NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM

No. 1169

DESCRIPTION OF RUSSIAN AIRCRAFT ENGINES "AM 35" AND "AM 38"

By H. Denkmeier and K. Gross

Translation
"Beschreibung der russischen Flugmotoren "AM 35" und "AM 38"
Deutsche Luftfahrtforschung, Untersuchungen und Mitteilungen Nr. 690
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Only the following excerpts, which describe the Russian developed swirl throttle, have been translated and are presented here.

A. DESCRIPTION OF AM 35 AND AM 38 ENGINES

IV. Construction of Engines

10. Supercharger. - The AM 35 supercharger and the AM 38 supercharger (fig. 3) are of a single-stage centrifugal type. Mounted on a 16-blade half-open impeller is a steel inducer. Adjoining the impeller is a nonbladed annular casing of large radial dimension to which the swirl throttle is attached (figs. 21 and 22). The technically most modern part is the swirl throttle (fig. 26) mounted on the inlet to the supercharger; the mechanical construction of this throttle is strikingly simple. Because the swirl throttle has up to the present time never been found on other engines, the assumption may be made that this throttle is a purely Russian development. Twelve radial guide vanes carried by journals at the outer ends are simultaneously controlled by means of toothed segments and a toothed ring. Motion is transmitted by a boost-pressure regulator mounted on the side of the supercharger housing to one of the guide vanes. Placement of the vanes in an oblique position imparts a spiral motion to the air in the direction of rotation of the supercharger and reduces the supercharger driving power. The smaller amount of supercharger work is accompanied by a smaller temperature rise in the compressor. Because the swirl throttle also has the functions of a boost-pressure regulating valve, its effect on the adiabatic pressure head of the supercharger is greatest near sea level because of the markedly oblique setting of the vanes and decreases with increasing altitude, that is, with the increase of the angle to which the blades are open.

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*"Beschreibung der russischen Flugmotoren "AM 35" und "AM 38." Deutsche Luftfahrtforschung, Untersuchungen und Mitteilungen Nr. 690. Deutsche Versuchsanstalt f. Luftfahrt E. V., Inst. f. Triebwerk-Gestaltung, Motoren-Prüffeld, Berlin-Adlershof, ZWB, Aug. 1, 1942.

The supercharger work saved by this method of throttling is considerable; it will be discussed further in the description of investigations, which follows.

The swirl throttle installed in the AM 35 and the AM 38 allows very high supercharger speeds at sea level and therefore allows the elimination of a gear shift for low altitudes.

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B. TEST RUNS OF AM 35 AND AM 38 ENGINES

II. Test Run of AM 38 Engine

The engine is a purely low-altitude engine equipped with a supercharger, the full pressure altitude of which is 2.2 kilometers. The influence of the swirl throttle, which is noticeable only below full pressure altitude, did not appear very strongly in these tests because of the low design altitude of the supercharger. This characteristic first became fully evident in the operation of the AM 35-A engine, which is equipped with a high-altitude supercharger. [NACA comment: The statement had previously been made that "The superchargers of the two engines are of exactly the same design except for the gear ratios", namely 11.05:1 and 14.6:1.]

. . . The maximum output was reached at an altitude of approximately 2.2 kilometers; from there the output curve passes into the normally falling branch by way of an arc. This arc-shaped bend at full pressure altitude is caused by the swirl throttle. The advantage of the swirl throttle, to which in effect the possibility of eliminating the sea-level stage of the supercharger is due, becomes apparent in a very considerable increase of output below full pressure altitude as compared to operation with the normal throttle. For example, if for the output curve at $p_L = 1.56$ atmospheres absolute and $n = 2150$ rpm, the indicated outputs of the engine with and without the swirl throttle are calculated according to

$$N_i \text{ with throttle} = \frac{\eta_i \times 714 \times G_L \text{ with throttle}}{632}$$

where $\eta_i = 0.32$, for indicated output with swirl throttle at $p_L = 1.56$ atmospheres absolute, $t_L = 95^\circ$ C, and $n = 2150$ rpm.

$$N_i \text{ with throttle} = \frac{0.32 \times 714 \times 4920}{632}$$

$$N_i \text{ with throttle} = 1780 \text{ horsepower}$$

Because the quantities of air with and without swirl throttle at equal boost pressure vary in proportion to the absolute temperature, for the air delivery without swirl throttle at $p_L = 1.56$ atmospheres absolute and $t_L = 116^\circ$ C the following results are obtained:

$$G_L \text{ without throttle} = \frac{T_L \text{ with throttle}}{T_L \text{ without throttle}} G_L \text{ with throttle}$$

$$= \frac{368}{389} \times 4920 = 4650 \text{ kilograms per hour.}$$

and therefore

$$N_i \text{ without throttle} = \frac{0.32 \times 714 \times 4650}{632} = 1680 \text{ horsepower}$$

At an altitude of 0, a gain in power of 100 horsepower, which decreases to 0 at full pressure altitude (hatched area in fig. 30), is calculated. The same power gain is found in actual test. The reduction of temperature due to the swirl throttle was measured as 21° C; corresponding to the temperature behavior of the engine, a power gain of 70 horsepower is attained. To this gain is added the reduction in power used to drive the supercharger, in accordance with

$$N_{e-l} = \frac{G_s \, c_p \, \Delta t \times 427}{75}$$

with swirl throttle

$$N_{e-l} = \frac{1.37 \times 0.24 \times 80 \times 427}{75} = 149.5 \text{ horsepower}$$

without swirl throttle

$$N_{e-l} = \frac{1.29 \times 0.24 \times 101 \times 427}{75} = 178 \text{ horsepower}$$

$$\Delta N_{e-l} = 28.5 \text{ horsepower}$$

$$\frac{\Delta Hw}{Hw \text{ total}} = 0.192$$

$$\frac{\Delta \text{Had}}{\text{Had total}} = 0.405$$

Thus with a 40.5-percent reduction of the adiabatic pressure head a saving in supercharger driving power of 19.2 percent is obtained.

For the 100 horsepower calculated power gain, an experimentally observed gain of $70 + 28.5 = 98.5$ horsepower, that is, 70 horsepower, is gained from the reduction of temperature and about 30 horsepower from the reduction of power input to the supercharger. The decrease in power gain as full pressure altitude is approached is caused by the increased opening angle of the swirl throttle (fig. 30), which is controlled by the boost-pressure regulator.

[NACA comment: A further power gain should result from the decreased supercharger outlet temperature. Decreased mixture temperature will result in higher permissible power output with fuel of a given knock rating.]

. . .

Figure 31 shows the pressures behind the supercharger corresponding to the altitude-power graph. These pressure curves have the same shape as is usual with conventional regulating valves. Only at full pressure altitude is there, due to the nature of the swirl throttle, a curved transition instead of an angle in the curve. The pressure loss in supercharger duct and carburetor with fully opened swirl throttle amounts to 100 millimeters of mercury.

The temperature reduction caused by the swirl throttle at full pressure altitude is shown in figure 32. Here the temperature, like the supercharger-outlet pressure, remains at the same level until above full pressure altitude. The thin lines below an altitude of 3.2 kilometers show the curve of boost air temperature that would be attained without the swirl throttle. Only at an altitude of 3.2 kilometers does the actual temperature difference $T_{II} - T_I$ reach the values corresponding to operation with open swirl throttle. The inlet-air temperatures to the supercharger correspond to the Ina temperatures.

In figure 33, air consumption is plotted against altitude. In spite of the relatively great scattering of the data points, it may be seen that each curve is convex downwardly until full pressure altitude is reached. The part of the curve rising again as full pressure altitude is approached corresponds to the usual air-quantity curves for multicylinder engines, which rise at a uniform rate until full pressure altitude is reached. In the same engine, the improved flow coefficient at low altitudes due to the swirl throttle produces an increase in air quantity at sea level. Beyond full pressure altitude, the curves follow a normal course.

. . .

Figure 35 shows the variation of certain engine operating characteristics with engine speed, which at the usual operating speeds of 1800 to 2200 rpm is very slight. The influence of the swirl throttle is particularly apparent here in the boost air temperature. The numbers printed beside the data points indicate the opening angles of the swirl throttle. Below $n = 1640$ rpm, the swirl throttle is wide open because of the low boost pressure and therefore has no effect. In this region the temperature rises as a function of the speed in the usual manner. Only with the closing of the swirl throttle does a break appear in the temperature curve. Thereafter, the observed temperatures run far below the temperatures without swirl throttle, which are shown by the thin line. Breaks are also evident in the power and specific fuel consumption curves.

