REPORT No. 237

TESTS ON THIRTEEN NAVY TYPE MODEL PROPELLERS

By W. F. DURAND
Stanford University

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PURPOSE OF TEST

The tests on these model propellers were conducted at Stanford University under research authorization of the National Advisory Committee for Aeronautics and were undertaken for the purpose of determining the performance coefficients and characteristics for certain selected series of propellers of form and type as commonly used in recent Navy designs.

The first series includes seven propellers of pitch ratio varying by 0.10 from 0.50 to 1.10, the area, form of blade, thickness, etc., representing an arbitrary standard propeller which had shown good results.

The second series covers changes in thickness of blade section, other things equal, and the third series, changes in blade area, other things equal.

These models are all of the standard 36-inch diameter employed in this laboratory.

The dimensions of these model forms are as shown in Figures 1 to 14.

It will be noticed that propellers A to G form the series on pitch ratio, C, N, I, J the series on thickness of section, and K, M, C, L the series on area.

METHOD OF TEST

The methods followed in these tests were similar to those of like tests previously reported, and need not be more particularly described here.

RESULTS

The results are presented in tabular and graphical form as follows:

Tabular results.—In Table I are given the observed values for the following quantities:

(*a*) The dynamic wind pressure $\rho V^2/2$ in pounds per square foot.

(*b*) The wind velocity in feet per second V.

(*c*) The revolutions per minute (N).

(*d*) The value of the slip function V/nD.

(*e*) The thrust in pounds (T).

(*f*) The torque in foot-pounds (Q) from which are calculated

(*g*) Values of the thrust coef. $C_T=\frac{T}{\rho n^2 D^4}$.

(*h*) Values of the power coef. $C_{P1}=\frac{P}{\rho n^3 D^5}$.

(*i*) Values of the power coef. $C_{P2}=\frac{P}{\rho V^3 D^2}$.

(*j*) Values of the power coef. $C_{P3}=\frac{P}{\rho V^5 n^2}$.

In addition, in Table II are given, as derived from smooth curves drawn through and among the observed points, values of the following:

(*a*) The thrust coef. $\frac{T}{\rho n^2 D^4}$.

(*b*) The power coef. $\frac{P}{\rho n^3 D^5}$.

(*c*) The efficiency η.

Graphical results.—In Figures 15 to 27 are shown for each propeller the following:

(*a*) The observed points for the thrust coef. $\frac{T}{\rho n^2 D^4}$.

(*b*) The observed points for the power coef. $\frac{P}{\rho n^3 D^5}$.

(*c*) The smooth curve through and among the points of (*a*) and giving the adjusted or most probable values as in Table II.

(*d*) The smooth curve through and among the points of (*b*) and giving the adjusted or most probable values as in Table II.

(*e*) The curve of values of the efficiency η as derived from the value of the coefficients of thrust and power, as in Table II.

DISCUSSION

The slip function V/nD is otherwise $(V/n) \div D$ and this is the ratio of the advance per revolution to the diameter. If the propeller blade consisted simply of an ideally thin true helicoidal surface screwing through the air without slip or action on the air, the advance per revolution would be equal to the pitch of the helicoidal surface. In such case there would be developed, of course, no thrust on or by the propeller. In an actual propeller the advance per revolution which produces no thrust gives an equivalent or virtual pitch and the ratio of this to diameter gives a form of equivalent or virtual pitch ratio. This will obviously give a point on the axis of V/nD where the thrust is zero and will thus furnish one limit of the various performance curves for the propeller. The other limit will likewise be found at the point where $V/nD=0$ or where the speed of advance $V=0$.

Turning to the values as given in the tables and figures, it is seen that in all cases the value of V/nD for $T=0$ is greater than the nominal or face pitch ratio, and in consequence the value of the virtual pitch based on advance for $T=0$ is in all cases greater than the face or nominal pitch. This is, of course, a well-known characteristic of actual propellers resulting from the aerodynamic properties of the standard form of propeller section with a practically plane driving face and a definitely rounded back. The amount of increase in pitch, as indicated by the value of V/nD for $T=0$ as compared with the nominal pitch ratio, is seen in general to be of the order of 20 to 40 per cent, the increase being greater for thick blades than for thin, as would naturally be expected.

The general character of the coefficients C_T, C_{P_l}, and of the efficiency η is plainly shown by the diagrams, Figures 15 to 27. The coefficient C_T begins on the axis of V/nD at the point for $T=0$ and rises sloping to the left, nearly straight at first and then curving over more definitely to some final limit value for $V/nD=0$. The coefficient C_{P_l} starts with a definite value for the V/nD value which gives $T=0$ and rises at first steeply and then curves more and more definitely toward the horizontal until over the working range of the propeller it is often nearly horizontal. In general, furthermore, these curves reach a maximum value for some small value of V/nD and then droop slightly to the terminal value for $V/nD=0$.

The curve of η begins, of course, at 0 where $T=0$ on the right and ends at 0 where $V=0$ $(V/nD=0)$ on the left. It rises, at first rapidly, to a maximum usually at a value of V/nD near or somewhat less than that equal to the nominal pitch ratio, and thence it declines more gradually to the origin where $V=0$.

Comparing now the values for the propellers A to G, constituting a series with pitch ratio advancing from 0.50 to 1.10, the increase in range along the axis of V/nD, with advancing pitch will be noted in the various diagrams. Likewise, for any given value of V/nD, the values of C_T and of C_{P_l} are seen to increase continuously and at a nearly uniform rate based on increase of pitch ratio.

For propellers within this series (A to G, inclusive), the maximum or peak efficiency is greater for propellers of higher pitch ratios.

For any given value of V/nD there is but one propeller which is operating at its maximum efficiency. However, its efficiency is not the highest which can be obtained at that value of

V/nD. There is one other propeller, having a higher pitch ratio, which gives the highest possible efficiency at the given V/nD for propellers of the particular form used in this series. This is clearly shown on Figure 28, where curve No. 1 is drawn through the maximum or peak efficiency of each propeller, while curve No. 2 shows the maximum possible efficiency for each V/nD.

Referring next to the results for models K, M, C, L, constituting a series on increasing blade area, it will be noted that with the form and proportions of blade section employed there is but slight variation in the value of V/nD for $T=0$. The values of C_T and C_{P1} for any given value of V/nD increase, however, continuously with increase in area, and according to a nearly linear law over the range of area represented by these models. For C_T there is, as must be expected, an evident though small decrease in the rate of increase of value and, of course, with further increase in width these values would rapidly approach a limit. The point of special interest in these results lies in the fact that with the generally oval form of blade contour employed, and with the maximum width varying from about $0.07D$ to $0.10D$, the values of the coefficients increase nearly in proportion to the area.

An examination of the values for efficiency will show, however, that in detail and over the working range of V/nD the rate of increase in the value of the power coefficient is greater than that for the thrust coefficient and that in consequence, over this range of V/nD, increase in area is accompanied generally with decrease in efficiency. This is entirely in accord with normal expectation and likewise with previous tests relating to the same point.

However, as there is some tendency toward an increase of V/nD for $T=0$ with increased area, it follows that the efficiency for very large values of V/nD may be greater for large area than for small. In consequence the efficiency curves tend to cross at large values of V/nD, thus reversing the efficiency relation which holds over the working range.

The actual variation of efficiency over the working range for these propellers is noted to lie between 3 and 5 per cent for an area increase of 50 per cent.

In comparing the results for these four models it will be noted that the area increments are not equal, the successive areas being in the ratio 0.80, 0.92, 1.00, 1.20.

As a further point of interest, it will be noted that for area change the variation in the values of C_T and C_{P1} is relatively small at large values of V/nD and large at small values.

Turning next to the results for models C, H, I, J, constituting a series on blade thickness, it will be noted that there is a marked change in the values of V/nD for $T=0$, the value increasing with increase of thickness as would be expected. Likewise, for any given value of V/nD, the values of C_T and C_{P1} continuously increase with increase in thickness, at least over the range represented in these models. It will also be noted that the increase in the values of the coefficients is relatively large for large values of V/nD and that it becomes markedly less for small values, showing a tendency to disappear at extreme values. It will also be noted that this particular tendency is the reverse of that noted in connection with increase in area, where the large rate of change is found for small values of V/nD and the small rate for large values.

Likewise over the working range of V/nD and, as would be expected, the value of the power coefficient increases with thickness more rapidly than that of the thrust coefficient and it results that the efficiency continuously decreases as the thickness is increased. Here, again, the point of special interest is the relatively small change in efficiency lying within 2 per cent, resulting from a change of 30 per cent in the thickness.

Likewise, since with increased thickness the value of V/nD for $T=0$ is increased, it follows that for very large values of V/nD the efficiency will be greater for the thick blade than for the thin and that in general two efficiency curves for blades of differing values of the thickness will cross and thus for very large values of V/nD reverse the relations which hold over the working range.

