

Library L.M.A.L.

TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

~~NSA 17~~

313

No. 301

DRAG AND COOLING WITH VARIOUS FORMS OF COWLING FOR A
"WHIRLWIND" ENGINE IN A CABIN FUSELAGE

By Fred E. Weick
Langley Memorial Aeronautical Laboratory

~~PROPERTY~~

Presented to
the staff of the Langley
Memorial Aeronautical
Laboratory

Washington
November, 1928

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL NOTE NO. 301.

DRAG AND COOLING WITH VARIOUS FORMS OF COWLING FOR A
"WHIRLWIND" ENGINE IN A CABIN FUSELAGE.

By Fred E. Weick.

Summary

The National Advisory Committee for Aeronautics has undertaken an investigation, in the 20-foot Propeller Research Tunnel at Langley Field, on the cowling of radial air-cooled engines. A portion of the investigation has been completed, in which several forms and degrees of cowling were tested on a Wright "Whirlwind" J-5 engine mounted in the nose of a cabin fuselage. The cowlings varied from the one extreme of an entirely exposed engine to the other in which the engine was entirely enclosed. Cooling tests were made and each cowling modified if necessary until the engine cooled approximately as satisfactorily as when it was entirely exposed. Drag tests were then made with each form of cowling, and the effect of the cowling on the propulsive efficiency determined with a metal propeller.

The propulsive efficiency was found to be practically the same with all forms of cowling. The drag of the cabin fuselage with uncowed engine was found to be more than three times as great as the drag of the fuselage with the engine removed and nose rounded. The conventional forms of cowling, in which at

least the tops of the cylinder heads and valve gear are exposed, reduce the drag somewhat, but the cowling entirely covering the engine reduces it 2.6 times as much as the best conventional one. The decrease in drag due to the use of spinners proved to be almost negligible.

The use of the cowling completely covering the engine seems entirely practical as regards both cooling and maintenance under service conditions. It must be carefully designed, however, to cool properly. With cabin fuselages its use should result in a substantial increase in high speed over that obtained with present forms of cowling on engines similar in contour to the J-5.

Introduction

The problem of cowling radial air-cooled engines has puzzled aircraft designers since the adoption of the static radial engine. The cowling has an important effect on both the cooling of the engine and the drag of the airplane, and no reliable data on either have been available.

At the conference of aircraft manufacturers held at Langley Field on May 24, 1927, several requests were made that an investigation of the cowling and cooling problem in regard to radial air-cooled engines be undertaken in the new full scale Propeller Research Tunnel which was then just being completed. A program for a series of tests was drawn up and submitted to the manufacturers for criticisms and suggestions, several of which were

adopted.

The program as finally arranged includes ten main forms of cowling to be tested on a J-5 engine in connection with two fuselages, three on an open cockpit fuselage and seven on a closed cabin type. The seven forms of cowling on the cabin fuselage range from the one extreme of an engine entirely exposed except for the rear crank case, to the other extreme of a totally enclosed engine. One of the cowlings with the open cockpit fuselage includes individual fairings behind each cylinder. Three forms of cowling, two of which are on the cabin fuselage, afford direct comparisons with and without a propeller spinner. The program involves the measurement of the engine cylinder temperatures, each cowling being modified, if necessary, until the cooling is satisfactory. The cowling is then tested for its effect on drag and propulsive efficiency.

Since this program necessitates extensive structural changes between the tests on the various cowlings, it is requiring a considerable period of time. The portion of the investigation involving the cabin fuselage is now finished and is being reported in a preliminary manner in this note in order to make the results available to those interested as quickly as possible. A more complete report covering the entire investigation will be published later.

Although the tests are being made in the Propeller Research Tunnel, a great deal of help has been received from other sec-

tions of the laboratory, especially the Flight Operations Section, which made a beautiful job of the cowling and also contributed many helpful suggestions, and the Power Plants Division, which conducted the measurement of the cylinder temperatures.

Methods and Apparatus

The Propeller Research Tunnel is of the open-throat type with an air stream 20 ft. in diameter, in which velocities up to 110 M.P.H. can be obtained. A complete description of the tunnel, balances, and other measuring devices is given in Reference 1.

A standard Wright "Whirlwind" J-5 engine delivering 200 HP. at 1800 R.P.M. was used for these tests. It was mounted on a dynamometer enclosed within the fuselage so that the engine torque could be measured directly. The torque as measured included the torque on the engine cylinders due to the twist of the slip stream. In order to correct for this effect a special test was made in which three J-5 cylinders complete with valve housings were mounted under the front portion of a water-cooled Wright E-2 engine on a VE-7 fuselage in the Propeller Research Tunnel (Fig. 11). The cylinders were in the same position relative to the propeller as on a J-5 engine. The middle cylinder only was supported in such a manner that its torque about the engine axis could be measured, and the same propeller used in the cowling tests was driven by the E-2 engine. The torque on

the middle cylinder was then found for various engine and air speeds with different amounts of cowling, and the results have been used to apply a correction, amounting to as much as 3 per cent in some cases, to the engine torque and power.

The cabin fuselage was designed to have a shape and size approximating the average of the fuselages of several commercial "Whirlwind" engined cabin monoplanes. The fuselage was of rectangular cross section from the maximum section to the tail, and the forward portion was gradually faired to a circular section at the engine. This whole forward portion was rebuilt for the various cowlings.

In order to make certain that the tests would be directly applicable to the present day high-wing cabin monoplanes, a stub wing and pilot's extension cabin and windshield were mounted on the fuselage and tested with three different cowlings. The wing, which was constructed of flat sheet aluminum over a wooden frame, had the Göttingen 398 section, with a 7-foot chord and 16-foot span.

The open cockpit fuselage is similar in shape to that of a Vought UO-1 airplane, and a UO-1 type landing gear is being used with both the open and cabin fuselages in this investigation in order to keep the landing gear factor constant.

The cylinder temperatures of the J-5 engine were measured at 69 different points, 47 being on the top (No. 1) cylinder and

the rest distributed at two or three representative points on each of the other cylinders. A mass of other engine data such as the manifold depression, fuel consumption, and carburetor air temperature, were also obtained. Only a small portion of the engine data is necessary to the present investigation, and most of it, along with a complete description of the thermocouples, pyrometers, and other instruments, will be published in a separate report by the Power Plants Division of the laboratory.

The entire program includes ten main sets of cowling. Nos. 1, 2, and 3 are to be used with the open cockpit fuselage and have not yet been tested. The cowlings tested on the cabin fuselage may be outlined as follows:

- No. 4 No cowling over cylinders or crank case. Tested with and without wing (Fig. 1).
- No. 5 Cowling covering slightly less than one-half of each cylinder and over crank case. Tested with and without wing (Fig. 2).
- No. 6 Same as No. 5 but with spinner. Tested with and without wing (Fig. 3).
- No. 7 Cowling over nearly all of each cylinder and over crank case (Fig. 4).
- No. 8 Same as No. 7 but with spinner (Fig. 5).

No. 9 Single cowling completely covering cylinders but no cowling over crank case (Fig. 6).

No.10 Same as No. 9 but with internal cowling similar to No. 5 over lower portion of cylinders and crank case (Fig. 7).

All of the cowlings were constructed in a practical manner with fire walls and louvers.

The first test made with each cowling was on the cooling properties, the cylinder temperatures with the uncowed engine (No. 4) being used as a criterion. In the first few series of cooling tests the engine was run at full throttle at air speeds of 60, 80, and 100 M.P.H. At each speed the run was maintained until the temperature conditions had become constant. It was found that in each case the engine ran slightly warmer at 80 M.P.H. than at either 60 or 100, so the remainder of the tests were run at 80 M.P.H. as representing the worst flight conditions for cooling. The conditions were therefore similar to those in an extended full throttle climb in flight. If the cooling with any cowling was not as satisfactory as that with the uncowed engine, the cowling was modified until satisfactory.

Drag tests were run with the various cowlings, both as they were originally constructed and as they were finally modified to cool properly.

After a cowling cooled properly, propeller tests were made to determine the effect of the cowling on the propulsive efficiency. The propeller, which had adjustable aluminum alloy blades (Fig. 31), was tested at both a low and a high pitch setting with each cowling. The hub to which the blades were fitted was of steel, and in order to save weight, had been made 1 inch shorter than the hub for which the blades had been designed, so that while the drawing shows a 9-foot propeller, the diameter in these tests was actually 8 ft. 11 in. The propulsive efficiency found from these propeller tests includes the increase in drag of all parts of the body affected by the slip stream and also the effect of the body interference on the propeller thrust and power.

Cooling Tests

The cylinder temperatures obtained with cowling No. 4 (engine uncowled, Figs. 1, 12 and 13) at full throttle and 80 M.P.H. were used as a criterion by which to judge the cooling with the other forms of cowling. The particular temperatures used for comparison are tabulated in Table I. The hottest part of each cylinder was the rear spark plug boss, and it was at first thought that the average of the rear spark plug boss temperatures for all nine cylinders would be used as a measure for comparison. In some runs, however, one or two cylinders had very low temperatures, probably because they were not developing full power, so the average of the five hottest cylinders has been

taken as a better criterion of the cooling. The highest temperature recorded on any cylinder was also used as a criterion, and also three representative points on cylinder No. 1 (top cylinder). One of these was at the rear spark plug boss, one at the rear central portion of the barrel, and the third at the rear lower portion of the barrel. The rear points were chosen because they represented the highest temperatures around the cylinders. In addition to the above cylinder temperatures, the lubricating oil temperature and the temperature of the air in the tunnel were considered.

The temperature conditions under which these tests were made in the wind tunnel were more severe than the conditions found in flight in a temperate climate, and probably correspond to those of a sustained full throttle climb in a tropical climate. The cylinder temperatures recorded were therefore in the neighborhood of 100° higher than have been found in flight tests.

The cooling with cowling No. 5 (Figs. 2 and 14), in which the cowling covered the crank case and nearly half of each cylinder, was better than with no cowling whatever over the engine. The hottest five cylinder head temperatures averaged nearly 70°F. lower than with cowling No. 4, while the cylinder barrel and oil temperatures were the same. With cowling No. 6 (Figs. 3 and 15), which was the same as No. 5 excepting for the spinner, the cooling effect would be obviously about the same as with No. 5, so no cooling tests were considered necessary. (Since the full throt-

the running seemed unusually severe, and since it was necessary to run the engine with thermocouples attached for over 100 hours in all no full throttle running was done which was not necessary.)

No. 7 cowling (Figs. 4 and 16) as originally constructed enclosed the whole engine except for the tops of the cylinder heads and the valve gear. At the front of the cylinder the cowling came just under the spark plug, and at the rear it came just over the cylinder head proper, enclosing the rear spark plug. The cooling with this cowling was not satisfactory, for the oil and cylinder barrel temperatures were excessive, although the head temperatures, even those of the enclosed rear spark plug boss, were considerably lower than with no cowling over the engine. Apparently with cowling Nos. 5, 6, 7 and 8, the air flows past the cylinder heads at greater speed than with no cowling over the engine. In order to improve the oil and cylinder barrel cooling with cowling No. 7, four slots were cut in the nose as shown in Fig. 17. These were effective in reducing the oil and barrel temperatures somewhat, but the temperatures were still too high, and on this run the piston in cylinder No. 9 failed due apparently to excessive temperature. The high piston temperature was probably due to the fact that with the high oil and cylinder wall temperatures with cowling No. 7, the heat was not conducted away from the piston skirt rapidly enough. The engine was repaired, and six larger slots were put in the nose cowling over the crank case as shown in Figure 18. Enough louvers were

already in the cowling behind the engine to permit the escape of the air passing through the nose slots. With this arrangement the cooling was considered satisfactory as compared with that of the uncowled engine (No. 4). The cylinder head temperatures were a little lower than for the uncowled engine, the oil temperature was practically the same, and the barrel temperatures were a little higher.

Incidentally, a series of tests with different sized carburetor jets was run with cowling No. 7. It was found that the cylinder temperatures could be reduced materially by increasing the jet size.

Cowling No. 8, which was the same as No. 7 except that it had a spinner, is shown as originally constructed in Figures 5, 19, and 20. On account of the large spinner, nose slots similar to those in cowling No. 7 could not be used. Instead, the cowling was cut away immediately in front of each cylinder, as shown in Figure 21, to make the engine cool properly.

Cowling No. 9 completely covered the engine (Figs. 6 and 22). The air was taken in at the nose and allowed to flow past the engine, which was entirely uncowled inside of the outer hood, and out of an annular slot similar in section to some wing slots which have been tested. This type of nose and slot were designed to offer as little disturbance to the flow of air over the fuselage as possible, separating the air for cooling the engine from the general flow and then feeding it back smoothly through the

slot. No information was available when this cowling was designed regarding the necessary size of the hole in the nose or the slot. In the cooling test with the original No. 9 cowling the cylinder head temperatures became excessive in a very short time.

No. 10 cowling was the same as No. 9 except that it had No. 5 cowling inside also (Figs. 7 and 23), so that the air was directed more particularly at the cylinder heads, and at the same time had a smoother path past the engine. This improved the cooling of the cylinder heads slightly, but they still ran much too hot. During the test the head of No. 3 cylinder developed a small hole about 1/8 inch in diameter, apparently caused by a defective spot in the aluminum alloy becoming too hot to withstand the cylinder pressures. This cylinder was therefore replaced. It is interesting to note that the two cylinders which gave trouble due to cooling, Nos. 3 and 9, were deprived of their full share of cooling air by the magnetos, which on the J-5 engine are placed in front of the cylinders.

