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GROUND-COOLING AND FLIGHT TESTS OF AN AIRPLANE EQUIPPED WITH A NOSE-BLOWER ENGINE COWLING

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SUMMARY

Flight and ground-cooling tests were conducted with a Northrop attack airplane (Air Corps designation, A-17A) to determine the merits of a nose-blower engine cowling designed and built at the N.A.C.A. Laboratory. The chief object of the tests was to determine the cooling characteristics of the nose blower, particularly for ground and low-speed operation. Of secondary interest was the effect on the speed or drag of the airplane.

The tests showed that the nose-blower cowling was definitely superior to the N.A.C.A. cowling from the standpoint of ground cooling, since the engine was operated at full throttle for 15 minutes with cylinder temperatures well below the recommended limit. Although there was a slight decrease in speed with the nose blower for the particular installation tested, the results of the speed tests were really inconclusive as regards the possibilities of improved high-speed performance. The nose-blower cowling was definitely more powerful as a blower than it need have been for satisfactory ground cooling, and consequently the power absorbed was excessive.

INTRODUCTION

During the past year, the N.A.C.A. conducted experiments in the 20-foot tunnel on several cowling models intended to improve the cooling of radial engines at low air speeds and to reduce the drag. Tests were made on a wing-duct system, described in reference 1, which showed that improved cooling could be obtained if the wing were sufficiently thick to accommodate efficient entrance ducts. Several blower systems for use when wing ducts are not practicable are described in references 2 and 3 in which the air is drawn in through entrances located in the wing roots, in the side of the cowling, and in the nose of the cowling. These systems showed promise of fulfilling the requirements set forth, so further tests with an engine appeared to be advantageous for further developing the systems and demonstrating their qualities.

A Northrop attack airplane (Air Corps designation, A-17A) was borrowed from the Air Corps early in 1939 to carry out further the cowling experiments in flight. The nose blower type, described in reference 3, was selected for the first experiment because it was the easiest to install, and, if it proved successful, it would have the greatest immediate application.

The chief object of these tests was to determine the cooling characteristics of the cowlings. It was realized that there was little chance for increasing the speed of this airplane by any improvements in the nose shape because the drag contributed by the N.A.C.A. cowling is only a small part of the drag of the entire airplane.

APPARATUS

Airplane.- The principal characteristics of the A-17A airplane are as follows:

Airplane:

Span, 47 feet 9 inches.

Length, 31 feet 8 inches.

Weight, 7,150 pounds.

Engine: Pratt & Whitney R-1535-13.

Rated horsepower, 750 at 2,500 feet at 2,500 r.p.m.

Gear ratio, 4:3.

Propeller: Controllable two-position.

Blade drawing No. 6101A-6.

Diameter, 9 feet 6 inches.

Settings, 19.5° and 26.0° at 42-inch station.

Photographs of the airplane with the standard N.A.C.A. cowling are given in figures 1, 2, and 3. Performance characteristics for the engine are given in figure 4. The recommended maximum cylinder-head temperatures are as follows:

Continuous high speed, 260° C. (500° F.),

Continuous cruising, 235° C. (455° F.).

Nose-blower cowling.- A sketch of the nose-blower cowling is given in figure 5. One modification was made to the original blower during the tests, as noted on the sketch. This modification consisted in restricting the front opening area to 46 percent of the original value by means of an extension to the nose of the blower. The primary purpose of this modification was to determine the effect of reducing the pumping action. It was expected that the quantity of cooling air would be greatly reduced with resulting higher temperatures, although it was realized that the efficiency of the blower would suffer owing to the rapid expansion in the internal passages. Modification of the blower to reduce the pumping action efficiently would have required the construction of a completely new cowling, which appeared to be unwarranted for the purpose intended.

The original form of the nose blower was patterned after a model blower previously tested (blower 5, reference 3) but was modified with the intention of improving the internal-flow characteristics. The length-diameter ratio was increased, the expansion rate of the passages reduced, and the radius of curvature of the blades increased. It was hoped that, with these modifications, the internal-flow separation noted for blower 5 would be eliminated and the efficiency improved. In view of the departures from the design of blower 5, it was impossible to predict the performance characteristics of the A-17A blower. A conservative design was adopted which would insure cooling of the engine under all conditions and little regard was given to the resulting speed of the airplane.

Figures 6 to 9 show various views of the nose blower as initially installed. One may note the cowl-flap extensions which were added in order that the exit slot could be closed tighter than possible with the standard flaps. The entire flaps were replaced by new ones after a few flights were made because of excessive air leakage around the edges of each flap. Also the vent slot at the fire wall was almost entirely closed, as well as other leakage openings, because it was found that, with the nose blower, the high pressure within the cowling caused jets of air to flow out the leak openings, a condition that presumably increased the drag, since it was found that the maximum speed increased after the leaks were sealed.

Figures 10 to 12 show the nose-blower installation at the completion of the tests. Note the paper and metal seals over the leak openings. These photographs also show the extension which was added to the nose for the purpose of reducing the opening area to 46 percent of its original value. The area of the front opening was reduced to determine the effect of throttling the blower on the cooling characteristics and also the effect on the speed.

Instruments.-Measurements of temperatures were made as follows:

(a) Cylinder head at front and rear spark plug bosses on cylinders 4, 5, 11, and 12 with thermocouples inserted in the metal.

(b) Cylinder barrel at their midpoints in the front and rear of cylinders 4, 5, 11, and 12 with thermocouples welded on the steel. (Cylinders were numbered in the direction of propeller rotation, beginning with the uppermost, which was in the rear bank; i.e., cylinders 4 and 5 were on the right side, 11 and 12 on the left side of the engine, 4 and 12 in the front bank, 5 and 11 in the rear bank.)

(c) Free air in a wing recess.

(d) Cooling air behind the cylinders on each side of engine.

(e) Accessory compartment.

(f) Carburetor air.

(g) Mixture in one manifold pipe close to the cylinder on cylinder 6.

(h) Intake manifold pipe close to the cylinder on cylinder 6.

Measurements of total cooling-air pressure drop across the engine were made with three tubes located at 120° spacing around the engine in the front of the cylinders at the head bases, and with corresponding tubes behind the engine near the exit slot. The front and rear tubes were connected to the two sides of a recording air-speed meter, which measured the pressure drop across the engine at the tube locations.

The engine rotational speed was measured with a recording centrifugal tachometer in addition to an indicating electric tachometer.

The air speed was likewise measured with a recording instrument in addition to the pilot's indicating instrument. These instruments were calibrated in flight with a suspended bomb.

A statoscope, which records small changes in pressure height, was installed as a means for determining the condition of level-flight operation.

The pressure altitude was measured with a sensitive altimeter.

METHODS AND TESTS

The purpose of the tests was to establish the merits of the nose-blower cowling relative to the standard N.A.C.A. cowling, primarily from the standpoint of cooling and secondarily from the standpoint of speed or drag. Time histories of temperature during full-throttle operation on the ground were selected as the most severe and most reliable criterion of cooling. Temperatures were also taken in the full-throttle high-speed condition of flight with cowl flaps closed.

Two types of flight runs were made: (a) Level flight at full throttle to establish the maximum speed, the mixture being adjusted in each test to obtain the maximum engine speed; (b) level flight over a range of speeds with the propeller blade angle maintained constant at the high setting to establish the relation between air speed and engine speed. Such data are useful in judging the reliability of full-throttle runs, as will be discussed later. The flight tests were made at a pressure altitude of about 8,000 feet, which in most cases corresponded to a density altitude of approximately 10,000 feet.

Assurance that the airplane was not changing altitude excessively during the runs was obtained from the statoscope records.

RESULTS AND DISCUSSION

The results of the ground-cooling tests are given in figures 13 and 14, while those for the full-throttle level-flight tests are given in table I. Figure 15 shows the recorded pressure drops across the engine. The speed results are given in figures 16 to 18 and table II.

<u>Cooling</u>.- The time history curves of cylinder temperatures given in figure 13 show very convincingly the superiority of the nose-blower cowling over the N.A.C.A. cowling from the standpoint of ground cooling. With the N.A.C.A. cowling in place, the engine was operated for 6 minutes full throttle and shut down when it appeared that certain temperatures were exceeding the limits set. The curves show that the head temperatures had nearly stabilized but that the barrel temperatures were still rising in some cases.

The engine was run full throttle for about 15 minutes with the original nose-blower cowling and could have been run indefinitely as far as the cooling is concerned. Temperatures for only 10 minutes are given. All the temperatures were fairly well stabilized after 6 minutes well below the operating limit. The head temperatures ran uniformly about 130° F. below those for the N.A.C.A. cowling at the 6-minute point. The barrel temperatures also ran, in general, from about 100° F. to 145° F. lower.

Even though the blower modification resulted in increased temperatures of about 40° F., the temperatures were yet about 100° F. below those for the N.A.C.A. cowling and well below the maximum limit. Although the engine was shut down after 6 minutes of operation at full throttle, it could have been run indefinitely.

Figure 14 shows that the nose-blower cowling resulted in substantially lower oil temperatures for the ground operation. The temperatures of the oil entering the engine reached 200° F. after 5 minutes of full-throttle operation with the N.A.C.A. cowling and it was rising rapidly; whereas it reached only 153° F. with the nose-blower cowling for the same period even though the free-air temperature was 10° higher. The temperature stabilized at about 180° F. in about 14 minutes for the nose blower.

The temperatures of the oil entering the engine were about 20° F. higher for the modified blower than for the blower in the original condition. A stabilizing temperature of about 200° F. for a free-air temperature of 95° F. is indicated. This higher temperature may be explained in part by the fact that the accessory compartment was not ventilated so well for the blower in the modified condition as for the other two cowlings, resulting in air of a higher temperature surrounding the oil tank.

It appears from these ground-cooling tests that the blower was entirely too powerful for this engine. There probably is no need in any service condition for a cooling system which will maintain temperatures as low as those recorded for full-throttle operation on the ground. A blower of greatly reduced pumping capacity would probably cool this engine satisfactorily under all ordinary operating conditions with resulting power savings.

