

REPORT No. 389

THE EFFECT OF SMALL ANGLES OF YAW AND PITCH ON THE CHARACTERISTICS OF AIRPLANE PROPELLERS

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SUMMARY

The subject tests were carried out in the 20-foot wind tunnel of the National Advisory Committee for Aeronautics to determine the effect on the characteristics of a propeller of inclining the propeller axis at small angles to the relative wind. Tests were made of a full-scale propeller and fuselage combination at four angles of yaw (0° , $+5^\circ$, $+10^\circ$, and $+15^\circ$), and of a model propeller, nacelle, and wing combination at five angles of pitch (-5° , 0° , $+5^\circ$, $+10^\circ$, and $+15^\circ$).

The results of the full-scale tests of a propeller and fuselage, without a wing, show that the effect on the propeller performance is small. Similar results are shown by the model test data except that where the propeller is directly in front of the wing there is an appreciable decrease in effective thrust and propulsive efficiency with increase of angle of pitch.

INTRODUCTION

In the prediction of airplane performance it is usual to assume that the line of thrust of the propeller is parallel to the flight path. This condition exists, of course, for only one particular angle of attack of the airplane. For any other angle of attack, especially when climbing or flying horizontally at low speeds, the thrust line is inclined at an angle to the line of flight. Previous model propeller tests have shown that the reduction in thrust is negligible for small angles of pitch. (Reference 1.) Such tests have been made, however, with the propeller alone, so the conditions do not correspond to those found in practice, where the propeller usually operates in front of a body such as a fuselage, nacelle, or wing.

The object of the tests described in this report was to determine the effect of inclining the thrust line at small angles to the relative wind on the characteristics of a propeller operating in front of a body. Two series of tests were made. The first series consisted of yaw tests of a full-scale propeller and fuselage. It would have been desirable to change the angle of pitch instead of that of yaw, but this was not possible with the torque dynamometer available, since it would not function properly except when in a level position. However, for the propeller and fuselage, without a wing, it is

obvious that changing the angle of yaw will cause a similar effect on the propeller performance to that caused by changing the angle of pitch. In the second series, a model propeller and nacelle were tested alone and in two positions relative to a wing, the combination being pitched at various angles. All the tests were made in the 20-foot tunnel of the National Advisory Committee for Aeronautics.

APPARATUS AND TESTS

The full-scale propeller and fuselage are shown mounted in the wind tunnel in Figure 1. The propeller was 9 feet in diameter and had two adjustable aluminum alloy blades. The curves for the blade form and pitch distribution are given in Figure 2. The propeller was driven by a 435-horsepower Curtiss D-12 engine mounted in an open-cockpit fuselage. A dynamometer for measuring the torque of the engine was also mounted in the fuselage. A description of this dynamometer, the thrust balance, and other wind-tunnel apparatus will be found in reference 3.

Tests were made at propeller pitch settings of 15.5° and 23.5° (at 0.75 radius) with the propeller axis yawed at 0° , 5° , 10° , and 15° . The method of conducting the tests was the same as that described in reference 2.

The method of supporting the model wing and nacelle in the wind tunnel is shown in Figure 3. The wing and nacelle pivoted about the top of the two wing supports, and the angle of pitch was changed by raising or lowering the end of the long sting extending in the rear of the wing. A 25-horsepower electric motor, for driving a 4-foot model propeller, was mounted in the nacelle. No means were available by which the torque of the motor could be measured directly; the motor torque was therefore calibrated, for a constant field excitation, using a Prony brake. Later the calibration was checked by means of a dynamometer. The wing was 15 feet 10 inches in span, 3 feet 2 inches in chord, and had a Clark Y airfoil section.

The 4-foot metal propeller used in the model tests was geometrically similar to the propeller used in the full-scale tests. It was first tested with the nacelle alone (fig. 4a), second with the nacelle above the



FIGURE 1.—Full-scale propeller and fuselage

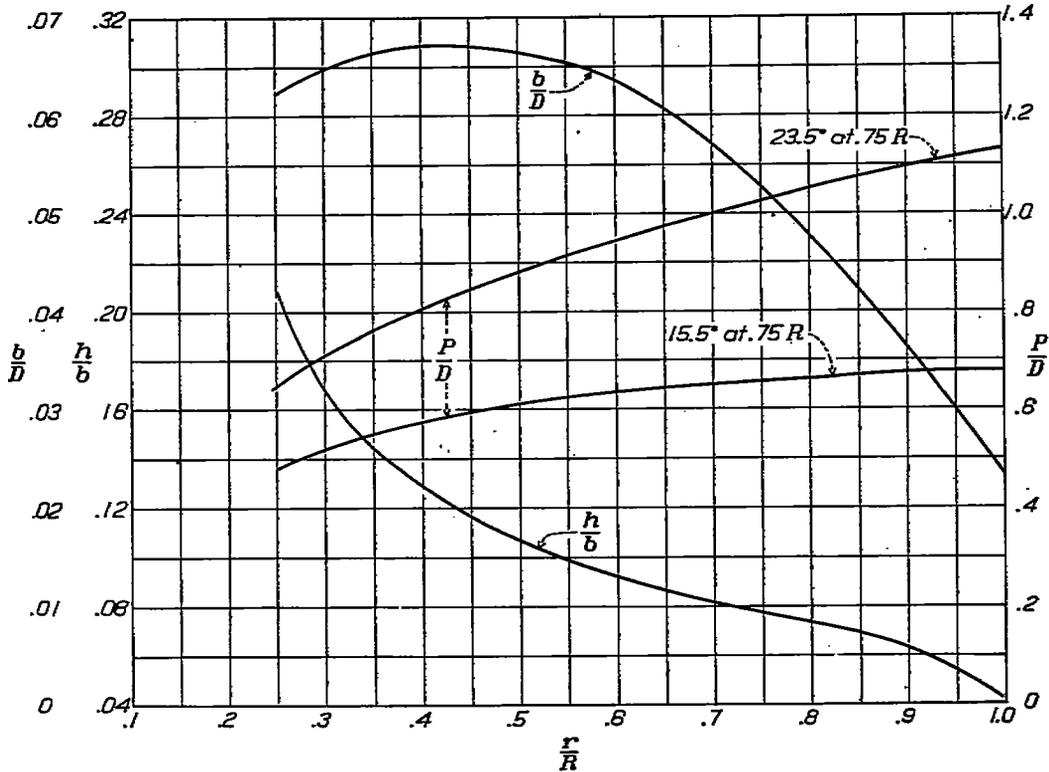


FIGURE 2.—Blade form curves. Propeller No. 4412. b =blade width; D =diameter of propeller; P =pitch; h =maximum blade thickness; R =radius of propeller; r =section radius

