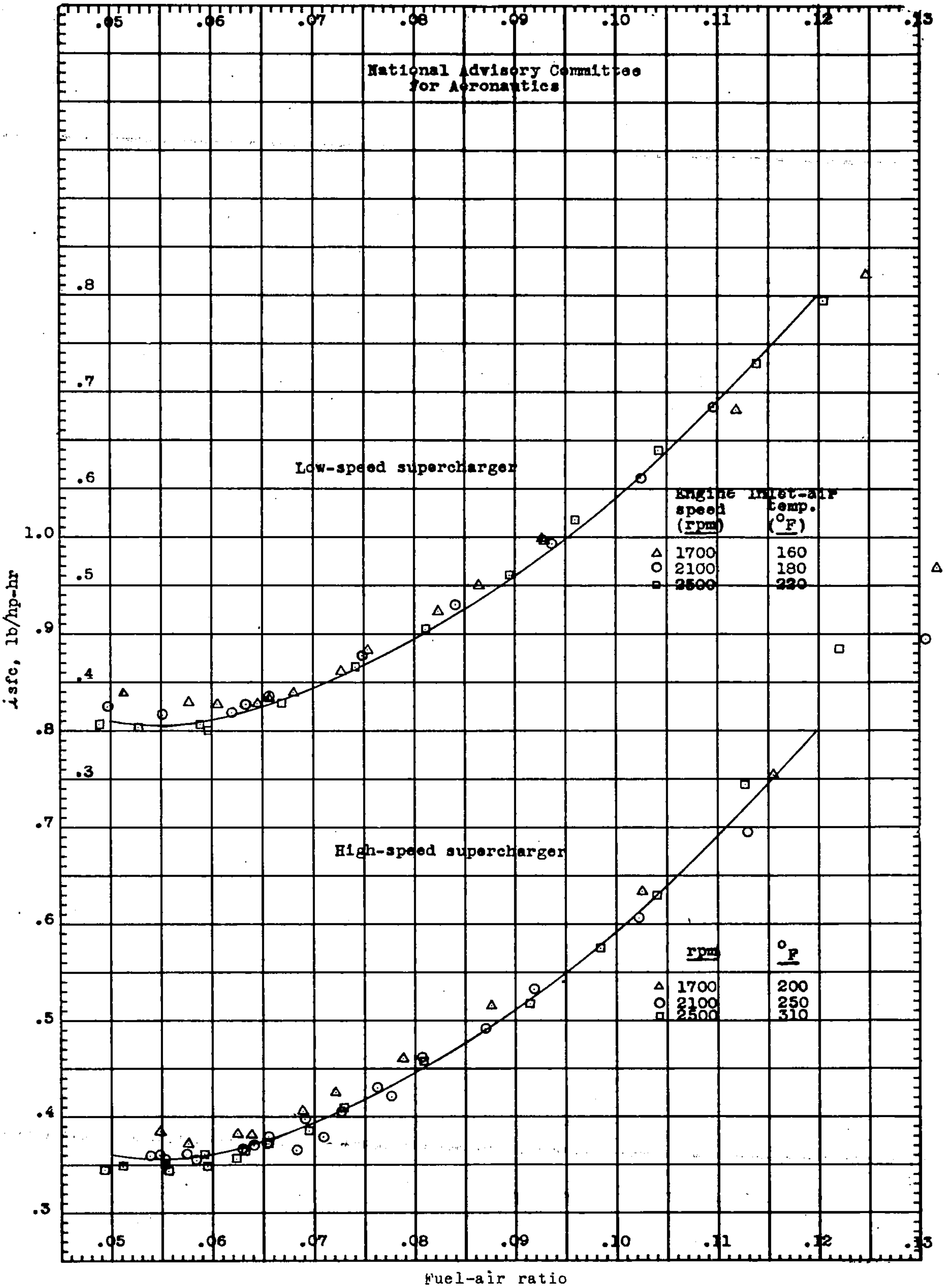


Figure 6. - Relation between fuel-air ratio and indicated specific fuel consumption. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 185° F; compression ratio, 7.0.