Following is a table of various engine temperatures for full-throttle level flight at 8,000 feet.

TABLE I

Average Engine Temperatures During Full-Throttle Flight at 8,000 Feet Altitude
Air speed, 200 miles per hour

Cylinder	Location	Temperatures above free air, °F.				Temperature change from N.A.C.A. cowling, °F.		
			Nose-blower cowling		Modified nose-blower cowling	Nose-blower cowling		Modified nose-blower cowling
		N.A.C.A. cowling; adjustable flaps; 2-inch exit opening	Adjustable flaps; 1/2-inch exit opening	Fixed flaps; 1/4-inch exit opening	adjustable flaps; 1/2-inch exit opening	Adjustable flaps; 1/2-inch exit opening	Fixed flaps; 1/4-inch exit opening	adjustable flaps; 1/2-inch exit opening
-	Accessory compartment	44	77	99	79	33	55	35
-	Carburetor intake air	38	28	41	27	-10	3	-11
-	Engine compartment, left	69	76	88	74	7	19	5
-	Engine compartment, right	73	74	100	75	1	27	2
4	Barrel, front	255	215	250	215	-40	-5	-40
4	Spark plug, front	355	240	275	260	-115	-80	-95
4	Spark plug, rear	390	330	370	335	-60	-20	-55
4	Barrel, rear	260	215	255	225	-45	-5	-35
5	Barrel, front	245	210	250	220	-35	5	-25
5	Spark plug, front	360	265	305	280	-95	-55	-80
5	Spark plug, rear	400	340	395	365	-60	-5	-35
5	Barrel, rear	300	250	285	260	-50	-15	-40
11	Barrel, front	[a]125	[a]150	[a]180	[a]150	[a]25	[a]65	[a]25

[a]These readings, which are inconsistent with the others, are believed to have been affected by improperly functioning thermocouples or by some peculiar local cooling condition. They are considered insignificant and have been neglected in comparing various cowling arrangements.

TABLE I (continued)

Cylinder	Location	Temperatures above free air °F.				Temperature change from N.A.C.A. cowling, °F.		
		N.A.C.A. cowling; adjustable flaps; 2-inch exit opening	Nose-blower cowling		Modified nose-blower cowling; adjustable flaps; 1/2-inch exit opening	Nose-blower cowling		Modified nose-blower cowling; adjustable flaps; 1/2-inch exit opening
			Adjustable flaps; 1/2-inch exit opening	Fixed flaps; 1/4-inch exit opening		Adjustable flaps; 1/2-inch exit opening	Fixed flaps; 1/4-inch exit opening	
11	Spark plug, front	335	255	300	265	-80	-35	-70
11	Spark plug, rear	385	340	385	350	-45	0	-35
11	Barrel, rear	[a]220	225	270	235	[a]5	[a]50	[a]15
12	Barrel, front	230	200	235	200	-30	5	-30
12	Spark plug, front	305	240	270	235	-65	-35	-70
12	Spark plug, rear	355	315	355	305	-40	0	-50
12	Barrel, rear	315	255	295	265	-60	-20	-50
6	Intake manifold wall	55	56	73	56	1	18	1
6	Intake manifold interior	88	67	85	62	-21	-3	-26

[a]These readings, which are inconsistent with the others, are believed to have been affected by improperly functioning thermocouples or by some peculiar local cooling condition. They are considered insignificant and have been neglected in comparing various cowling arrangements.

In each condition, the cowl flaps were closed to the stops existing at the time, but the actual openings were different. The standard N.A.C.A cowling flaps were shorter by several inches than the flaps for the nose blower and the exit opening was considerably greater. New cowl flaps were made for the nose-blower installation with the intention of throttling the cooling air to the point that the engine temperatures would equal those for the N.A.C.A. cowling. Columns 2 and 5 show that, with the flaps closed as tightly as the resilient flap mechanism permitted, the cylinder temperatures were from 30° F. to 150° F. lower than for the N.A.C.A. cowling. (Two sets of doubtful readings are neglected.)

The first speed runs with the nose-blower cowling indicated that the airplane was several miles per hour slower than with the N.A.C.A. cowling. It was thought that the high cowl pressure was causing air to flow out through many holes and cracks in cowling to disturb the flow over the fuselage. All the openings were therefore sealed, including the accessory compartment ventilating slot at the fire wall except for a portion near the bottom. The airplane speed immediately increased several miles per hour, but it may be noted that the accessory-compartment temperatures increased 33° F.

The next step consisted of fastening the flap trailing edges to the cowling, leaving a 1/4-inch slot opening. The cylinder temperatures approached those for the N.A.C.A. cowling fairly closely in general. (See columns 3 and 6.) The accessory-compartment temperature exceeded that for the N.A.C.A. cowling by 55° F. and the engine-compartment temperature ran some 19° F. to 27° F. higher. Since the cooling-air temperature rise through the engine was increased some 25 percent for the same cylinder temperatures, it is reasonable to assume that less air was passing through the baffles and that the rate of heat exchange was materially increased. This higher heat-transfer rate can be explained from studies of the flow leaving the blower. It was pointed out in reference 3 that the air leaving the blower was in the form of a series of high-speed jets, which were directed into the cylinders along a helical path. It seems reasonable that the combination of the high jet velocity and the angles at which the air strikes the fins would result in a greater scouring action and consequently greater heat-transfer rate.

Reducing the blower-entrance opening had no important effect on the cooling at high speed as the temperatures were only a few degrees higher than with the unmodified blower. (See columns 4 and 7.)

Engine pressure drop.- The pressures across the engine are plotted in figure 15 in the form of the nondimensional coefficients $\Delta p/\rho n^2 D^2$ and $\Delta p/\rho n^2 d^2$ where

Δp is the pressure drop across the engine.

ρ, the mass density of air.

n, the propeller rotational speed.

d, the blower design diameter.

D, the propeller diameter.

The pressure coefficients are plotted against V/nD and V/nd, where V is the forward speed of the airplane. The coefficients are based on the propeller diameter for the N.A.C.A. cowling and the blower-design diameter for the nose blower, but both scales are given for the nose blower to facilitate direct comparisons, if direct comparisons can be made.

It should be borne in mind that the pressures recorded were only the local pressure differences at the tubes and not necessarily the average or representative pressure differences across the engine. It is pointed out in reference 3 that a very steep radial pressure gradient exists behind the nose blower. The tubes were located at the base of the heads (see fig. 5), which corresponds to a low pressure region approaching the static value for the nose blower. Surveys made with a model blower indicated that the maximum pressure at the outer surface of the cooling air stream was several times the static value near the center of the cowling. For this reason, comparisons between the nose-blower cowling and the N.A.C.A cowling made on the basis of pressure drop probably have little significance.

Of interest, however, are the differences in pressure available at the ground point. Whereas very little pressure is recorded at the ground for the N.A.C.A. cowling, the nose-blower cowling produced about the same pressure as was required for full-throttle level flight. (See point for 1/4-inch exit slot.)

Opening the N.A.C.A. cowl flaps increased the pressure at high speed by about 30 percent; whereas opening the nose-blower flaps from the 1/4-inch position increased the pressure about 150 percent. The cooling power was very high under the conditions of flaps open since it is proportional to $\Delta p\sqrt{\Delta p/\rho}$. For example, if the blower absorbs 25 horsepower for a $\Delta p/\rho n^2 d^2 = 2$ at sea level, then it will absorb 71 horsepower at 10,000 feet with the flaps open ($\Delta p/\rho n^2 d^2 = 4.85$). This point is of interest in connection with the very small difference in maximum speeds recorded for various settings of the cowl flaps with the nose blower, as will be further discussed in connection with the speed tests.

Maximum speed and drag.- The results of full-throttle runs for various cowling arrangements are presented in table II. It was found that the highest speeds for the nose-blower cowling were obtained with the cowl flaps in some intermediate position, neither entirely opened nor closed to the point at which the engine temperatures approximated those for the N.A.C.A. cowling. Only the results for those intermediate positions are included. The engine temperatures during these runs were definitely lower than with the N.A.C.A. cowling.

A correction for the effect on maximum speed of the small altitude differences experienced between different tests was made by deriving a curve of maximum speed against altitude for the airplane equipped with the N.A.C.A. cowling, using the experimentally determined relation between air speed and engine speed, the engine characteristics given in figure 4, and assuming propeller characteristics from reference 5. The values thus corrected to the same altitude, so that they may be directly compared, are listed in table II under the heading "Adjusted to 10,000 feet." No corrections for differences in engine speed were made.