III. Test Run of AM 35 Engine

. . . Due to the greater full pressure altitude [NACA comment: 6 km], the effect of the use of the swirl throttle is much greater as compared with the AM 38 engine.

. . .

. . . Full pressure altitude is 6 kilometers with an output of 1240 horsepower. Equal pressure altitude is 9.5 kilometers with an output of 870 horsepower. The power gain produced by the swirl throttle is made clearly evident by some data points obtained with the throttle disconnected (fig. 40).

Thus at an altitude of 2 kilometers, $p_L = 1.35$ atmospheres absolute, and $n = 1750$ rpm, a power difference of approximately 100 horsepower is observed. By extending this power line in the usual manner as a straight line towards an altitude of 0, at that point with these same operating data, a power gain of 150 horsepower, which becomes still greater for higher speed and higher boost pressure, appears. Because of the high boost air temperatures, these measurements could be made only at lower speeds and higher altitudes. In the same figure the respective opening angles of the swirl throttle are shown.

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The respective pressures ahead of the supercharger and the supercharger-outlet pressures measured at full throttle are shown in figure 41. Here the swirl throttle acts simply as a boost pressure regulator. The pressure loss in the air duct and the carburetor amounts to 100 millimeters of mercury.

The effect of the marked temperature reduction produced by the swirl throttle is most clearly evident in the graph of boost air temperatures plotted against altitude (fig. 42). At an altitude of 0 and $n = 2050$ rpm, there is a temperature reduction of 43° C. The supercharger pressure has no influence on the temperature level.

Figure 43 shows air consumption plotted against altitude. Here, as in the AM 38 engine, the saddle-shaped form of the curves below full pressure altitude may be observed. The thin lines show air flow in the tests with the swirl throttle disconnected and correspond to the usual curves with a clack throttle. In these air-consumption curves the effect of the swirl throttle is again clearly evident.

The flow coefficient for the same operating condition with and without swirl throttle is plotted in figure 44. The air quantities for the flow coefficient without swirl throttle were extrapolated on the basis of the available data points.

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The variation of certain operating characteristics with the speed (fig. 46) is very small between $n = 1900$ to 2150 rpm. At $p_L = 1.1$ atmospheres absolute, this range extends to 1600 rpm. Because the high supercharger gear ratio in this engine produces even at lower engine speeds a high supercharger-outlet pressure that keeps the swirl throttle constantly in an almost closed position, there is no visible effect of the swirl throttle in these curves, as contrasted with those for the AM 38 engine. The numbers adjoining the data points give the opening angles of the swirl throttle.

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In figure 53, the curves of external driving power are plotted against altitude. The inputs were observed with the normal operating condition of the engine and with open and closed gas throttle. The swirl throttle operated in the normal manner; to this operation must be attributed the deviation of the curves from the normal course below full pressure altitude because of reduction of supercharger power input. At an altitude of $H = \infty$ kilometers, the curves with open and with closed gas throttle intersect at the points that correspond to the power necessary to overcome friction alone without any work of gas changing.

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IV. SUMMARY

. . . The presence of the swirl throttle permits a gain of 100 horsepower at sea level; operation of the engine below full pressure altitude, which, as stated in the Russian manual, is reached at an altitude of 2 kilometers, is not possible without the swirl throttle. . . .

Translation by Edward S. Shafer,
National Advisory Committee
for Aeronautics.

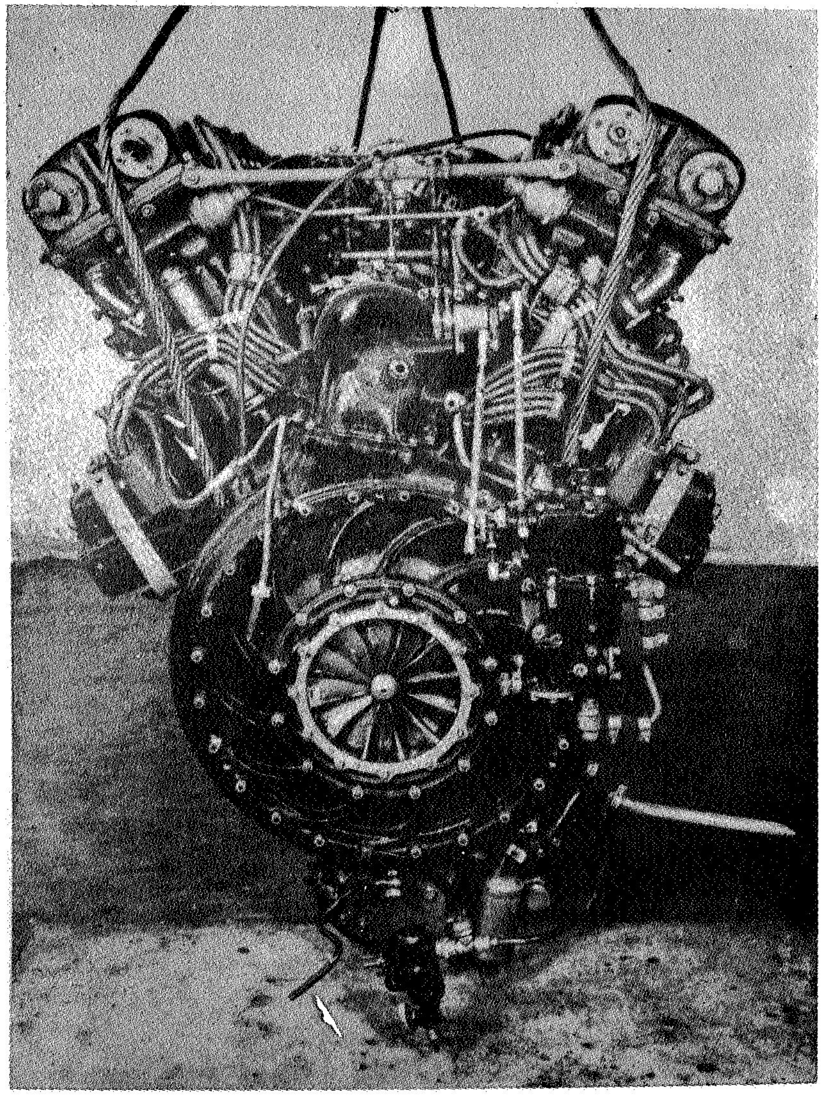

Figure 3. - View of accessories and supercharger of AM 38.

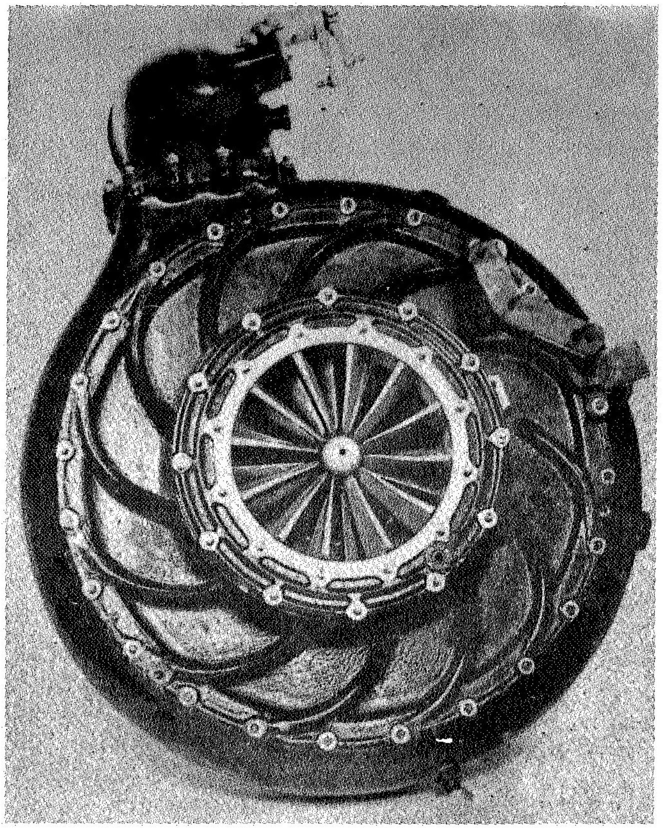

Figure 21. - Supercharger. View of swirl throttle.