The outlet area at the slot had originally been made smaller than the inlet area, and the cowling was then modified by cutting 3 inches off of the skirt of the hood or nose piece, which increased the area of the slot to that of the opening at the nose. With this modification the cooling was fairly satisfactory except for the cylinders located behind the magnetos (Nos. 2, 3, 8, and 9). The magnetos effectively blocked most of the air from those cylinders.

Next, deflectors, as shown in Figure 9, were installed between the cylinders to direct the air to the hottest portions at the rear. These also reduced the temperatures slightly and were retained. The next modification was to enlarge the hole in the nose from 24 in. to 23 in. in diameter. It was thought that this would not only allow more air to flow past the engine, but also enable some air to pass over the magnetos. With the 23-inch opening the cooling was much better but the cylinders behind the magnetos, especially No. 9, still ran too hot.

Next a cut-out was made in the nose piece over each magneto. This improved the conditions somewhat, but not sufficiently, so the cut-outs over the magnetos were enlarged, the cowling as it then appeared being as shown in Figures 8, 24, and 25. With this arrangement, the cooling was fairly satisfactory, but the temperatures were still a little higher than for the uncowled engine, especially at the lower portion of the cylinder barrels.

In the original design, the slot had been placed as far forward as possible in the hope that it would help remove the boundary layer near the region of rather sharp curvature at the nose, and thereby help reduce the drag. This necessitated a sharp rise in the internal cowling immediately behind the cylinders, which hindered the flow of the cooling air. In an effort to reduce mainly the barrel, but also the head temperatures, still further, the rise behind the cylinders was made gradual and the slot moved farther back as shown in Figures 8 and 26. The inside deflectors

were retained as before. With this arrangement the cooling was very nearly as good as with the uncowled engine, and for the first time with the cowling completely covering the engine, the test was continued until the temperature conditions became constant (about 10 minutes). The five highest head temperatures averaged about 30°F. higher than for the uncowled engine, the barrel temperatures averaged about 60°F. higher, and the oil temperature was only 5°F. higher. The oil temperature could, of course, be reduced by reducing the cowling covering the crank case. One thermocouple had consistently recorded the highest temperatures with No. 10 cowling, and this one was still somewhat high.

A run was made next without the deflectors which directed the air around the cylinders. All of the cylinder temperatures became rather high in a short time, and the run was stopped.

Since the above deflectors were evidently very helpful in cooling the engine, another run was made with improved ones. The original deflectors directed the air around both sides of the cylinders, but the second set turned the air in one direction only, as shown in Figures 10 and 27. They were larger than the first ones, and directed about two-thirds of the air between each two cylinders around the exhaust valve and rear spark plug. The cooling with this arrangement was considered approximately as satisfactory as with the uncowled engine. The cylinder head temperatures were about the same, and the cylinder barrel temperatures, which still averaged about 60°F. higher, were considered permissible.

In order to determine whether enclosing the propeller hub in a spinner would help the air flow, and consequently the cooling and drag, the above cowling was tested with No. 6 nose inside as shown in Figure 28. After a few minutes of running it was apparent that the cooling and drag were about the same as without the spinner, so the run was discontinued.

Results of Drag Tests

The observed drag test data are given in Table II and the results are plotted in Figure 30. The drag of the bare fuselage (without supports or landing gear) with the various cowlings is given for an air speed of 100 M.P.H. in the following table.

Cowling	Fuselage and engine drag, lb. at 100 M.P.H.	Reduction from uncowed engine, lb. at 100 M.P.H.
No. 4 Engine uncowed	125	0
No. 5 No spinner. Original	119	6
No. 6 Spinner. Original	116	9
No. 7 No spinner. Original	103	22
No. 7 Modified to cool	111	14
No. 8 Spinner. Original	100	25
No. 8 Modified to cool	106	19
No.10 Combination of 9 and 5. Original	64	61
No.10 Modified to cool	75	50

Cowling	Fuselage and engine drag, lb. at 100 M.P.H.	Reduction from uncowed engine lb. at 100 M.P.H.
No. 10 Modified to cool. With spinner	75	50
No. 4 Engine removed. Nose rounded	40	85

The last item listed, No. 4 cowling with the engine removed and the nose rounded as shown in Figure 29, has been included as an ideal with which to compare the effect of the various cowlings. Using this as a basis, the uncowed engine is responsible for an increase in drag of 85 lb. at 100 M.P.H.

The outstanding feature of the drag tests is the large reduction in drag obtained with the cowling which completely covers the engine. Considering only the cowlings which cool properly, the reduction of drag with No. 10 cowling is about 60 per cent of the total possible reduction, and is 2.6 times as great as with the next best, No. 8.

The drag of the bare fuselage without engine is only 40 lb. at 100 M.P.H. When the uncowed engine is placed on the nose the drag is increased to 125 lb., or 3.13 times that of the bare fuselage without engine. With the best conventional cowling (No. 8) the drag is 106 lb. or 2.65 times that of the fuselage alone, and with the cowling totally enclosing the engine (No. 10) the drag is 75 lb. or 1.87 times that of the fuselage without engine.

The forms of cowling most used in service are similar to Nos. 5 and 6, and these have a very slight effect on the drag, and consequently an almost insignificant effect on the performance of an airplane. The reduction of drag is small even when practically the whole of the cylinders are cowled in, as in No. 8. Apparently, if even a small portion of the engine is exposed, it is sufficient to disturb the smooth flow over the body, and the turbulent flow is associated with high drag. When the entire engine is covered and the cooling air is separated from and returned to the outside air smoothly as with cowling No. 10, the smoother flow is evidently accompanied by a substantial decrease in drag.

It is interesting to note that with cowling Nos. 7, 8, and 10, it cost respectively 8 lb., 6 lb., and 11 lb. in drag at 100 M.P.H. to make the original designs cool properly. Apparently, the method used with No. 8, which was to cut away the cowling immediately in front of the cylinders, costs slightly less in drag than the slots of No. 7.

The value of spinners in reducing the drag, when used in front of radial air-cooled engines, is shown by a comparison of cowling Nos. 5 and 6 and Nos. 7 and 8 as originally designed. In each case the drag with spinner was 3 lb. less at 100 M.P.H. than the drag without spinner. This would represent a difference in speed of a small fraction (about one-third) of a mile per hour on an average airplane with a J-5 engine.

It is interesting that the stub wing with windshield increased the drag only 57 lb. at 100 M.P.H. with cowling No. 4, and 50 lb. with Nos. 5 and 6 (No. 4 had slightly more pilot's windshield exposed), although the drag of the wing alone would be about 75 lb. as computed from model tests.

Results of Propeller Tests

A large mass of propeller test data has been obtained during these cowling tests, only a small portion of which is necessary to show the effect of the various cowlings on propulsive efficiency. The rest will be used in another report dealing with body interference. The propulsive efficiencies obtained with the various cowlings are shown in Figure 32 for a propeller blade angle of 15° at the 42-inch radius, and in Figure 33 for 23° at the 42-inch radius. (These angle settings correspond to pitch-diameter ratios of .66 and 1.02, the pitch being taken at 75 per cent of the radius. The pitch of this propeller is approximately uniform for all working sections when the pitch-diameter ratio is about .5.) The curves of propulsive efficiency are very nearly the same for all cowlings, although for both pitch settings the efficiencies with cowling No. 10 are the highest. The power and thrust coefficients were also practically the same for all cowlings.

D i s c u s s i o n

Effect on Airplane Performance:

It is interesting to compare the various forms of cowling with regard to their effect on the performance of a typical "Whirlwind" engined cabin monoplane. Suppose such an airplane with an uncowled engine similar to No. 4 required 200 HP. to fly horizontally at 125 M.P.H. If the airplane were equipped with the usual amount of cowling, similar to Nos. 5 and 6, the power required would be reduced to 196 or 194 HP. respectively, at 125 M.P.H. If a cowling similar to No. 8, which is the best of the conventional forms, were used, the airplane would require only 187 HP., and with a cowling covering the entire engine similar to No. 10, 167 HP. The airplane with the latter cowling could therefore fly at 125 M.P.H. with the engine throttled more than 100 R.P.M. from the revolution speed required with the uncowled engine. If the full 200 HP. were to be used, a cowling similar to No. 6 (with spinner) would increase the speed less than one M.P.H., one similar to No. 8, about 3 M.P.H., and one similar to No. 10, about 8 M.P.H.

Considering all types of cabin airplanes having the same engine, the higher the speed attained with ordinary forms of cowling, the greater will be the improvement possible. This is, of course, due to the fact that in the faster airplanes the fuselage-engine drag is a larger portion of the total.

Practicability:

All of the forms of cowling tested have been used on airplanes in service excepting the one entirely covering the engine. The forms enclosing a large portion of the engine have been found rather poor from a maintenance standpoint because of the large number of small parts which must be removed when it is necessary to work on the engine. This difficulty is accentuated where metal spinners are used, but fortunately, as these tests have shown, spinners have an almost negligible effect on the performance of airplanes.

The No. 10 cowling is similar to No. 5 in construction, except for the nose piece. When this is removed, most parts of the engine requiring frequent attention are accessible. As made for the tests, the nose piece for No. 10 cowling was a one-piece ring which was easily constructed and easily handled, its shape being such that it was stiff and strong without bracing. It had the disadvantage, however, that in order to remove it, it was first necessary to take off the propeller. To avoid this in practice it would probably be desirable to make the nose piece in two or three quick-detachable sections.

With the J-5 engine it was necessary to have a rather sharp curvature at the nose of the No. 10 cowling. A better shape, and therefore still better performance, could be obtained with an engine having (1) a greater distance between the cylinders and the propeller, (2) smaller over-all diameter, (3) the valve

gear at the rear of the cylinders instead of projecting in front, and (4) magnetos at the rear of the cylinders.

C o n c l u s i o n s

1. The drag of an average sized cabin fuselage with the engine removed and the nose rounded is tripled by placing an uncowled J-5 engine on the nose.

2. With the conventional forms of cowling, in which a portion of the cylinders and valve gear is exposed, the drag becomes less as the cowling is increased, but even in the most extreme case the reduction amounts to only about 23 per cent of the increase in drag due to an uncowled engine.

3. A spinner, if used in front of a radial engine, decreases the drag but a very small amount and has an almost negligible effect on the performance of an airplane.

4. With a cowling similar to No. 10, which covers the entire engine and separates the cooling air from the general flow about the body, the reduction in drag is about 60 per cent of the increase due to an uncowled engine. This is about 2.6 times as great as with the best conventional form of cowling.

5. The use of cowling similar to No. 10 seems entirely practical as regards both cooling and maintenance under service conditions. It must be carefully designed, however, to cool properly.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 5, 1928.

R e f e r e n c e

1. Weick, Fred E. : The Twenty-Foot Propeller Research
 and : Tunnel of the National Advisory
Wood, Donald H. : Committee for Aeronautics.
 : N.A.C.A. Technical Report No. 300.
 : (1928)

TABLE I.

Cooling Test Data
Temperatures in Degrees Fahrenheit.

C o w l i n g	Average temp. 5 hottest cyl. heads, rear plug boss	Highest temp. on any cyl.	Cyl. No. 1 rear plug boss	Cyl. No. 1 barrel, middle rear	Cyl. No. 1 barrel bottom rear	Oil temp.	Air temp.
No. 4	673	728	583	353	378	140	84
No. 5	605	666	585	361	379	138	86
No. 7	626	681	618	476	557	167	88
*No. 7, 4 holes in nose	638	702	612	397	458	144	88
No. 7, 6 large holes	664	750	653	432	447	146	82
*No. 9	731	800+	673	377	438	127	93
*No. 10	755	800+	682	403	430	133	97
*No. 10, larger slot	740	800+	654	335	355	126	91
*No. 10, 28-inch hole in nose, cylinder deflection	695	768	635	428	467	133	75
*No. 10, cut-outs over magnetos	705	760	658	452	477	132	77
*No. 10, larger cut-outs	697	778	670	460	498	140	82
No. 10, slot moved back	701	772	668	396	428	145	86
*No. 10, cyl. deflectors removed	704	778	670	460	498	145	86
No. 10, single cyl. deflectors	683	753	662	430	432	149	86

*Run stopped because of high temperatures before constant conditions were reached.

TABLE II.

Observed Gross Drag Data, Including Landing Gear and Supports.

No. 4 Without wing		No. 5 Without wing		No. 6 Without wing		No. 7-0 Without wing		No. 4 With wing		No. 5 With wing		No. 6 With wing		No. 4 With wing Without Eng.	
q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag	q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.
18.25	169	16.50	149	17.99	161	16.92	143	17.78	202	16.31	182	17.07	186	18.40	147
18.32	169	16.50	149	18.01	161	16.97	143	17.78	202	16.49	182	16.94	185	18.39	147
20.95	193	17.92	161	18.90	169	19.06	160	25.05	279	18.14	198	18.21	199	20.43	161
20.73	191	17.92	162	18.96	169	19.08	160	25.05	281	18.02	198	18.21	199	20.62	161
25.40	231	20.00	179	20.18	181	20.30	169	25.85	290	19.42	212	20.35	221	25.40	202
25.05	230	20.00	179	19.11	170	20.15	170	26.26	295	19.35	212	20.23	220	25.70	202
25.96	235	24.82	221	25.00	220	26.18	215	20.06	228	22.70	247	24.48	265	16.72	135
25.76	236	24.58	219	24.95	220	26.28	217	20.60	232	22.61	247	24.82	265	16.72	134
16.82	156	14.76	135	14.88	134	13.92	118	18.15	207	15.13	168	14.98	164	15.25	124
16.87	157	14.83	135	15.14	137	13.58	116	18.38	208	15.13	168	15.03	166	15.05	124
15.32	143	13.29	123	12.59	115	11.25	98	15.03	172	14.04	155	13.35	147	13.30	109
15.20	143	13.08	119	13.18	121	11.28	97	14.95	172	13.89	155	13.39	150	13.30	110
15.39	129	11.59	108	10.58	97	9.43	81	13.03	150	11.42	130	10.22	118	11.58	96
13.50	128	11.50	106	10.89	99	9.88	85	13.12	153	11.42	129	10.17	114	11.24	94
11.98	114	9.05	85	8.34	78			11.00	128	10.01	114	8.64	95	9.40	79
11.53	110	8.97	84	8.65	81			11.14	129	10.12	115	8.86	100	9.41	79
9.27	90							9.08	107	8.95	102			8.24	69
9.95	96							8.72	102	8.80	100			8.37	72
7.94	79							7.84	93						
8.04	78							7.84	93						

Note.- 0 denotes original.