TABLE II

Results of Full-Throttle Runs

Cowling arrangement	Pressure altitude (ft.)	Free-air temperature (°F.)	Density altitude (ft.)	Observed V (m.p.h.)	Observed Engine speed, N_e (r.p.m.)	Adjusted to 10,000 ft. V (m.p.h.)	Adjusted to 10,000 ft. Engine speed, N_e (r.p.m.)	Cowl-flap setting
N.A.C.A. cowling	7,070	31	7,100	193.0	2,270	188.4	2,230	Cowl flaps closed; 2-inch exit slot
	9,900	8	9,000	192.3	2,260	190.4	2,250	
	8,310	37	9,000	203.0	2,350	201.1	2,340	
	8,160	59	10,300	206.0	2,380	206.5	2,390	
	8,140	59	10,300	203.6	2,370	204.1	2,370	
	8,135	59	10,300	203.2	2,360	203.7	2,360	
	8,120	56	10,100	202.9	2,360	203.0	2,360	
	8,125	56	10,100	202.9	2,360	203.0	2,360	
	8,130	56	10,100	203.1	2,360	203.2	2,360	
	8,125	56	10,100	202.7	2,360	202.8	2,360	
Nose-blower cowling	8,105	54	9,900	196.5	2,310	196.2	2,310	Cowl flaps closed; 1/2-inch exit slot
	8,135	55	10,000	197.5	2,320	197.5	2,320	
	8,200	56	10,200	197.4	2,320	197.7	2,320	
	8,115	54	9,900	196.9	2,330	196.6	2,330	Cowl flaps partly closed; 1-3/4-inch exit slot
	8,135	55	10,000	197.6	2,340	197.6	2,340	
	8,345	54	10,200	192.9	2,290	193.2	2,290	
Modified nose-blower cowling	8,180	53	9,900	197.5	2,330	197.2	2,330	Cowl flaps closed; 1/2-inch exit slot
	7,920	59	10,100	197.1	2,340	197.2	2,340	
	8,150	53	9,900	195.0	2,320	194.7	2,320	Cowl flaps partly closed; 1-inch exit slot
	8,000	59	10,100	198.5	2,360	198.6	2,360	

Accurate and consistent determinations of the maximum speed are quite difficult, since they are appreciably affected by several sources of error: condition of the engine, adjustment of the mixture control, atmospheric pressure and temperature, small deviations from steady level flight, and the presence of vertical currents in the atmosphere. The results, however, are fairly consistent, with the exception of two evidently low values for the N.A.C.A. cowling. There is no significant difference between the values for the two forms of the blower nose, and the variation in flap setting from about half closed (1-3/4-inch exit slot) to fully closed (1/2-inch exit slot) appears to have a negligible effect.

That the flap setting for the nose blower had very little effect on the speed seems strange because of the large changes in internal cooling power resulting from changing the setting as previously noted. There are two possible explanations to this paradox: (a) Opening the flaps may have resulted in greater engine power; or, (b) opening the flaps may have reduced the drag. In the preliminary tests with the nose blower, it was found that the drag was greatly increased because the high pressure within the cowling caused air to flow out through various holes resulting in disturbed flow. It is quite likely that this condition existed for all the tests to some extent. If a blower were installed which would be less powerful, it is likely that the drag, as well as the power absorbed for cooling purposes, would have been less.

A more significant comparison of full-throttle runs, indicating the consistency and reliability of the values, is obtained by considering the maximum-speed points in conjunction with the corresponding curves of engine (or propeller) speed against air speed. These data are presented for 10,000 feet in figure 16, in which the adjusted values from table II are plotted on the faired curves of N_e (engine speed) against V (true air speed). Full-throttle runs for both forms of the nose blower have been plotted together on the curve for the nose blower, since there seems to be a negligible difference in their aerodynamic characteristics.

The curves in figure 16 were derived from the experimental data of figures 17 and 18. The curves of these last figures are the so-called quantity "indicated propeller speed" required against indicated air speed. As explained in detail in reference 6, a single curve of $\sigma^{\frac{1}{2}}N$ against $\sigma^{\frac{1}{2}}V$ (where σ is the relative density) is applicable to level flight at all altitudes and depends only on the aerodynamic characteristics of the airplane-propeller combination. This quality is advantageous in flight testing, for the data obtained are independent of the engine and the altitude at which the tests are made. In other words, runs at different altitudes will define the same curve. On such a curve, however, the end point, or maximum speed, depends on the maximum speed available from the engine, which varies with altitude; the data must therefore be reduced to the form of figure 16 before they are useful in a comparison of maximum speeds.

Considering first the curves of figure 16 (or those of figs. 17 and 18) without regard to the full-throttle points, it is evident that, for a given forward speed, the engine speed required is greater for the nose blower than for the N.A.C.A. cowling. If the installation of the blower nose had not affected the propeller characteristics, the displacement of the two curves would afford a reliable measure of the change in drag, since the comparison of two curves is relatively free from the uncertainties of attempting to compare the isolated values of maximum speed tests, which are affected by engine performance and altitude. For the same propeller characteristics, the increased engine speed for the nose blower could be attributed only to an increased drag coefficient.

It is shown in figure 46 (reference 5), however, that there are marked changes in the propeller characteristics with change in body shape. As the nose becomes less blunt, the blocking effect of the body decreases, the velocity through the propeller disk increases, and the angle of attack of the propeller blades is reduced. As a result, the thrust coefficient at a given V/nD is decreased by the blower nose. The effect of such a decrease is to shift the N_e against V curve for the nose blower upward if any accompanying change in drag coefficient is neglected. The displacement of the curves is thus a measure of the combined effects of changes in thrust and drag coefficients and cannot be used as a criterion of the drag of the two cowlings, for at least a part of the increased engine speed required for the nose blower is caused by the change in propeller characteristics. It is quite possible that the drag coefficient is decreased by the blower nose; the curves are inconclusive in this respect, showing only that any such decrease is overbalanced by the decrease in thrust coefficient.

An approximate analysis of the speed-power relations of the two cowlings from figure 16 may indicate the effect of the nose blower on the drag. The averages of the two groups of points are about 197 miles per hour and 2,330 r.p.m. for the nose blower, and 203 miles per hour and 2,360 r.p.m. for the N.A.C.A. cowling. From figure 4, the corresponding brake horsepowers at 10,000 feet are 533 and 542, respectively, a difference of 1.7 percent. A certain part of the former value, however, is absorbed in the blower; if this is taken as 46 horsepower ($\Delta p/\rho n^2 d^2 = 3.7$ and $\sigma = 0.74$), then the engine powers used in overcoming the drag in the two cases are 487 and 542 horsepower, or a difference of about 11.3 percent. The speed difference is 6 miles per hour or about 3.0 percent. If the variations in drag coefficient and propeller efficiency with change in speed are neglected, the 3.0-percent difference in speed represents a 9.0-percent difference in power. This value is in fair agreement with the 11.3-percent difference previously found from the engine speeds and blower power. In other words, if the thrust horsepower available had been the same for both cowling conditions, the maximum speeds would have been practically equal. This fact indicates no significant change in drag coefficient within the precision of the tests, the observed difference in speed being accounted for by the difference in engine speed and the power absorbed by the blower.

The results of the speed tests are obviously inconclusive in view of the fact that the blower was excessively powerful. This is shown by further computations in which a value of 68 horsepower is computed for the blower operating with the cowl flaps closed to a 1-3/4-inch exit slot, with a negligible change in maximum speed. This computation indicates a reduction in drag of the airplane of 7.5 percent with the nose blower.

CONCLUSIONS

1. The nose-blower cowling definitely overcooled the engine on the ground. The spark-plug boss temperatures for full-throttle operation stabilized at about 300° F. above the air temperature while the highest barrel temperatures recorded were about 225° F. above the air temperature. These temperatures were roughly 125° F. below those obtained with the N.A.C.A. cowling for a full-throttle run of only 6 minutes. The temperature of the oil entering the engine was also correspondingly lower.

2. The rise in temperature of the cooling air through the engine baffles was roughly 25 percent greater for the nose-blower cowling than for the N.A.C.A. cowling when the cowl flaps were closed to obtain approximately the same cylinder temperatures. This indicates that less air was required to cool the engine, which means that the heat-transfer rate from fins to air was greater.

3. Modifying the nose blower by restricting the front entrance to 46 percent of its original area resulted in only slightly higher engine temperatures.

4. Although slightly higher full-throttle speeds were obtained with the N.A.C.A. cowling than with the nose-blower cowling, the tests were inconclusive from the speed standpoint owing to the fact that the nose blower was too powerful for this engine and consequently absorbed more power than it need have to obtain satisfactory ground cooling.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 22, 1939.

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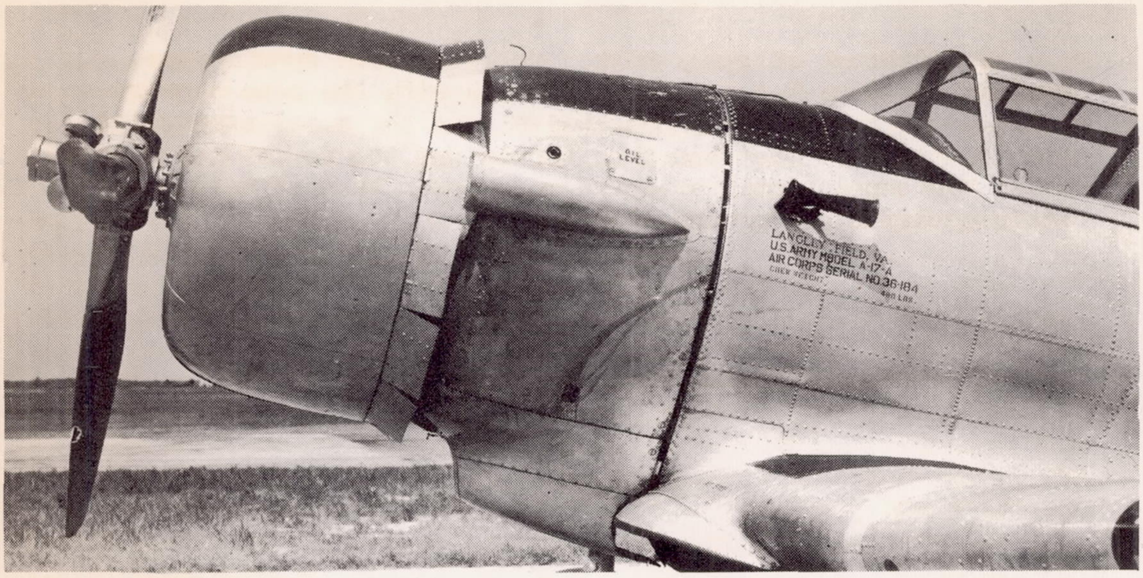

Figure 1.-Side view of N.A.C.A. cowling.