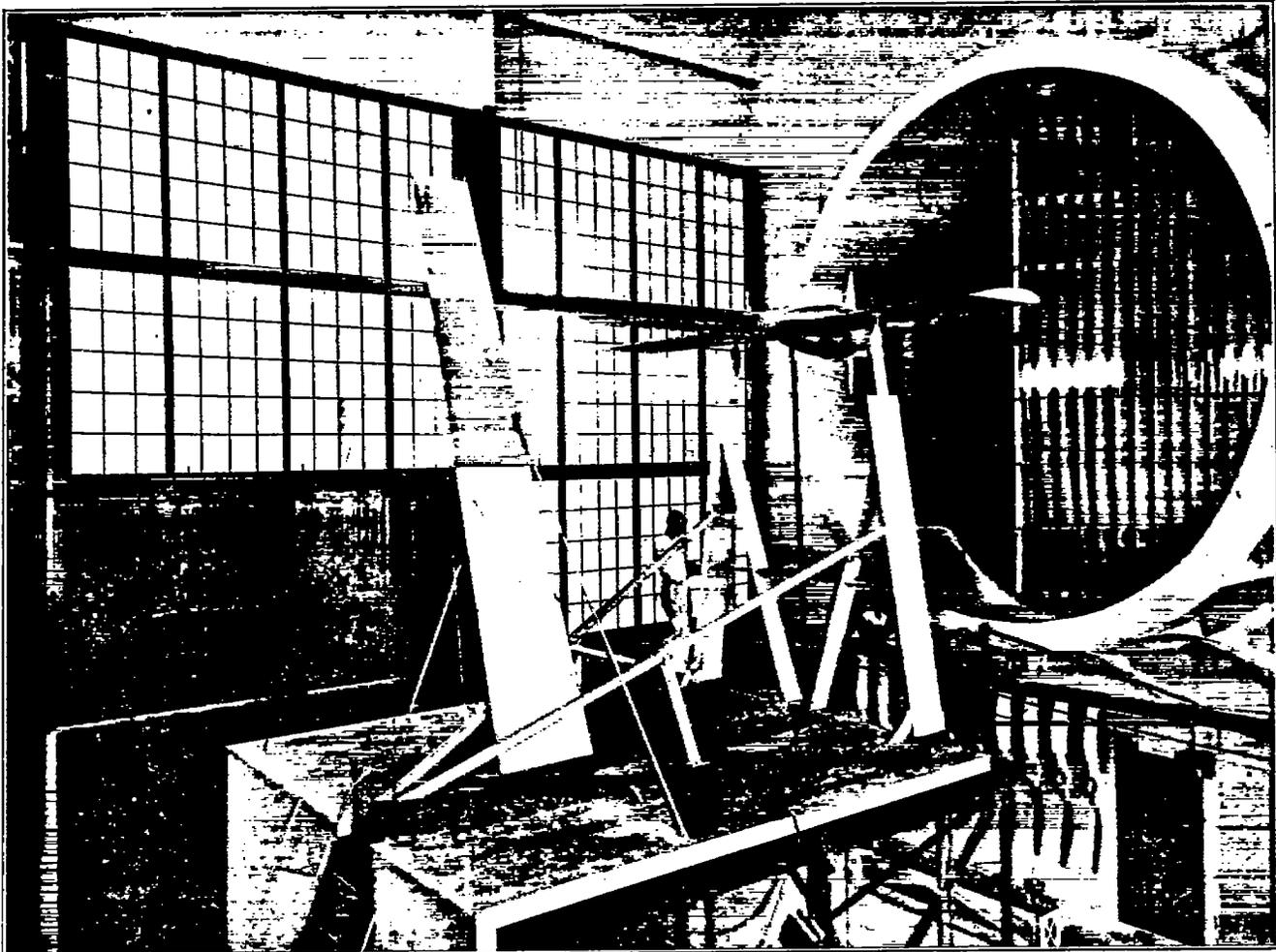
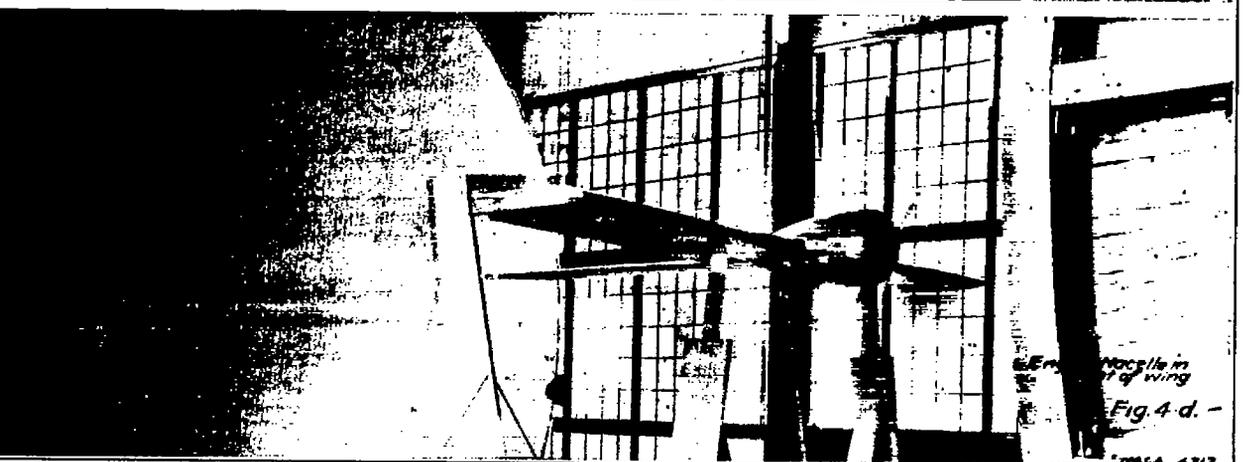