TABLE II (Continued)

Observed Gross Drag Data, Including Landing Gear and Supports.

No. 8-0 Without wing		No. 7-M Without wing		No. 8-M Without wing		No. 10-0 Without wing		No. 10-M Without wing		No. 10-M With spinner Without wing		Landing gear and supports only	
q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.	q lb. per sq.ft.	Drag lb.
16.71	140	16.63	146	16.42	141	16.58	115	15.96	117	16.60	122	16.44	72
16.70	140	16.58	145	16.46	141	16.56	115	15.96	117	16.62	122	16.56	72
19.09	157	18.70	163	18.33	156	18.34	127	17.32	127	18.10	131	17.05	74
18.86	157	18.70	163	18.60	156	18.43	127	17.38	127	18.09	131	17.07	75
20.25	168	20.00	174	19.95	169	20.43	140	18.12	131	19.29	139	17.01	74
20.35	167	20.00	174	19.91	159	20.08	138	18.00	131	19.30	140	18.71	80
24.95	203	25.48	219	24.45	206	24.60	167	19.30	142	20.42	148	18.60	80
24.95	205	25.38	218	24.90	209	24.67	167	19.30	140	20.44	149	19.76	85
15.45	130	17.07	150	14.40	123	14.98	106	19.35	141	24.50	175	19.66	85
15.14	127	17.13	150	14.92	129	15.18	106	14.52	109	24.95	179	20.91	89
14.04	117	14.64	130	13.01	113	13.43	94	14.45	107	14.88	110	25.82	110
14.14	119	14.64	130	13.02	113	13.37	94	13.70	92	14.68	108	15.40	68
12.98	111	12.30	110	11.24	97	11.83	84	12.60	94	13.41	100	15.30	67
12.69	107	12.52	111	11.15	98	11.90	85	20.50	148	13.10	97	13.95	62
11.84	101	11.00	99	9.66	84	9.60	68	20.55	149	11.82	89	14.14	62
11.92	101	11.25	101	9.69	85	9.48	69	25.00	180	11.96	90	12.63	56
9.92	85	8.65	79	9.07	80	8.67	61	24.35	174	10.31	77	12.60	57
10.19	87	8.84	79	9.00	80	8.65	61	24.95	180	10.42	78	10.94	50
9.00	77							10.97	83	9.79	73	10.94	50
8.41	73							11.11	84			9.86	45
								10.00	73			9.81	45
								10.09	77			8.24	39
												8.24	38

Note.-- O denotes original.
M " modified to cool.

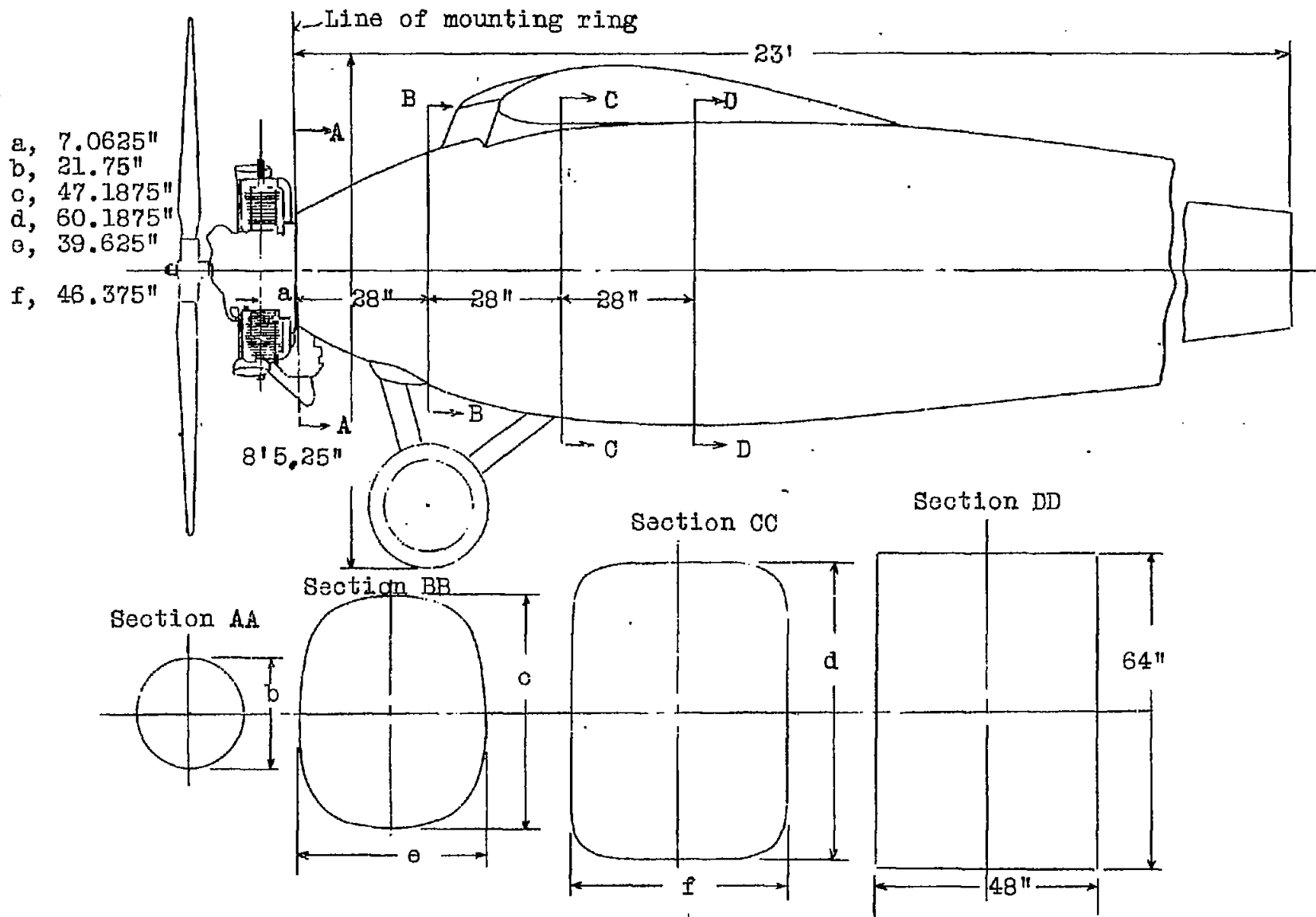


Fig. 1 Cowling No. 4

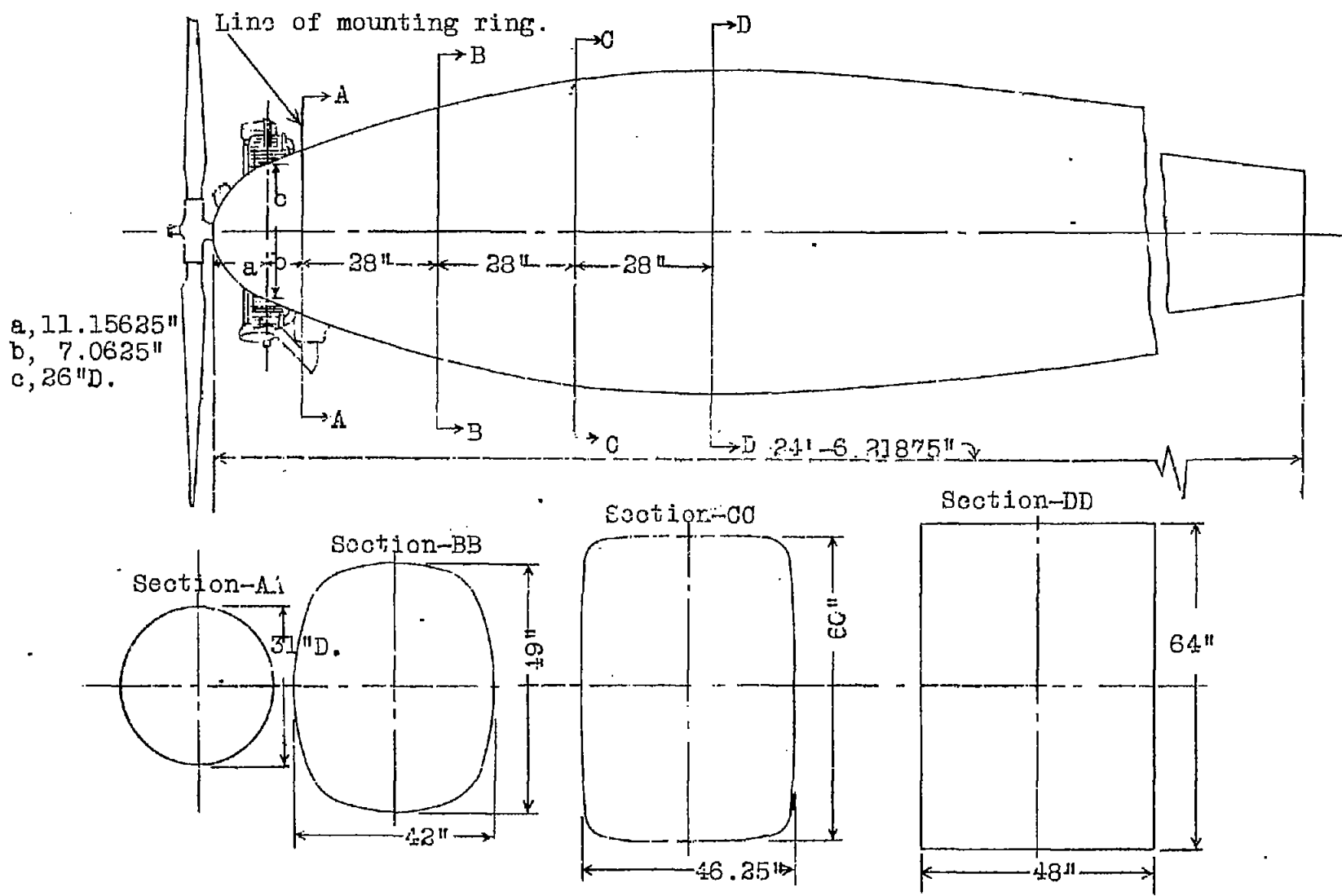
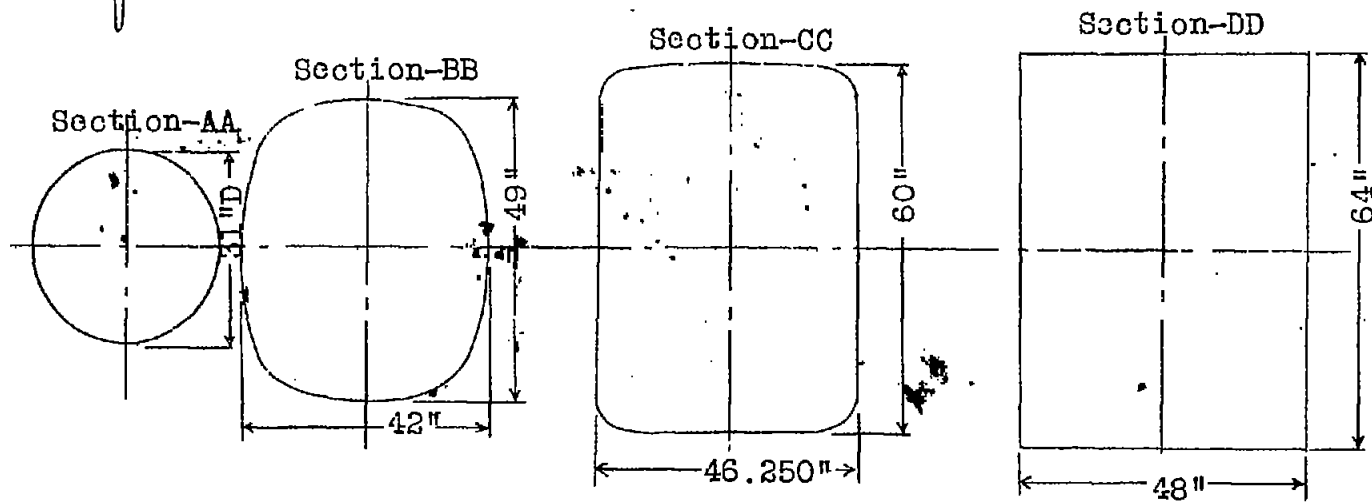
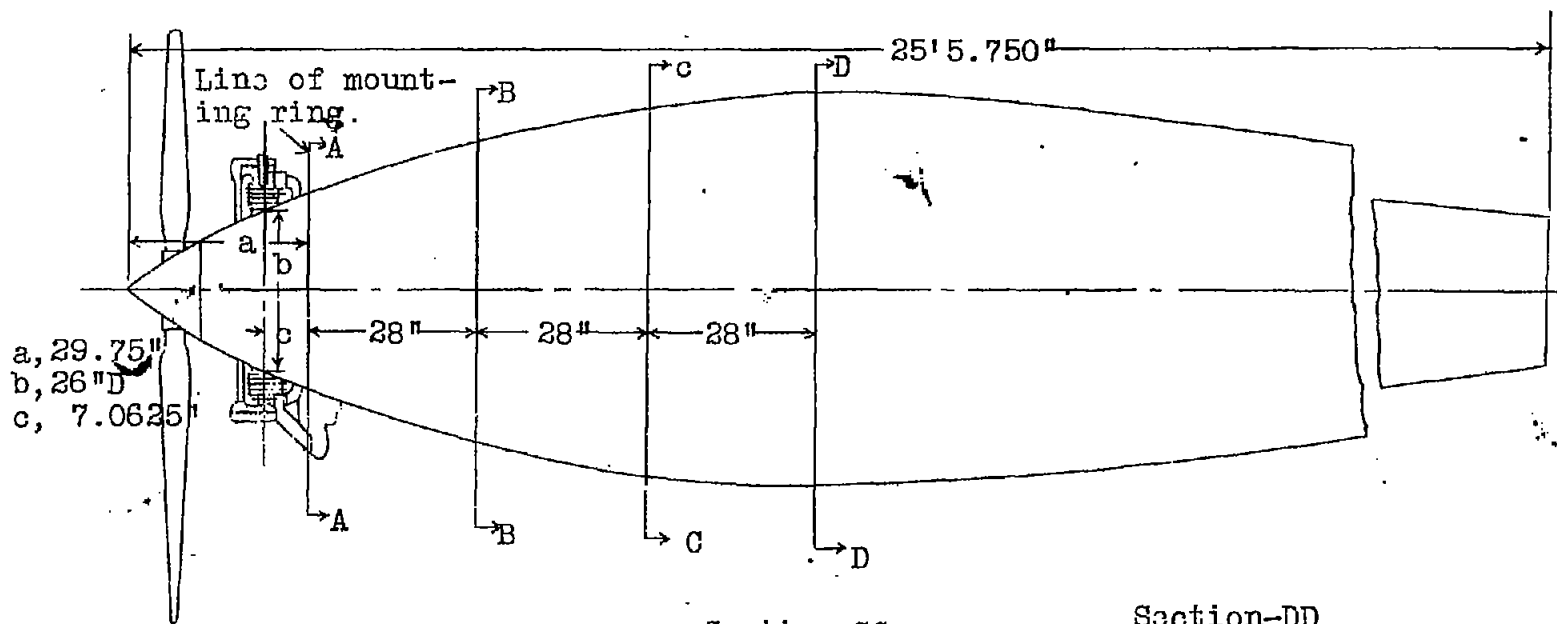