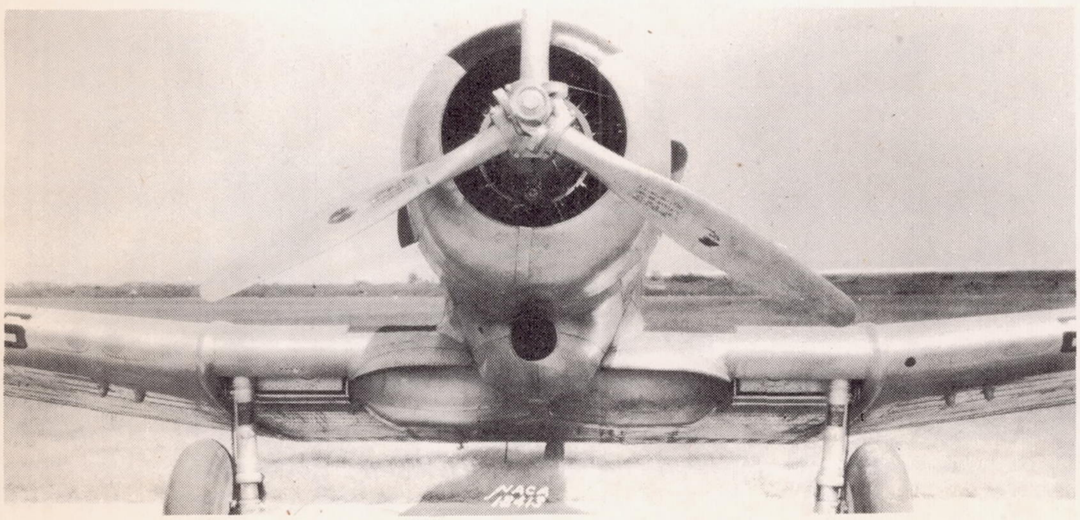

Figure 2.-Front view of N.A.C.A. cowling.

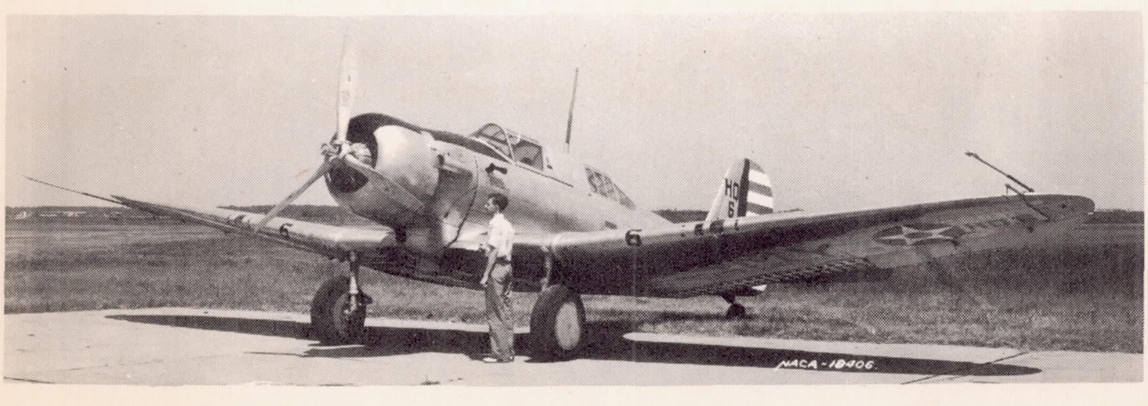

Figure 3.-One-quarter view of A-17A airplane with N.A.C.A. cowling.

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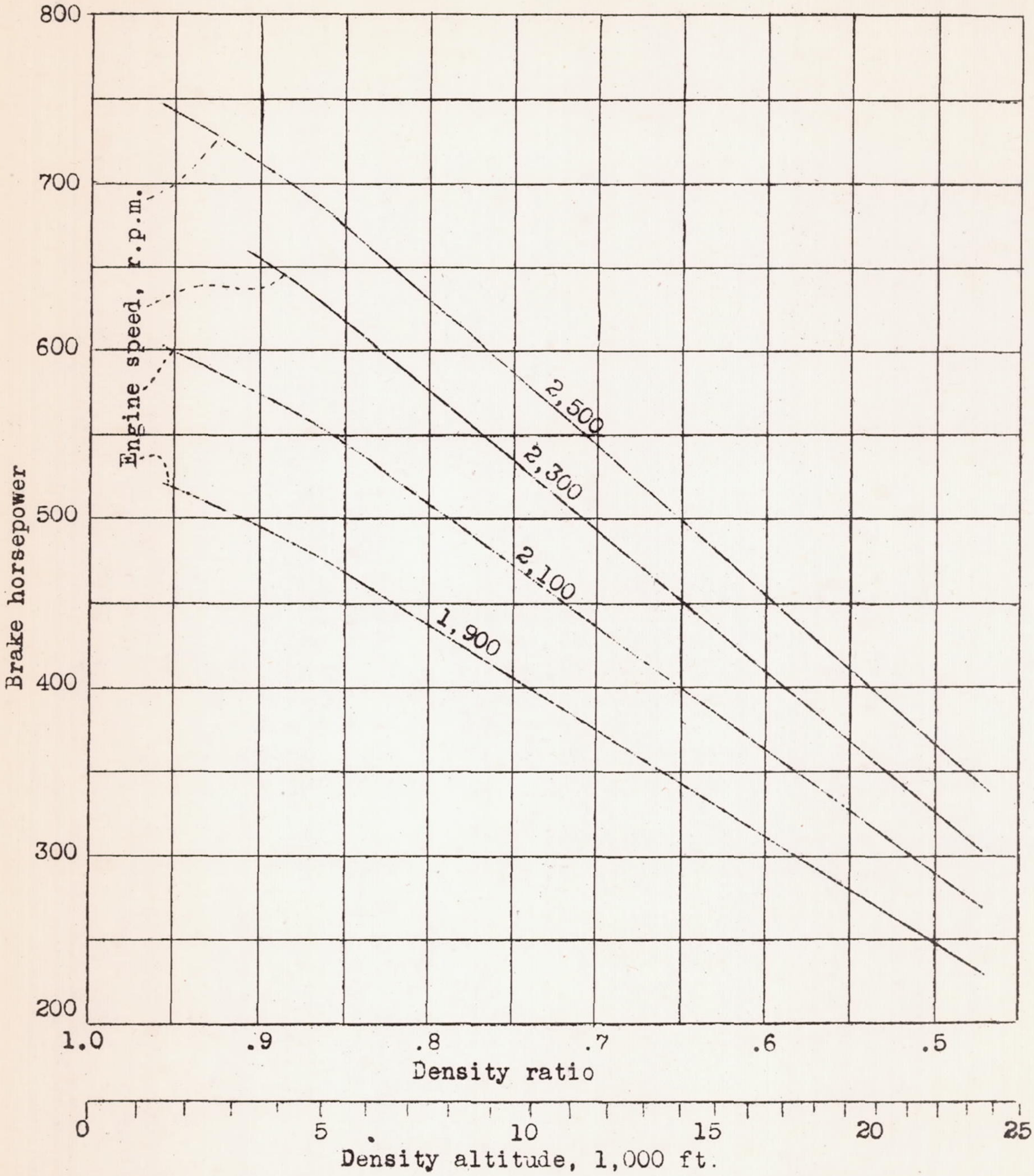

Figure 4.- Pratt and Whitney R-1535-13 full-throttle engine characteristics at altitude. (From reference 4.)

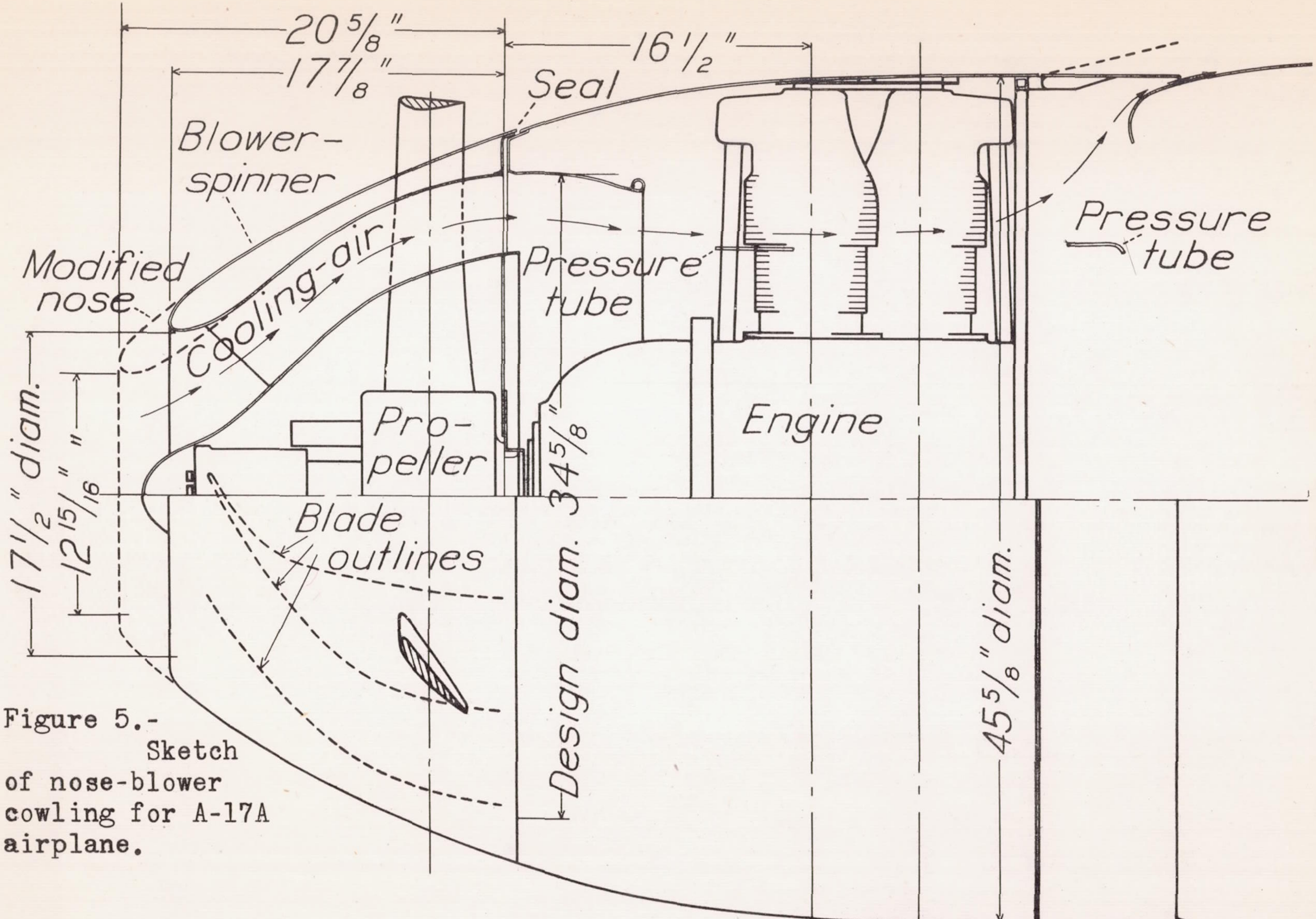

Figure 5.- Sketch of nose-blower cowling for A-17A airplane.