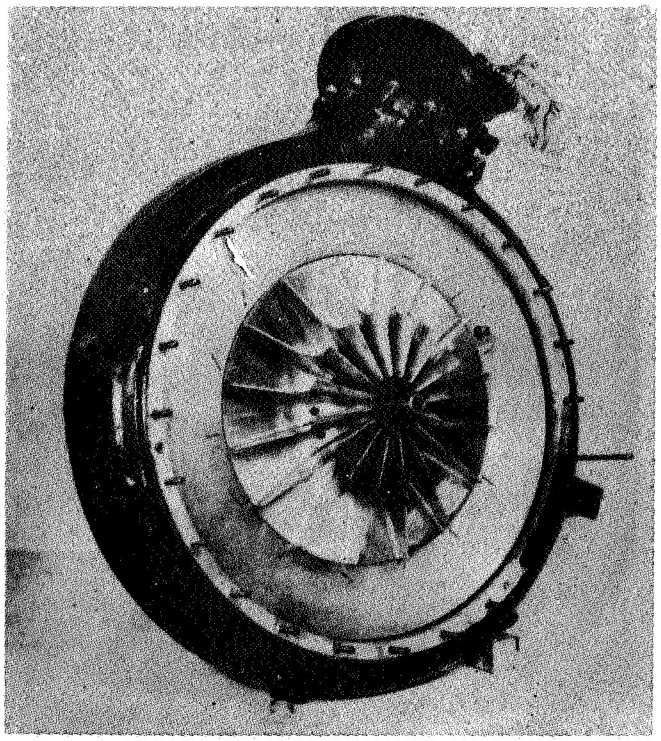

Figure 22. - Supercharger with impeller.

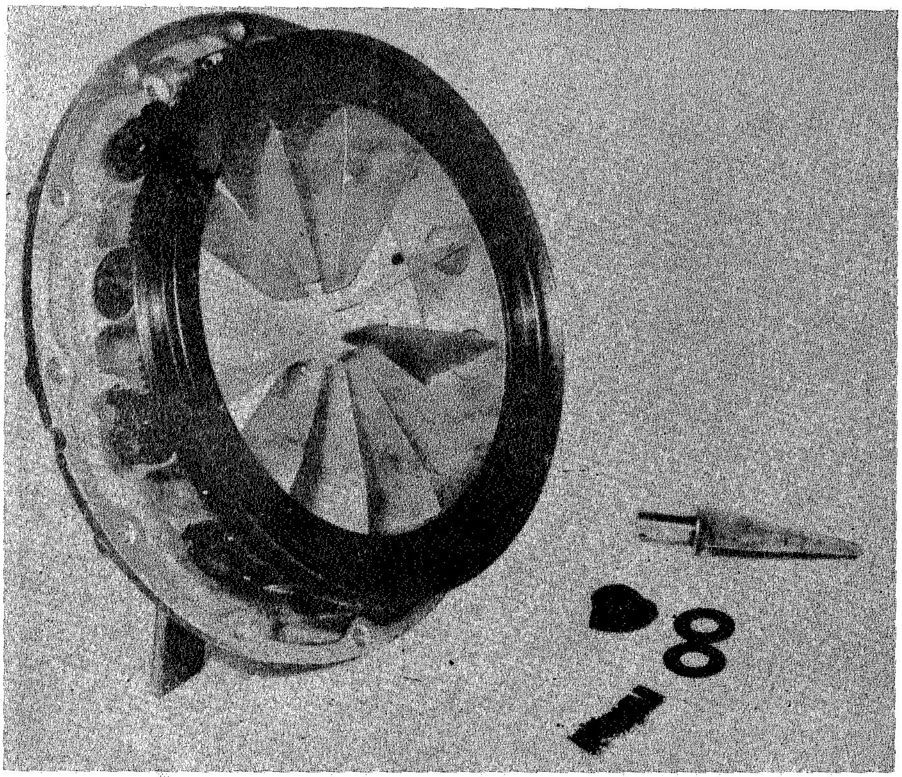

Figure 26. - Swirl throttle.

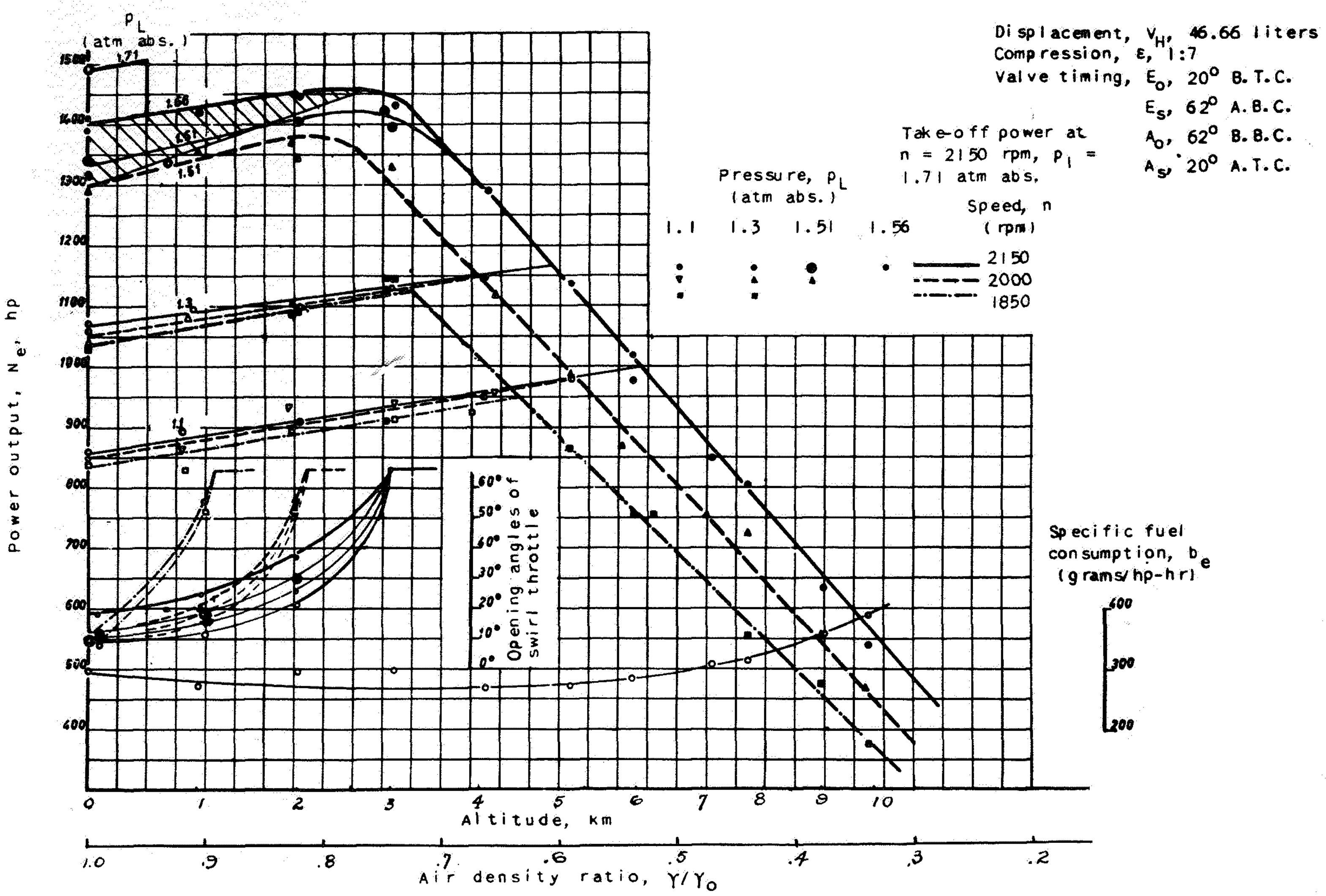

Figure 30. - Altitude-power graph for AM 38 engine (Russian captured engine, work No. 65).