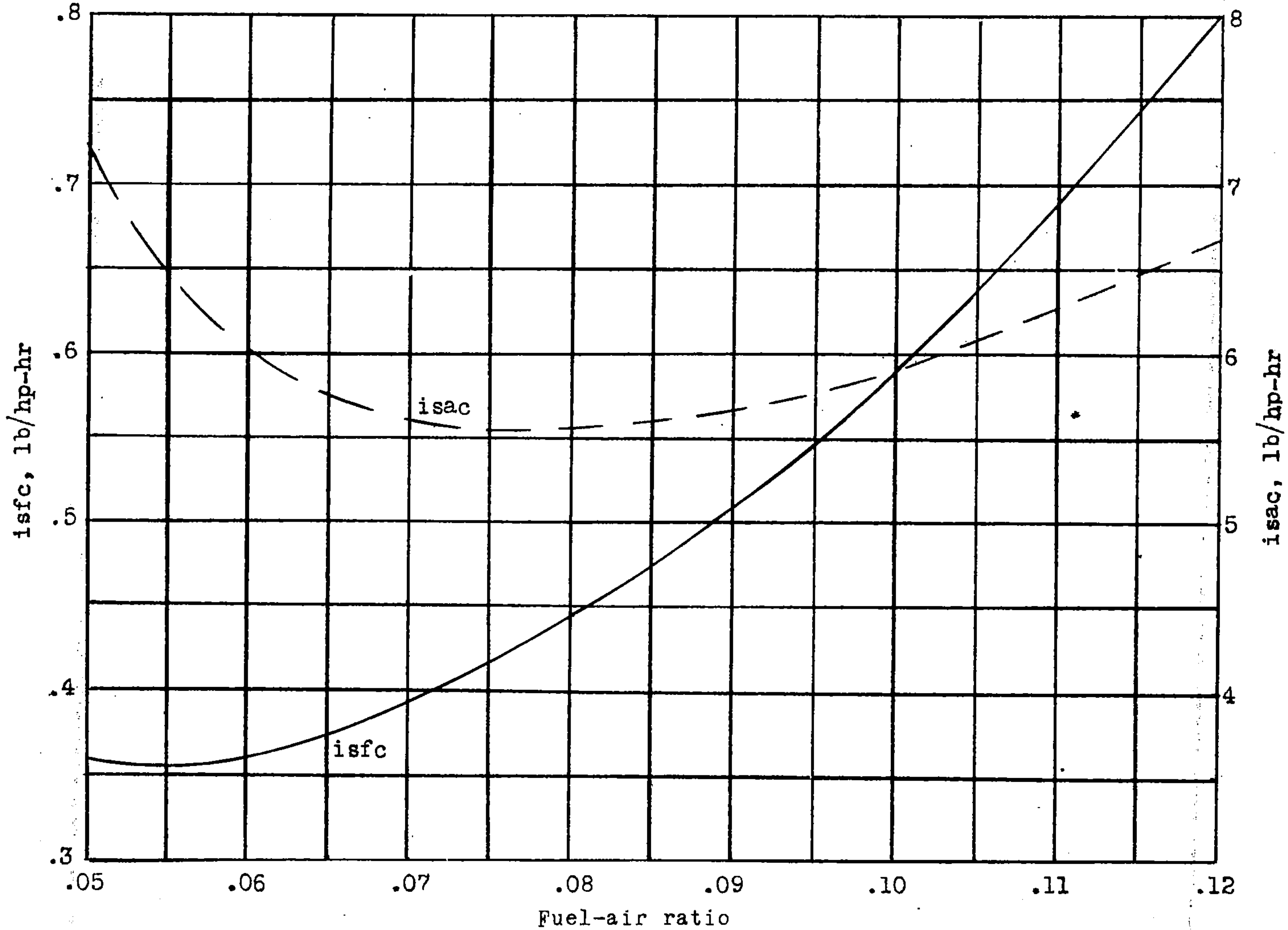


Figure 7. - Relation between fuel-air ratio and average indicated specific fuel and air consumptions. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 185° F; compression ratio, 7.0.

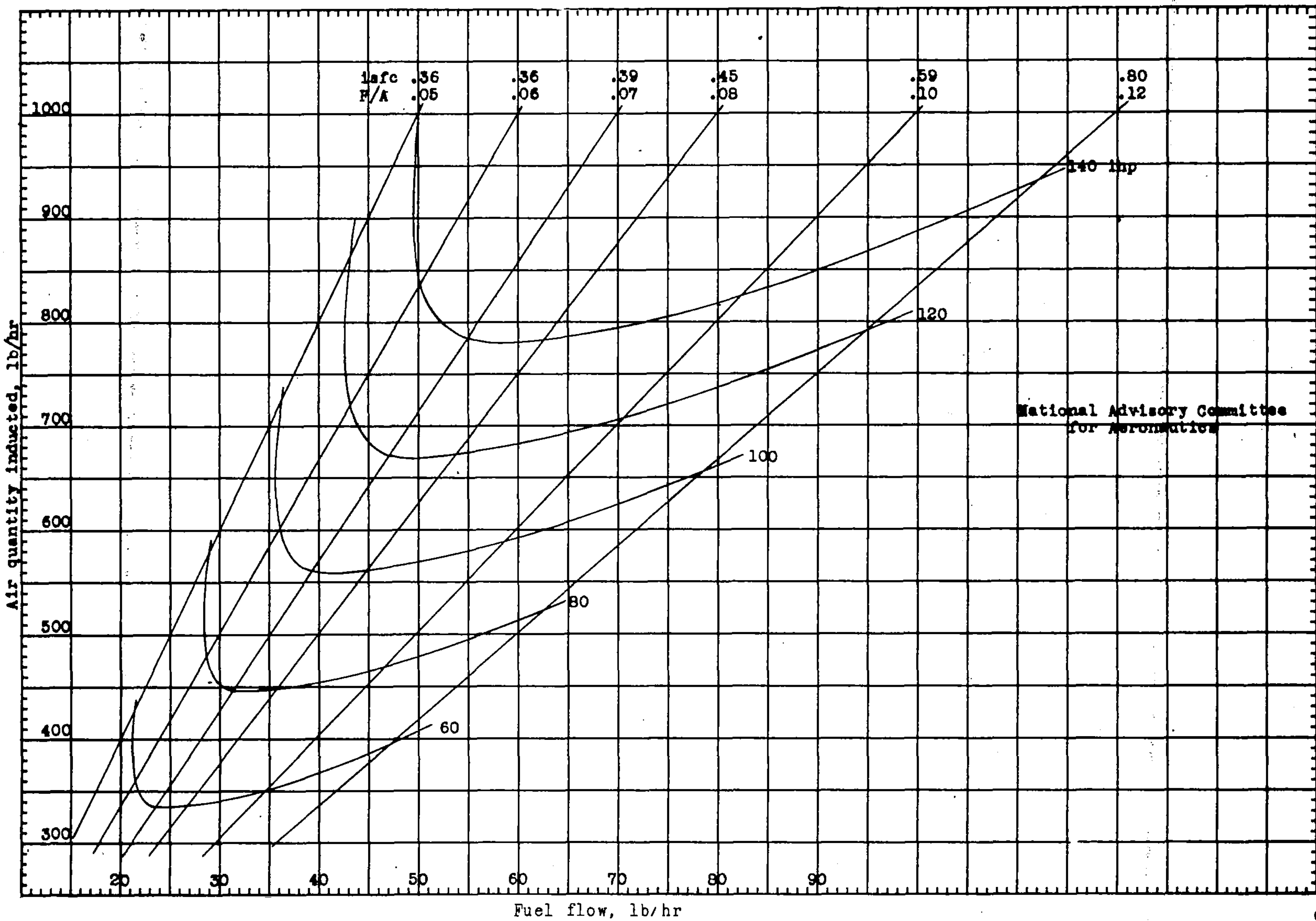


Figure 8. - Performance chart showing relation between fuel-air ratio and indicated horsepower and rate of fuel flow and air flow to the cylinder. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 185° F; compression ratio, 7.0.