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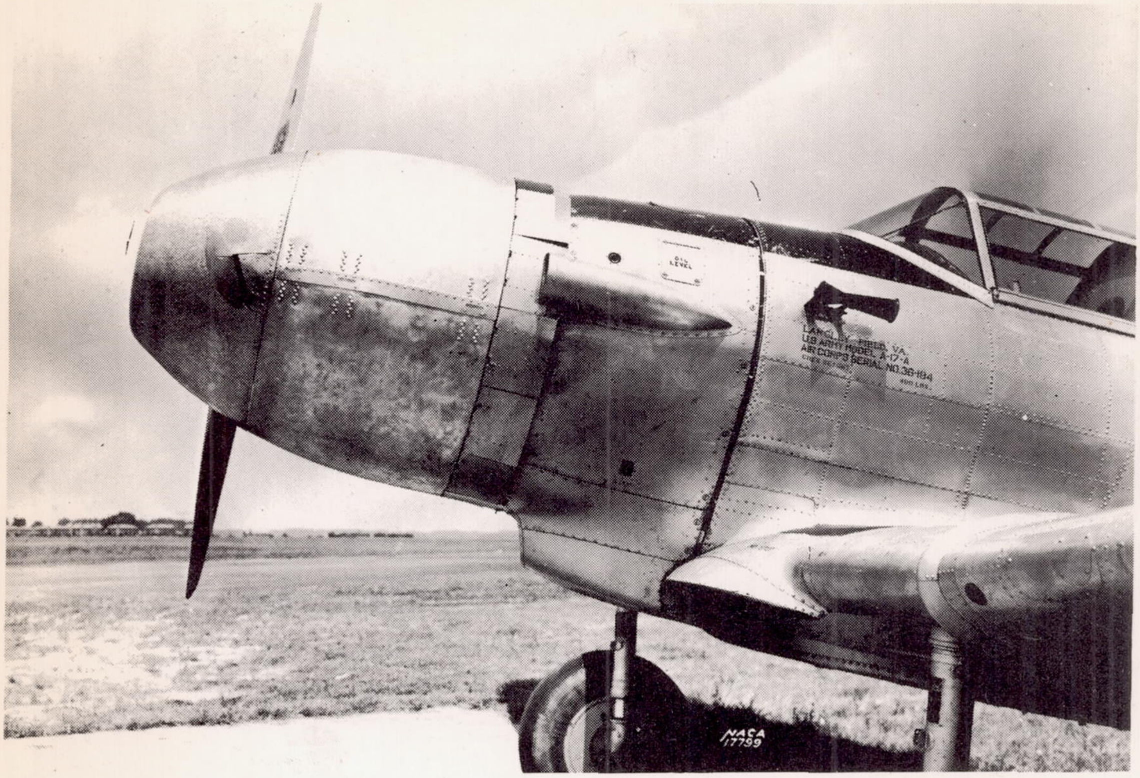

Figure 6.- Side view of nose-blower cowling.

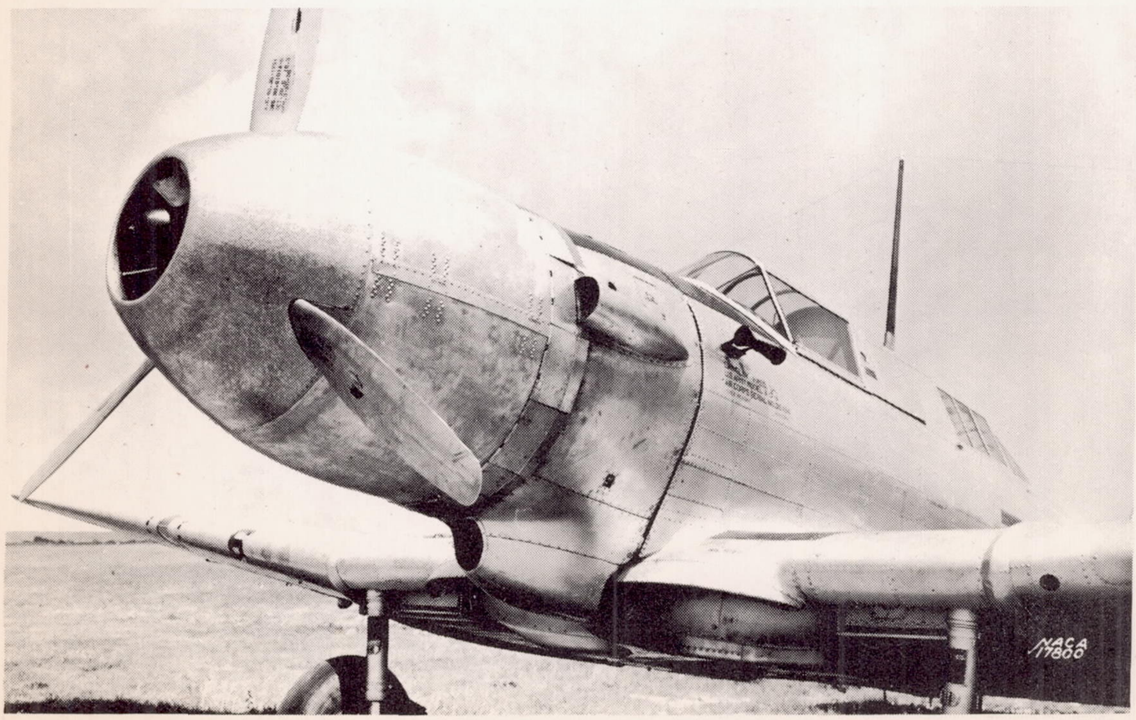

Figure 7.- One-quarter view of nose-blower cowling.

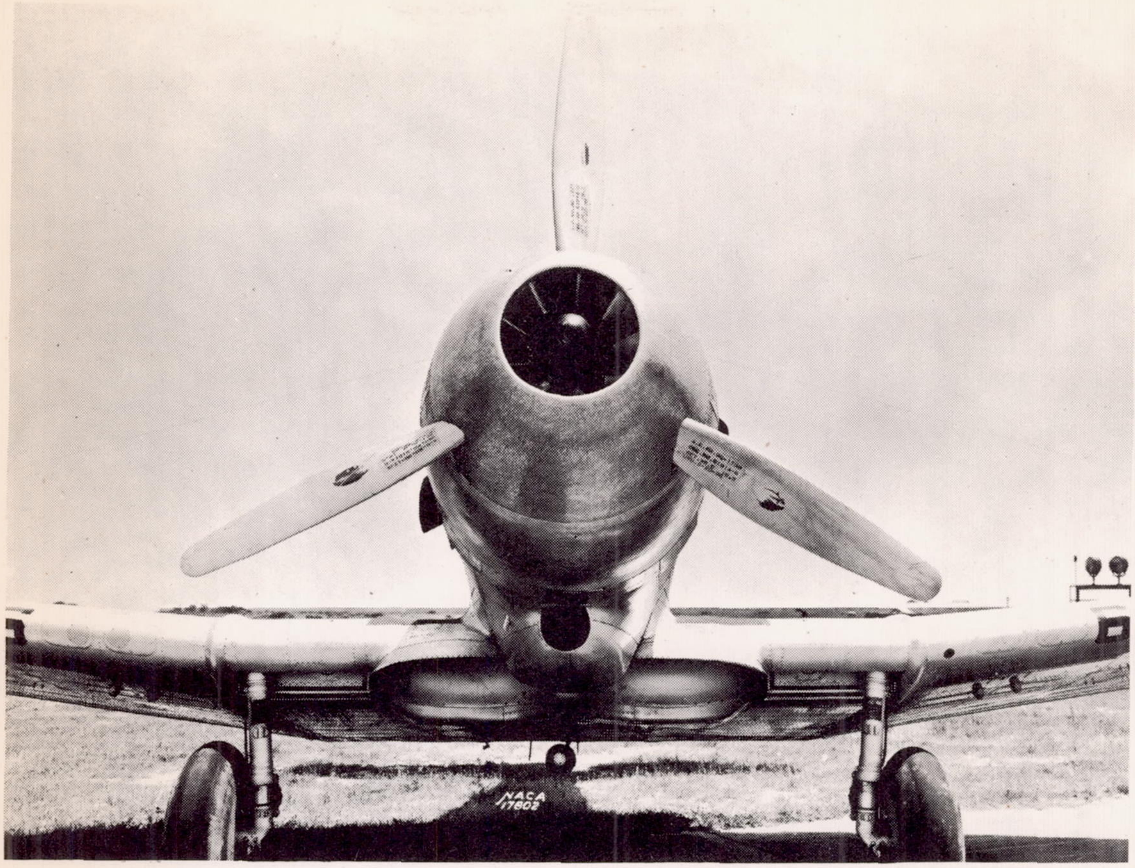

Figure 8.- Front view of nose-blower cowling.