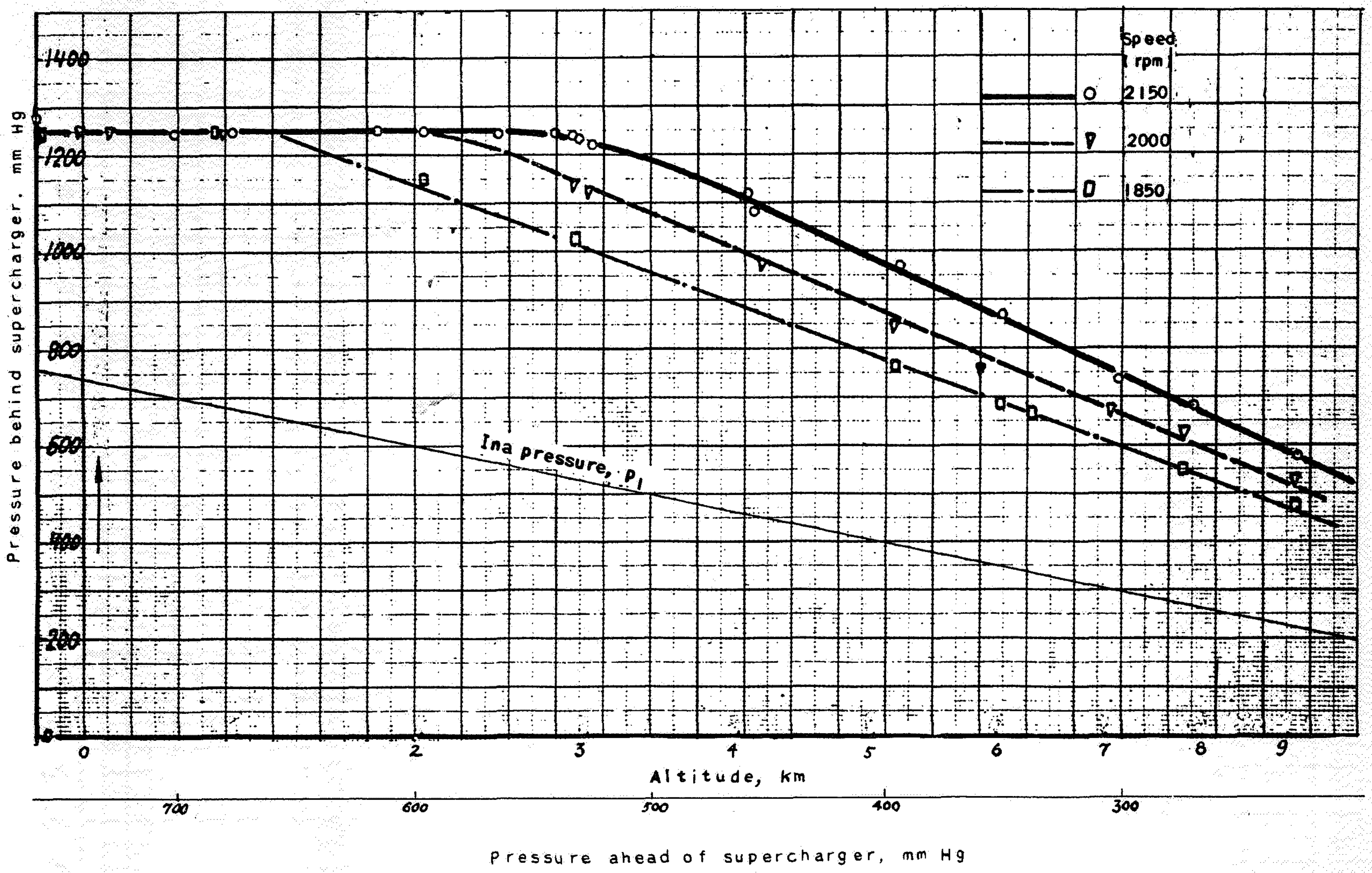

Figure 31. - Pressure behind supercharger (Russian captured engine AM 38, work No. 65).

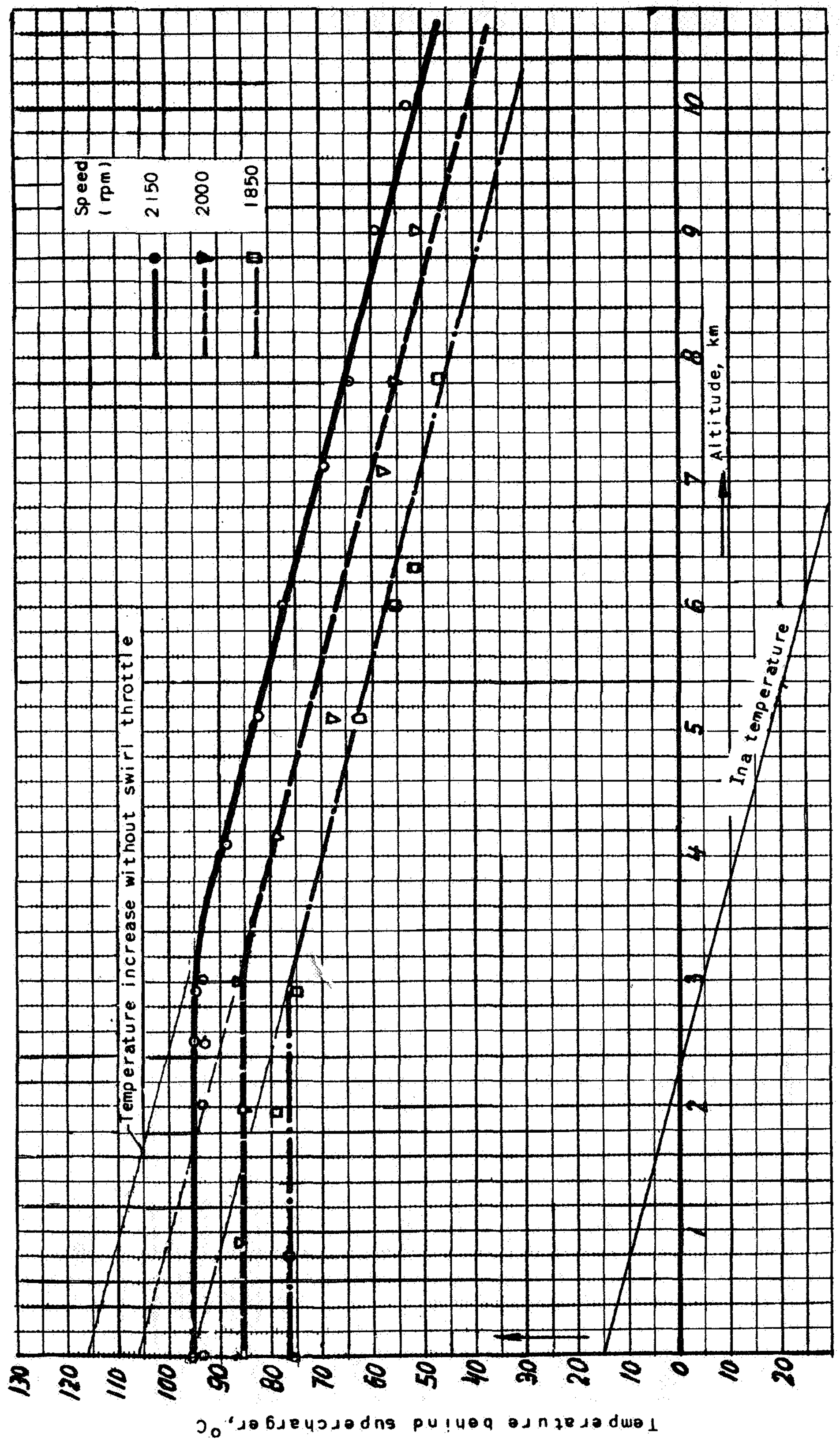

Figure 32. - Temperature behind supercharger (Russian captured engine AM 38; work No. 65).