Fig.2 Cowling No.5



Cowling No. 6

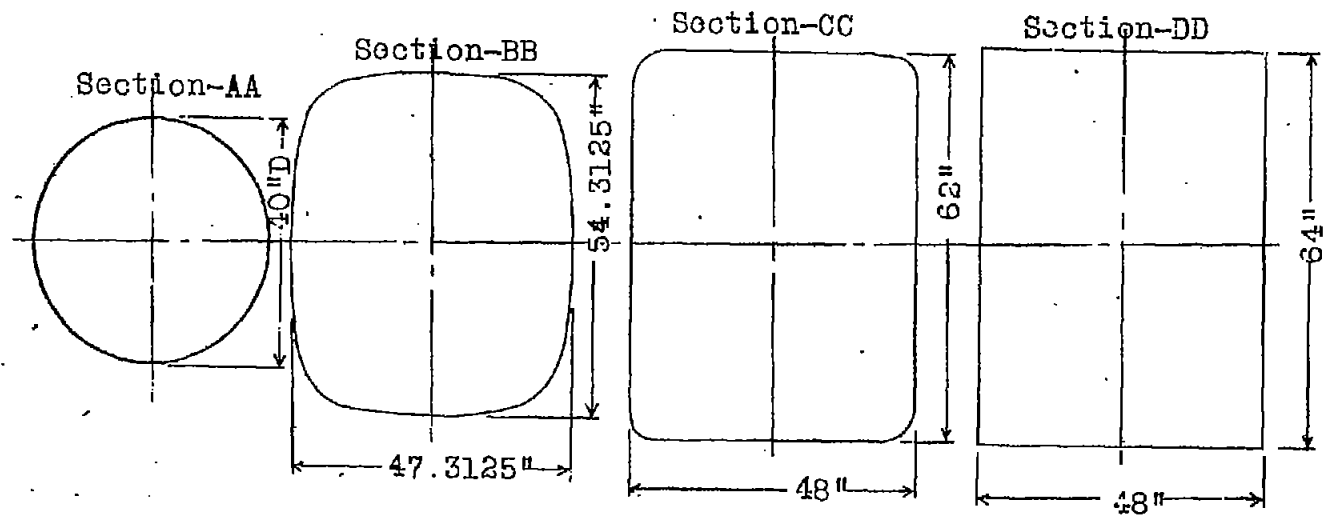
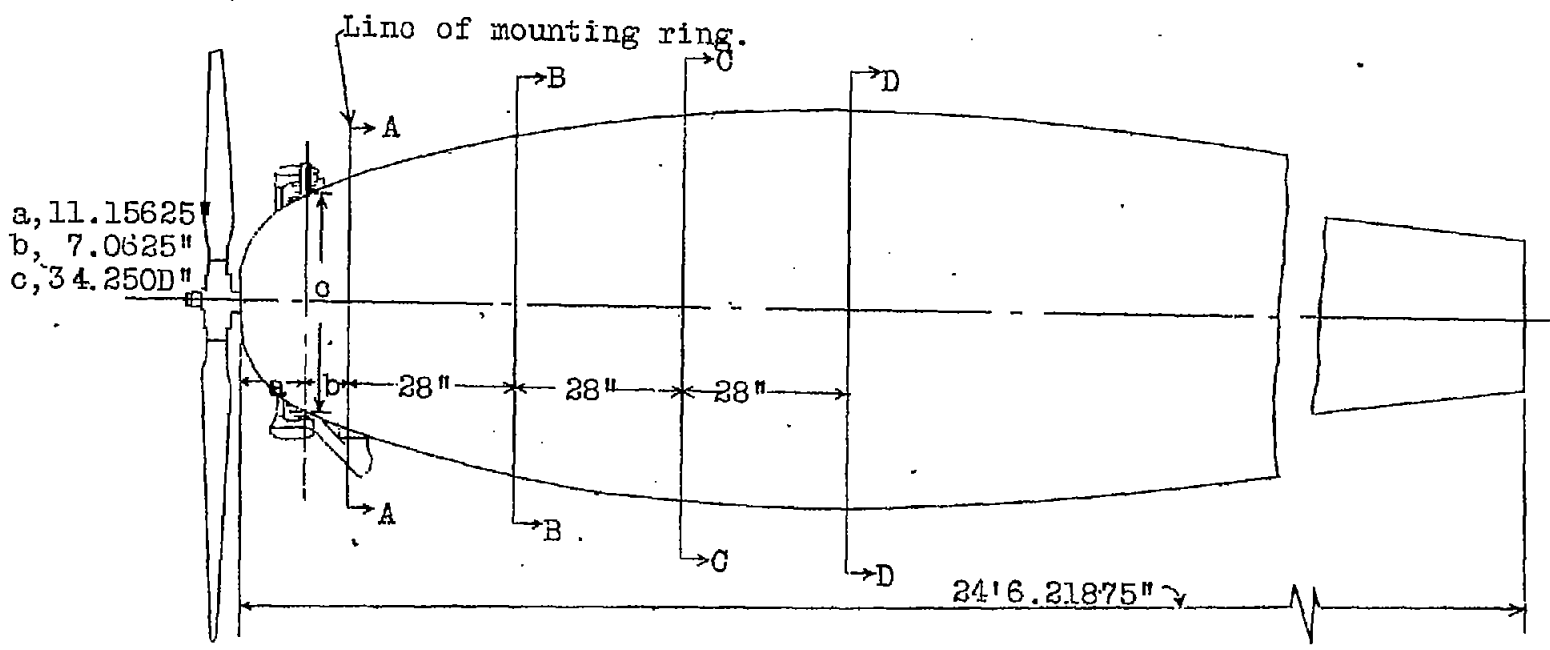