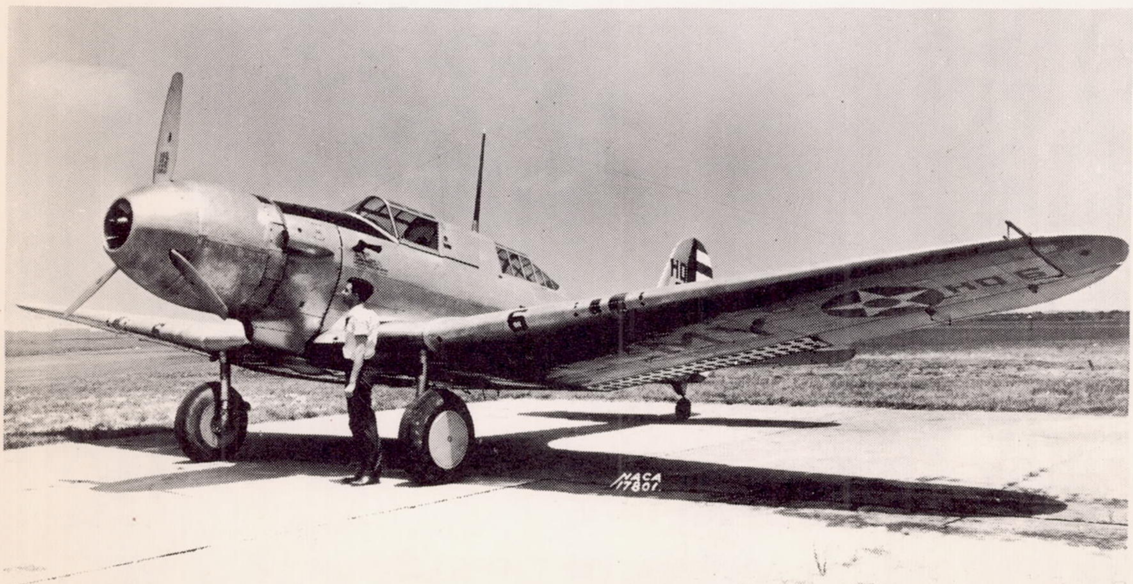

Figure 9.- One-quarter view of A-17A airplane with nose-blower cowling

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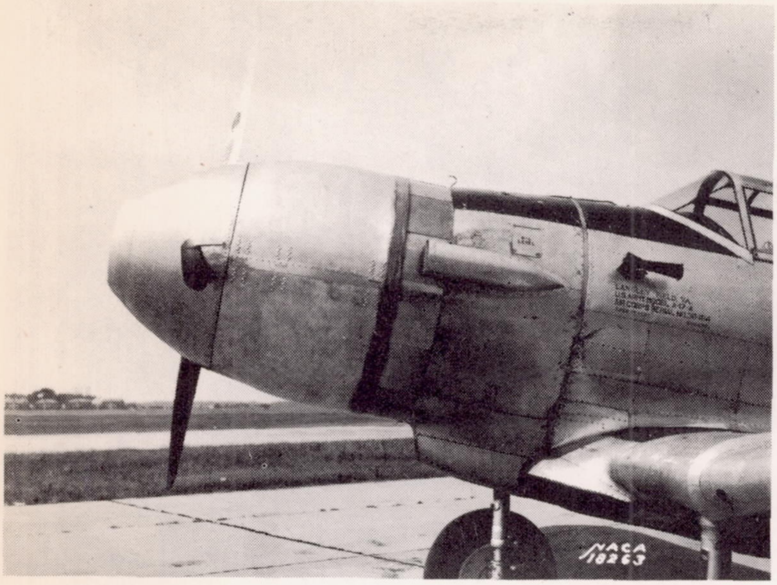

Figure 10.- Side view of modified nose-blower cowling.

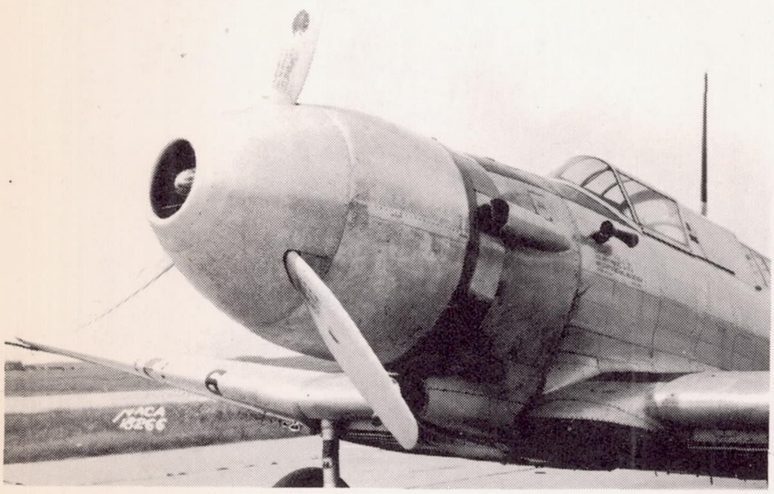

Figure 11.- One-quarter view of modified nose-blower cowling.

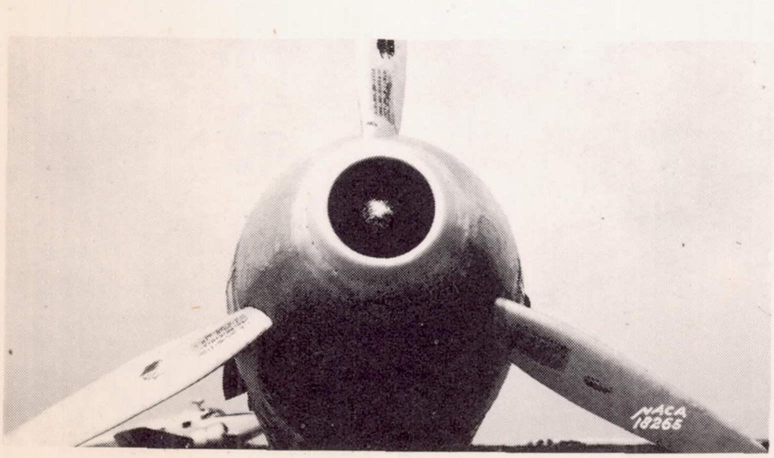

Figure 12. Front view of modified nose-blower cowling.

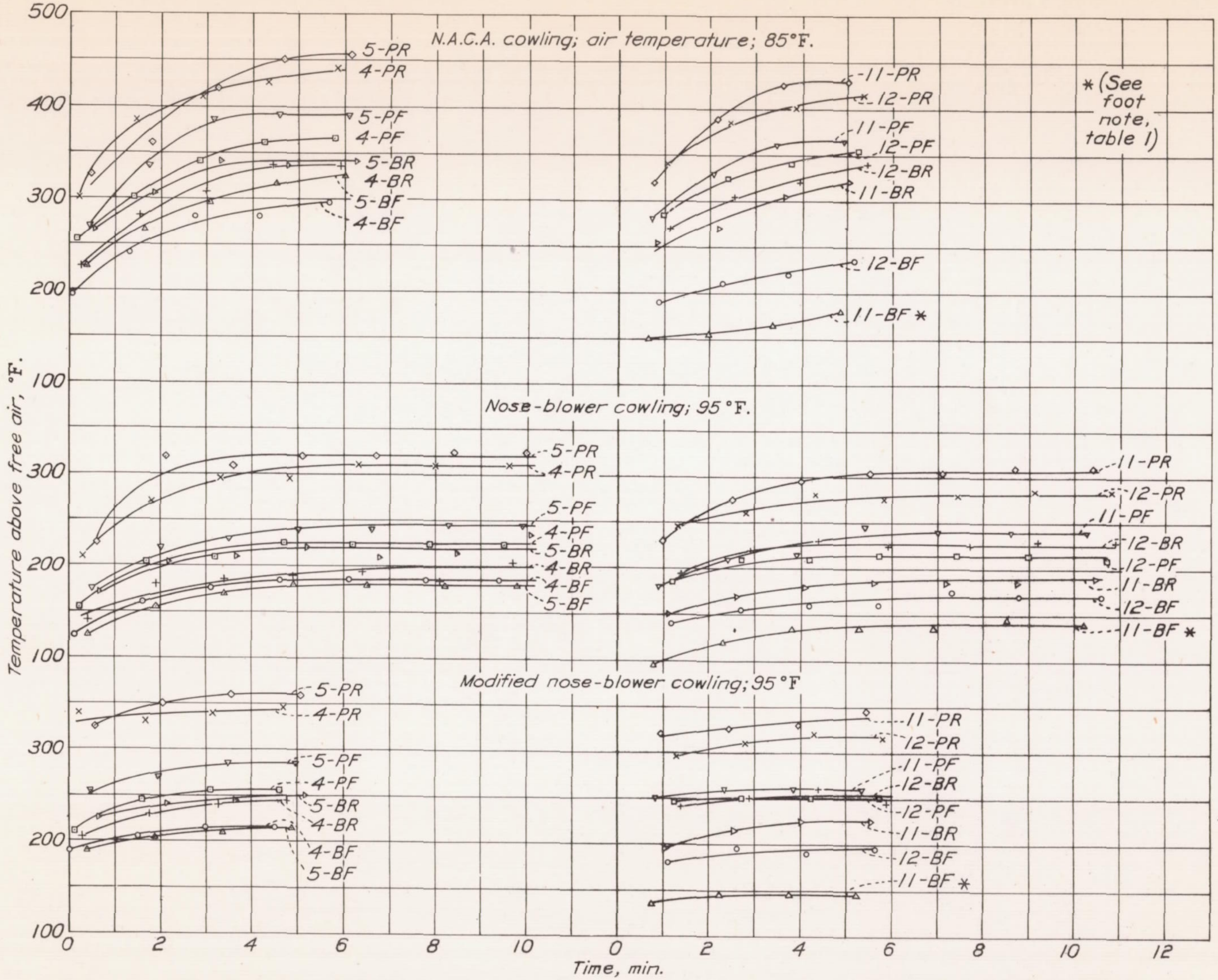

Figure 13.- Time histories of engine-cylinder temperatures for full-throttle ground operation. Cowl flaps open. Numbers correspond to cylinder numbers. P, indicates plug; B, barrel; F, front of cylinder; R, rear of cylinder.