FIGURE 3.—Model engine, nacelle, and wing



wing (fig. 4b), and third in front of the wing (fig. 4c). Later dummy cylinders were fixed to the nacelle to simulate a Wright J-5 engine. The model engine was

For zero pitch or yaw, the resultant horizontal force on the propeller-body combination, as measured on the thrust balance, is equal to:

$$R = T - \Delta D - D$$

where T = propeller thrust (tension in propeller shaft),
 D = drag of combination without propeller (at the same dynamic pressure q),
 ΔD = increment of drag due to slipstream.

The effective thrust may be defined as

$$T - \Delta D = R + D$$

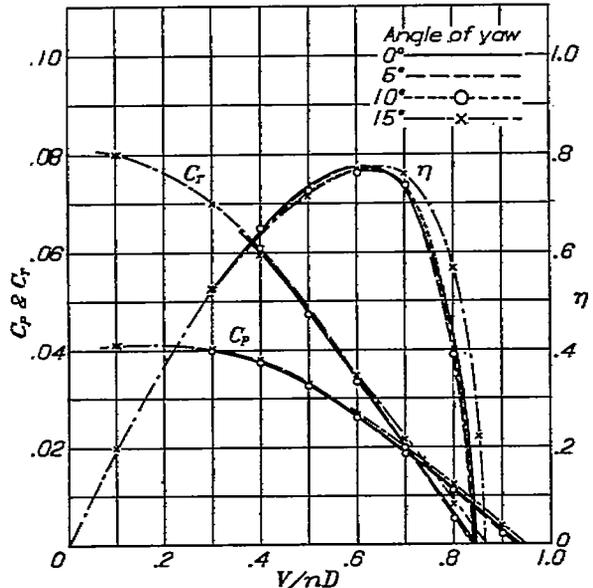


FIGURE 5.—Characteristics of propeller No. 4412, 15.5° at 0.75 R.; diam. 9 ft.

provided with an N. A. C. A. cowling. This arrangement (fig. 4d) was tested in the same position relative to the wing as that shown in Figure 4c. All the arrangements were tested at four propeller blade settings (12°, 17°, 22°, and 27° at 0.75 radius) and with the thrust line at five angles of pitch (-5°, 0°,

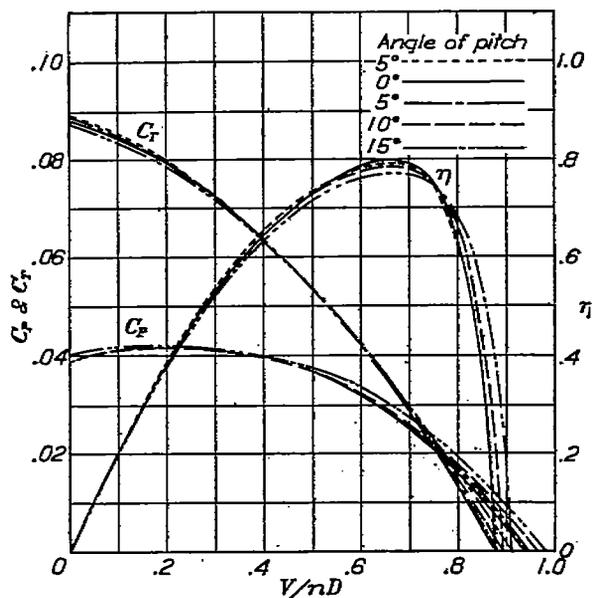


FIGURE 7.—Characteristics of propeller No. 4412; 4 ft. diam.; set 17° at 0.75 R.; nacelle alone

RESULTS AND DISCUSSION

The data are reduced to the usual nondimensional coefficients of thrust, power, and propulsive efficiency:

$$\text{Thrust coefficient} = C_T = \frac{\text{effective thrust}}{\rho n^2 D^4}$$

$$\text{Power coefficient} = C_P = \frac{\text{input power}}{\rho n^3 D^5}$$

$$\text{Propulsive efficiency} = \frac{\text{effective thrust} \times \text{velocity of advance}}{\text{input power}}$$

where ρ = mass density of the air,
 n = revolutions per unit time,
 D = diameter of propeller.

The observed data are given in Tables I and II for the full-scale tests.

The faired curves of these coefficients plotted against $\frac{V}{nD}$ are given in Figures 5 and 6. These curves show no consistent variation with the change in the angle of yaw. The change in the thrust and power coefficients is small and the greatest variation in the peak efficiency is only 2 per cent.

The results for the model propeller tests are given in Figures 7 to 10, inclusive. Only the curves for the 17° blade settings are presented, since these are repre-

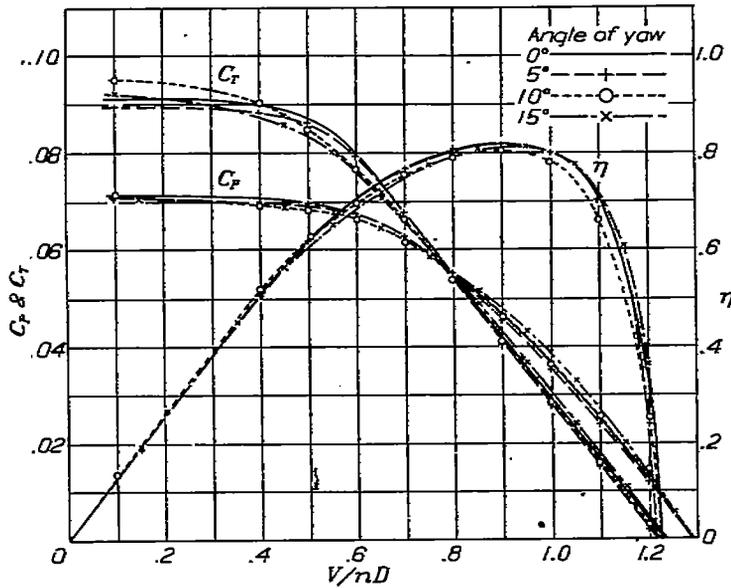


FIGURE 6.—Characteristics of propeller No. 4412, 23.5° at 0.75 R.; diam. 9 ft.