Fig. 4 Cowling No. 7

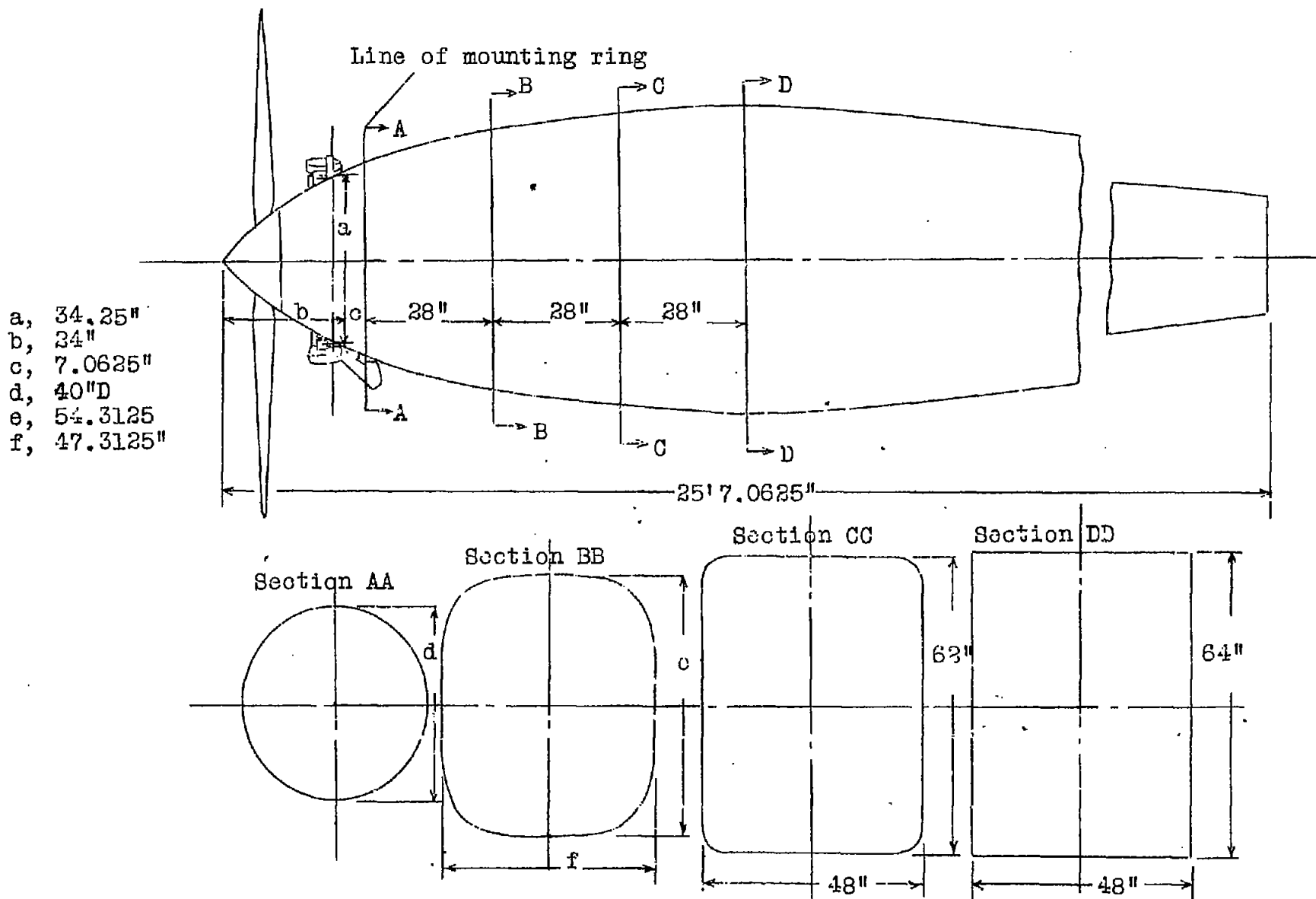


Fig. 5 Cowling No. 8

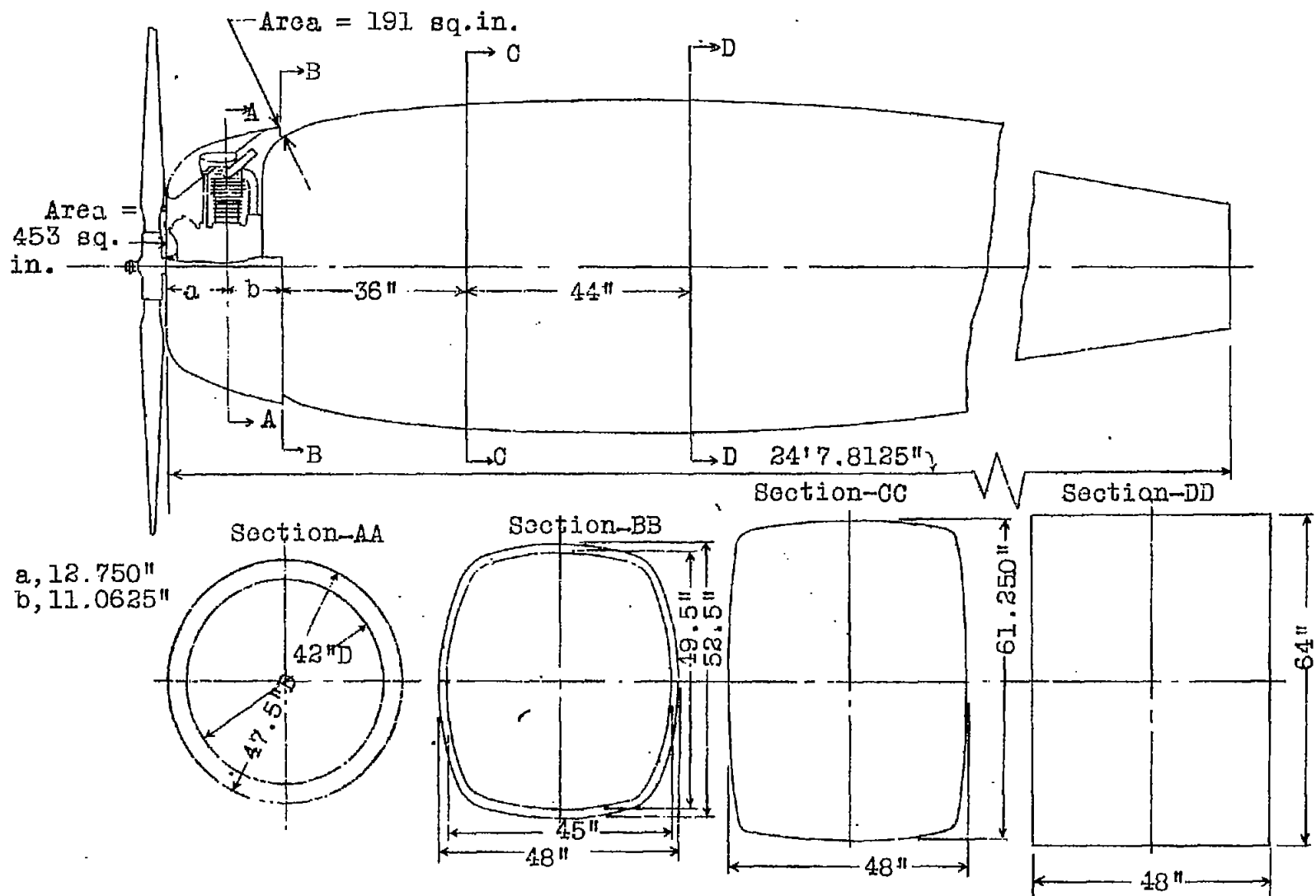


Fig.6 Cowling No.9

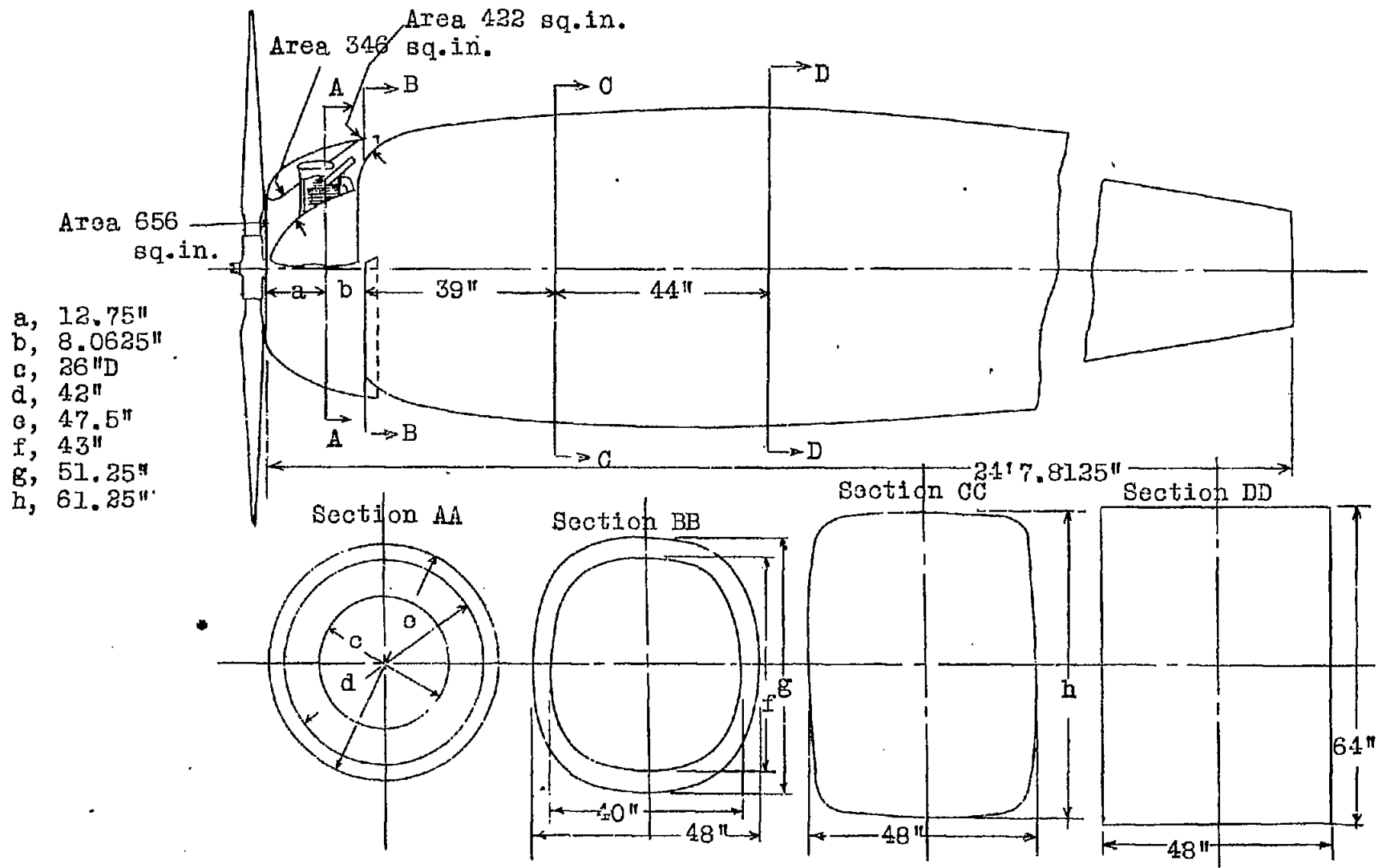


Fig.7 Cowling No.10 modified.

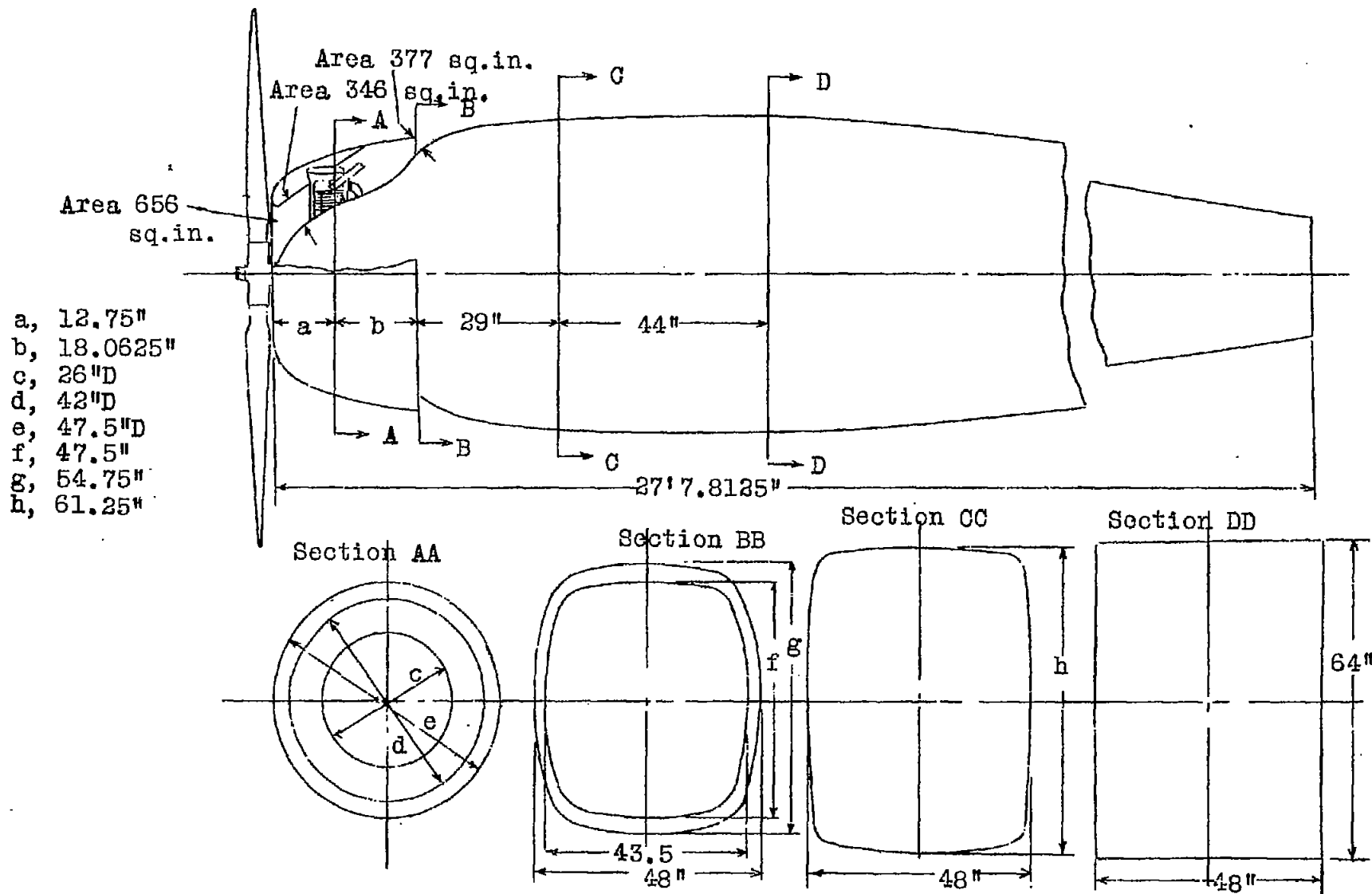


Fig.8 Cowling No.10 modified. Slot in nose moved back.

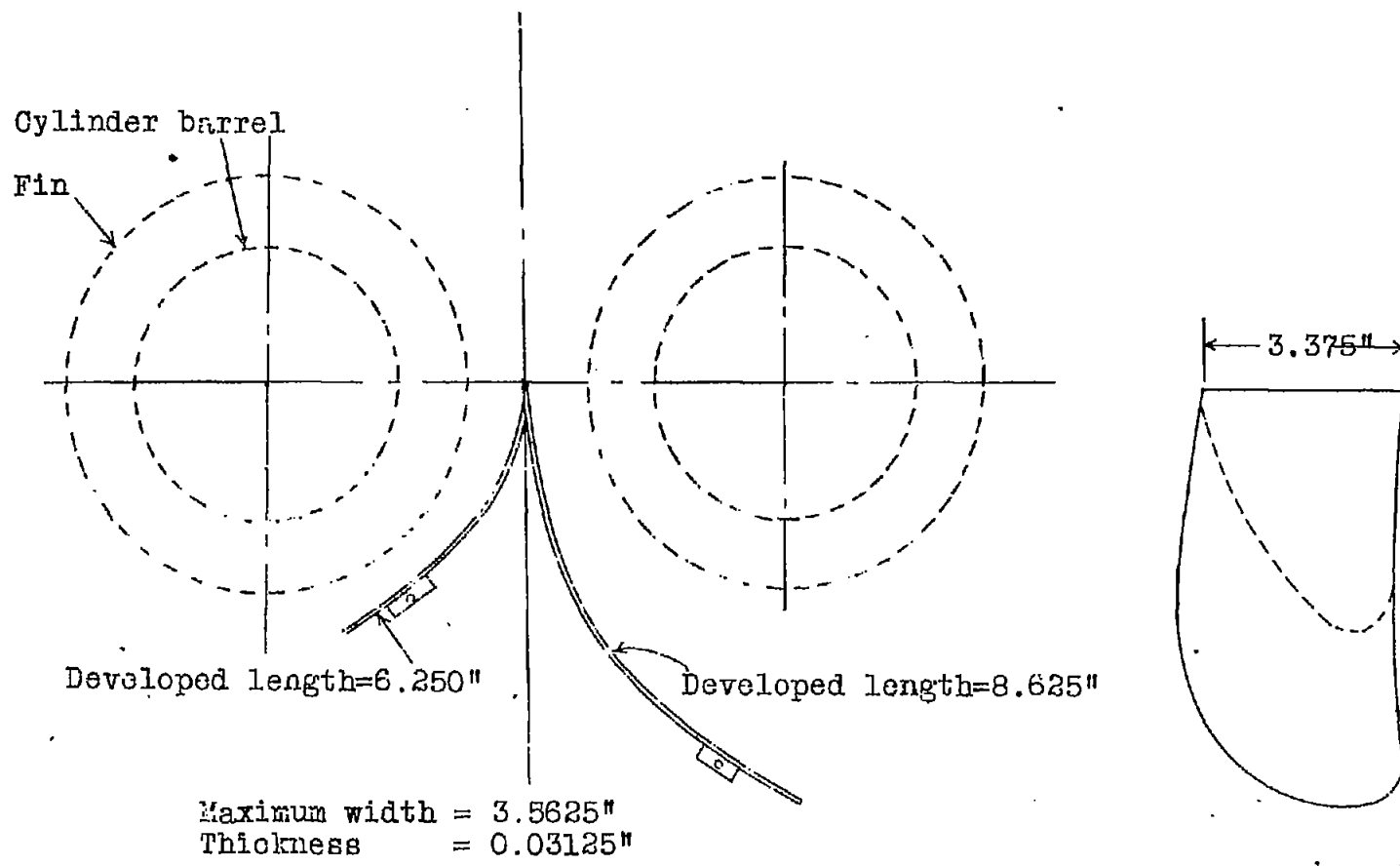


Fig.9 Double deflectors.