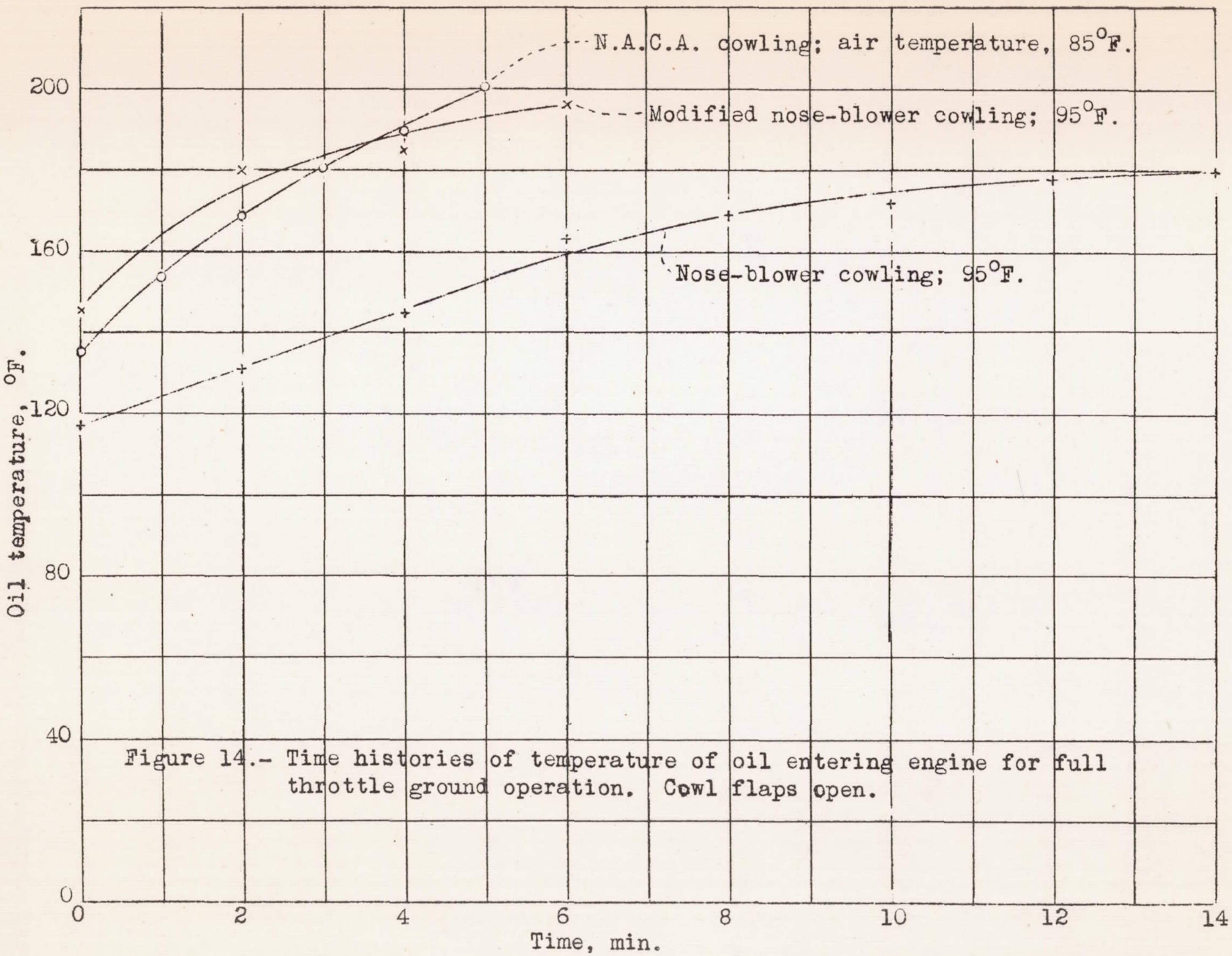

Figure 14.- Time histories of temperature of oil entering engine for full throttle ground operation. Cowl flaps open.

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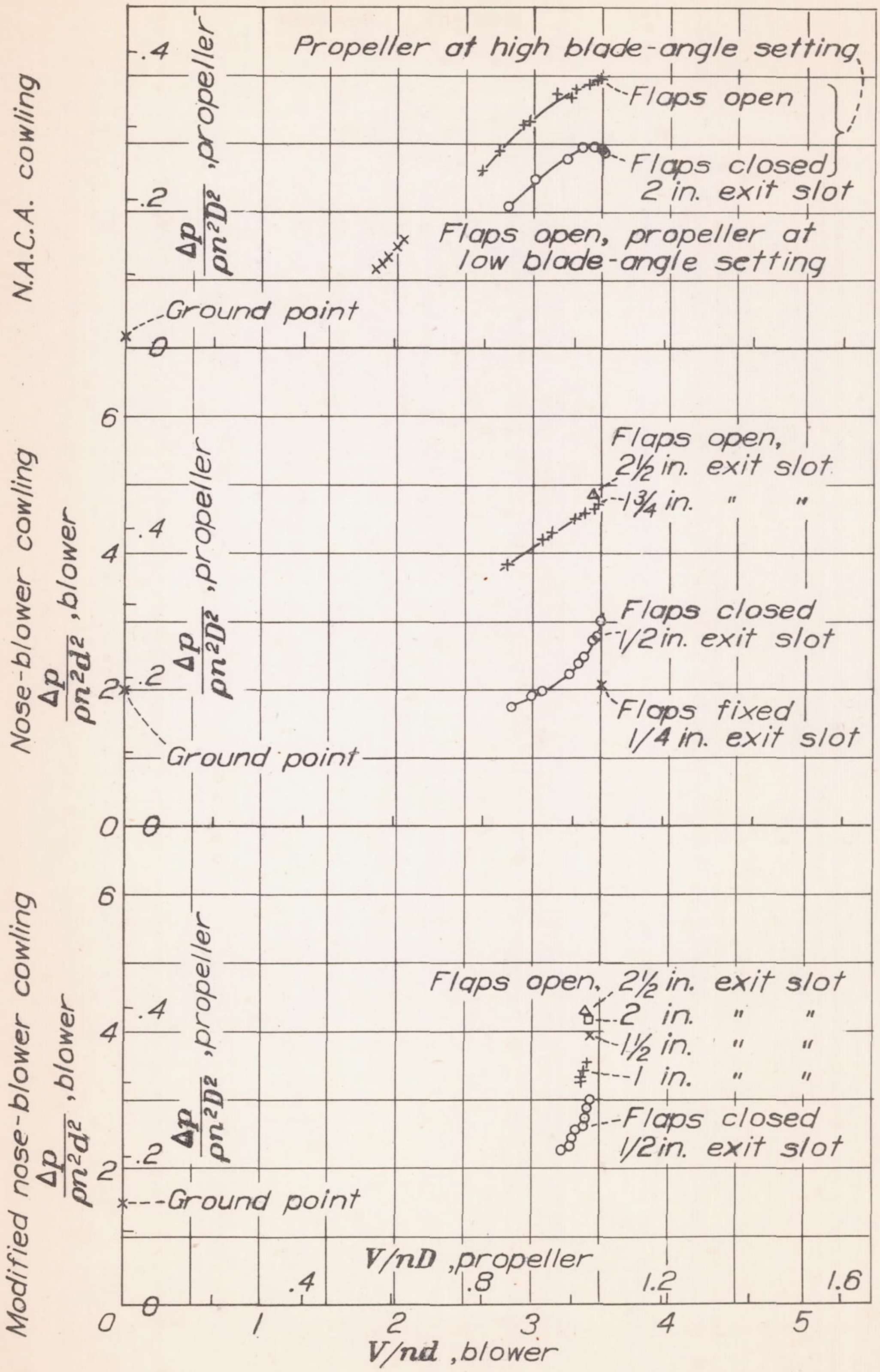

Figure 15.- Coefficients of engine pressure drop.