+5°, +10°, and +15°) relative to the wind direction. The forces in the model tests were measured in the same manner as those in the full-scale tests, except that the torque of the motor was obtained from the calibration curve (armature current versus torque) previously determined.

sentative of the curves for all the blade settings. The tables of these data have not been included in this report, since they are soon to be published in a report on wing-nacelle-propeller tests.

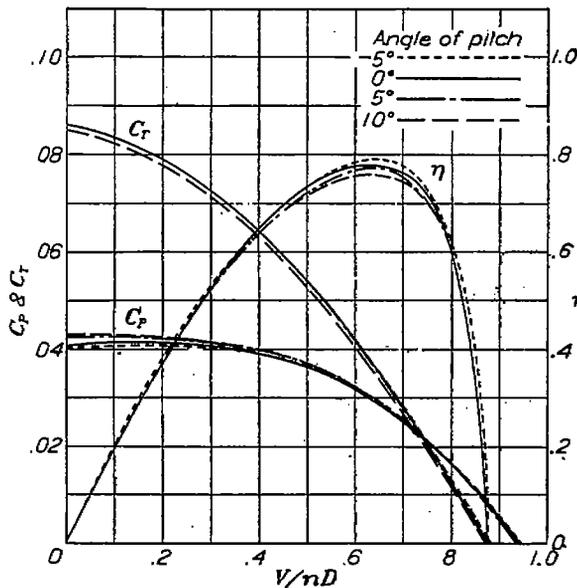


FIGURE 8.—Characteristics of propeller No. 4412; 4 ft. diam.; set 17° at 0.75 R; nacelle above wing

For the propeller with the nacelle alone (fig. 7) there is very little change in the characteristics of the propeller for the change in the angle of the thrust line. When the propeller and nacelle are placed above the

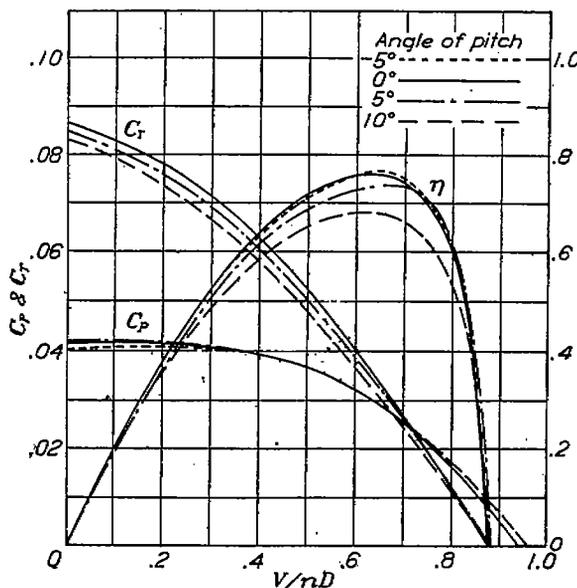


FIGURE 9.—Characteristics of propeller No. 4412; 4 ft. diam.; set 17° at 0.75 R; nacelle in front of wing

wing (fig. 8) there is a small but consistent decrease in effective thrust with increasing angle of pitch. Figures 9 and 10 show the results for the propeller and nacelle directly in front of the wing. For this condition the effective thrust decreases rapidly with increasing angle of the thrust line. For the model

engine nacelle with the propeller set at 17° (fig. 10) the decrease in effective thrust at the $\frac{V}{nD}$ of peak effi-

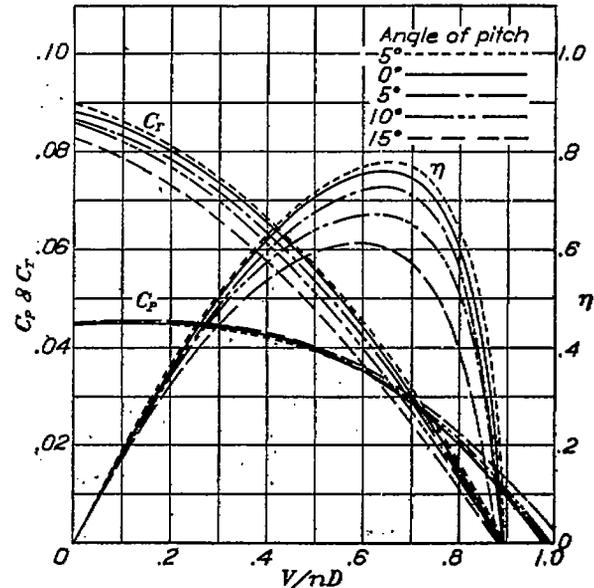


FIGURE 10.—Characteristics of propeller No. 4412; 4 ft. diam.; set 17° at 0.75 R; model engine nacelle in front of wing

ciency for a change in the angle of thrust line of 15° amounts to approximately 19 per cent.