In general the results found for the thirteen models which the present investigations covers, are entirely in accord with results found previously for models of the same general form and proportion. The results of the present investigation confirm, therefore, generally similar results for like models and furnish added series of performance coefficients for propellers of the form and proportion covered by them.

TABLE I

OBSERVED VALUES

PROPELLER A

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	2.786	49.64	1,456	0.00	0.597	0.682	0.00	0.0116	0.037	0.079
2	2.867	50.36	1,588	1.323	0.954	.634	.0103	.0156	.061	.152
3	2.861	50.32	1,712	2.977	1.426	.588	.0200	.0200	.098	.285
4	2.925	50.86	1,899	5.294	2.032	.536	.0289	.0232	.151	.525
5	2.899	50.63	2,093	8.272	2.768	.484	.0371	.0260	.229	.979
6	3.088	52.26	2,334	11.91	3.685	.448	.0430	.0278	.310	1.546
7	3.122	52.54	2,560	16.21	4.727	.410	.0486	.0297	.431	2.564
8	3.196	53.14	2,805	21.17	5.808	.379	.0528	.0304	.558	3.889
9	3.240	53.48	3,022	26.79	6.992	.354	.0576	.0315	.710	5.668
10	3.249	53.56	3,264	33.07	8.386	.328	.0609	.0324	.918	8.536
11	0.126	10.53	1,756	13.23	2.473	.119	.0839	.0329		
12	0.234	14.35	2,375	24.25	4.560	.121	.0841	.0331		

PROPELLER B

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	3.169	51.16	1,319	0.00	0.5418	0.775	0.00	0.0123	0.026	0.044
2	3.088	51.32	1,426	1.320	.9742	.720	.0123	.0190	.051	.098
3	3.141	51.85	1,556	2.979	1.487	.666	.0234	.0245	.083	.187
4	3.162	52.07	1,719	5.294	2.145	.606	.0341	.0290	.130	.354
5	3.231	52.69	1,905	8.272	2.974	.553	.0435	.0328	.194	.634
6	3.311	53.35	2,114	11.89	4.022	.505	.0508	.0360	.279	1.096
7	3.492	54.78	2,338	16.20	5.156	.468	.0566	.0377	.368	1.680
8	3.523	55.03	2,547	21.17	6.371	.432	.0623	.0393	.488	2.613
9	3.537	55.20	2,769	26.79	7.809	.399	.0669	.0409	.644	4.045
10	3.541	55.29	2,972	33.07	9.184	.372	.0718	.0418	.812	5.869
11	3.672	56.31	3,334	44.10	11.83	.338	.0761	.0428	1.109	9.708
12	0.180	12.45	1,831	16.98	3.433	.136	.0969	.0410		

PROPELLER C

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	3.541	55.39	1,239		0.4376	0.894		0.0115	0.016	0.020
2	2.858	50.08	1,132	0.00		.885	0.00			
3	3.563	55.58	1,347		.8896	.825		.0198	.035	.052
4	2.875	50.24	1,248	1.326		.805	.0166			
5	3.609	55.98	1,466		1.467	.764		.0276	.062	.106
6	2.966	51.02	1,387	2.980		.736	.0302			
7	3.609	55.98	1,619		2.196	.692		.0339	.103	.215
8	3.141	52.41	1,553		2.161	.675		.0365	.119	.261
9	3.033	51.60	1,559	5.294		.662	.0425			
10	3.709	56.80	1,814	8.272	3.165	.626	.0486	.0390	.159	.406
11	3.168	52.68	1,754		3.094	.601		.0410	.189	.525
12	3.082	52.01	1,751	8.272		.594	.0526			
13	3.798	57.55	2,020	11.91	4.313	.570	.0566	.0429	.232	.713
14	3.181	52.84	1,958	11.91		.539	.0606			
15	3.888	58.23	2,226	16.21	5.542	.524	.0634	.0454	.317	1.158
16	3.253	53.44	2,165	16.21		.494	.0674			
17	4.050	59.50	2,438		6.880	.488		.0471	.405	1.702
18	3.388	54.53	2,389	21.17		.456	.0723			
19	4.041	59.30	2,644	26.79	8.354	.449	.0742	.0484	.535	2.653
20	4.086	59.66	2,857	33.07	9.924	.418	.0785	.0493	.677	3.878
21	3.420	54.78	2,820	33.07		.389	.0811			
22	2.781	48.74	2,777	35.51	9.752	.351	.0874	.0503	1.163	9.444
23	1.904	40.35	2,813	39.47	10.091	.287	.0947	.0507	2.145	
24	.360	17.17	2,354	33.07	7.166	.145	.1086	.0493		

PROPELLER D

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	3.100	52.27	1,051	0.00	0.401	0.994	0.00	0.0149	0.015	0.015
2	3.137	52.57	1,160	1.323	.929	.906	.0192	.0283	.038	.046
3	3.159	52.78	1,283	2.978	1.518	.822	.0354	.0378	.068	.101
4	3.221	53.31	1,449	5.294	2.348	.736	.0494	.0459	.115	.213
5	3.308	54.02	1,639	8.276	3.382	.659	.0604	.0517	.181	.416
6	3.370	54.51	1,841	11.91	4.570	.592	.0688	.0553	.266	.760
7	3.420	54.92	2,028	16.21	5.876	.539	.0765	.0581	.371	1.277
8	2.778	48.03	1,920	16.21	5.645	.500	.0812	.0592	.474	1.895
9	2.925	49.30	2,127	21.17	7.072	.464	.0864	.0605	.606	2.811
10	3.006	49.98	2,330	26.79	8.695	.429	.0911	.0620	.786	4.271
11	.125	9.91	1,270	11.02	2.544	.156	.1193	.0579		

PROPELLER E

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	2.902	49.88	907	0.00	0.289	1.100	0.00	0.0140	0.011	0.009
2	2.898	49.88	1,007		.877	.990		.0346	.036	.036
3	2.898	50.27	1,020	1.323		.986	.0246			
4	3.006	50.81	1,147		1.564	.886		.0475	.068	.087
5	2.911	50.42	1,147	2.977		.879	.0439			
6	3.051	51.20	1,305	5.292	2.434	.785	.0593	.0572	.118	.192
7	3.064	51.56	1,492	8.274	3.52	.691	.0716	.0638	.193	.405
8	3.135	52.20	1,682	11.910	4.744	.621	.0814	.0679	.279	.725
9	3.222	52.92	1,875	16.210	6.103	.564	.0889	.0701	.391	1.025
10	3.244	53.15	2,075	21.170	7.611	.512	.0950	.0715	.532	2.030
11	3.238	53.04	2,273	26.79	9.257	.466	.0998	.0723	.708	3.260
12	3.411	54.77	2,661	38.58	12.627	.412	.1065	.0730	1.050	6.180
13	.234	14.13	1,811	22.05	5.590	.156	.1272	.0676		

TABLE I—Continued

OBSERVED VALUES—Continued

PROPELLER F

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	3.146	52.66	877	0.00	0.296	1.201	0.00	0.0153	0.0091	0.006
2	3.190	53.06	988	1.323	.947	1.074	.0266	.0398	.0321	.028
3	3.168	52.87	1,102	2.979	1.664	.959	.0481	.0562	.0637	.069
4	3.177	52.94	1,256	5.294	2.602	.842	.0658	.0677	.1134	.160
5	3.267	53.68	1,436	8.274	3.765	.748	.0787	.0750	.1792	.320
6	3.330	54.22	1,614	11.91	5.126	.672	.0897	.0809	.2666	.590
7	3.389	54.69	1,802	16.19	6.580	.607	.0978	.0832	.3721	1.010
8	3.450	55.23	1,999	21.15	8.230	.553	.1041	.0848	.5016	1.642
9	3.483	55.49	2,198	26.79	10.000	.505	.1090	.0852	.6616	2.595
10	3.531	55.88	2,380	33.07	11.910	.469	.1146	.0865	.8384	3.811
11	.144	11.25	1,336	12.13	3.327	.168	.1326	.0762	----------	----------

PROPELLER G

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	3.163	52.95	814	0.00	0.2748	1.300	0.00	0.0171	0.0078	0.005
2	3.180	53.16	922	1.323	.9620	1.153	.0307	.0468	.0305	.023
3	3.195	53.27	1,049	2.979	1.755	1.016	.0534	.0660	.0635	.062
4	3.199	53.32	1,199	5.306	2.744	.889	.0729	.0790	.1124	.142
5	3.240	53.66	1,369	8.300	3.948	.784	.0876	.0872	.1810	.295
6	3.339	54.48	1,545	11.97	5.348	.705	.0990	.0926	.2643	.532
7	3.366	54.69	1,730	16.19	6.886	.632	.1069	.0951	.3770	.944
8	3.330	54.44	1,915	21.17	8.542	.569	.1142	.0966	.5245	1.620
9	3.321	54.37	2,102	26.79	10.326	.517	.1200	.0969	.7010	2.623
10	3.402	55.02	2,302	33.07	12.480	.478	.1234	.0976	.8940	3.915
11	.129	10.34	1,235	11.02	3.595	.167	.1331	.0909	----------	----------
12	.328	16.48	1,864	26.46	8.210	.177	.1403	.0911	----------	----------