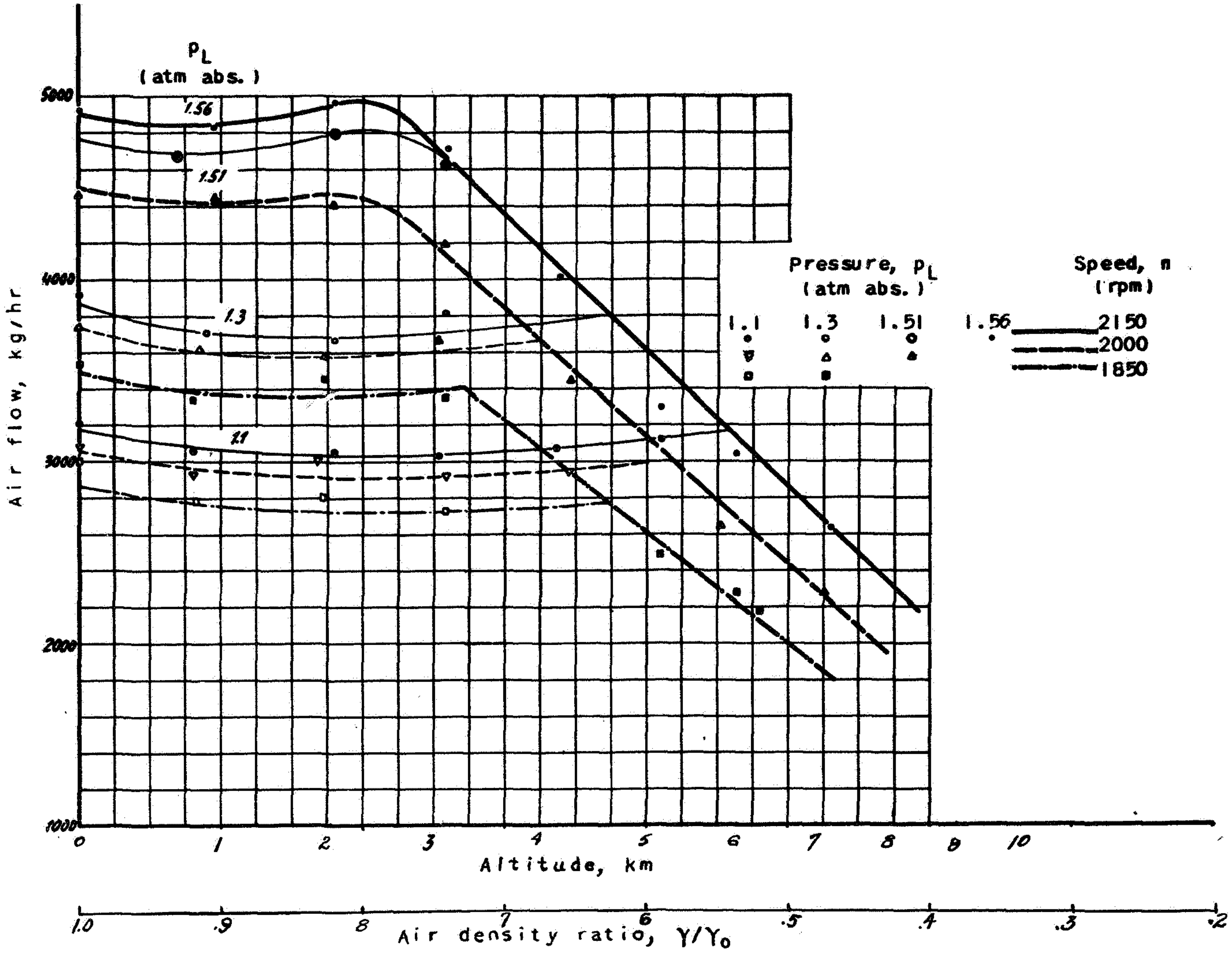

Figure 33. - Air flow at various boost pressures and speeds as function of altitude (Russian captured engine AM 38, work No. 65).

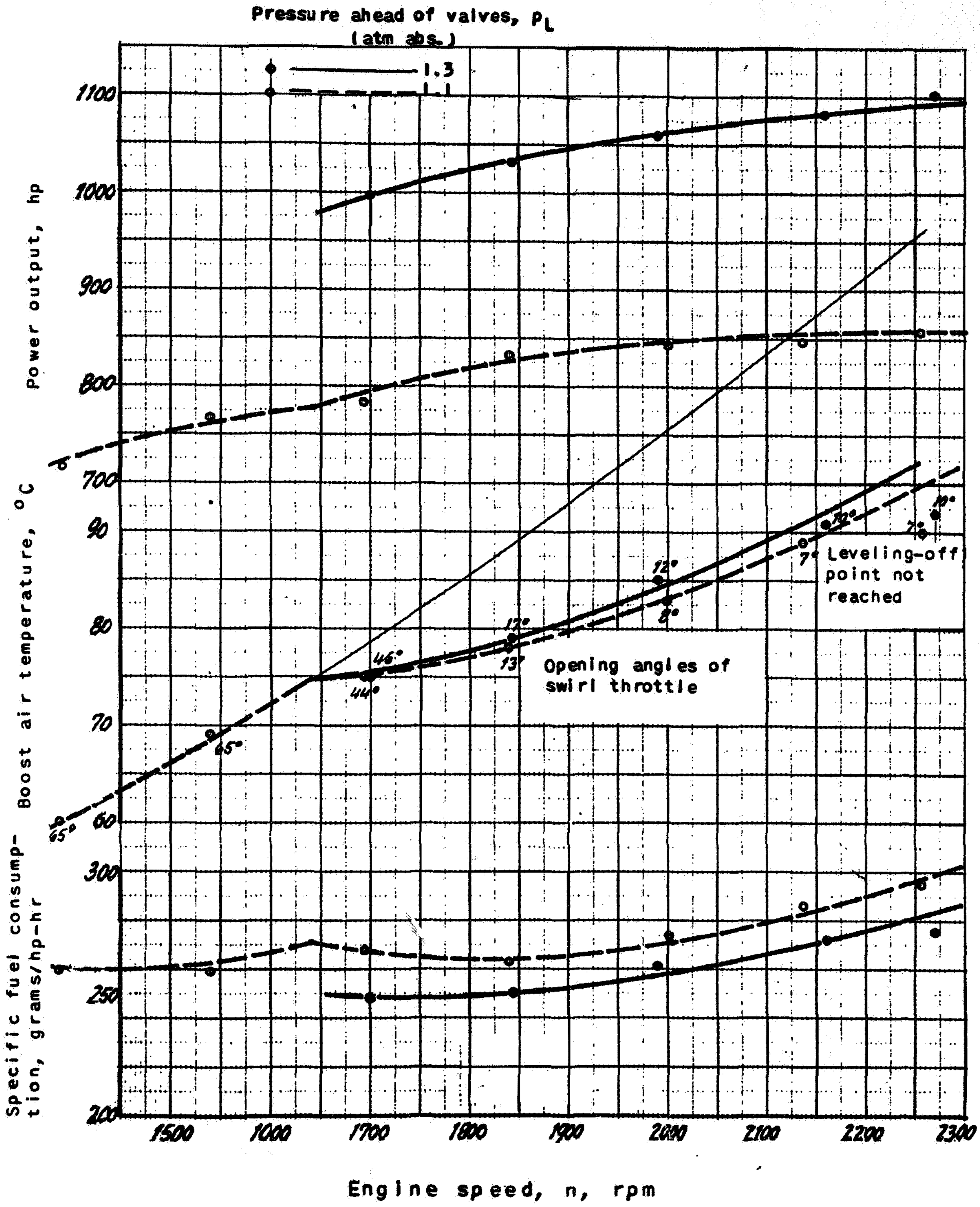

Figure 35. - Full power, boost air temperature, and specific fuel consumption as functions of engine speed (Russian captured engine AM 38, work No. 65). Pressure ahead of and behind engine, 760 millimeters of mercury; temperature ahead of engine, 15° C.