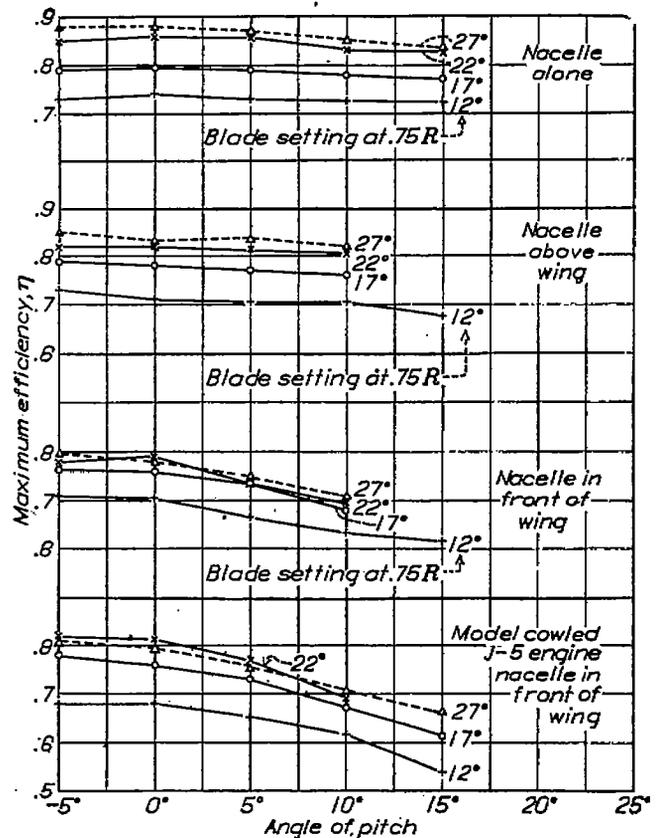


FIGURE 11.—Peak efficiencies against angles of pitch

In Figure 11 the peak efficiency, for the various blade settings and wing-nacelle combinations, has been

plotted against the angle of pitch. For the nacelle alone, the greatest change in peak efficiency for a 15° change in the angle of thrust line is 5 per cent. With the model cowled-engine nacelle, in front of the wing the greatest decrease in efficiency amounts to 15 per cent. The drop in peak efficiency is greater for the high blade settings than for the low, but the difference is small.

The results of the above tests indicate that the effect of small angles of yaw and pitch on the characteristics of a propeller is small provided there is no wing in the slipstream. However, if the propeller is working directly in front of a wing, the effective thrust and propulsive efficiency decrease rapidly with increasing angle of pitch.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., *January 20, 1931.*

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REPORT NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE I
 TEST RESULTS

PROPELLER 4412-23.5° AT 0.75R. 0° YAW

ρ	V m. p. h.	N r. p. m.	Q lb. ft.	T lb.	C_T	C_P	$\frac{V}{nD}$	η
0.002331	87.0	1,590	1,058	906	0.0854	0.0696	0.538	0.659
.002331	87.0	1,590	1,056	904	0.0850	0.0696	0.538	0.656
.002327	87.0	1,590	1,059	878	0.0815	0.0687	0.536	0.635
.002327	82.1	1,590	1,056	884	0.0823	0.0687	0.536	0.630
.002327	84.7	1,590	1,060	878	0.0820	0.0690	0.536	0.682
.002327	84.7	1,590	1,058	877	0.0820	0.0687	0.536	0.686
.002318	105.0	1,600	1,080	845	0.0782	0.0683	0.534	0.696
.002318	105.0	1,620	1,057	840	0.0760	0.0687	0.534	0.731
.002318	103.9	1,550	959	788	0.0749	0.0687	0.534	0.722
.002318	103.9	1,550	957	759	0.0749	0.0682	0.535	0.740
.002318	103.5	1,480	839	650	0.0703	0.0684	0.533	0.740
.002318	108.5	1,480	840	649	0.0703	0.0684	0.533	0.767
.002316	103.0	1,410	727	547	0.0651	0.0685	0.532	0.767
.002316	108.2	1,410	728	545	0.0649	0.0685	0.532	0.768
.002309	102.8	1,340	643	465	0.0616	0.0685	0.531	0.769
.002309	102.9	1,360	642	464	0.0609	0.0684	0.531	0.780
.002309	102.8	1,280	552	390	0.0567	0.0684	0.529	0.775
.002309	102.9	1,270	554	389	0.0574	0.0684	0.529	0.800
.002309	102.8	1,230	478	326	0.0512	0.0682	0.527	0.799
.002309	102.8	1,220	477	324	0.0510	0.0682	0.527	0.800
.002309	102.0	1,170	413	272	0.0473	0.0682	0.525	0.801
.002309	102.2	1,170	412	271	0.0472	0.0681	0.525	0.805
.002309	101.6	1,110	343	217	0.0410	0.0681	0.523	0.805
.002309	101.8	1,100	342	215	0.0423	0.0681	0.523	0.812
.002309	101.8	1,050	278	165	0.0358	0.0681	0.521	0.817
.002309	101.6	1,050	278	165	0.0358	0.0681	0.521	0.806
.002309	101.6	1,000	235	133	0.0316	0.0681	0.518	0.820
.002309	101.6	1,010	235	132	0.0316	0.0680	0.518	0.803
.002309	101.4	950	169	86	0.0227	0.0680	0.514	0.794
.002309	101.2	900	126	57	0.0167	0.0680	0.510	0.764
.002309	101.1	860	77	25	0.0107	0.0680	0.507	0.712
.002301	101.0	800	40	1	0.00372	0.0680	0.504	0.637
.002301	101.0	780	0	0	0.0135	0	0.504	0.442
.002313	78.5	1,588	1,058	926	0.0878	0.0700	0.537	0.608
.002313	78.9	1,580	1,051	920	0.0878	0.0698	0.537	0.616
.002313	74.3	1,580	1,058	920	0.0885	0.0702	0.537	0.580
.002313	71.1	1,580	1,053	930	0.0885	0.0700	0.537	0.441
.002316	67.3	1,580	1,058	936	0.0891	0.0702	0.537	0.527
.002316	67.0	1,580	1,056	937	0.0891	0.0702	0.537	0.526
.002316	62.8	1,580	1,062	939	0.0894	0.0703	0.538	0.493
.002316	63.0	1,580	1,060	940	0.0895	0.0704	0.538	0.496
.002319	57.4	1,590	1,065	948	0.0899	0.0695	0.538	0.451
.002319	56.4	1,590	1,061	940	0.0887	0.0693	0.537	0.445
.002325	23.3	1,590	1,068	940	0.0896	0.0705	0.538	0.1838
.002325	24.2	1,590	1,056	945	0.0893	0.0744	0.536	0.198