PROPELLER H

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	3.141	52.09	1,134	0.00	0.4586	0.919	0.00	0.0143	0.018	0.022
2	3.199	52.56	1,250	1.323	.9490	.841	.0163	.0244	.041	.058
3	3.258	53.35	1,390	2.977	1.498	.767	.0299	.0315	.070	.119
4	3.145	52.12	1,521	5.292	2.232	.685	.0439	.0388	.121	.258
5	3.352	54.21	1,736	8.268	3.199	.624	.0535	.0433	.178	.458
6	3.433	54.86	1,941	11.91	4.348	.565	.0616	.0471	.261	.818
7	3.276	53.18	1,900	11.91	4.228	.560	.0634	.0471	.268	.855
8	3.321	53.62	2,106	16.21	5.465	.509	.0703	.0497	.377	1.456
9	3.402	54.32	2,323	21.17	6.818	.467	.0756	.0510	.501	2.297
10	3.505	55.14	2,533	26.79	8.278	.435	.0805	.0521	.633	3.345
11	3.631	56.12	2,755	33.07	9.913	.407	.0840	.0527	.782	4.721
12	.124	10.35	1,433	11.91	2.613	.144	.1114	.0512	----------	----------

PROPELLER I

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	2.435	45.28	959	0.00	0.504	0.945	0.00	0.0215	0.025	0.029
2	3.213	52.28	1,210	1.323	1.094	.864	.0171	.0296	.046	.062
3	3.510	54.75	1,377	2.977	1.651	.795	.0298	.0346	.069	.109
4	2.502	45.96	1,225	2.977	1.479	.750	.0372	.0387	.092	.163
5	3.569	55.21	1,524	5.292	2.373	.725	.0433	.0406	.107	.202
6	2.669	48.20	1,423	5.292	2.243	.678	.0506	.0449	.144	.313
7	3.352	53.48	1,674	8.268	3.290	.639	.0560	.0466	.179	.437
8	3.402	53.87	1,864	11.91	4.397	.578	.0650	.0502	.260	.779
9	3.768	49.00	1,813	11.91	4.173	.540	.0698	.0513	.326	1.117
10	3.816	57.22	2,317	21.17	7.137	.494	.0752	.0531	.440	1.805
11	3.948	58.26	2,729	33.07	10.203	.427	.0849	.0548	.704	3.861
12	2.907	49.61	2,630	33.07	9.704	.377	.0900	.0553	1.032	7.264
13	.353	17.42	2,363	33.07	7.470	.147	.1132	.0535	----------	----------

PROPELLER J

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	2.16	51.73	1,042	0.00	0.6408	0.993	0.00	0.0233	0.0238	0.0241
2	3.20	51.04	1,136	1.323	1.129	.897	.0185	.0330	.0457	.0568
3	3.245	52.04	1,285	2.977	1.689	.810	.0335	.0398	.075	.114
4	3.321	52.62	1,450	5.292	2.457	.726	.0467	.0454	.119	.225
5	3.402	54.12	1,663	8.268	3.385	.651	.0572	.0490	.178	.419
6	3.483	54.78	1,875	11.91	4.542	.584	.0650	.0518	.260	.762
7	3.447	54.05	2,054	16.21	5.738	.526	.0723	.0536	.368	1.331
8	3.447	53.61	2,234	21.17	7.080	.480	.0786	.0550	.497	2.158
9	3.564	54.51	2,440	26.79	8.552	.447	.0834	.0557	.626	3.138
10	3.364	54.61	2,650	33.07	10.174	.412	.0872	.0562	.803	4.736
11	0.267	14.92	2,070	26.47	6.076	.144	.1144	.0550	----------	----------

PROPELLER K

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	3.064	52.10	1,190	0.00	0.414	0.875	0.00	0.0120	0.018	0.023
2	3.073	52.25	1,327	1.323	.832	.788	.0148	.0195	.040	.065
3	3.159	53.00	1,490	2.977	1.388	.711	.0265	.0259	.072	.143
4	3.141	52.89	1,652	5.292	2.069	.640	.0384	.0314	.120	.292
5	3.186	53.26	1,873	8.268	2.954	.569	.0466	.0349	.189	.585
6	3.285	54.26	2,104	11.91	3.950	.516	.0534	.0371	.270	1.014
7	3.307	54.33	2,332	16.21	5.095	.466	.0591	.0389	.384	1.770
8	3.375	54.88	2,572	21.17	6.352	.427	.0634	.0399	.513	2.812
9	3.420	55.26	2,815	26.79	7.681	.393	.0671	.0403	.664	4.300
10	0.283	15.35	2,307	26.47	5.446	.133	.0920	.0396	----------	----------

TABLE I—Continued

OBSERVED VALUES—Continued

PROPELLER L

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	3.048	51.38	1,151	0.00	0.524	0.893	0.00	0.0159	0.022	0.028
2	3.119	51.99	1,257	1.323	1.028	.827	.0161	.0262	.046	.068
3	3.253	53.17	1,385	2.977	1.585	.767	.0300	.0334	.074	.126
4	3.343	53.90	1,540	5.292	2.378	.700	.0430	.0405	.118	.241
5	3.348	53.93	1,702	8.268	3.326	.634	.0552	.0465	.182	.453
6	3.429	54.61	1,892	11.91	4.4[illegible]	.577	.0644	.0509	.265	.796
7	3.523	55.46	2,104	16.21	5.7[illegible]	.527	.0710	.0532	.363	1.308
8	3.560	55.75	2,307	21.17	7.260	[illegible]23	.0772	.0554	.492	2.105
9	3.677	56.65	2,513	26.79	8.862	.451	.0823	.0570	.622	3.053
10	3.717	56.97	2,719	33.07	10.607	.419	.0868	.0583	.793	4.515
11	0.108	9.51	1,285	11.02	2.524	.148	.1242	.0596		

PROPELLER M

No.	$\frac{1}{2}\rho V^2$	V	N	T	Q	V/nD	C_T	C_{P1}	C_{P2}	C_{P3}
1	3.312	53.23	1,217	0.00	0.472	0.875	0.00	0.0127	0.019	0.025
2	3.335	53.45	1,327	1.323	.940	.806	.0143	.0213	.041	.063
3	3.379	53.87	1,452	2.977	1.461	.742	.0269	.0277	.068	.124
4	3.402	54.10	1,613	5.292	2.175	.671	.0389	.0335	.111	.247
5	3.470	54.64	1,813	8.268	3.106	.603	.0481	.0378	.173	.476
6	3.294	54.17	2,018	11.91	4.190	.537	.0577	.0425	.274	.952
7	3.366	54.75	2,250	16.21	5.396	.487	.0634	.0442	.383	1.614
8	3.555	56.28	2,471	21.17	6.594	.456	.0686	.0448	.472	2.272
9	3.645	57.00	2,699	26.79	8.123	.422	.0728	.0462	.615	3.452
10	3.693	57.37	2,918	33.07	9.714	.393	.0769	.0473	.779	5.048
11	0.112	9.68	1,412	11.02	.238	.137	.1028	.0465		

TABLE II

ADJUSTED VALUES

Prop.	A		B		C		D		E		F		G	
V/nD	C_{P1}	η	C_{P1}	η	C_{P1}	η	C_{P1}	η	C_{P1}	η	C_{P1}	η	C_{P1}	η
0.20														
.25														
.30	0.0326	0.594	0.0432	0.566	0.0506	0.549								
.35	.0316	.637	.0422	.622	.0504	.601								
.40	.0300	.669	.0406	.655	.0497	.644	0.0623	0.604	0.0730	0.586	0.0872	0.560	0.0975	0.543
.45	.0280	.689	.0386	.699	.0485	.680	.0613	.646	.0727	.628	.0867	.604	.0976	.587
.50	.0250	.690	.0361	.720	.0467	.711	.0597	.687	.0718	.667	.0860	.645	.0975	.626
.55	.0220	.660	.0330	.728	.0442	.739	.0577	.715	.0705	.701	.0850	.680	.0970	.661
.60	.0184	.571	.0295	.714	.0413	.755	.0550	.745	.0687	.732	.0835	.711	.0960	.694
.65	.0143	.323	.0255	.663	.0379	.763	.0520	.766	.0663	.756	.0812	.743	.0945	.722
.70			.0210	.557	.0338	.756	.0485	.779	.0632	.782	.0785	.767	.0925	.748
.75					.0290	.724	.0445	.782	.0597	.798	.0750	.790	.0896	.770
.80					.0233	.618	.0400	.768	.0557	.804	.0715	.806	.0864	.790
.85							.0349	.731	.0510	.800	.0670	.818	.0825	.806
.90							.0292	.641	.0460	.783	.0624	.818	.0782	.817
.95							.0224	.445	.0401	.732	.0570	.807	.0734	.828
1.00									.0331	.650	.0510	.775	.0678	.826
1.05									.0245	.471	.0439	.725	.0619	.814
1.10											.0361	.640	.0552	.794
1.15											.0267	.452	.0475	.751
1.20													.0390	.677
1.25													.0290	.504