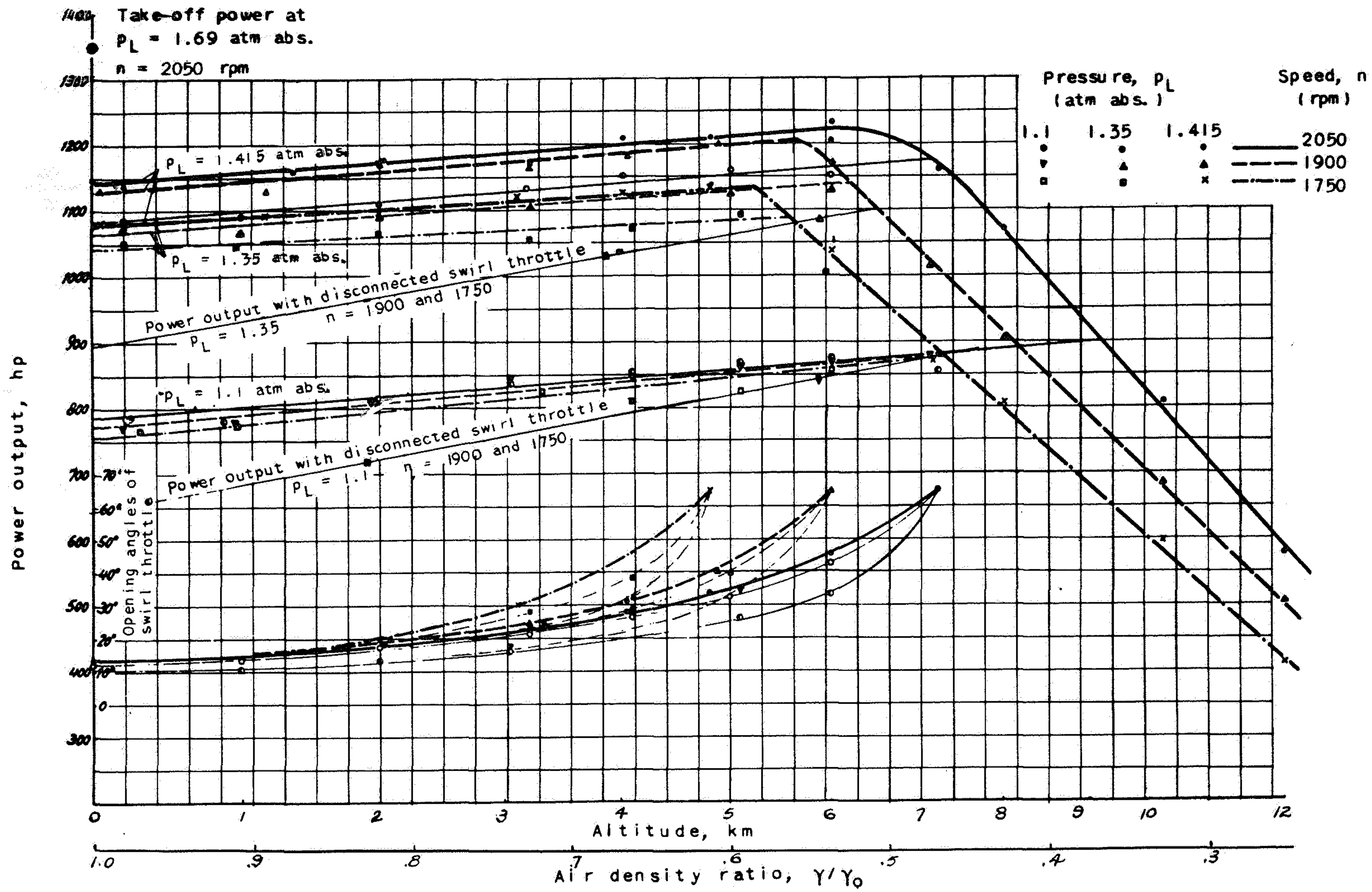

Figure 40. - Power outputs and opening angles of swirl throttle with various boost pressures and speeds as functions of altitude (Russian captured engine AM 35-A, work No. 3853).

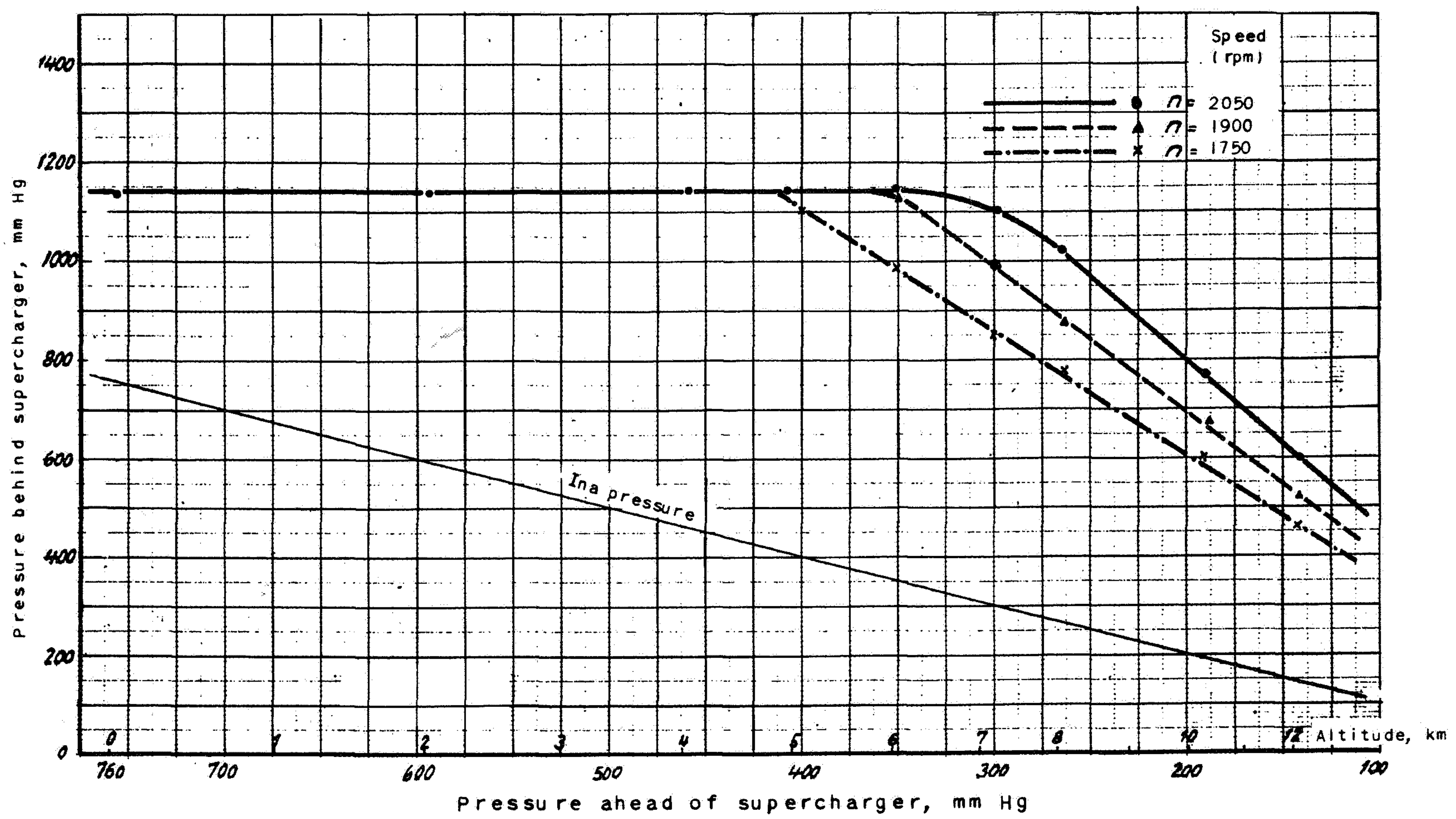

Figure 41. - Pressure behind supercharger as function of altitude (Russian captured engine AM 35-A, work No. 3853).

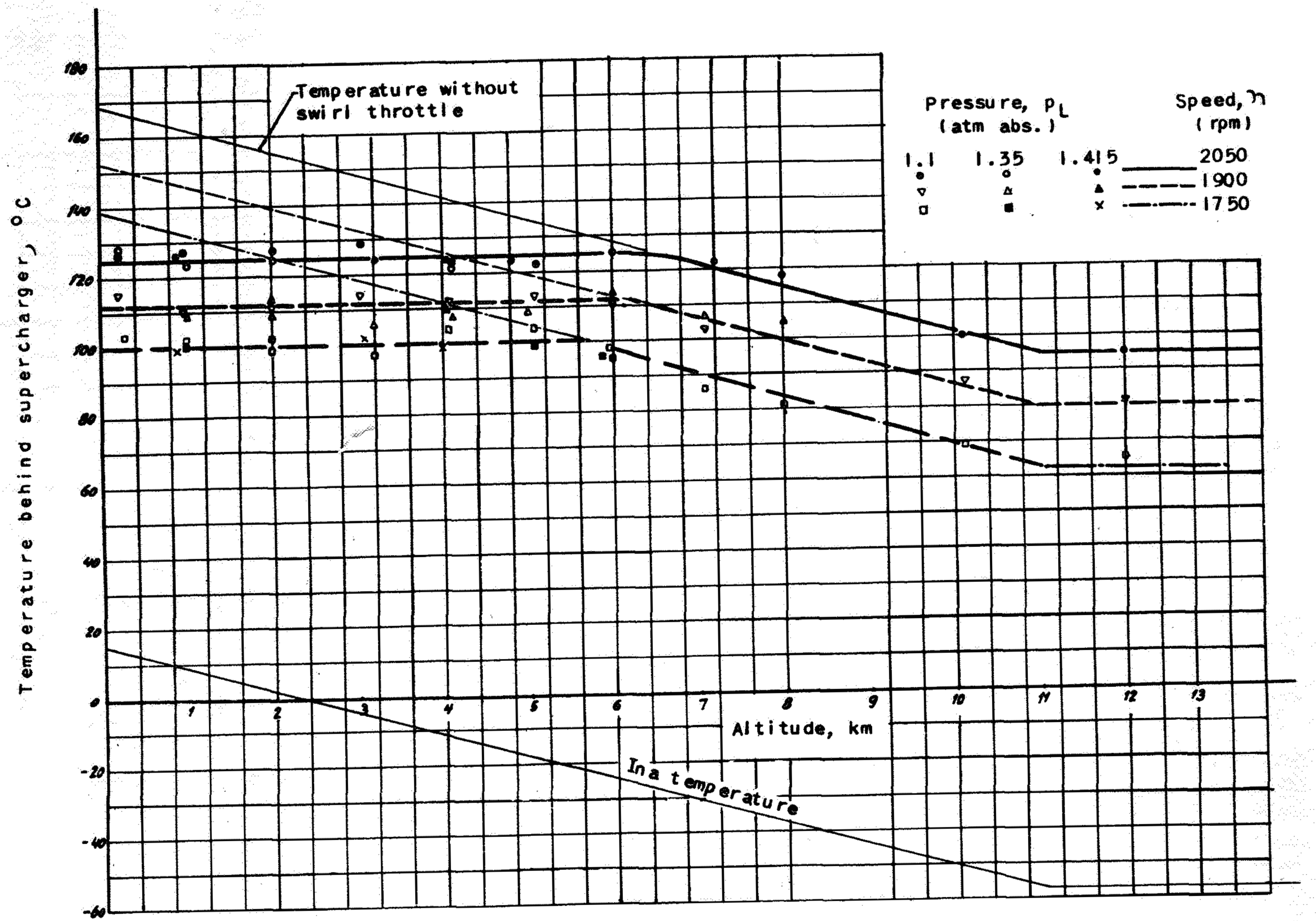

Figure 42. - Boost air temperature at supercharger outlet as function of altitude (Russian captured engine AM 35-A, work No. 3853).