TABLE I—Continued
 TEST RESULTS

PROPELLER 4412-23.5° AT 0.75R. 5° YAW

ρ	V m. p. h.	N r. p. m.	Q lb. ft.	T lb.	C_T	C_P	$\frac{V}{nD}$	η
0.002275	85.8	1,600	1,036	899	0.0846	0.0681	0.525	0.652
.002275	85.8	1,600	1,036	898	0.0845	0.0681	0.525	0.652
.002275	90.6	1,600	1,042	882	0.0830	0.0683	0.525	0.673
.002275	90.5	1,600	1,040	883	0.0830	0.0683	0.525	0.672
.002265	95.5	1,610	1,041	890	0.0801	0.0679	0.526	0.687
.002265	95.6	1,600	1,040	891	0.0815	0.0687	0.526	0.694
.002259	106.5	1,600	1,040	825	0.0764	0.0664	0.524	0.724
.002259	106.2	1,600	1,037	821	0.0743	0.0655	0.524	0.717
.002259	106.0	1,600	1,037	821	0.0743	0.0655	0.524	0.717
.002259	106.0	1,580	960	787	0.0735	0.0662	0.525	0.741
.002259	105.8	1,580	959	787	0.0735	0.0662	0.525	0.741
.002250	105.8	1,580	977	835	0.0717	0.0659	0.526	0.759
.002250	105.0	1,480	878	685	0.0675	0.0659	0.526	0.757
.002250	105.0	1,480	878	685	0.0675	0.0659	0.526	0.757
.002250	106.1	1,470	791	607	0.0675	0.0659	0.526	0.758
.002250	104.9	1,410	685	508	0.0623	0.0658	0.526	0.781
.002250	104.9	1,400	683	508	0.0623	0.0658	0.526	0.781
.002250	104.9	1,340	611	435	0.0563	0.0658	0.526	0.782
.002250	104.8	1,340	611	435	0.0563	0.0658	0.526	0.782
.002250	104.2	1,270	510	354	0.0537	0.0658	0.526	0.800
.002250	104.0	1,280	508	353	0.0543	0.0658	0.526	0.806
.002254	104.0	1,220	438	297	0.0486	0.0650	0.523	0.807
.002254	103.8	1,220	439	295	0.0482	0.0650	0.523	0.807
.002254	103.2	1,160	378	243	0.0440	0.0647	0.520	0.808
.002248	103.4	1,170	382	249	0.0442	0.0647	0.520	0.802
.002248	103.4	1,100	311	194	0.0391	0.0639	0.519	0.820
.002246	103.4	1,100	311	194	0.0391	0.0639	0.519	0.820
.002246	103.0	1,040	243	148	0.0334	0.0632	0.517	0.829
.002246	103.0	1,040	246	144	0.0325	0.0638	0.517	0.810
.002246	103.2	970	186	96	0.0223	0.0611	0.514	0.770
.002246	103.2	930	131	63	0.01775	0.0588	0.512	0.746
.002246	103.0	890	81	35	0.01101	0.0500	0.509	0.633
.002246	103.0	820	41	—	0.00445	0.00786	0.507	0.428
.002256	80.3	1,590	1,033	909	0.0873	0.0694	0.537	0.621
.002256	79.8	1,600	1,031	910	0.0865	0.0682	0.537	0.619
.002256	74.8	1,600	1,037	919	0.0872	0.0686	0.537	0.580
.002256	74.8	1,590	1,036	918	0.0883	0.0695	0.537	0.584
.002259	69.4	1,600	1,010	922	0.0876	0.0687	0.537	0.540
.002259	69.4	1,600	1,037	922	0.0875	0.0685	0.537	0.541
.002262	65.2	1,610	1,041	927	0.0870	0.0707	0.538	0.487
.002262	63.5	1,600	1,040	925	0.0890	0.0687	0.538	0.497
.002262	59.0	1,600	1,045	929	0.0882	0.0689	0.538	0.462
.002262	59.3	1,600	1,044	928	0.0881	0.0689	0.538	0.463
.002262	56.1	1,590	1,046	931	0.0894	0.0698	0.538	0.443
.002262	56.1	1,590	1,046	931	0.0895	0.0698	0.538	0.444
.002267	23.8	1,590	1,051	906	0.0866	0.0703	0.536	0.181
.002267	24.4	1,590	1,045	900	0.0908	0.0734	0.534	0.191

TABLE I—Continued
 TEST RESULTS

PROPELLER 4412-23.5° AT 0.75R. 10° YAW

ρ	V m. p. h.	N r. p. m.	Q lb. ft.	T lb.	C_T	C_P	$\frac{V}{nD}$	η
0.002223	83.8	1,590	1,012	873	0.0848	0.0686	0.516	0.639
.002223	83.8	1,590	1,010	873	0.0848	0.0686	0.516	0.638
.002230	88.4	1,600	1,012	855	0.0821	0.0678	0.516	0.654
.002230	88.4	1,590	1,012	858	0.0826	0.0685	0.516	0.670
.002230	94.0	1,605	1,013	840	0.0803	0.0676	0.516	0.679
.002230	94.6	1,620	1,011	834	0.0781	0.0662	0.516	0.674
.002217	103.8	1,630	1,011	801	0.0748	0.0659	0.516	0.683
.002217	102.8	1,610	1,009	801	0.0746	0.0673	0.516	0.710
.002217	102.8	1,560	922	738	0.0747	0.0654	0.516	0.736
.002217	102.6	1,670	923	729	0.0730	0.0647	0.516	0.719
.002217	102.9	1,620	855	668	0.0715	0.0640	0.516	0.734
.002217	102.8	1,610	853	606	0.0723	0.0646	0.516	0.743
.002217	102.8	1,490	772	589	0.0684	0.0627	0.516	0.750
.002217	102.8	1,470	778	589	0.0674	0.0616	0.516	0.747
.002217	102.5	1,410	708	525	0.0655	0.0613	0.516	0.766
.002217	102.5	1,410	705	526	0.0656	0.0612	0.516	0.762
.002217	101.9	1,350	636	460	0.0624	0.0601	0.516	0.765
.002217	101.9	1,350	632	458	0.0622	0.0599	0.516	0.765
.002217	101.7	1,300	544	382	0.0590	0.0555	0.516	0.772
.002217	101.7	1,290	539	381	0.0587	0.0556	0.516	0.785
.002213	102.0	1,240	457	337	0.0544	0.0536	0.516	0.816
.002213	102.0	1,250	457	338	0.0537	0.0528	0.516	0.810
.002213	101.2	1,210	436	294	0.0498	0.0516	0.516	0.790
.002213	101.2	1,210	436	295	0.050	0.0516	0.516	0.791
.002213	101.0	1,190	389	256	0.0472	0.0501	0.516	0.802
.002213	101.0	1,165	389	256	0.0468	0.0497	0.516	0.800
.002213	100.7	1,110	330	208	0.0418	0.0462	0.516	0.802
.002213	100.7	1,110	326	205	0.0413	0.0455	0.516	0.802
.002213	100.7							