ADJUSTED VALUES

Prop.	H		I		J	
V/nD	C_{P1}	η	C_{P1}	η	C_{P1}	η
0.40	0.0530	0.639	0.0553	0.632	0.0563	0.628
.45	.0519	.676	.0545	.670	.0558	.664
.50	.0503	.708	.0532	.703	.0546	.697
.55	.0480	.735	.0515	.730	.0531	.724
.60	.0452	.752	.0494	.749	.0512	.744
.65	.0418	.760	.0462	.758	.0492	.753
.70	.0379	.756	.0426	.756	.0468	.749
.75	.0335	.728	.0388	.730	.0441	.733
.80	.0287	.649	.0347	.668	.0408	.687

ADJUSTED VALUES

Prop.	K		L		M	
V/nD	C_{P1}	η	C_{P1}	η	C_{P1}	η
0.40	0.0403	0.657	0.0588	0.607	0.0468	0.649
.45	.0396	.691	.0570	.651	.0456	.685
.50	.0381	.722	.0547	.690	.0437	.717
.55	.0359	.751	.0520	.719	.0413	.745
.60	.0330	.767	.0486	.744	.0385	.762
.65	.0299	.770	.0450	.751	.0350	.762
.70	.0262	.748	.0405	.743	.0312	.747
.75	.0224	.689	.0355	.699	.0268	.695
.80	.0184	.544	.0296	.619	.0220	.575

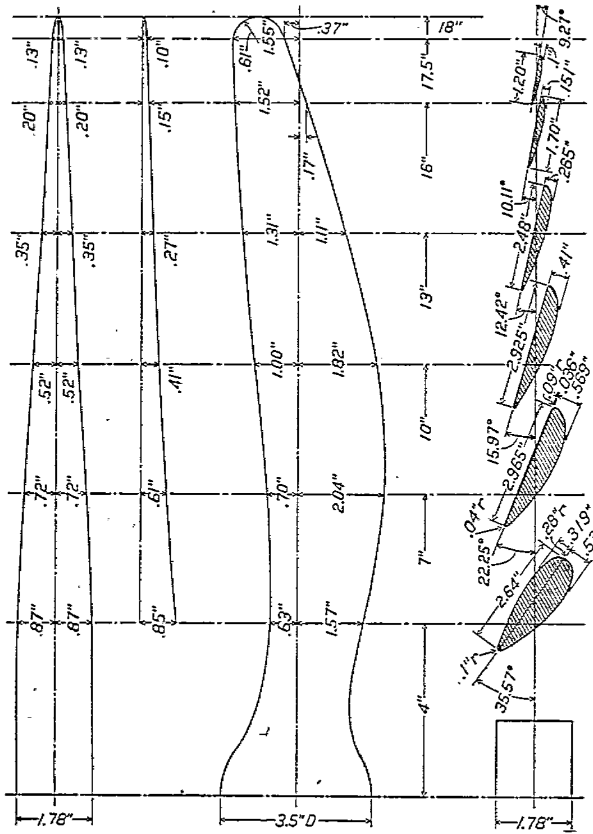

FIG. 1.—Propeller A. Diameter, 3 feet. Aspect ratio, 6. Maximum blade width, 3 inches. Pitch, 18 inches. Pitch ratio, 0.5. Camber ratio, minimum

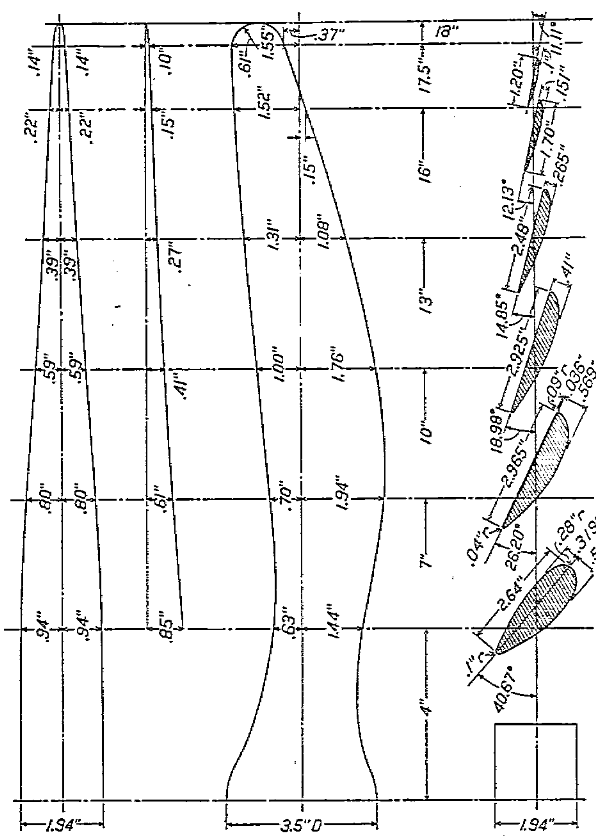

FIG. 2.—Propeller B. Diameter, 3 feet. Aspect ratio, 6. Maximum blade width, 3 inches. Pitch, 21.6 inches. Pitch ratio 0.6. Camber ratio, minimum

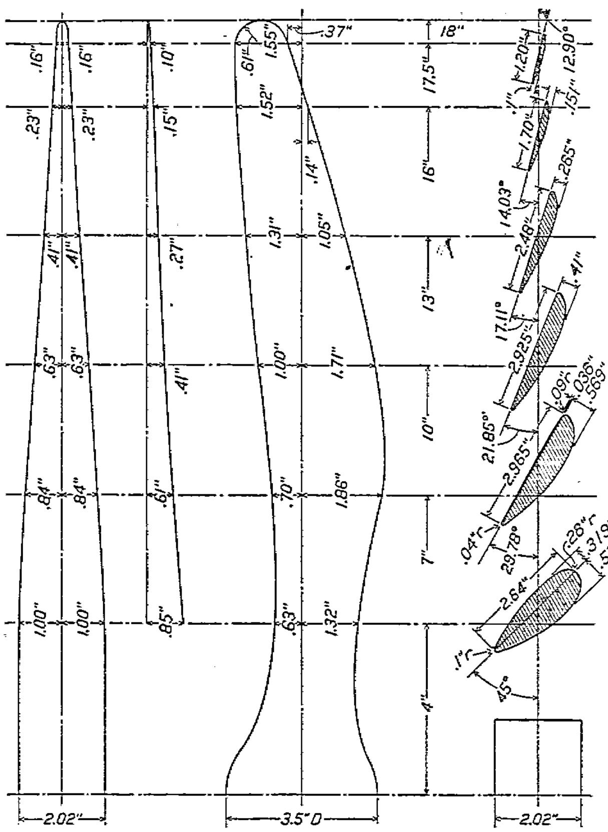

FIG. 3.—Propeller C. Diameter, 3 feet. Aspect ratio, 6. Maximum blade width, 3 inches. Pitch, 25.2 inches. Pitch ratio 0.7. Camber ratio, minimum

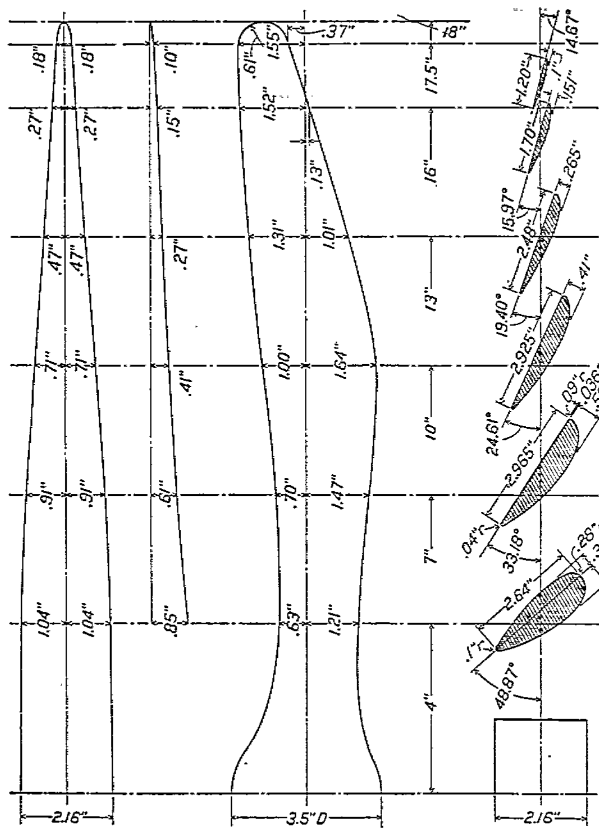

FIG. 4.—Propeller D. Diameter, 3 feet. Aspect ratio, 6. Maximum blade width, 3 inches. Pitch, 28.8 inches. Pitch ratio 0.8. Camber ratio, minimum

