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REPORT ON TESTS OF METAL MODEL PROPELLERS IN COMBINATION WITH A MODEL VE-7 AIRPLANE

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REPORT ON TESTS OF METAL MODEL PROPELLERS IN COMBINATION WITH A MODEL VE-7 AIRPLANE.

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Summary

This report, prepared at the request of the National Advisory Committee for Aeronautics, describes tests of three metal model propellers, in a free air stream and in front of a model of a VE-7 airplane.

The effect of introducing the model airplane is shown to be an increase in thrust and power coefficients and efficiency at small slip, and a decrease in the same at large slip.

In one of the models, a pressed steel design, the sections near the hub are shown to be relatively unimportant. The thrust and power coefficients of this model are shown to vary widely with constant V/nD but with V and n varying in the same proportion. A wood model of conventional form is shown to have practically constant coefficients under these conditions.

Model Propellers

The three model propellers, which were sent to the Stanford University Laboratory from the Bureau of Aeronautics, U. S. Navy, are shown in Figs. 1, 2, and 3. Fig. 1 shows the model designated as Charles Ward Hall two blade, Fig. 2 the one designated as Charles Ward Hall three blade, and Fig. 3 the model known as the pressed steel design.

As may be seen, the Hall models are made with a cylincrical hub into which loose blades are fastened. Only three blades, numbered 1, 2, and 3, were supplied, numbers 1 and 2 being used for both models and No. 3 for the three blade model only.

The blades of these models are made of aluminum or an aluminum alloy. The blade sections are unusual in that the driving face has a practically constant negative camber of considerable amount.

The pressed steel model has a central steel hub and sheet steel blades fastened thereto with clamps similar to hose clamps. As originally furnished, the blades were entirely covered with fabric, presenting an appearance similar to the portion near the hub, Fig. 3. When entirely covered with fabric they were thus without camber on the driving face. After the fabric was removed, they had about the same negative camber on the driving face as positive camber on the back, the sheet steel of which they were made being approximately uniform in thickness, about 1/16". All models were 3 feet in diameter.

Free Air Stream Tests

The three models were subjected to the usual tests in a free or unobstructed air stream. With a wind speed of about

55 feet per second, the propellers were driven at various angular velocities as required to develop a series of thrusts from zero to about 35 pounds. For greater slip than obtainable under these conditions the wind velocity was reduced.

The pressed steel model was tested under three conditions: first, with the blades completely covered with a cloth fairing; second, with a partial fairing as shown in Fig. 3; and third, with all fairing removed.

The observed and computed data for the free air stream tests are shown in Table I, in which

$\frac{\rho V^2}{2}$ = dynamic pressure of wind stream - pounds per square foot.

ρ = mass density of air - pound, foot, second, units.

V = velocity - feet per second.

n = revolutions per second.

T = thrust - pounds.

Q = torque moment - pound-feet.

D = diameter - feet.

C_T = thrust coefficient = $\frac{T}{\rho n^2 D^4}$.

C_P = power coefficient = $\frac{P}{\rho n^3 D^5}$ where P is power in foot pounds per second.

η = efficiency = $\frac{TV}{P} = \frac{C_T}{C_P}\frac{V}{nD}$.

The coefficients C_T, C_P, and η, as derived in these tests, are shown in Figs. 4 to 8 inclusive. A set of consistent curves, representing what appear to be the laws of variation of these coefficients with V/nD under the conditions of the tests, is drawn for each propeller.

In the tests on the pressed steel model, it appeared that with moderate variations in angular velocity and corresponding variations in wind speed there was considerable variation in the power and thrust coefficients derived. There were run, therefore, three tests, each at approximately constant angular velocity, the observed and computed data for which are given in Table II. The derived coefficients for the three angular velocities are shown in Fig. 9.

For comparison, similar tests were made on a U. S. Navy standard plan form wood model. The results are given in Table III and are shown graphically in Fig. 10.

In addition to being tried in a free air stream, each model was tested in front of a model VE-7 airplane. The model airplane was that used in the tests described in N.A.C.A. Report No. 220 (Reference 1). It was hung from the ceiling of the experiment chamber by fine wires, a drag wire being led forward to a balance outside the tunnel where measurements of drag were made. The model airplane was thus supported independently of the propeller dynamometer.

With the model airplane in the gravity position and the model propeller thrust balance in the null position, the space relation of model airplane and propeller corresponded to that of full scale airplane and propeller in service. The appearance of the model airplane and propeller is shown in Fig. 11. The model propeller here shown is the U. S. Navy standard plan form wood model previously mentioned, an accident having wrecked the model airplane before photographs showing the metal propellers in front of it could be taken.