TABLE II
 TEST RESULTS

PROPELLER 4412-15.5° AT 0.75R. 0° YAW

P	V m. p. h.	N r. p. m.	Q lb. ft.	T lb.	C _T	C _P	V πD	η
0.002310	83.6	1,890	789	866	0.0576	0.0366	0.33	0.681
0.002310	84.1	1,890	789	870	0.0579	0.0366	0.35	0.688
0.002310	88.6	1,890	788	826	0.0550	0.0366	0.488	0.708
0.002310	88.0	1,900	788	826	0.0544	0.0352	0.454	0.701
0.002307	93.7	1,890	727	756	0.0505	0.0338	0.435	0.725
0.002307	93.5	1,890	731	761	0.0508	0.0340	0.434	0.723
0.002304	102.8	1,890	669	658	0.0430	0.0311	0.533	0.751
0.002304	102.8	1,890	674	662	0.0441	0.0318	0.531	0.750
0.002304	102.4	1,890	571	545	0.0401	0.0293	0.557	0.764
0.002304	101.5	1,810	573	550	0.0399	0.0290	0.549	0.755
0.002304	101.2	1,700	463	426	0.0351	0.0266	0.582	0.769
0.002304	101.2	1,700	463	425	0.0350	0.0266	0.582	0.766
0.002297	101.0	1,600	370	318	0.0300	0.0244	0.621	0.765
0.002297	101.2	1,600	372	320	0.0299	0.0242	0.620	0.766
0.002297	101.0	1,495	291	236	0.0252	0.0217	0.660	0.764
0.002297	100.3	1,420	236	173	0.0206	0.0152	0.691	0.730
0.002297	100.0	1,310	160	96	0.0133	0.0152	0.746	0.643
0.002297	99.8	1,190	83	18	0.00804	0.00976	0.820	0.266
0.002297	99.0	1,090	24	—	0.00305	0.0337	0.836	0.643
0.002309	76.0	1,890	814	923	0.0513	0.0378	0.297	0.644
0.002309	76.0	1,900	816	919	0.0404	0.0375	0.297	0.638
0.002309	72.0	1,880	810	925	0.0421	0.0379	0.275	0.615
0.002309	72.0	1,850	808	925	0.0421	0.0378	0.275	0.616
0.002309	66.7	1,885	826	946	0.0432	0.0389	0.246	0.582
0.002309	66.7	1,890	837	953	0.0440	0.0392	0.247	0.586
0.002312	61.2	1,890	859	992	0.0459	0.0393	0.217	0.526
0.002312	61.2	1,890	860	994	0.0460	0.0399	0.217	0.525

TABLE II—Continued
 TEST RESULTS

PROPELLER 4412-15.5° AT 0.75R. 5° YAW

P	V m. p. h.	N r. p. m.	Q lb. ft.	T lb.	C _T	C _P	V πD	η
0.002274	88.8	1,890	743	1,360	0.0537	0.0352	0.480	0.701
0.002274	88.8	1,890	744	1,360	0.0537	0.0352	0.480	0.701
0.002274	94.6	1,890	702	1,273	0.0495	0.0336	0.493	0.726
0.002274	98.0	1,890	708	1,290	0.0508	0.0338	0.434	0.720
0.002274	96.1	1,870	680	1,237	0.0478	0.0328	0.503	0.733
0.002274	95.7	1,870	685	1,245	0.0483	0.0330	0.501	0.734
0.002261	105.5	1,890	656	1,140	0.0427	0.0311	0.545	0.760
0.002261	105.5	1,900	654	1,145	0.0426	0.0307	0.543	0.764
0.002261	105.5	1,820	566	1,047	0.0392	0.0289	0.567	0.770
0.002261	105.5	1,820	565	1,044	0.0390	0.0289	0.567	0.766
0.002261	105.3	1,705	447	903	0.0326	0.0260	0.604	0.758
0.002261	104.0	1,705	443	928	0.0343	0.0261	0.596	0.784
0.002260	76.0	1,870	797	1,605	0.0622	0.0394	0.398	0.645
0.002260	75.0	1,880	799	1,604	0.0615	0.0390	0.390	0.631
0.002260	82.0	1,900	795	1,459	0.0566	0.0370	0.422	0.670
0.002260	82.0	1,890	793	1,461	0.0568	0.0372	0.424	0.676
0.002261	105.7	1,620	364	828	0.0293	0.0235	0.637	0.795
0.002261	105.0	1,510	263	713	0.0214	0.01995	0.630	0.730
0.002261	104.8	1,400	188	633	0.01485	0.01626	0.732	0.660
0.002261	104.8	1,300	123	564	0.00705	0.01230	0.787	0.451
0.002256	104.5	1,190	45	802	0.00258	0.00575	0.869	0.607
0.002263	70.3	1,890	798	1,536	0.0623	0.0381	0.366	0.608
0.002263	70.3	1,870	801	1,535	0.0633	0.0386	0.368	0.608
0.002271	64.1	1,870	807	1,661	0.0643	0.0388	0.341	0.570
0.002271	64.8	1,870	817	1,563	0.0649	0.0394	0.339	0.558
0.002271	60.7	1,890	812	1,686	0.0652	0.0383	0.316	0.531
0.002271	60.7	1,870	813	1,667	0.0660	0.0391	0.317	0.535