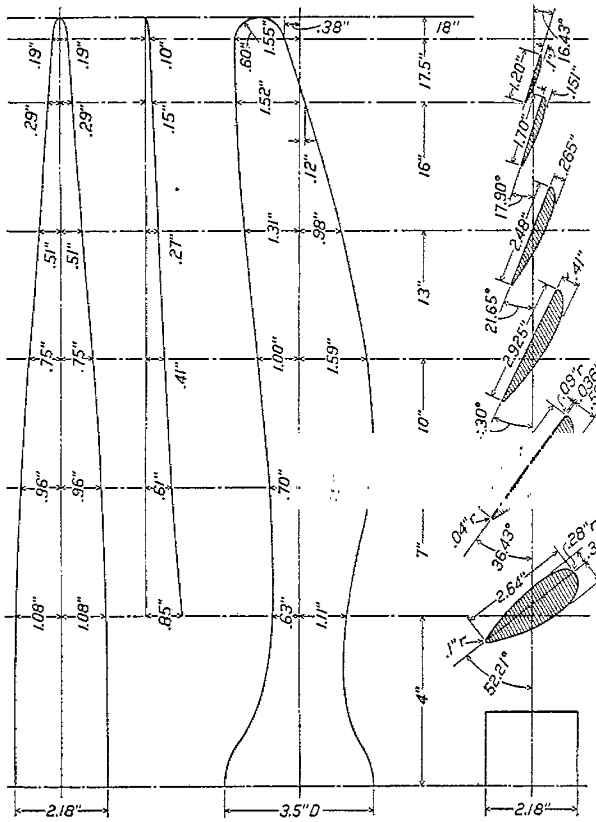

FIG. 5.—Propeller E. Diameter, 3 feet. Aspect ratio, 6. Maximum blade width, 3 inches. Pitch, 32.4 inches. Pitch ratio, 0.9. Camber ratio, minimum

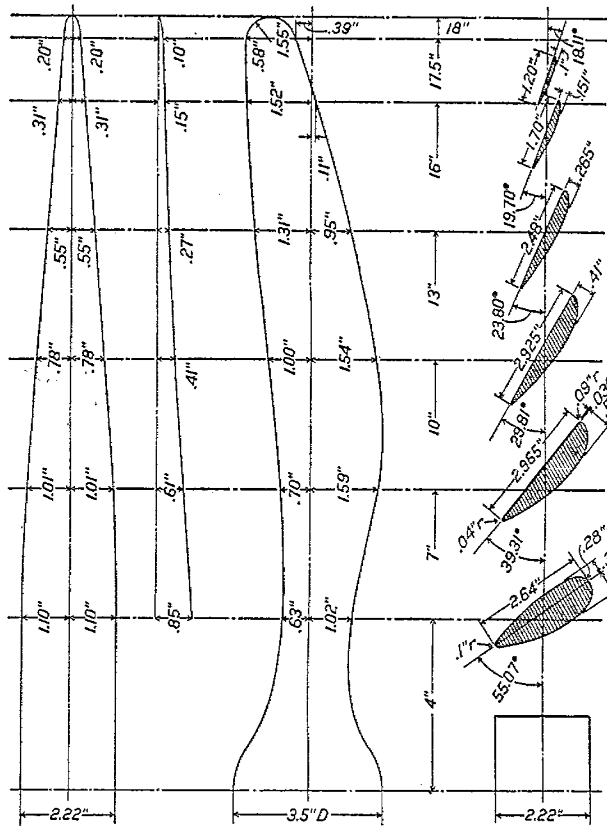

FIG. 6.—Propeller F. Diameter, 3 feet. Aspect ratio, 6. Maximum blade width, 3 inches. Pitch, 36 inches. Pitch ratio, 1. Camber ratio, minimum

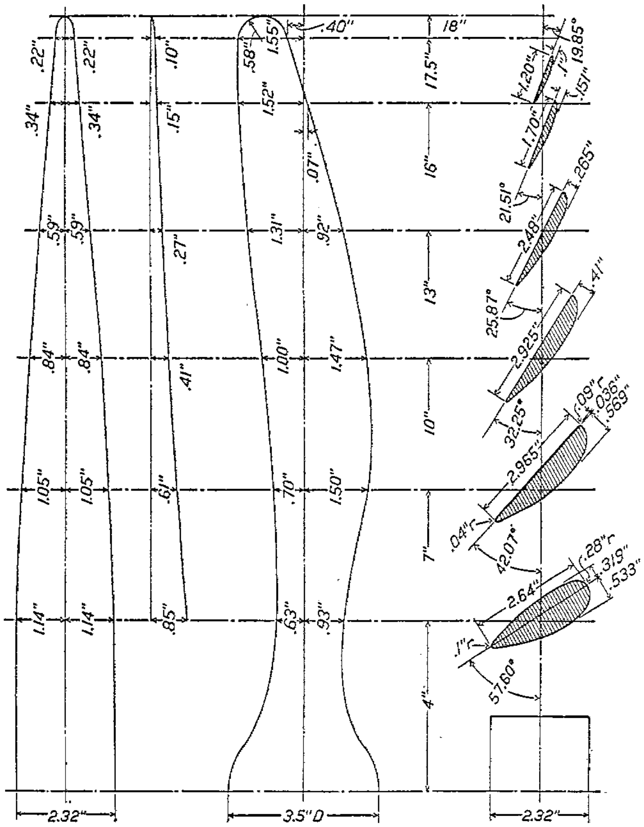

FIG. 7.—Propeller G. Diameter, 3 feet. Aspect ratio, 6. Maximum blade width, 3 inches. Pitch, 39.6 inches. Pitch ratio, 1.1. Camber ratio, minimum

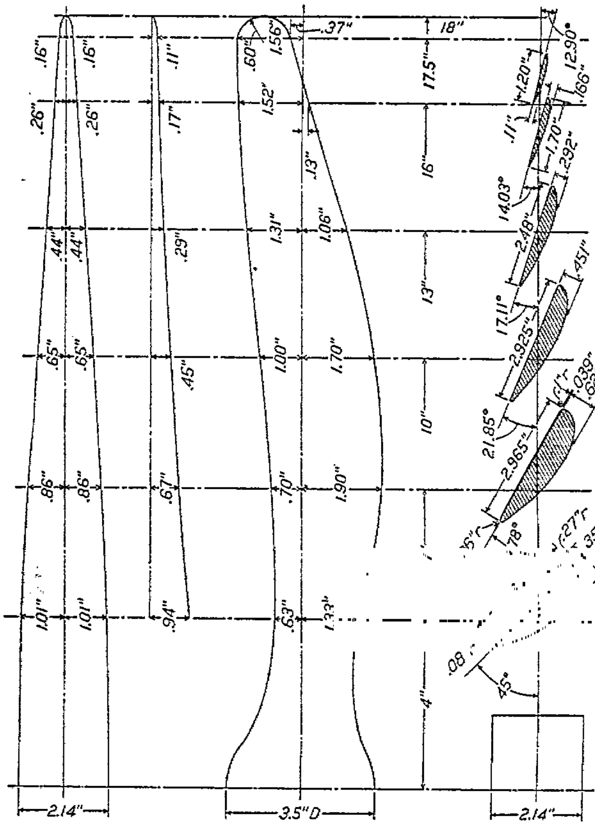

FIG. 8.—Propeller H. Diameter, 3 feet. Aspect ratio, 6. Maximum blade width, 3 inches. Pitch, 25.2 inches. Pitch ratio, 0.7. Camber ratio, minimum +10 per cent

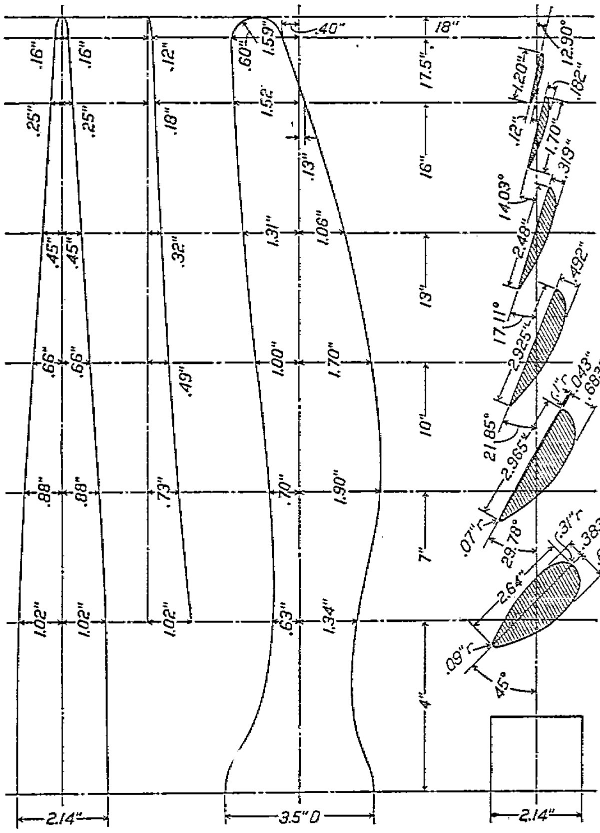

FIG. 9.—Propeller I. Diameter, 3 feet. Aspect ratio, 6. Maximum blade width, 3 inches. Pitch, 25.2 inches. Pitch ratio, 0.7. Camber ratio, minimum +20 per cent