Fig. 8

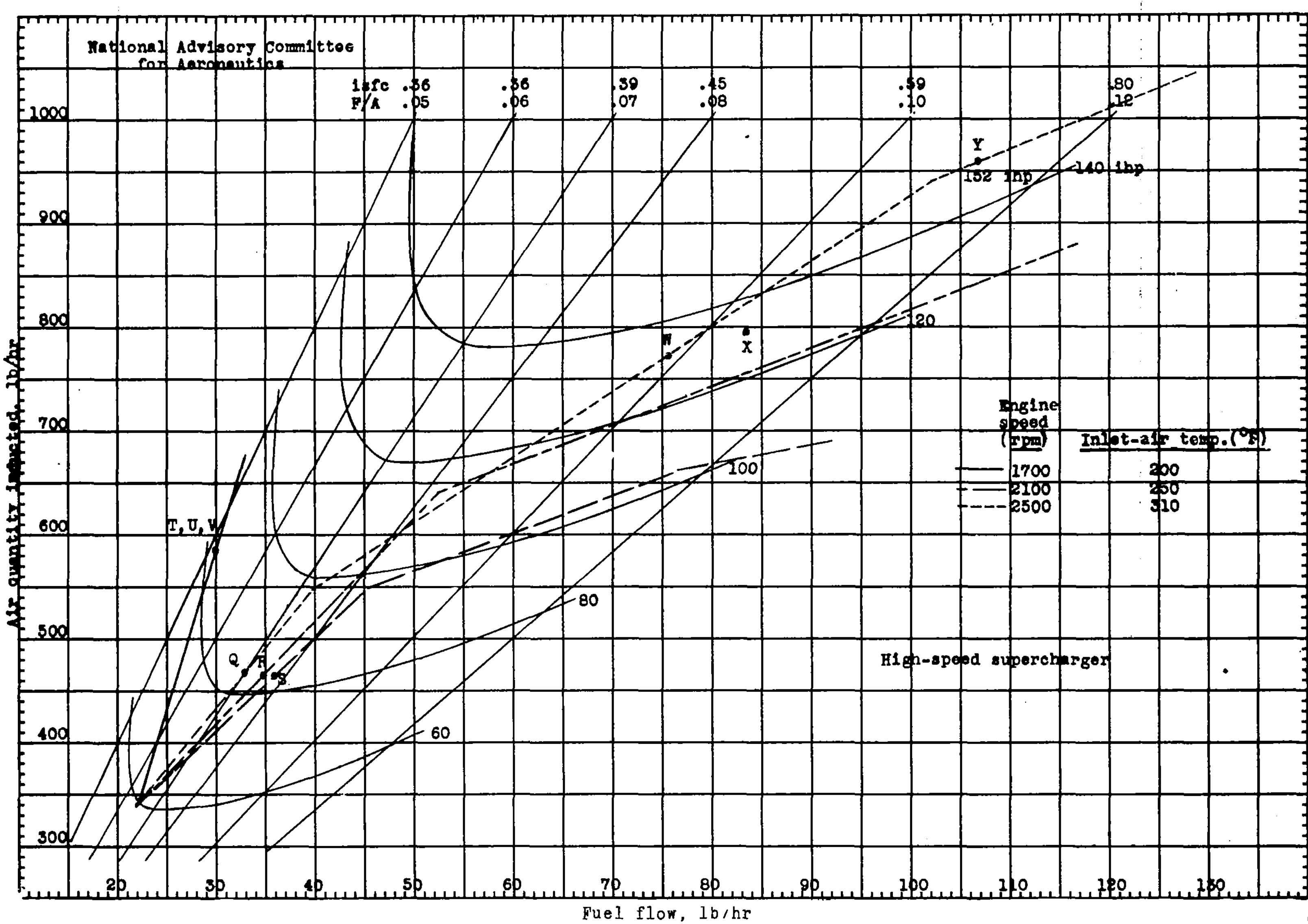


Figure 9. - Performance chart for single-cylinder test engine using current 100-octane-number aviation gasoline. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 185° F; compression ratio, 7.0.

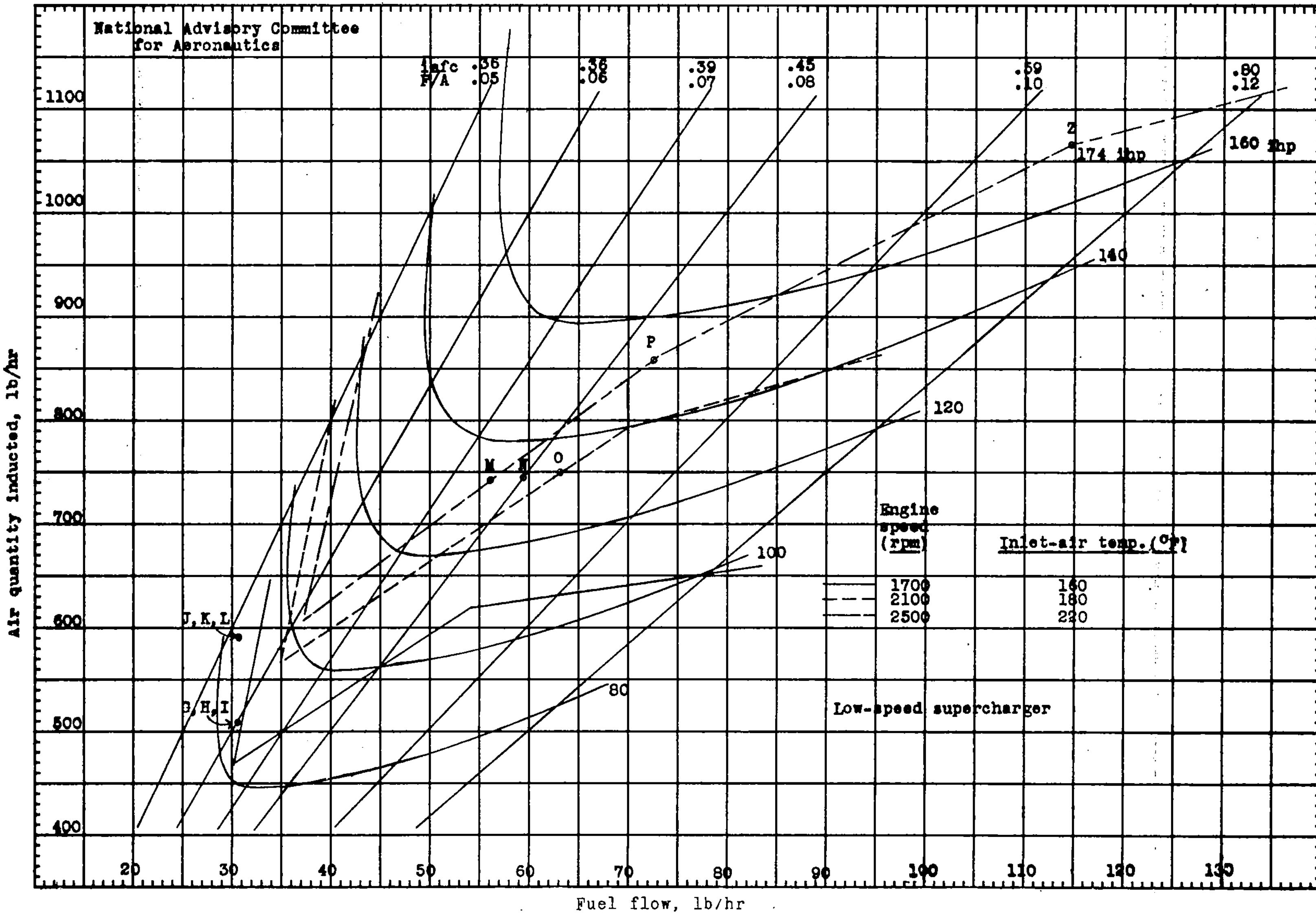


Figure 10. - Performance chart for single-cylinder test engine using current 100-octane-number aviation gasoline. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 180° F; compression ratio, 7.0.