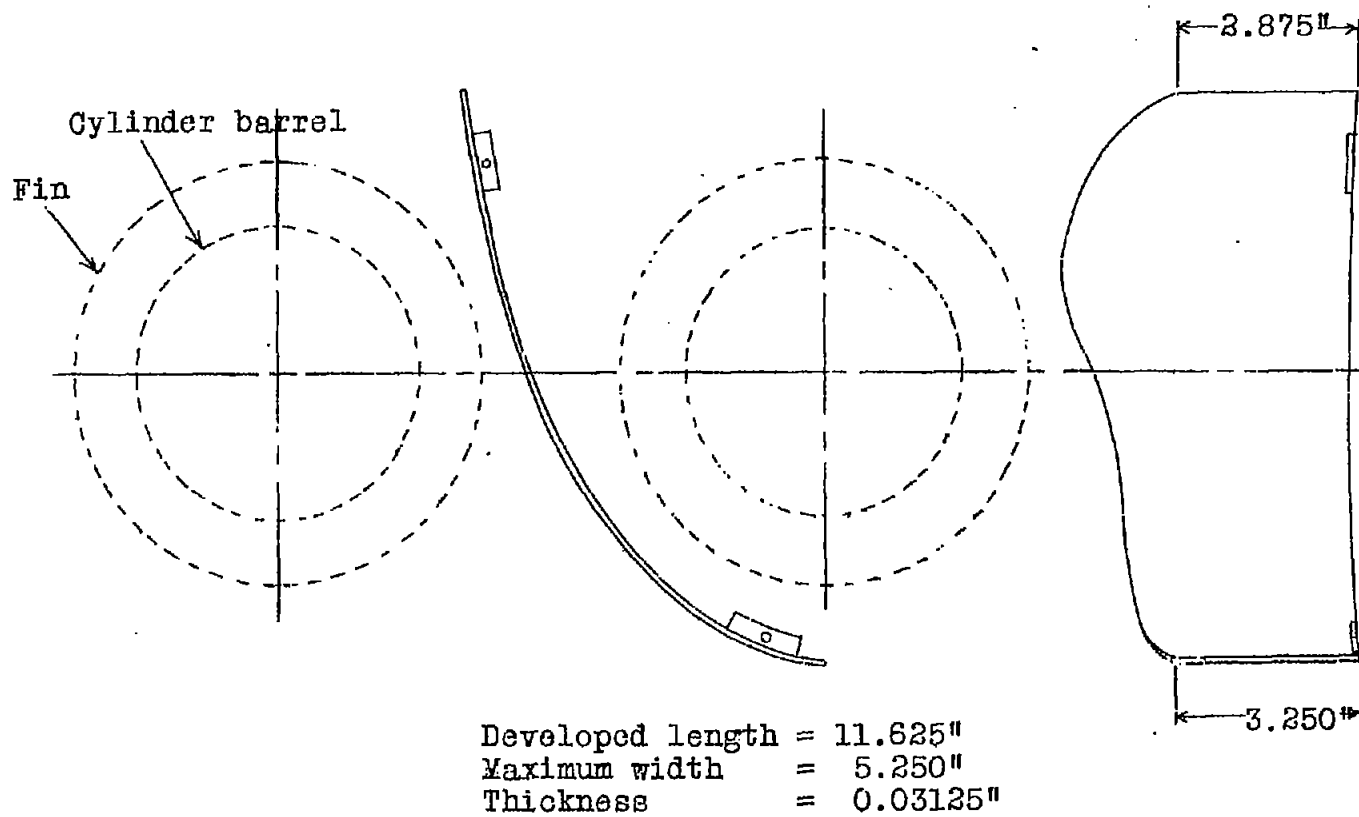


Fig.10 Single deflector.

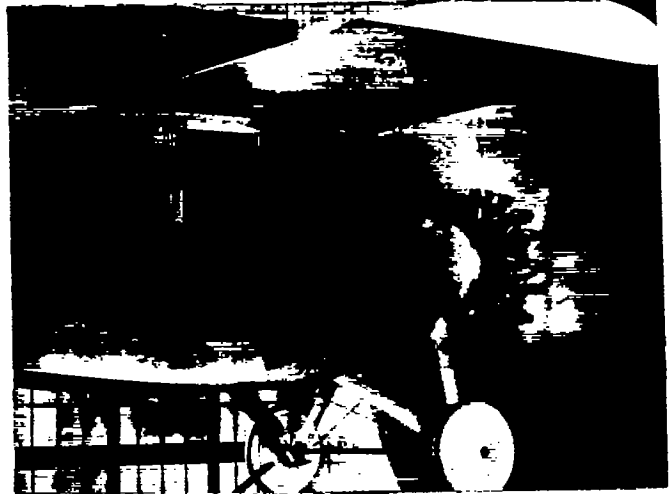
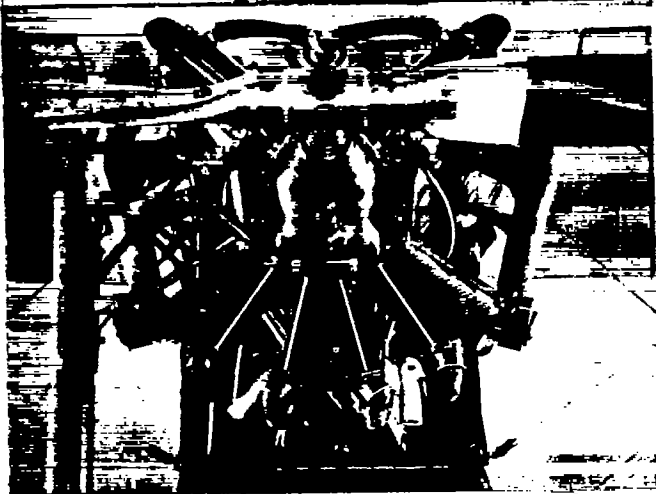


Fig.11 J-5 cylinders mounted on E-2 engine for slipstream torque tests.

Fig.12 Cowling No.4, engine exposed.

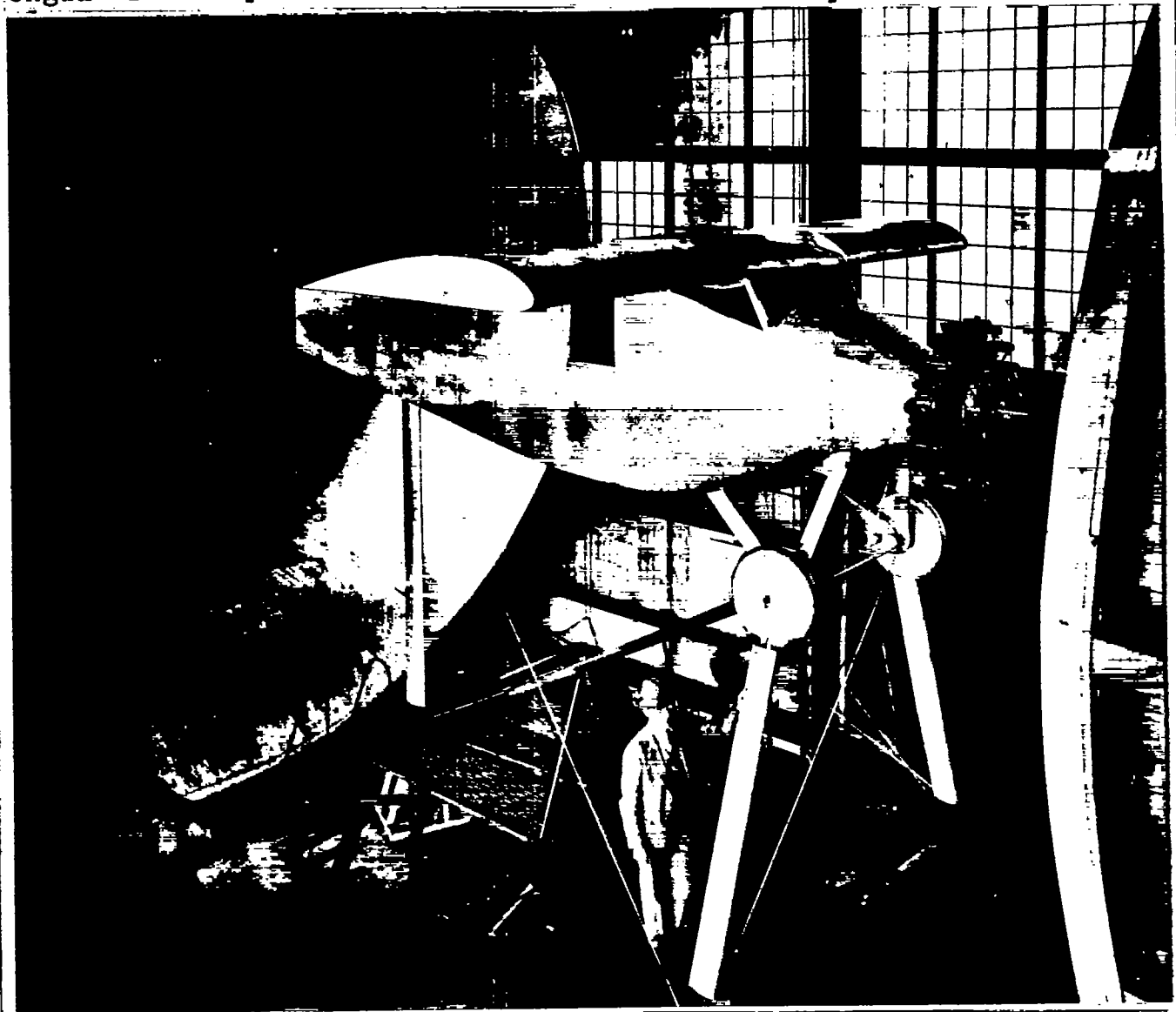


Fig.13 Cowling No.4 on fuselage with stub wing and landing gear, mounted in the Propeller Research Tunnel.

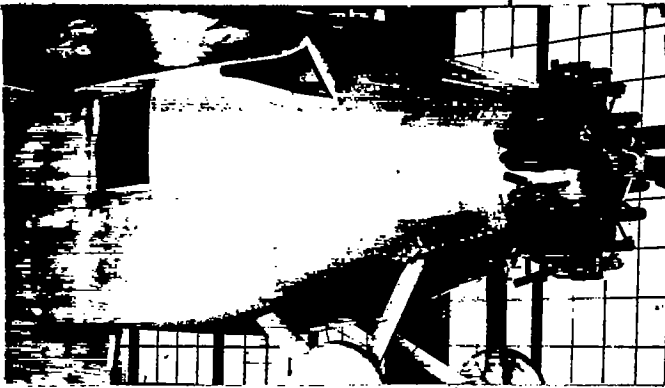


Fig.14 Cowling No.5

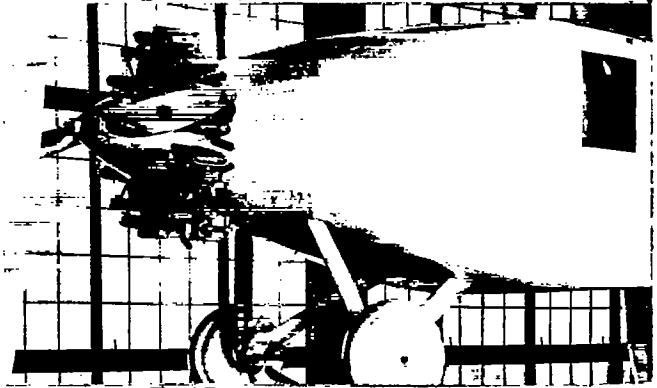


Fig.15 Cowling No.6



Fig.16 Cowling No.7,original.



Fig.17 Cowling No.7,four slots.

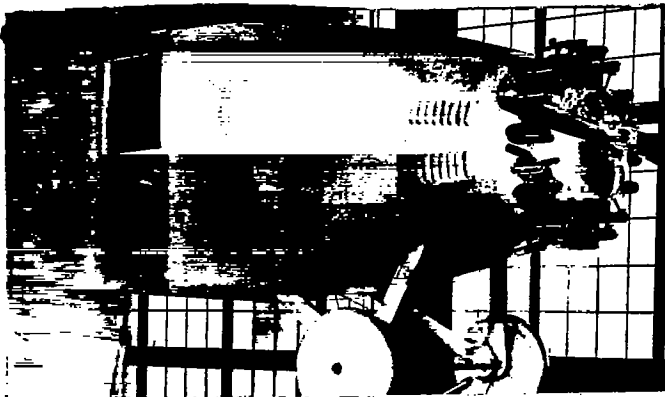


Fig.18 Cowling No.7,six large slots.

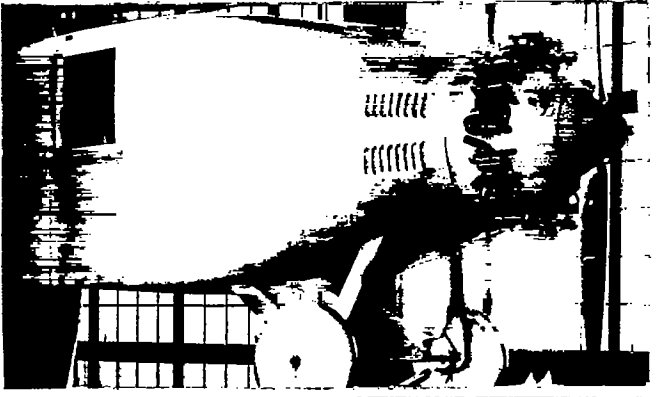


Fig.19 Cowling No.8,original.