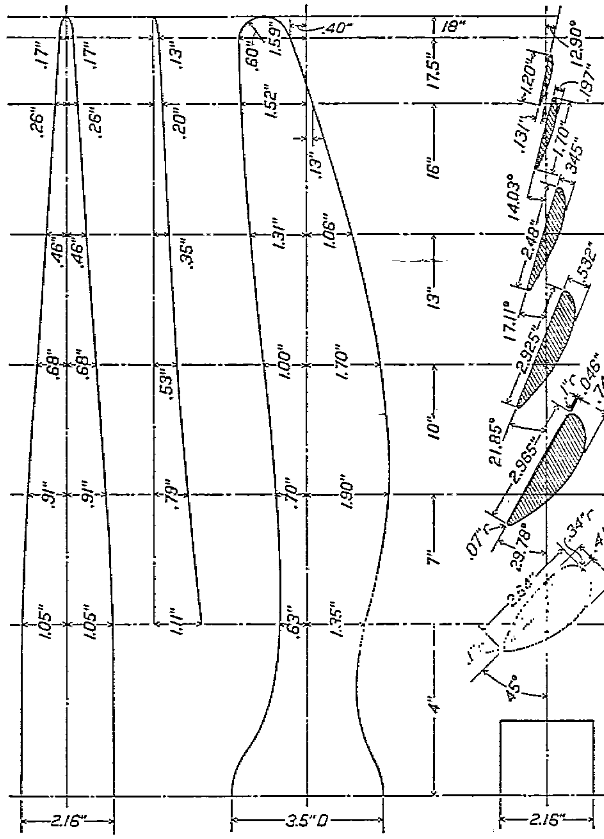

FIG. 10.—Propeller J. Diameter, 3 feet. Aspect ratio, 6. Maximum blade width, 3 inches. Pitch, 25.2 inches. Pitch ratio, 0.7. Camber ratio, minimum +30 per cent

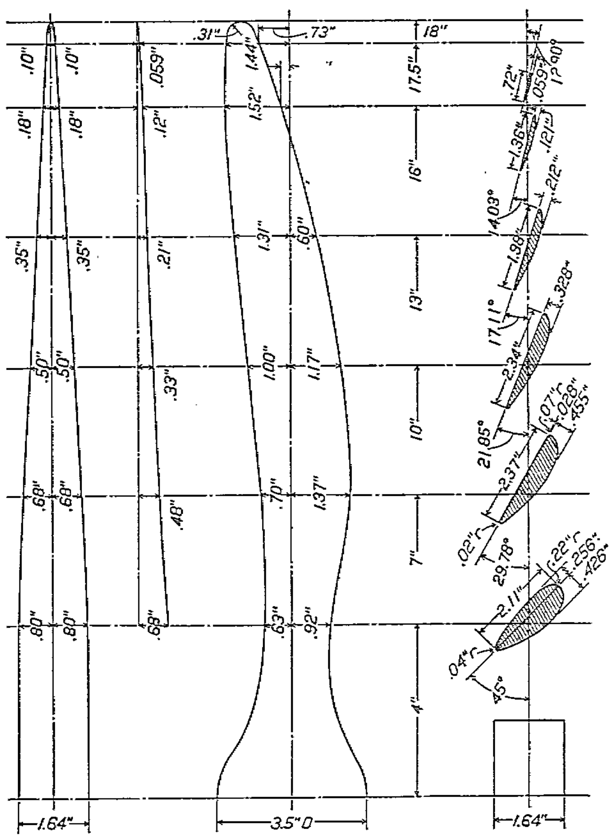

FIG. 11.—Propeller K. Diameter, 3 feet. Aspect ratio, 7.5. Maximum blade width, 2.4 inches. Pitch, 25.2 inches. Pitch ratio, 0.7. Camber ratio, minimum

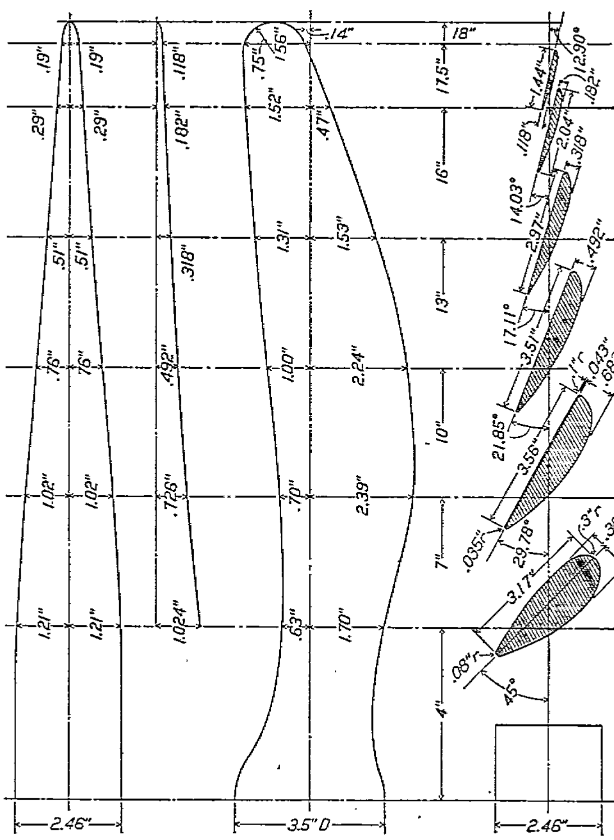

FIG. 12.—Propeller L. Diameter, 3 feet. Aspect ratio, 5. Maximum blade width, 3.6 inches. Pitch, 25.2 inches. Pitch ratio, 0.7. Camber ratio, minimum

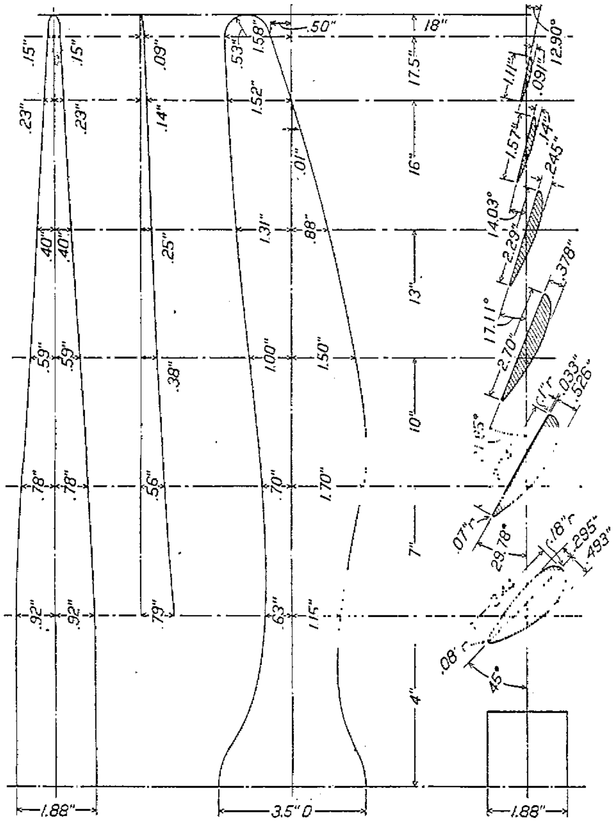

Fig. 13.—Propeller M. Diameter, 3 feet. Aspect ratio, 6.5 inches. maximum blade width, 2.77 inches. Pitch, 25.2 inches. Pitch ratio, 0.7. Camber ratio, minimum