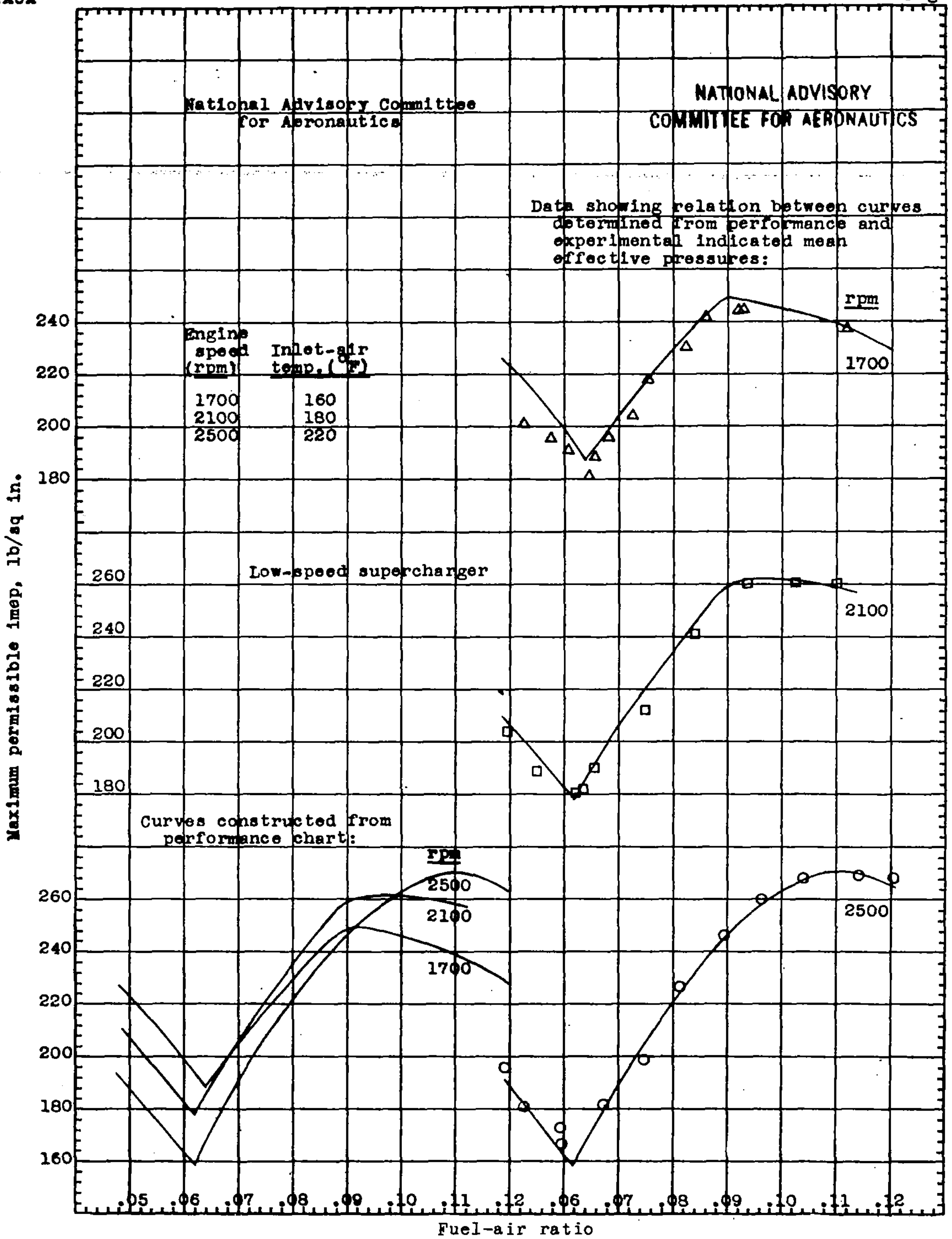


Figure 11. - Relation between fuel-air ratio and maximum permissible indicated mean effective pressure for assumed inlet-air temperatures at three different engine speeds. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 180° F; compression ratio, 7.0.