For the tests in front of the model airplane, observations were made, as in the free air stream tests, of dynamic pressure ($\rho V^2/2$), density (ρ), thrust (T), turning moment (Q), and angular velocity (η). In addition, the drag of the model airplane was observed.

Previous to the tests of the model propellers in front of the model airplane, the resistance of the model airplane alone had been measured for various values of dynamic pressure. The results of these measurements were as follows; each figure given being the average of a number of observations:

$\frac{1}{2}\rho V^2$	Resistance - pounds
1.72	1.57
2.96	2.66
4.68	4.12
5.79	5.04

The preceding data are plotted in Fig. 12. From the curve drawn the resistance of the model alone, at any dynamic pressure, may be determined.

The tests of model propellers in front of the model VE-7 were made at about the same velocities, both angular and translational, as were employed in the free air stream tests. The observed and reduced data for these tests are given in Table IV. Additional notation to that for the free air stream tests is employed as follows:

R_a = augmented resistance of the model airplane as measured during the propeller test - pounds.

R_o = resistance of model airplane alone in a wind stream of equal $\frac{1}{2}\rho V^2$. This is determined from Fig. 12.

A = $R_a - R_o$ = augmentation of model resistance.

T as before, is the shaft thrust, but for the determination of the thrust coefficient C_T, and the efficiency η, the thrust that is credited to the propeller is $T - A$. The coefficients C_T, C_P, and η as derived are shown in Figs. 13 to 17.

Remarks

The performance of the Charles Ward Hall propellers does not seem remarkable. The efficiency realized from the two blade model is about what would be expected of a well designed wood model of the same dynamic pitch. That of the three blade model is considerably lower. The power coefficient for the three blade model is about 47% more than that for the two blade. The thrust coefficient of the three blade is only about 38% more than for the two blade.

By comparison of Fig. 4 with Fig. 13, and Fig. 5 with Fig. 14, it may be seen that the effect of operation in front of the model airplane is as follows:

a. The thrust coefficient is increased at small slip (large V/nD) and decreased at large slip (small V/nD).

b. The power coefficient is increased at small slip and slightly decreased at large slip.

c. The efficiency is decreased over the usual working range (from V/nD for maximum efficiency toward smaller values) but is increased at the larger values of V/nD.

The pressed steel model with complete fairing shows lower thrust and power coefficients and efficiency than when fairing is partially or wholly removed. This difference is at least partly due to the greater dynamic pitch of the model with partial or with no fairing. The lower maximum efficiency of the completely faired model may also be due in part to roughness, the cloth being considerably rougher than the steel.

Comparisons of Figs. 7 and 8 and of 16 and 17 show that the sections near the hub are of little importance, or at least that the difference between blades faired at hub only or not faired at all is small.

Comparisons of Fig. 6 with Fig. 15, Fig. 7 with Fig. 16, and Fig. 8 with Fig. 17, show the same general differences between operation in front of the model airplane and in a free air stream as do comparisons for the Hall propellers. The differences in efficiency, however, appear to be generally less, the propeller when in front of the model airplane attaining practically the same or even slightly greater maximum efficiency as when in a free air stream.

The three tests at various angular velocities indicate that the pressed steel model warped considerably when under load and that the pitch increased with the load. By reference to Fig. 9, it is seen that power and thrust coefficients are greater for the greater angular velocities. Fig. 10 shows that, with a wood model of conventional design, the coefficients are practically independent of the angular velocity.

During some check tests of the pressed steel model in front of the model airplane, a sharp metallic click, as if the metal propeller occasionally struck a loose wire, was heard. The propeller at the time was developing about 35 pounds thrust. The dynamometer was shut down and the apparatus examined. Nothing unusual was discovered, and the test was resumed. Again the click was heard and suddenly one blade of the propeller broke square off near the hub. The broken off piece was thrown upward and through the roof of the tunnel, made of three-quarter inch pine flooring, and landed about 20 feet away. The remaining portion of the model propeller is shown in Fig. 18.

The breaking of the model propeller put the apparatus so out of balance that the dynamometer was thrown from the supporting frame, the shaft housing broken, and the model airplane wrecked.

Reference.

1. Durand, W. F. and Lesley, E. P. : Comparison of Tests on Air Propellers in Flight with Wind Tunnel Model Tests of Similar Forms. N.A.C.A. Technical Report No. 220 - 1926.

Table I.