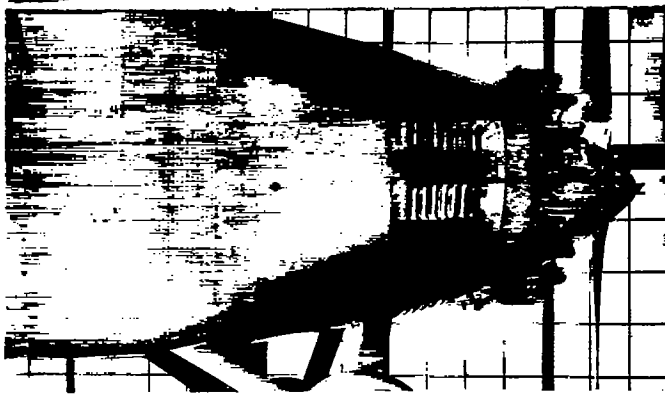


Fig.20 Cowling No.8,original.

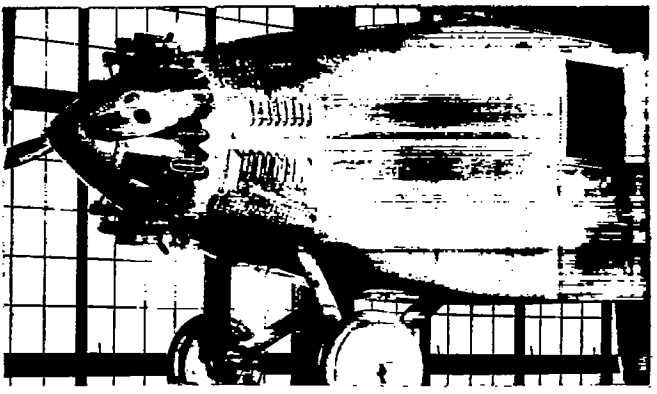


Fig.21 Cowling No.8,with cut-outs.



Fig.22 Cowling No.9

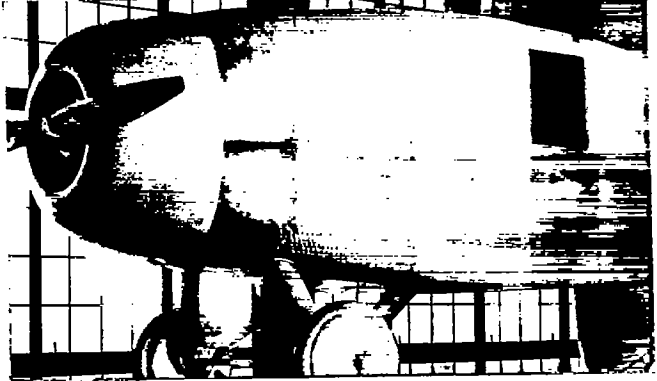


Fig.23 Cowling No.10



Fig.24 Cowling No.10, enlarged slot and cut-nose hole and cut-outs over magnetos.



Fig.25 Detail view of cut-outs over magnetos.



Fig.26 Cowling No.10 with slot moved back.

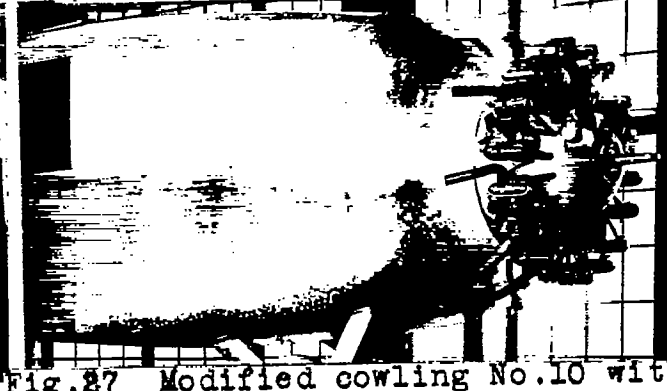


Fig.27 Modified cowling No.10 with nose piece removed showing deflectors between cylinders.



Fig.28 Cowling No.10 with No.6 nose with spinner.

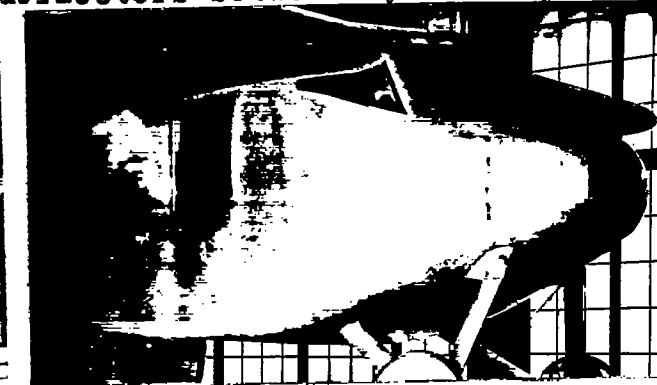
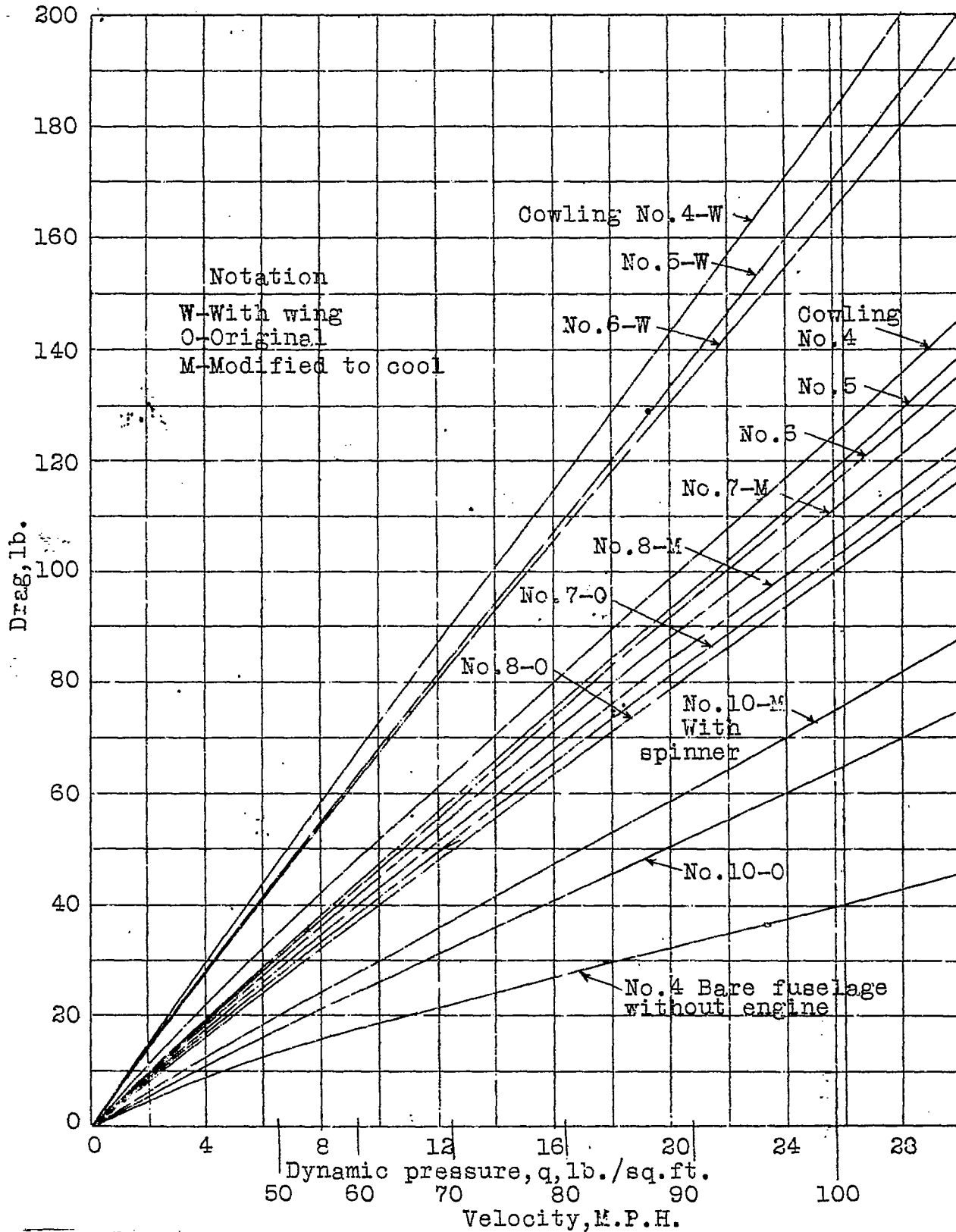
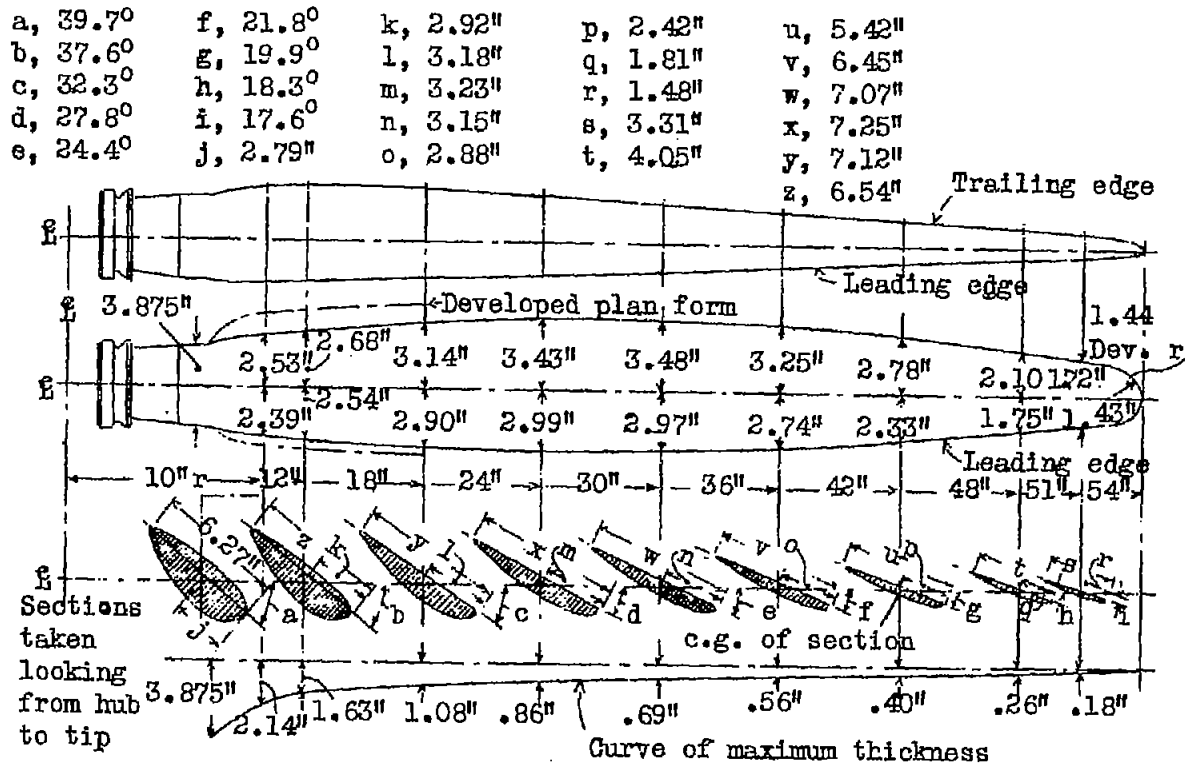


Fig.39 No.4 with engine removed and nose rounded.



Drag of fuselage and engine with various cowlings.



Metal propeller blade, 9 ft. diameter, right hand. Navy Dept. Bureau of Aeronautics.