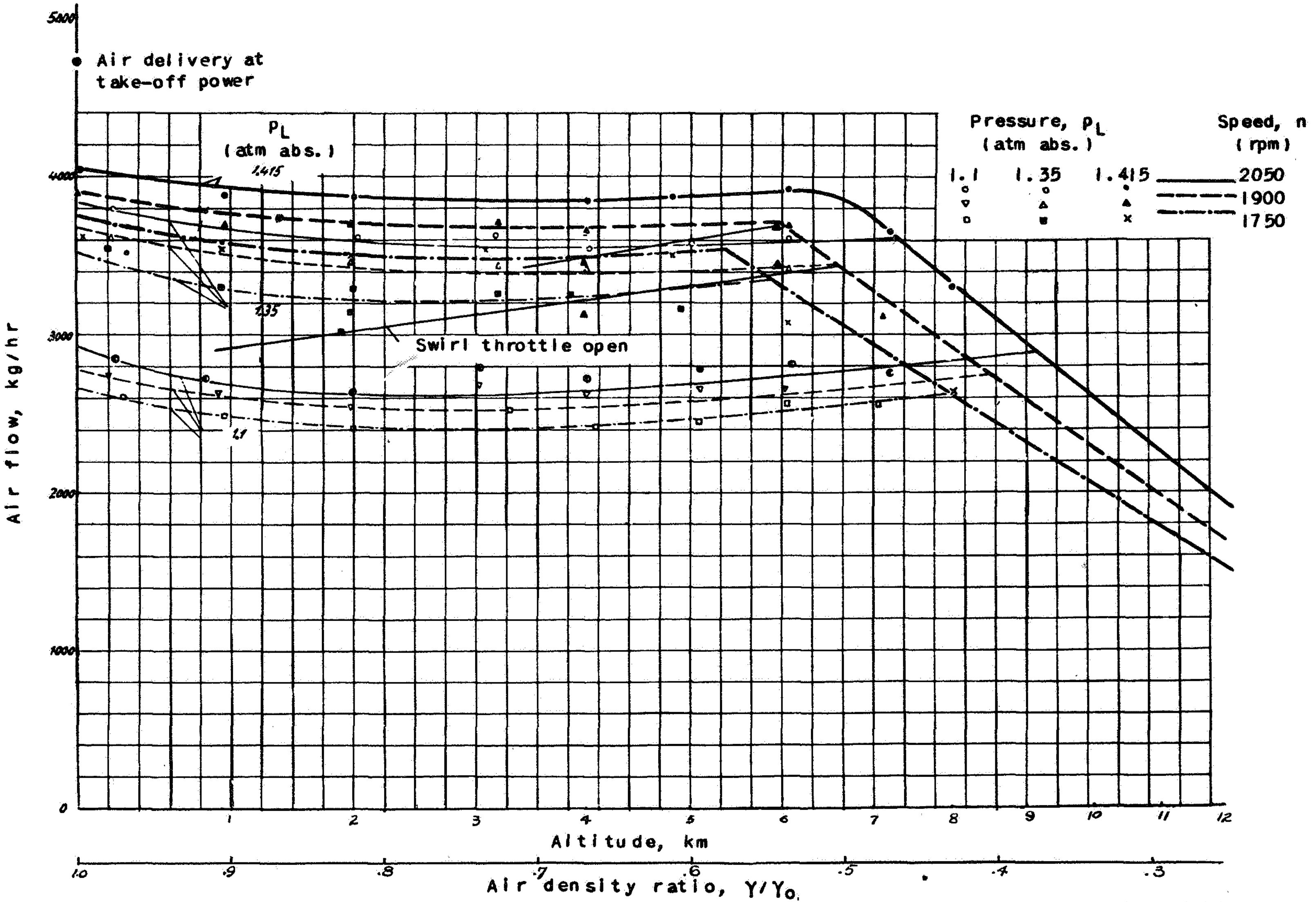

Figure 43. - Air flow at various boost pressures and speeds as function of altitude (Russian captured engine AM 35-A, work No. 3853).

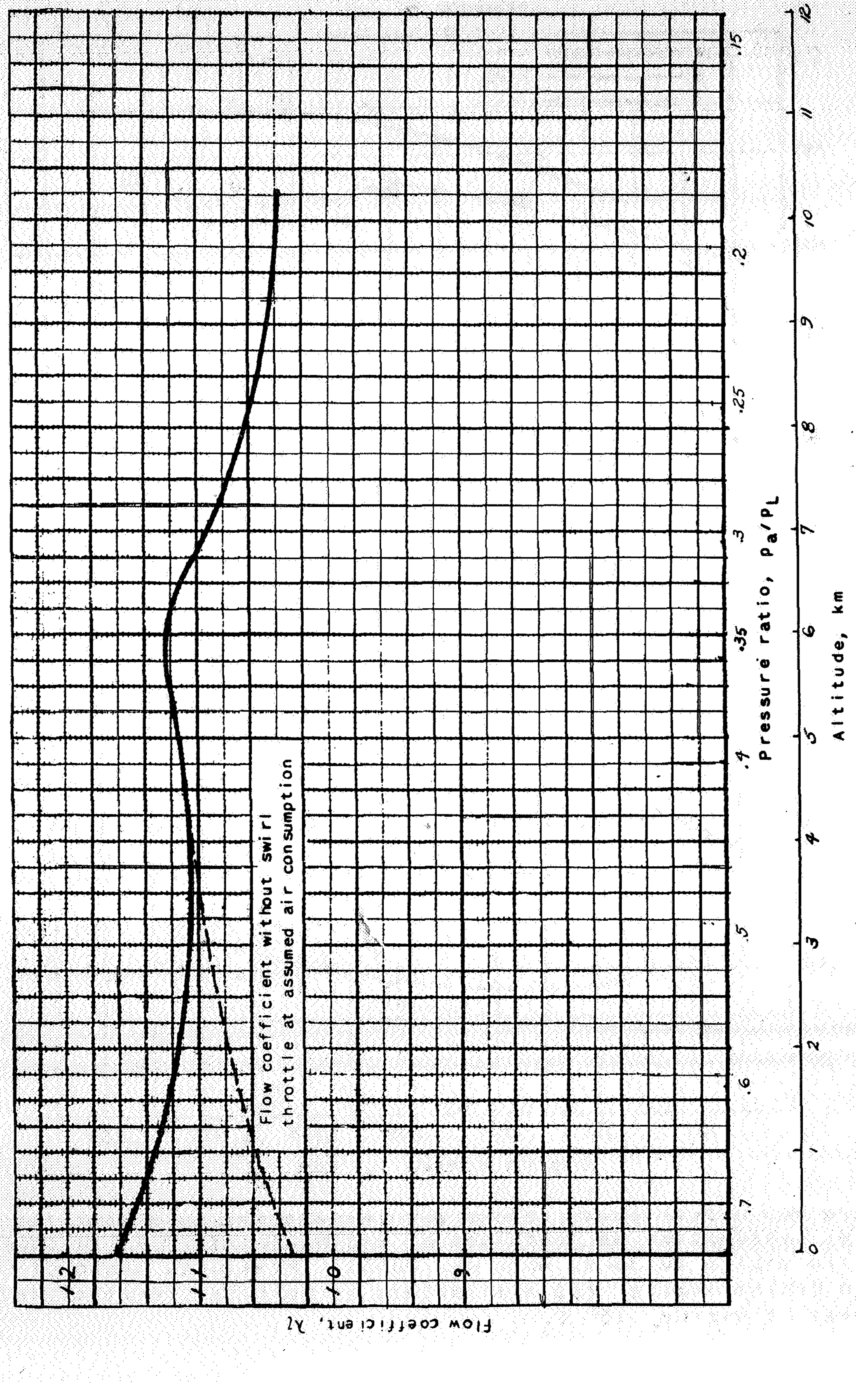

Figure 44. - Flow coefficient as a function of altitude (Russian captured engine AM 35-A, work No. 3853).