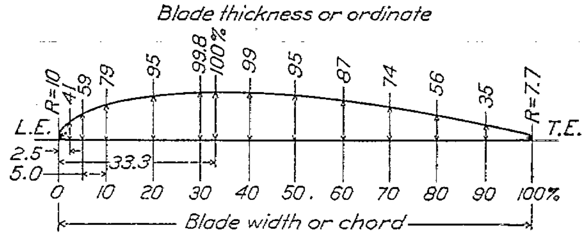

Fig. 14.—Standard blade section

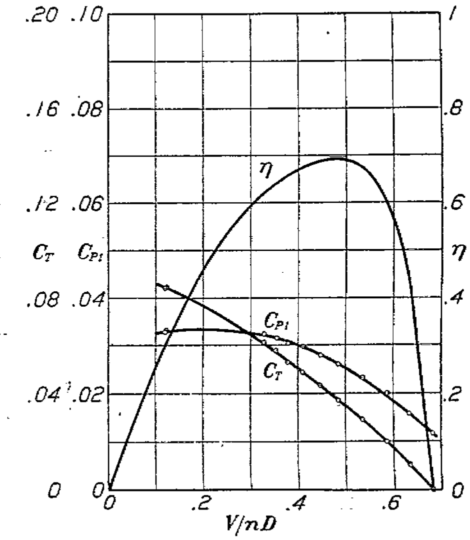

Fig. 15.—Propeller A

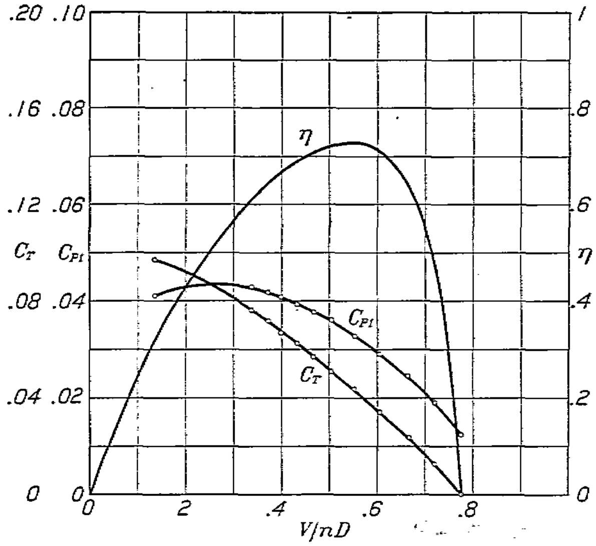

FIG. 16.—Propeller B

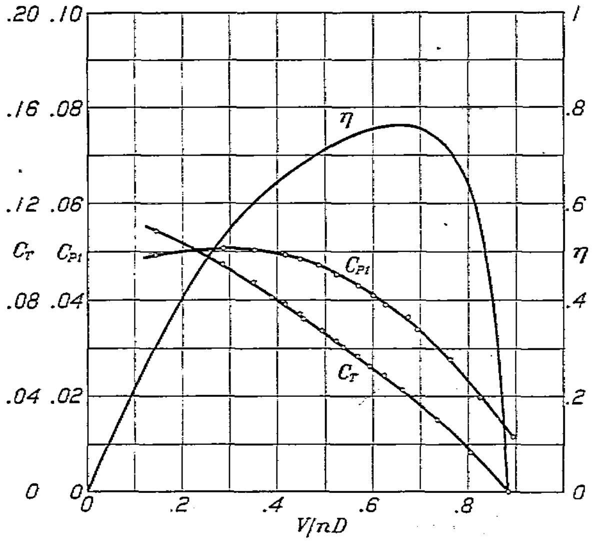

FIG. 17.—Propeller C

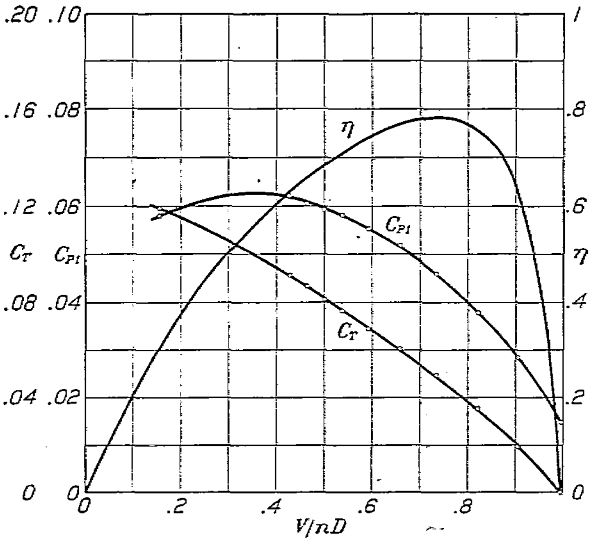

FIG. 18.—Propeller D

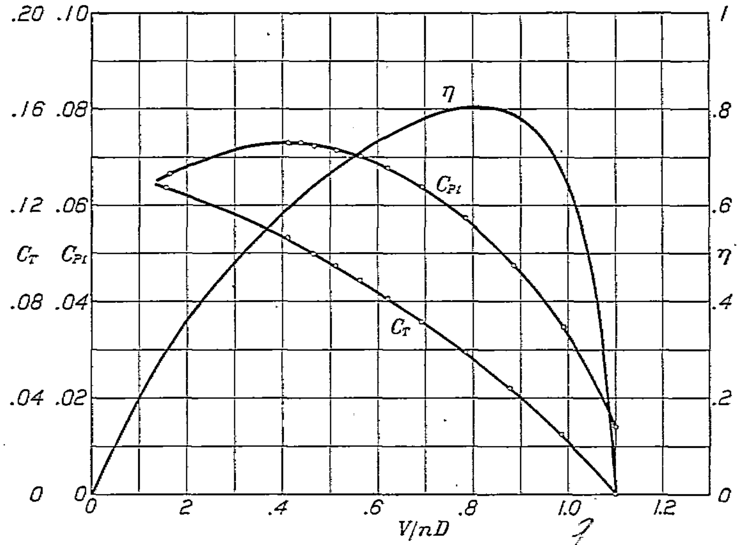

FIG. 19.—Propeller E

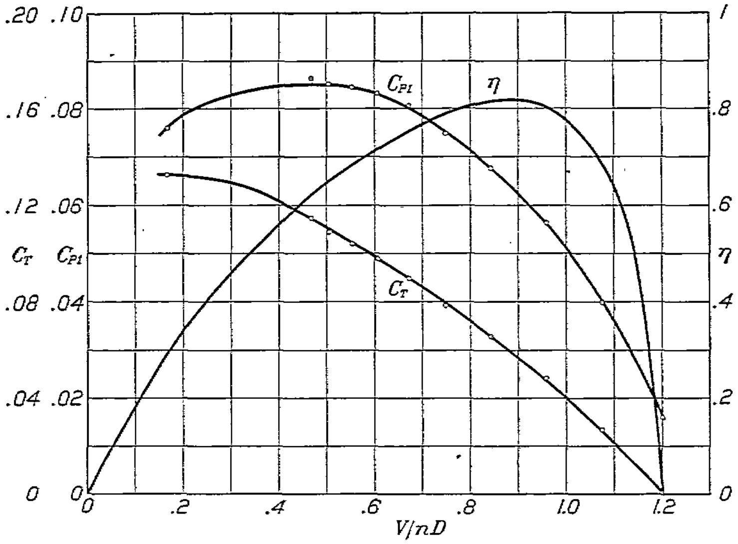

FIG. 20.—Propeller F

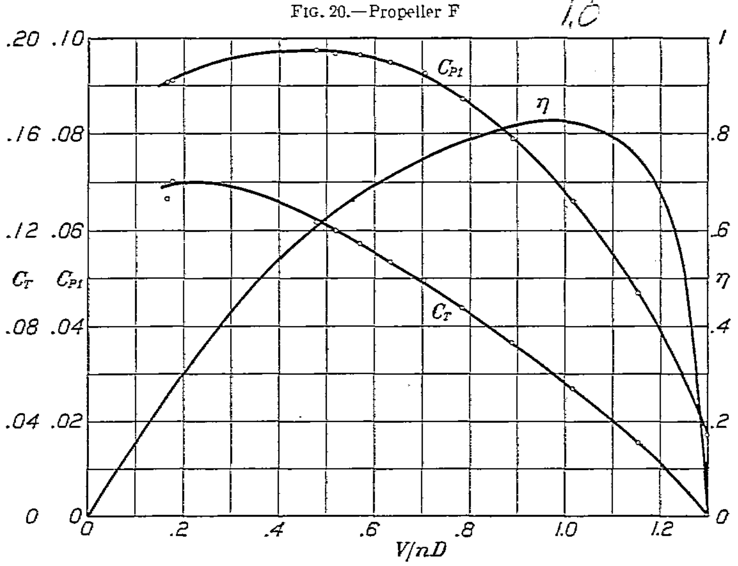

FIG. 21.—Propeller G