C. W. Hall Model Propeller

2-Blade

Free Wind Stream

Observed Data

$\rho V^2/2$	ρ	V	n	T	Q	V/nD	C_T	C_P	η
January 27, 1926.									
3.312	.002378	52.78	20.43	.00	.932	.861	.0000	.0243	.000
3.285	.002378	52.56	21.88	1.32	1.372	.801	.0143	.0312	.367
3.330	.002378	52.92	23.76	3.98	1.870	.743	.0274	.0360	.566
3.366	.002378	53.21	25.89	5.29	2.537	.685	.0410	.0411	.683
3.456	.002378	53.91	28.60	8.27	3.340	.628	.0525	.0444	.742
3.528	.002378	54.47	31.31	11.91	4.371	.580	.0631	.0485	.754
3.654	.002378	55.44	34.49	16.21	5.560	.536	.0707	.0508	.746
3.726	.002378	55.98	37.50	21.17	6.858	.498	.0782	.0530	.734
3.726	.002378	55.98	40.64	26.79	8.265	.459	.0842	.0544	.711
3.780	.002377	56.36	43.87	33.08	9.838	.428	.0893	.0556	.687
2.556	.002378	46.37	41.82	33.08	9.134	.370	.0982	.0568	.640
1.044	.002380	29.62	39.10	33.08	7.978	.253	.1122	.0567	.501
.378	.002381	17.82	37.56	33.08	7.095	.158	.1216	.0546	.352

Table I.

C. W. Hall Model Propeller

3-Blade

Free Wind Stream

Observed Data

$\rho V^2/2$	ρ	V	n	T	Q	V/nD	C_T	C_P	η
January 27, 1926.									
3.240	.002390	52.07	20.03	.00	1.323	.867	.0000	.0357	.000
3.258	.002390	52.21	21.25	1.32	1.785	.819	.0151	.0427	.289
3.276	.002389	52.37	22.64	2.98	2.327	.771	.0300	.0491	.472
3.303	.002389	52.58	24.38	5.29	3.070	.719	.0460	.0559	.591
3.420	.002389	53.51	26.52	8.27	3.987	.673	.0607	.0613	.667
3.456	.002385	53.83	28.81	11.91	5.050	.623	.0743	.0659	.702
3.654	.002383	55.38	31.53	16.21	6.361	.586	.0845	.0694	.713
3.726	.002383	55.92	34.06	21.17	7.818	.547	.0945	.0731	.707
3.744	.002383	56.06	36.56	26.79	9.304	.511	.1038	.0755	.703
3.798	.002384	56.45	39.17	33.08	11.033	.480	.1116	.0780	.687
3.249	.002384	52.21	42.43	44.10	13.567	.410	.1268	.0817	.636
2.682	.002384	47.44	41.51	44.10	13.164	.381	.1325	.0828	.610
1.251	.002383	32.40	38.89	44.10	11.859	.278	.1510	.0850	.494
.522	.002383	20.93	37.19	44.10	10.828	.188	.1651	.0848	.366

Table I.

Model Pressed Steel Propeller

Complete Fairing

Free Wind Stream

Observed Data

$\rho V^2/2$	ρ	V	n	T	Q	V/nD	C_T	C_P	η
September 26, 1925.									
3.249	.002346	52.63	20.05	.00	.340	.875	.0000	.0093	.000
3.320	.002346	53.20	21.83	1.40	.861	.812	.0155	.0199	.631
3.356	.002341	53.55	24.15	3.14	1.512	.739	.0284	.0286	.734
3.447	.002341	54.27	26.62	5.58	2.351	.680	.0415	.0366	.772
3.546	.002341	55.04	29.55	8.72	3.385	.621	.0527	.0428	.764
3.509	.002336	54.81	32.36	12.56	4.607	.565	.0634	.0487	.736
3.555	.002332	55.21	35.71	17.10	5.938	.516	.0710	.0516	.710
3.644	.002332	55.91	38.95	22.33	7.494	.479	.0779	.0547	.682
3.815	.002332	57.20	42.53	28.27	9.192	.448	.0827	.0563	.658
3.838	.002331	57.39	46.14	34.90	11.140	.415	.0868	.0580	.621
3.307	.002327	53.31	45.70	34.90	11.040	.389	.0887	.0587	.588
2.218	.002328	43.65	44.48	34.90	10.830	.326	.0935	.0608	.501
1.498	.002330	35.86	43.85	34.90	10.950	.273	.0961	.0631	.416
.364	.002330	17.68	42.80	34.90	12.130	.138	.1009	.0734	.190