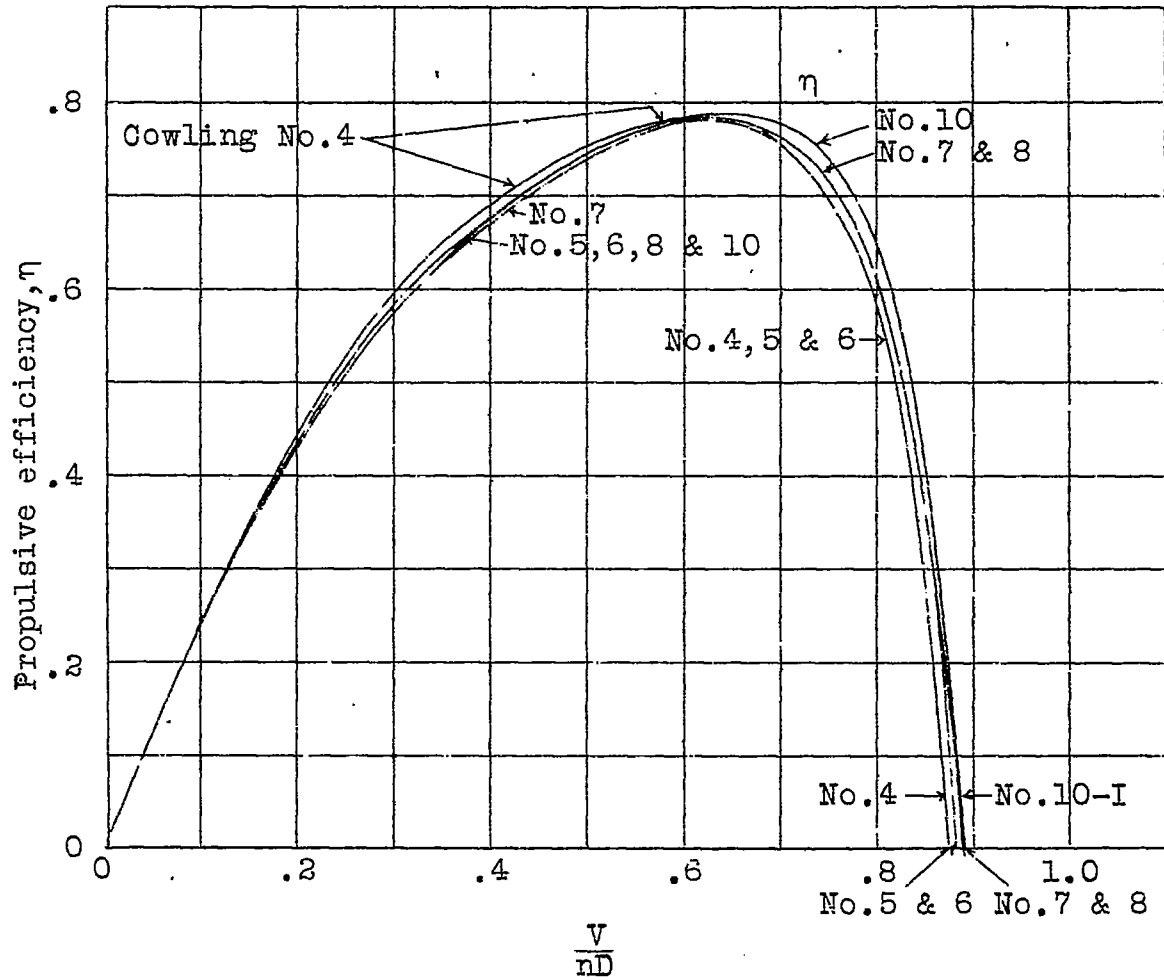


Fig.32 Propeller No.4412(15° at 42") on various cowlings without wing and with J-5 engine.

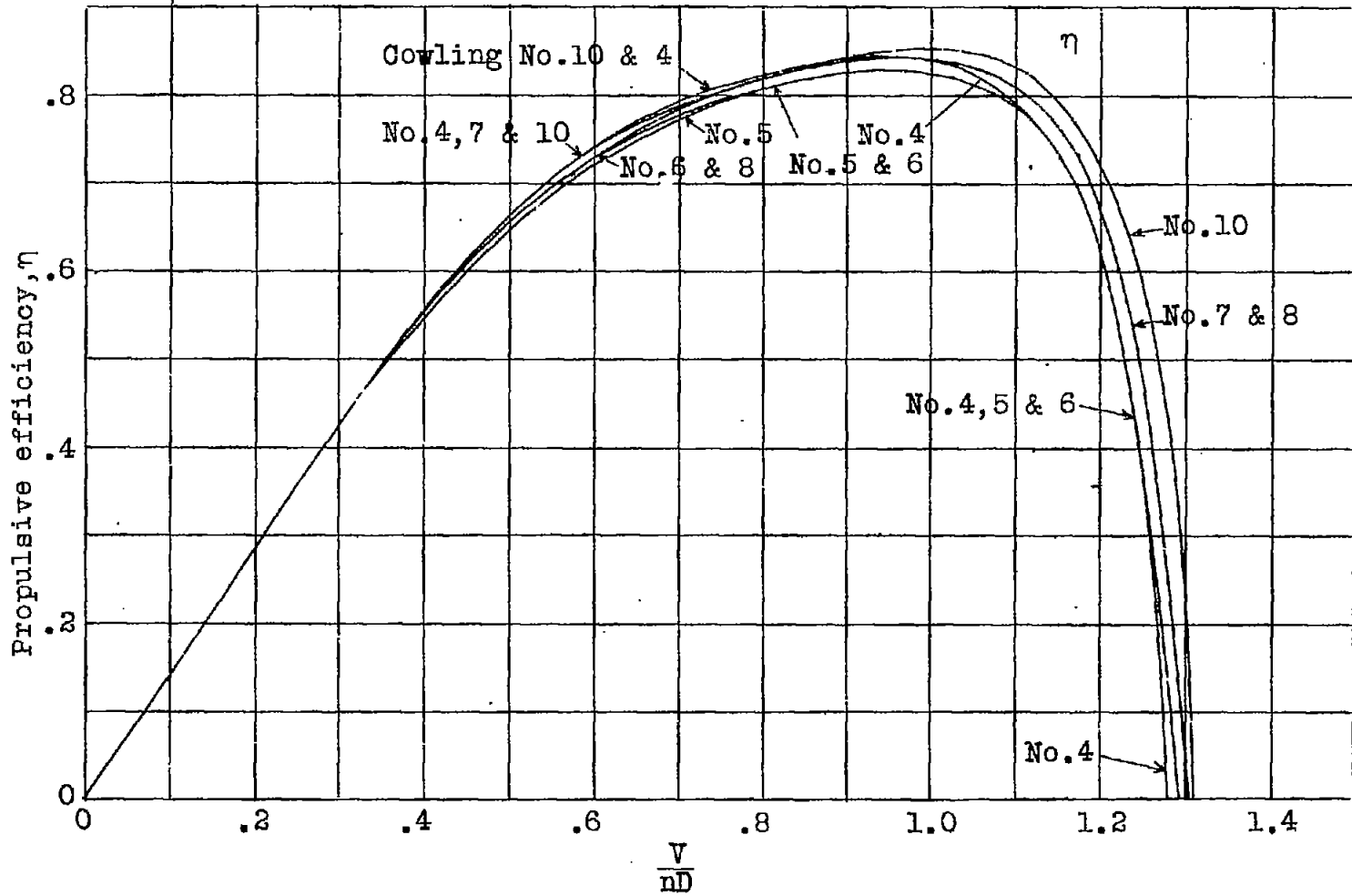


Fig. 33 Propeller No. 4413 (23° at $42''$) on various cowlings without wings and with J-5 engine.

A p p e n d i x

Flight Tests of No. 10 Cowling

By Thomas Carroll

In order that the practical value of the information in the foregoing report might be demonstrated, simple flight tests have been made of the No. 10 cowling.

Through the courtesy of the Army Air Corps at Langley Field, Virginia, a Curtiss AT-5A airplane was obtained on which an adaptation of the No. 10 cowling was installed as shown in Figures 34 and 35. A series of flights was made by the three pilots of the laboratory.

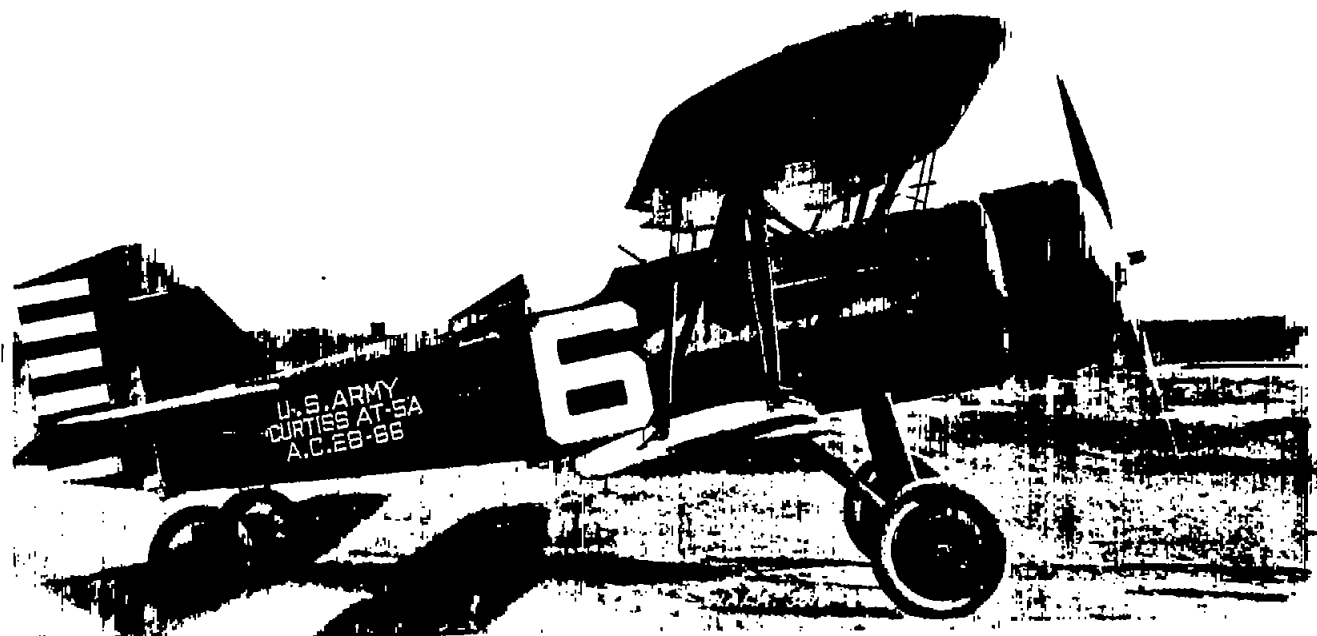
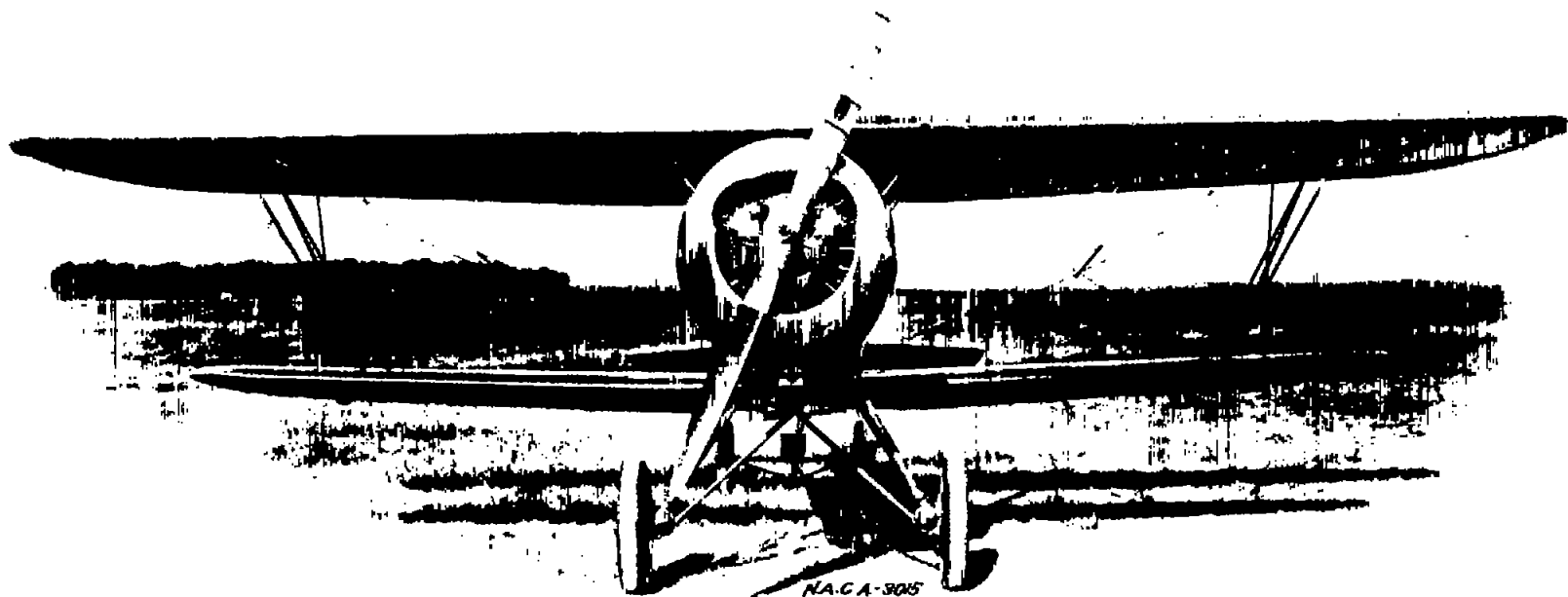
The maximum speed of this type airplane as in use at Langley Field had been reported at 118 miles per hour. This was checked by making a series of level runs with a Curtiss AT-5A airplane at low altitude over the water at full power. The maximum speed was found to be 118 miles per hour at 1900 R.P.M., both air speed and R.P.M. being measured on calibrated instruments. Similar high speed runs made with the modified AT-5A showed a performance of 137 miles per hour at 1900 R.P.M., an increase of 19 miles per hour. The original speed of 118 miles per hour was attained at 1720 R.P.M. on the modified airplane.

While the type of cowling as normally installed on an AT-5 is not particularly adaptable to speed, the increase is considered remarkable. Furthermore, the improvement of flying qualities in smoothness of operation was also very favorably

commented upon by all pilots who have flown it. The air flow over the fuselage and over the tail surfaces is very obviously improved.

The cooling of the engine was found to be normal in these tests. The oil temperature reached 58° and was fairly constant, and there was no other indication of overheating. Likewise, there was no interference to the pilot's vision in any useful field.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 13, 1928.



Figs. 34, 35 Curtiss A T--5 airplane with No. 10 cowling.