TABLE II—Continued
 TEST RESULTS

PROPELLER 4412-15.5° AT 0.75R. 10° YAW

P	V m. p. h.	N r. p. m.	Q lb. ft.	T lb.	C _T	C _P	V πD	η
0.002288	87.4	1,890	771	820	0.0551	0.0362	0.452	0.638
0.002288	86.7	1,890	771	822	0.0552	0.0363	0.445	0.634
0.002285	91.5	1,890	730	757	0.0509	0.0342	0.473	0.706
0.002285	91.5	1,890	731	761	0.0511	0.0344	0.473	0.704
0.002277	95.6	1,890	700	711	0.0456	0.0333	0.498	0.726
0.002277	95.6	1,890	700	712	0.0457	0.0333	0.498	0.728
0.002271	105.0	1,900	656	630	0.0422	0.0307	0.540	0.743
0.002271	104.9	1,900	656	639	0.0427	0.0307	0.540	0.751
0.002271	104.8	1,800	550	513	0.0383	0.0285	0.670	0.793
0.002271	104.8	1,810	560	508	0.0374	0.0284	0.667	0.749
0.002271	103.5	1,695	444	394	0.0332	0.0261	0.697	0.769
0.002271	103.5	1,690	442	396	0.0334	0.0261	0.699	0.766
0.002264	103.8	1,590	351	283	0.0250	0.0234	0.639	0.764
0.002264	103.8	1,590	352	283	0.0250	0.0235	0.639	0.762
0.002264	103.4	1,470	256	191	0.0214	0.0200	0.659	0.736
0.002267	102.5	1,400	201	189	0.0170	0.01736	0.715	0.709
0.002267	102.8	1,300	135	72	0.0132	0.01350	0.770	0.689
0.002267	102.0	1,220	84	19	0.00809	0.00852	0.817	0.265
0.002267	102.0	1,120	23	—	0.00784	0.00909	0.890	0.645
0.002276	78.2	1,890	789	881	0.0595	0.0372	0.404	0.646
0.002276	78.0	1,890	787	880	0.0594	0.0370	0.403	0.646
0.002279	78.7	1,890	810	929	0.0627	0.0382	0.381	0.625
0.002279	78.0	1,890	810	935	0.0632	0.0382	0.378	0.626
0.002279	67.4	1,890	827	884	0.0665	0.0389	0.345	0.595
0.002279	67.4	1,890	830	906	0.0673	0.0390	0.345	0.600
0.002282	61.7	1,870	835	1,020	0.0700	0.0401	0.323	0.564
0.002282	62.1	1,890	832	1,023	0.0696	0.0395	0.324	0.571

TABLE II—Continued
 TEST RESULTS

PROPELLER 4412-15.5° AT 0.75R. 15° YAW

P	V m. p. h.	N r. p. m.	Q lb. ft.	T lb.	C _T	C _P	V πD	η
0.00231	89.0	1,900	773	804	0.0540	0.0363	0.458	0.682
0.00231	89.0	1,900	773	806	0.0542	0.0363	0.458	0.684
0.00231	92.6	1,890	728	747	0.0507	0.0346	0.479	0.703
0.00231	92.4	1,890	727	748	0.0508	0.0345	0.478	0.705
0.002307	95.5	1,890	692	698	0.0477	0.0330	0.494	0.714
0.002307	94.2	1,890	692	709	0.0490	0.0334	0.490	0.719
0.002304	103.9	1,890	653	625	0.0423	0.0312	0.567	0.737
0.002304	103.7	1,890	659	632	0.0432	0.0314	0.536	0.737
0.002304	103.6	1,810	560	534	0.0395	0.0291	0.660	0.766
0.002304	103.3	1,810	560	532	0.0396	0.0291	0.558	0.760
0.002304	102.9	1,690	442	395	0.0337	0.0264	0.596	0.761
0.002304	103.0	1,690	442	395	0.0337	0.0264	0.596	0.761
0.002297	103.0	1,600	364	311	0.0298	0.0244	0.630	0.770
0.002297	103.0	1,600	367	312	0.0299	0.0246	0.630	0.765
0.002297	102.6	1,500	292	235	0.0256	0.0225	0.669	0.769
0.002297	102.1	1,410	253	173	0.0213	0.0200	0.708	0.755
0.002297	101.9	1,300	150	91	0.0132	0.0152	0.766	0.663
0.002297	101.6	1,210	94	37	0.00607	0.0110	0.821	0.462
0.002297	101.3	1,100	27	—	0.00507	0.00881	0.901	0.650
0.002309	81.2	1,890	778	843	0.0575	0.0371	0.420	0.650
0.002309	81.4	1,890	776	836	0.0571	0.0370	0.421	0.650
0.002309	75.9	1,890	808	890	0.0617	0.0385	0.393	0.627
0.002309	75.8	1,890	809	893	0.0610	0.0385	0.392	0.620
0.002309	71.4	1,890	820	926	0.0633	0.0391	0.369	0.597
0.002309	71.1	1,900	824	929	0.0635	0.0389	0.369	0.597
0.002312	63.8	1,890	826	973	0.0672	0.0398	0.332	0.560
0.002312	63.9	1,890	826	976	0.0668	0.0391	0.331	0.565
0.002312	59.5	1,890	831	999	0.0690	0.0400	0.310	0.535
0.002312	59.6	1,890	831	1,001	0.0691	0.0400	0.310	0.536
0.002312	58.3	1,890	833	1,011	0.0690	0.0401	0.303	0.520
0.002312	55.8	1,890	836	1,023	0.0705	0.0402	0.290	0.519
0.002312	17.80	1,890	871	1,164	0.0798	0.0418	0.026	0.177
0.002312	18.36	1,890	871	1,167	0.0800	0.0415	0.0260	0.183