Table I

Model Pressed Steel Propeller
Partial Fairing
Free Wind Stream
Observed Data

$\rho V^2/2$	ρ	V	n	T	Q	V/nD	C_T	C_P	η
			October 26, 1925.						
3.469	.002321	54.67	31.09	12.56	4.709	.586	.0691	.0543	.746
3.496	.002321	54.88	34.04	17.10	6.040	.538	.0785	.0581	.727
3.527	.002321	55.11	37.12	22.33	7.652	.495	.0862	.0618	.690
3.680	.002314	56.39	40.48	28.27	9.375	.464	.0920	.0639	.668
3.721	.002314	56.70	43.73	34.90	11.370	.432	.0974	.0664	.633
2.475	.002316	46.23	42.54	34.90	10.910	.362	.1028	.0673	.553
1.638	.002316	37.61	41.75	34.90	10.970	.300	.1067	.0702	.456
.374	.002318	17.96	40.51	34.90	11.850	.148	.1133	.0805	.208
			November 9, 1925.						
3.226	.002341	52.49	19.61	.00	.398	.892	.0000	.0114	.000
3.262	.002341	52.79	20.59	.70	.680	.855	.0087	.0177	.421
3.240	.002341	52.61	21.25	1.40	.919	.825	.0164	.0225	.601
3.289	.002341	53.01	22.12	2.21	1.208	.799	.0238	.0273	.697
3.303	.002341	53.12	22.99	3.14	1.526	.770	.0313	.0319	.756
3.307	.002341	53.15	23.87	4.30	1.931	.742	.0398	.0374	.790
3.329	.002341	53.33	25.18	5.58	2.358	.706	.0464	.0411	.797
3.338	.002340	53.42	26.52	6.98	2.835	.671	.0524	.0445	.790
3.379	.002340	53.74	27.89	8.72	3.407	.642	.0592	.0484	.785
3.406	.002340	53.95	29.22	10.47	3.927	.615	.0647	.0508	.783
3.469	.002339	54.46	30.84	12.56	4.680	.589	.0697	.0544	.755
3.527	.002339	54.91	33.85	17.10	6.047	.541	.0788	.0583	.731
			November 10, 1925.						
3.329	.002374	52.96	19.84	.00	.470	.890	.0000	.0130	.000
3.347	.002369	53.16	20.71	.70	.694	.856	.0085	.0177	.411
3.374	.002369	53.37	21.47	1.40	.940	.829	.0158	.0223	.588
3.388	.002364	53.54	22.27	2.21	1.230	.801	.0233	.0271	.688
3.415	.002364	53.75	23.18	3.14	1.562	.773	.0305	.0318	.741
3.451	.002364	54.03	24.32	4.30	1.989	.741	.0380	.0368	.764
3.465	.002364	54.14	25.43	5.58	2.430	.710	.0451	.0411	.778
3.487	.002358	54.39	26.64	6.98	2.893	.681	.0515	.0447	.784
3.523	.002358	54.67	28.06	8.72	3.457	.650	.0580	.0481	.783
3.564	.002358	54.98	29.41	10.47	4.000	.623	.0634	.0507	.779
3.604	.002358	55.29	31.01	12.56	4.745	.594	.0684	.0541	.751
3.631	.002357	55.51	33.88	17.10	6.083	.546	.0780	.0581	.733
3.802	.002357	56.80	37.09	22.33	7.645	.510	.0850	.0609	.712

Table I.

Model Pressed Steel Propeller

No Fairing

Free Wind Stream

Observed Data

$\rho V^2/2$	ρ	V	n	T	Q	V/nD	C_T	C_P	η
November 10, 1925.									
3.442	.002360	54.01	20.17	.00	.463	.893	.0000	.0125	.000
3.384	.002353	53.63	20.78	.70	.687	.860	.0085	.0175	.418
3.388	.002353	53.66	21.52	1.40	.926	.831	.0159	.0220	.599
3.420	.002353	53.91	22.35	2.21	1.215	.804	.0232	.0267	.699
3.438	.002353	54.06	23.16	3.15	1.512	.778	.0308	.0310	.773
3.460	.002353	54.23	24.29	4.30	1.960	.744	.0382	.0365	.779
3.478	.002353	54.37	25.42	5.58	2.409	.713	.0453	.0410	.788
3.510	.002354	54.61	26.64	6.98	2.886	.683	.0516	.0447	.788
3.546	.002354	54.88	28.03	8.72	3.457	.653	.0582	.0483	.787
3.591	.002354	55.23	29.39	10.47	4.072	.627	.0636	.0518	.769
3.627	.002354	55.51	30.85	12.56	4.745	.600	.0692	.0548	.758
3.627	.002354	55.51	33.72	17.10	6.068	.549	.0789	.0586	.739
3.703	.002354	56.09	36.77	22.33	7.589	.509	.0866	.0616	.716
3.843	.002354	57.14	40.01	28.27	9.397	.476	.0926	.0645	.683
3.861	.002354	57.27	43.08	34.90	11.260	.443	.0986	.0666	.656
2.610	.002357	47.06	42.12	34.90	10.990	.372	.1030	.0679	.564
1.138	.002359	31.06	40.74	34.90	11.280	.254	.1100	.0745	.375
.391	.002364	18.19	39.79	34.90	11.930	.152	.1151	.0824	.212

Table II.