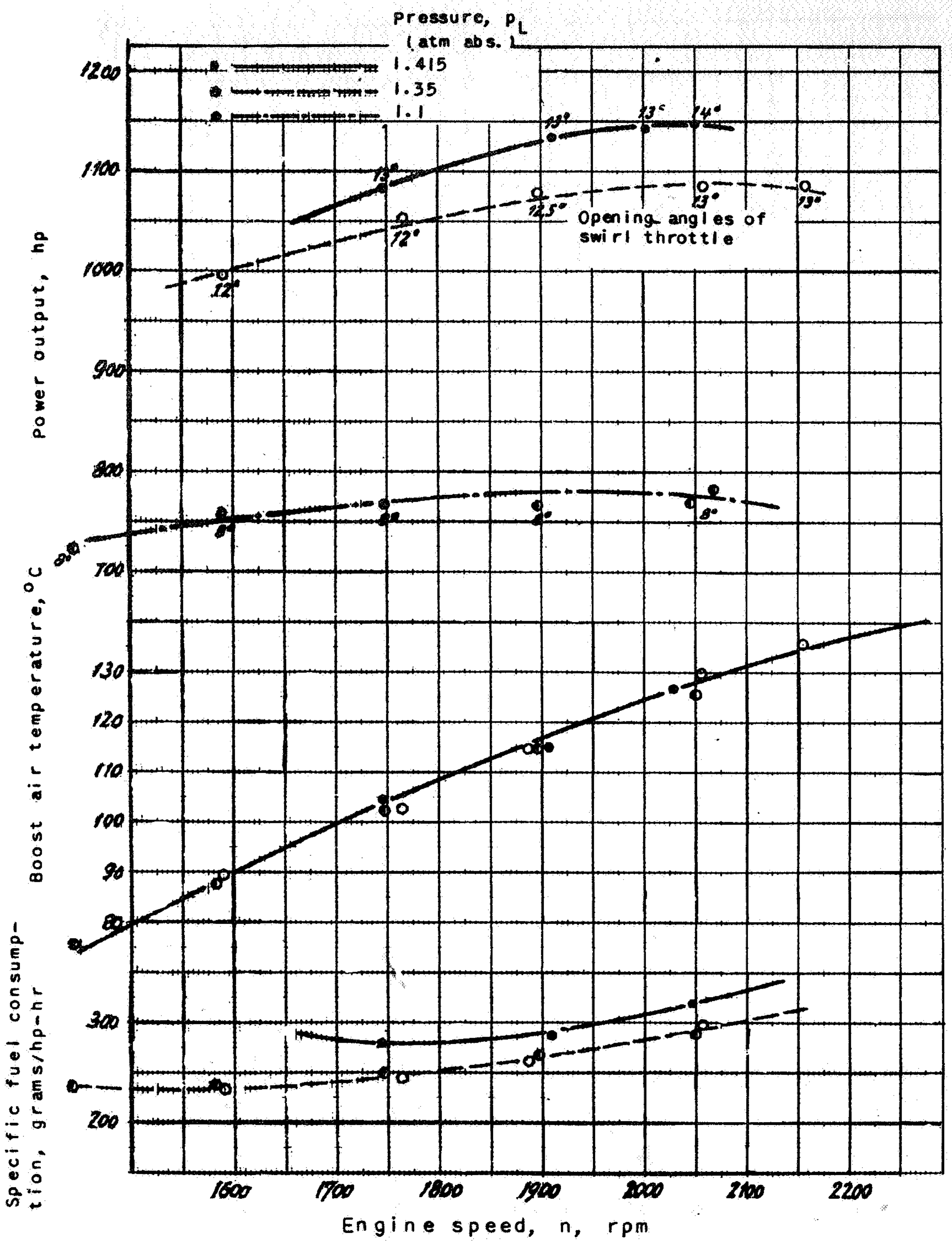

Figure 46. - Full power, boost air temperature, and specific fuel consumption as functions of engine speed (Russian captured engine AM 35-A, work No. 3853). Pressures ahead of and behind engine, 760 millimeters of mercury; temperature ahead of engine, 15° C.

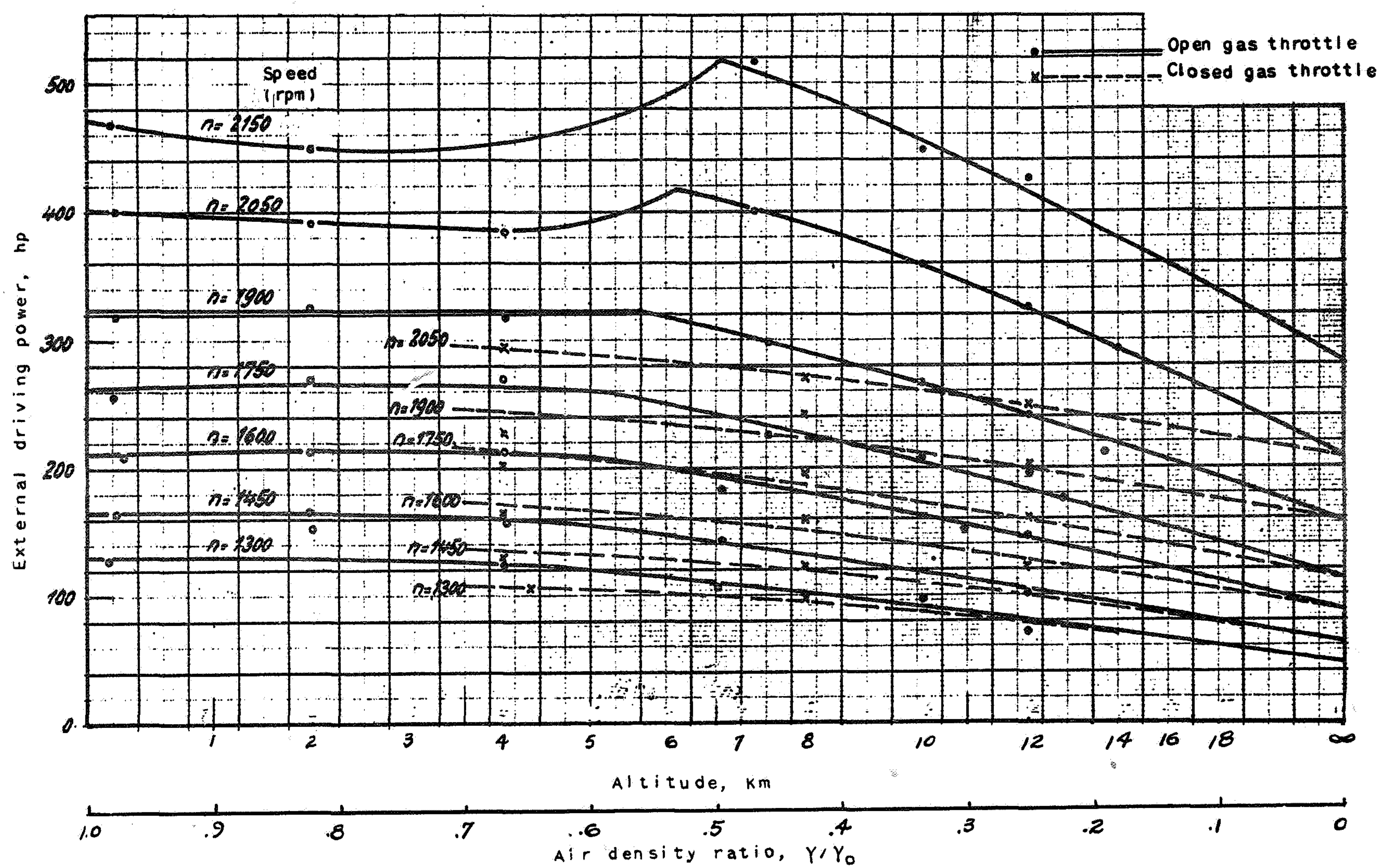

Figure 53. - External driving power as a function of altitude with open and with closed gas throttle (Russian captured engine AM 35-A, work No. 3853).