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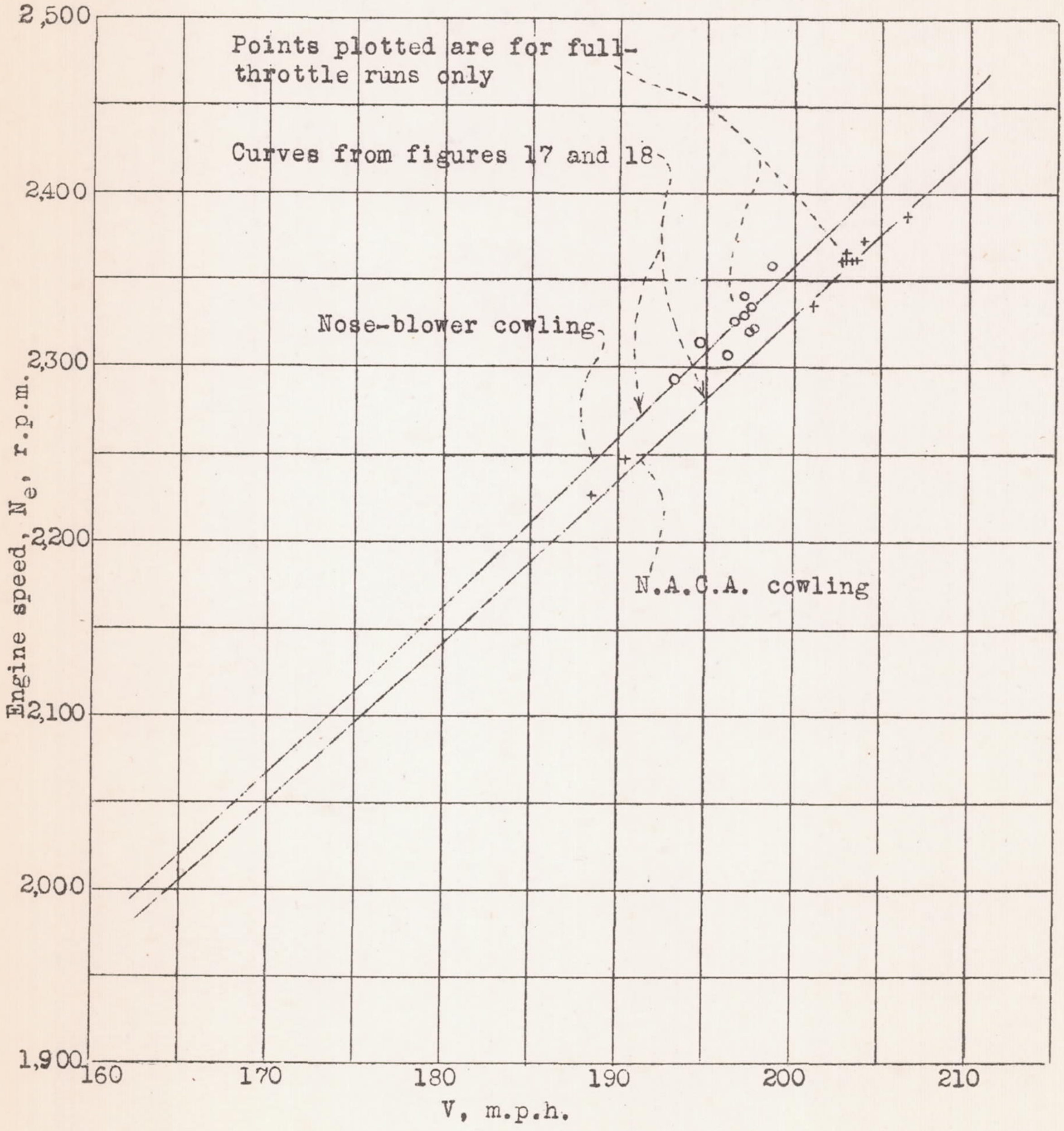

Figure 16.- True engine speeds and air speeds at 10,000 feet.

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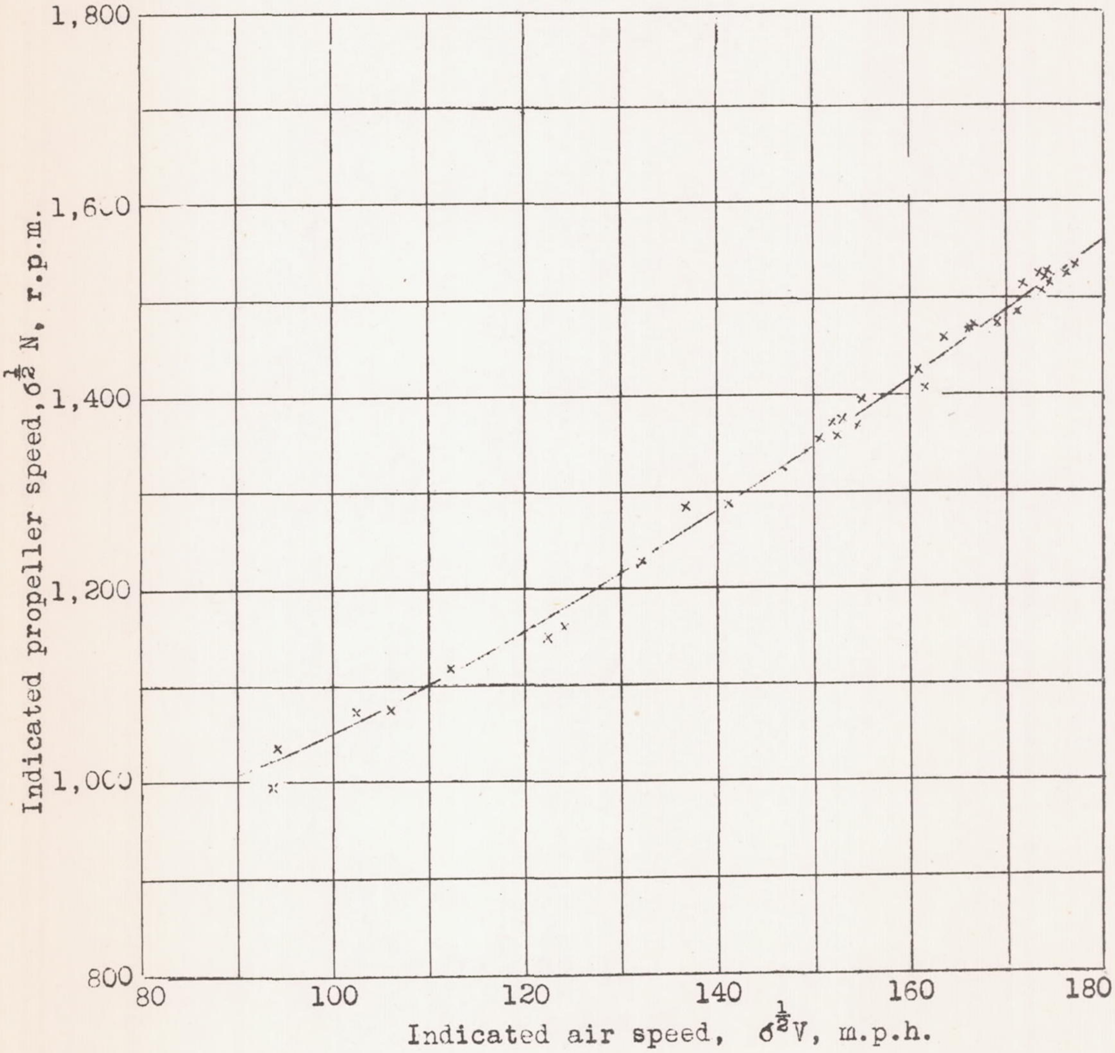

Figure 17.- Level-flight characteristics. N.A.C.A. cowling, cowl flaps closed

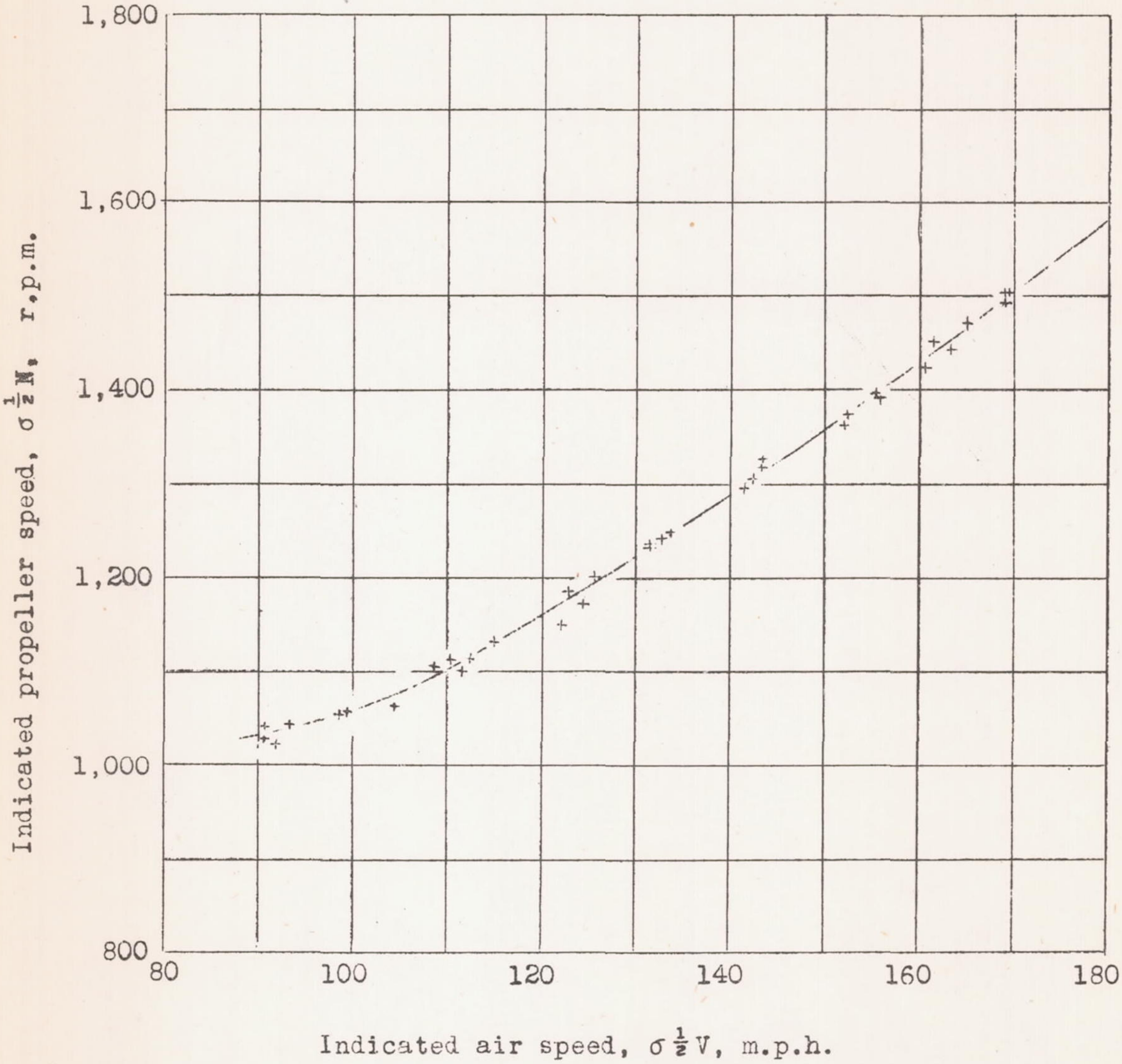

Figure 18.- Level-flight characteristics. Nose-blower cowling, cowl flaps closed.