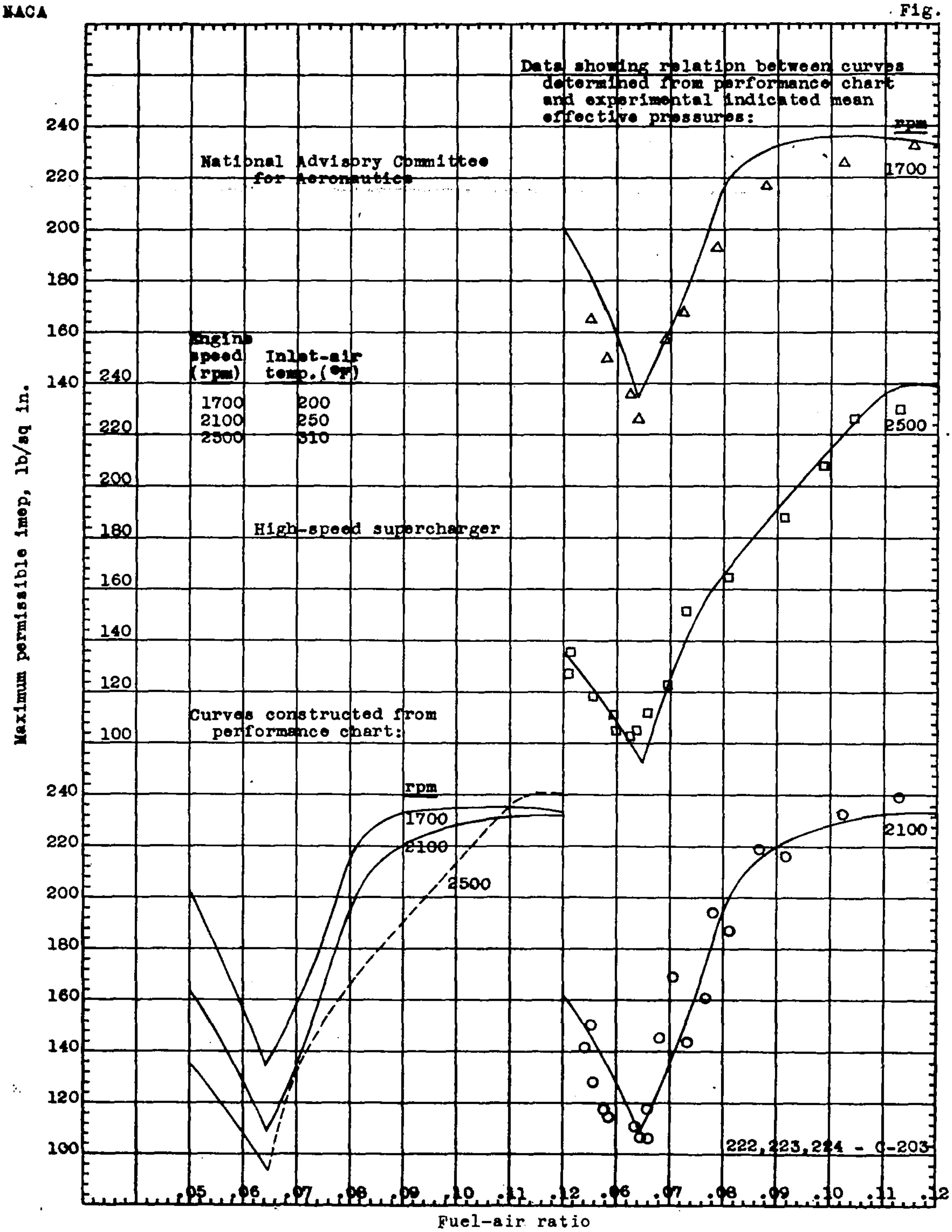


Figure 12. - Relation between fuel-air ratio and maximum permissible indicated mean effective pressure for assumed inlet-air temperatures at three different engine speeds. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 185° F; compression ratio, 7.0.

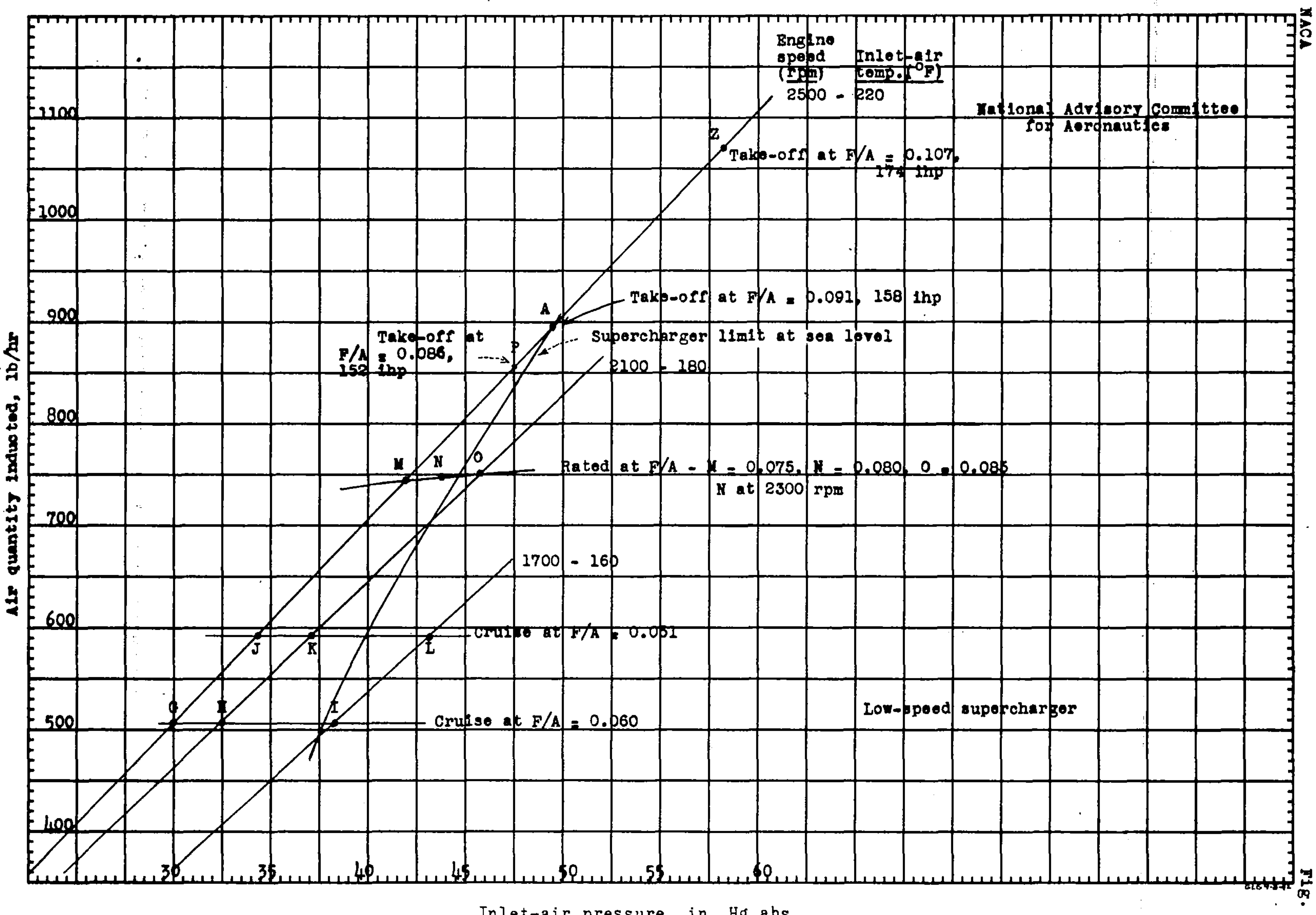


Figure 13. - Performance chart for cylinder as limited by knock or by supercharger capacity. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 180° F; compression ratio, 7.0.