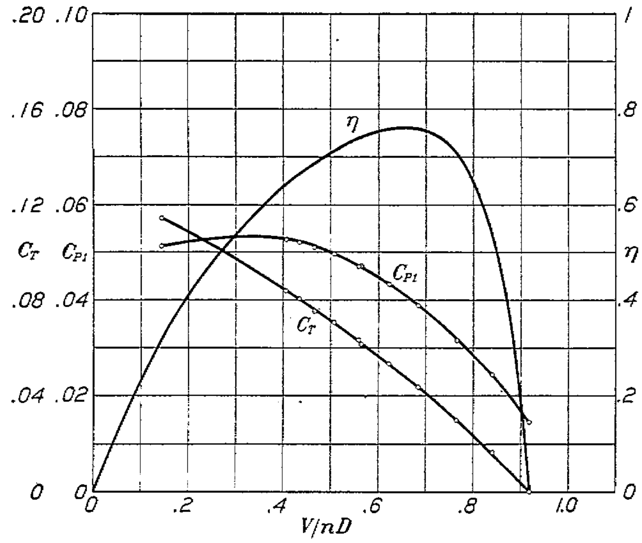

FIG. 22.—Propeller H

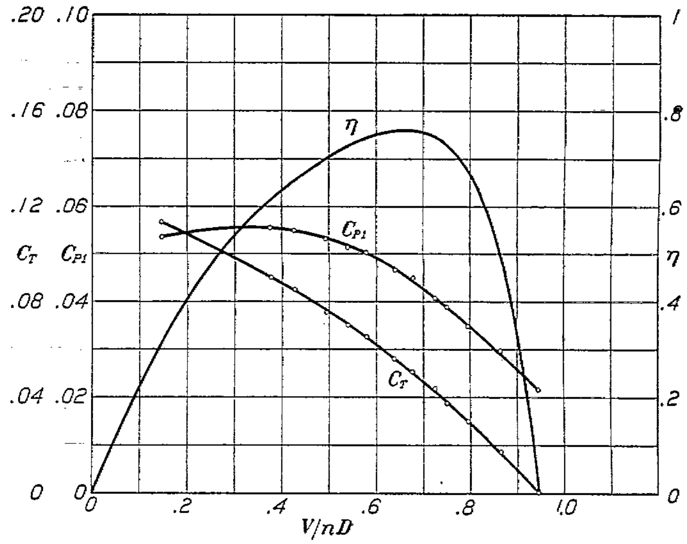

FIG. 23.—Propeller I

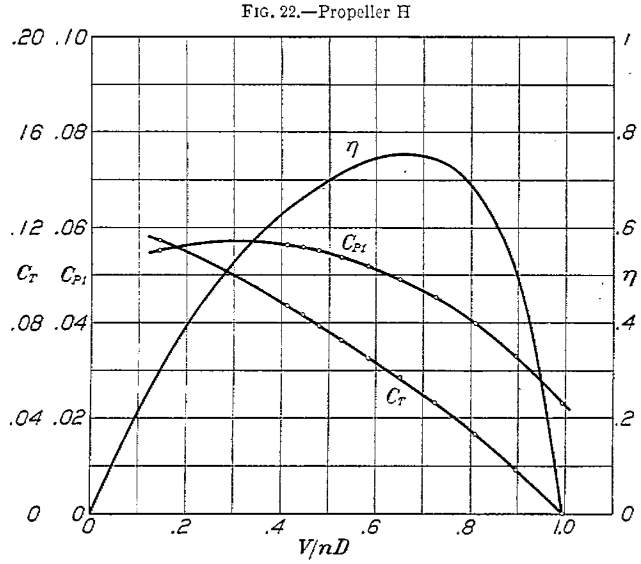

FIG. 24.—Propeller J

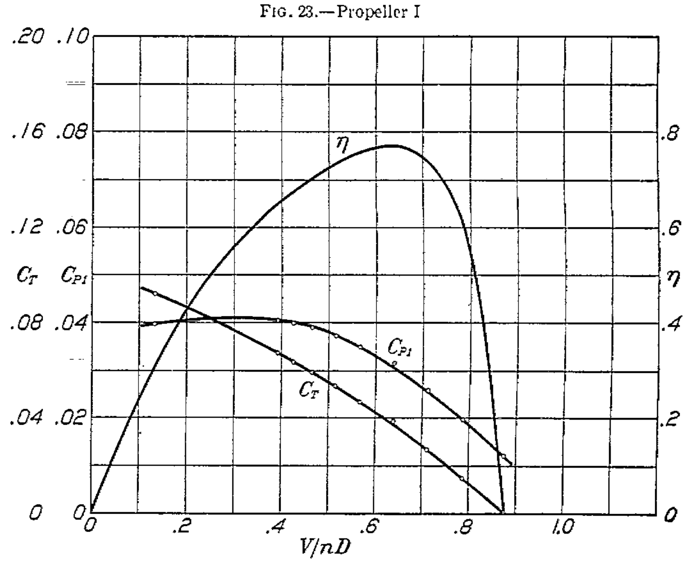

FIG. 25.—Propeller K

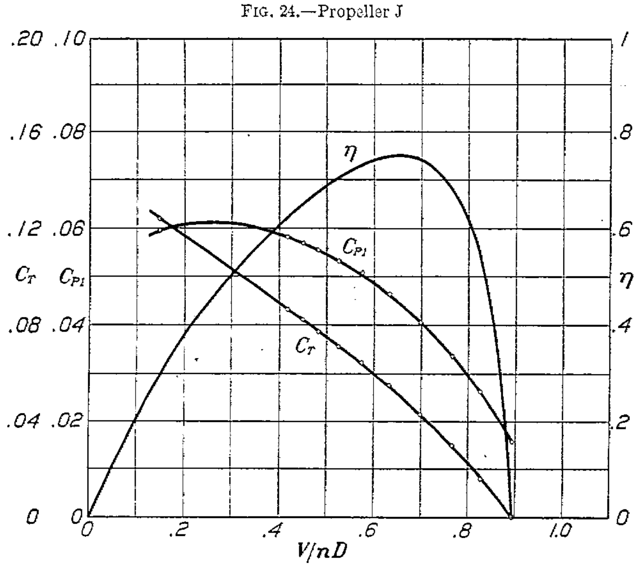

FIG. 26.—Propeller L

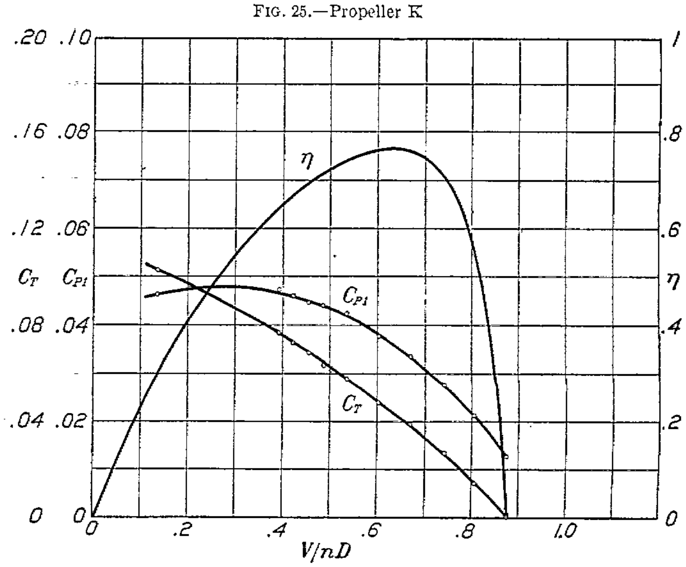

FIG. 27.—Propeller M

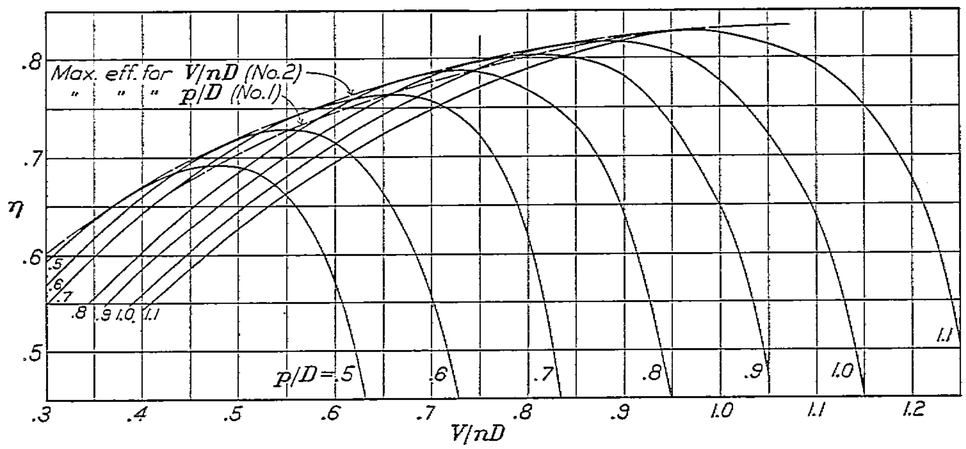

FIG. 28.—Propeller efficiencies for various P/D ratios and V/nD. Based on minimum camber and aspect ratio 6