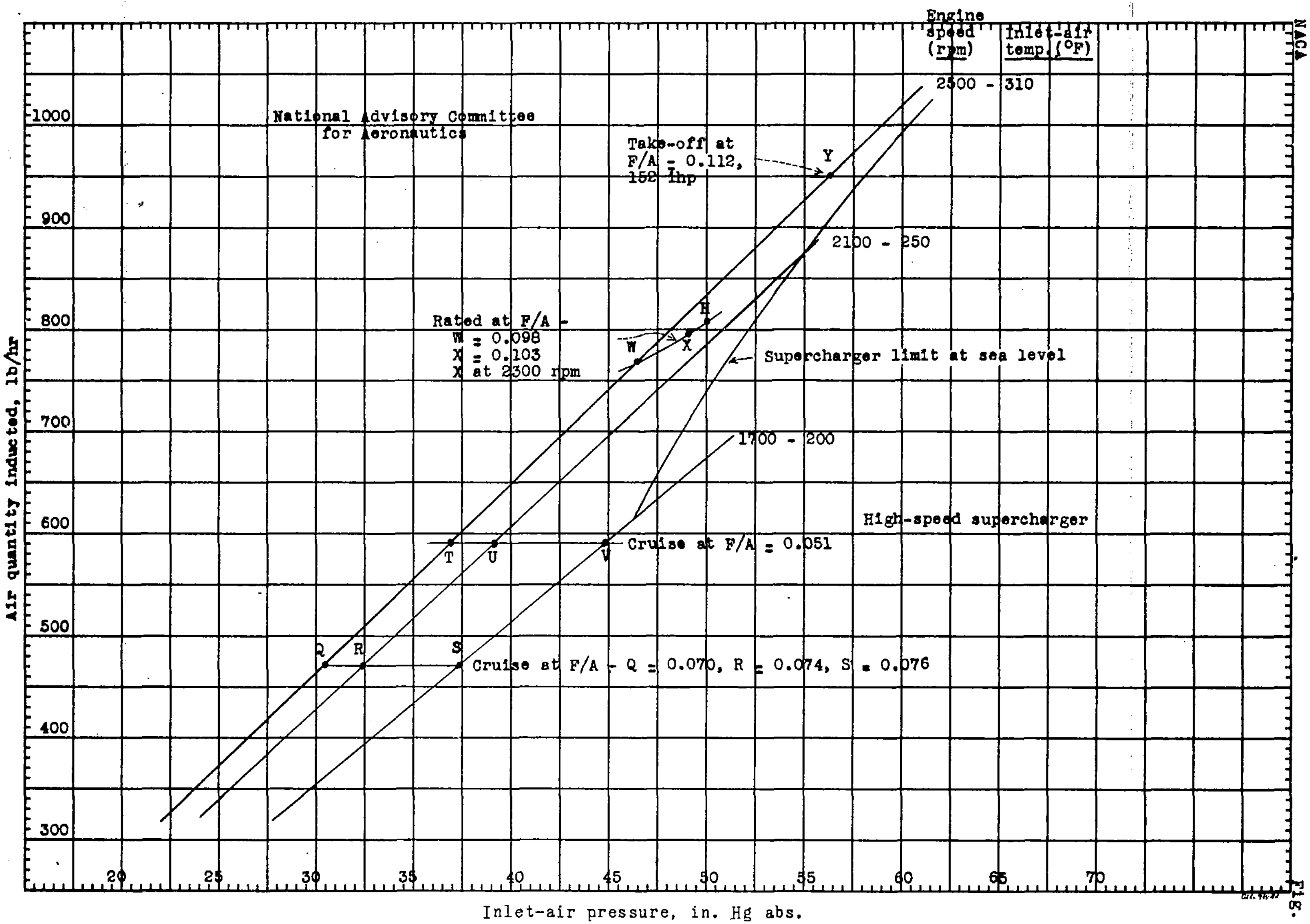


Figure 14. - Performance chart for cylinder as limited by knock or by supercharger capacity. Wright 1820-G-200 cylinder; spark advance, 20° B.T.C.; cooling-air pressure drop across cowling, 20 inches H_2O; cooling-air temperature, 125° F; oil-in temperature, 170 - 180° F; compression ratio, 7.0.

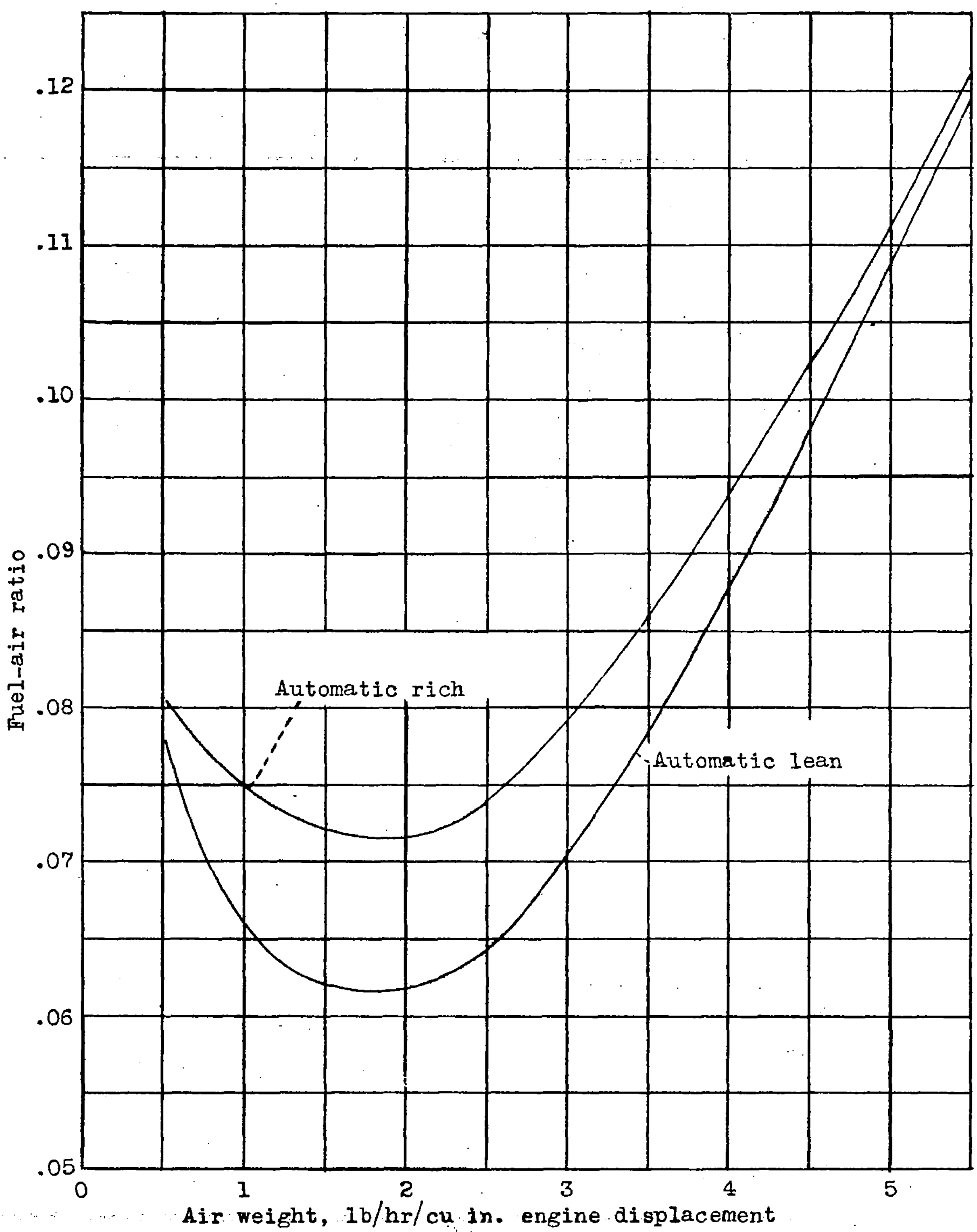
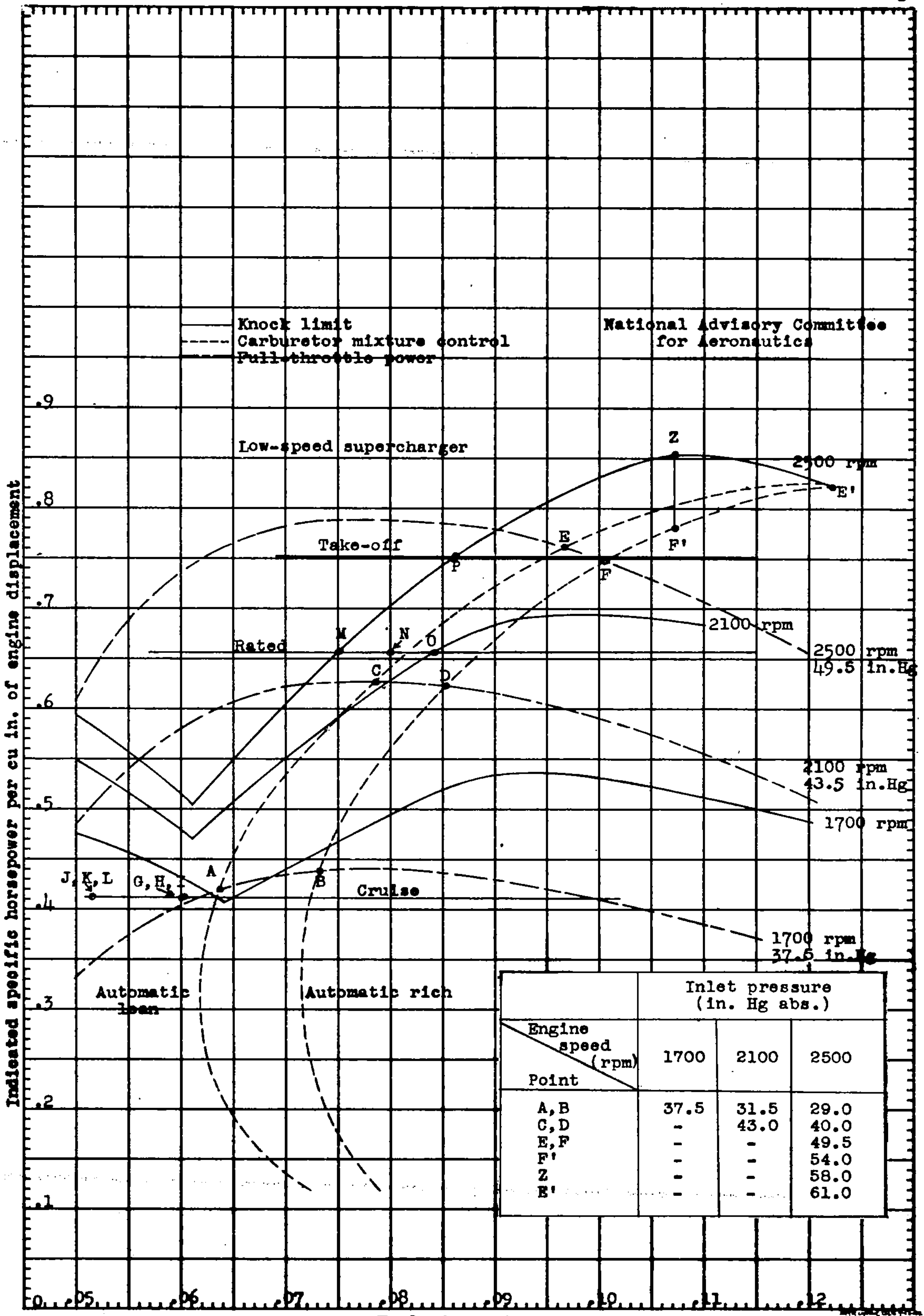


Figure 15.- Carburetor mixture-control characteristics for automatic rich and automatic lean.



Point \ Engine speed (rpm)	Inlet pressure (in. Hg abs.) 1700	2100	2500
A,B	37.5	31.5	29.0
C,D	-	43.0	40.0
E,F	-	-	49.5
F'	-	-	54.0
Z	-	-	58.0
E'	-	-	61.0

Figure 16. - Relation between knock-limit performance of fuel and supercharger and carburetor-mixture-control characteristics expressed in terms of indicated specific horsepower as a function of fuel-air ratio for a current 100-octane-number aviation gasoline.

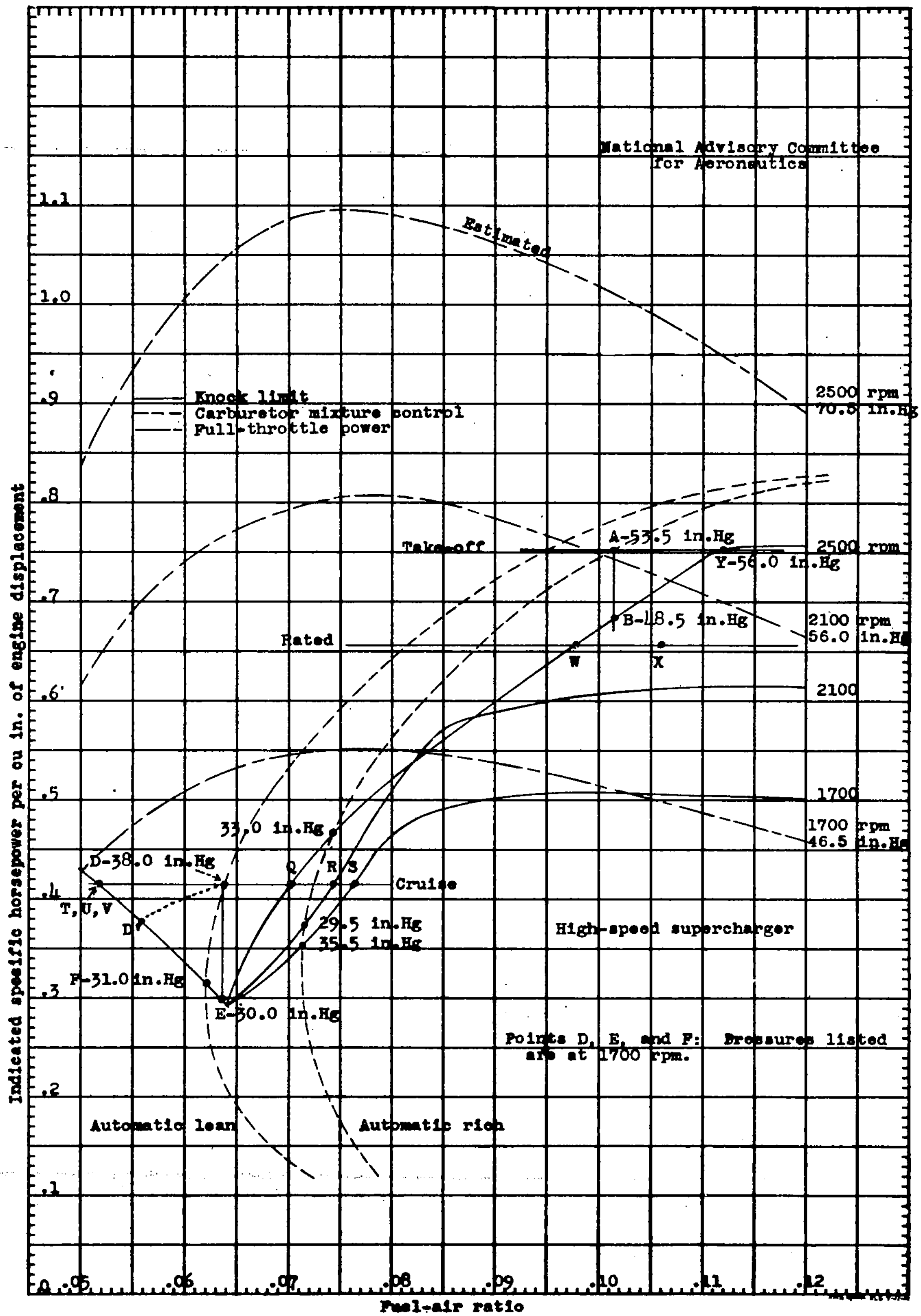


Figure 17. - Relation between knock-limit performance of fuel and supercharger and carburetor-mixture-control characteristics expressed in terms of indicated specific horsepower as a function of fuel-air ratio for a current 100-octane-number aviation gasoline.

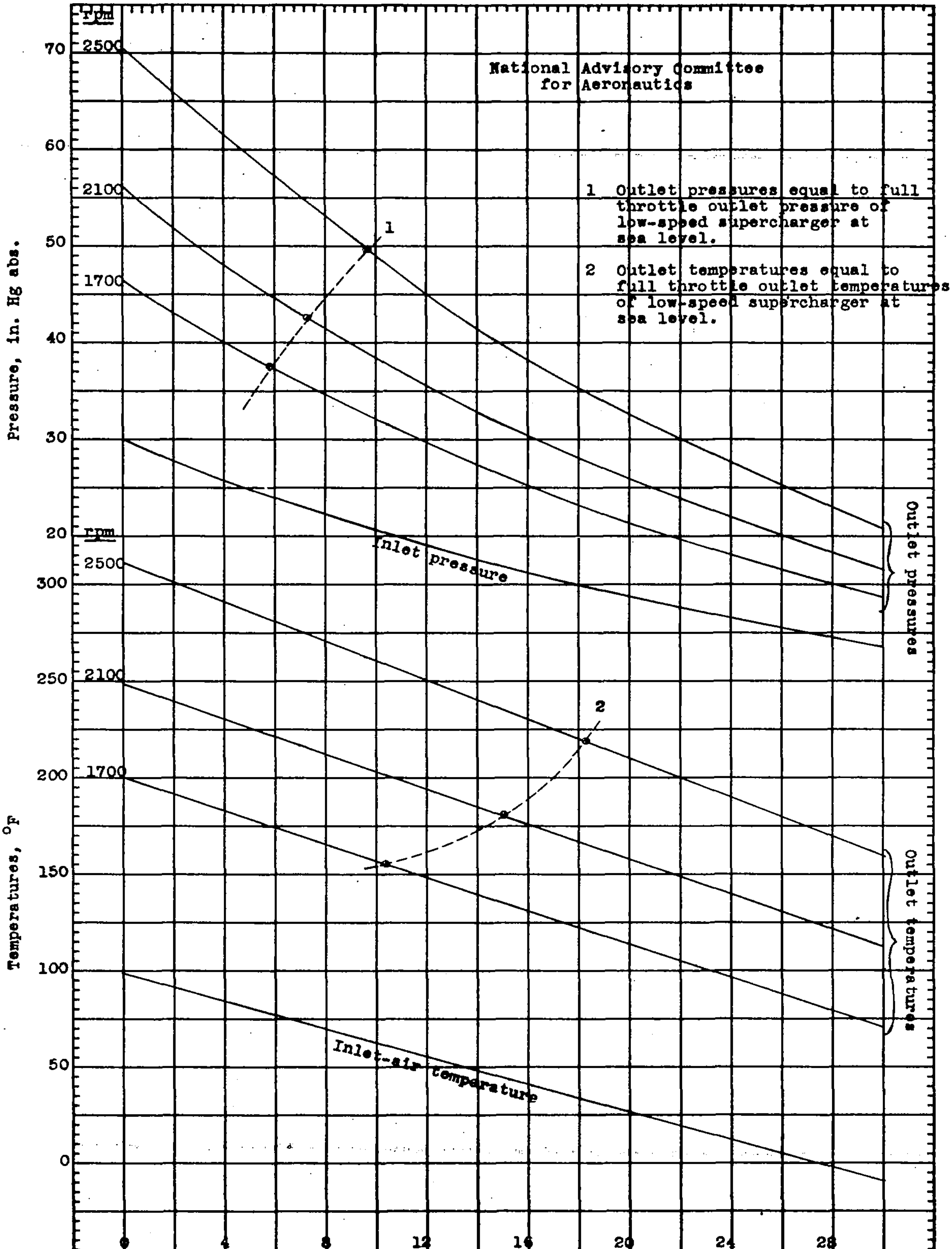


Figure 18. - Effect of altitude on condition of air at supercharger outlet. High-speed supercharger.