Model Pressed Steel Propeller
Complete Fairing
Free Wind Stream
Observed Data

September 22, 1925.

$\rho V^2/2$	ρ	V	n	T	Q	V/nD	C_T	C_P
			High Speed - (approx. 43.0 r.p.s.)					
.405	.002304	18.75	42.83	34.89	12.093	.146	.1019	.0740
1.296	.002300	33.57	42.70	33.26	10.314	.262	.0979	.0636
1.710	.002295	38.60	42.95	32.68	9.967	.300	.0953	.0609
2.016	.002294	41.92	42.53	31.70	9.482	.329	.0943	.0591
2.322	.002293	45.00	42.86	31.72	9.576	.350	.0930	.0588
2.853	.002288	49.94	43.25	31.19	9.554	.385	.0900	.0577
3.537	.002288	55.60	43.42	29.77	9.460	.427	.0852	.0567
4.104	.002281	59.98	43.19	28.26	9.242	.463	.0820	.0562
4.797	.002279	64.88	43.62	27.17	9.206	.496	.0774	.0549
5.436	.002279	69.07	42.67	23.73	8.440	.540	.0706	.0526
6.066	.002275	73.03	43.06	23.02	8.360	.566	.0674	.0512
6.732	.002274	76.95	43.55	22.14	8.289	.589	.0634	.0497
7.668	.002273	82.15	43.68	20.00	7.869	.627	.0569	.0469
8.532	.002271	86.68	42.93	16.74	6.871	.673	.0494	.0424
			Intermediate Speed - (approx. 35.5 r.p.s.)					
.261	.002304	15.05	35.04	23.26	7.429	.143	.1015	.0679
1.143	.002300	31.50	35.67	22.35	6.517	.294	.0943	.0576
1.557	.002295	36.83	35.71	21.49	6.336	.344	.0906	.0560
1.854	.002294	40.20	35.52	20.58	6.155	.377	.0878	.0550
2.151	.002393	43.31	35.59	20.05	6.155	.406	.0852	.0548
2.691	.002288	48.50	35.19	18.16	5.837	.459	.0791	.0533
3.393	.002288	54.46	35.94	17.47	5.866	.505	.0730	.0513
3.924	.002281	58.65	35.74	15.72	5.627	.547	.0666	.0499
4.527	.002279	63.03	35.52	13.84	5.251	.592	.0594	.0472
5.121	.002275	67.10	35.30	12.09	4.832	.634	.0527	.0441
5.805	.002275	71.44	35.15	10.24	4.362	.678	.0450	.0401
6.390	.002274	74.97	35.59	9.61	4.217	.702	.0412	.0379
7.515	.002273	81.32	35.71	7.33	3.559	.759	.0312	.0317
8.145	.002271	84.69	35.43	5.70	3.009	.797	.0247	.0273
			Low Speed - (approx. 25.1 r.p.s.)					
.144	.002304	11.18	25.10	11.63	3.443	.148	.0989	.0613
1.008	.002296	29.63	24.35	9.72	2.893	.406	.0813	.0507
1.431	.002295	35.31	25.08	8.49	2.669	.469	.0726	.0478
1.746	.002294	39.02	25.14	7.70	2.539	.517	.0656	.0455
2.025	.002293	42.03	25.02	6.93	2.459	.560	.0596	.0443
2.556	.002288	47.27	24.90	5.49	2.126	.633	.0478	.0388
3.168	.002288	52.62	25.11	4.26	1.815	.699	.0365	.0325
3.735	.002281	57.23	25.09	3.02	1.490	.760	.0260	.0268
4.347	.002279	61.76	25.84	2.37	1.360	.797	.0192	.0231
4.923	.002276	65.77	25.49	.79	.825	.860	.0066	.0144

Table III.

Model Propeller I - 178

Free Wind Stream

Observed Data

November 1, 1925.

$\rho V^2/2$	ρ	V	n	T	Q	V/nD	C_T	C_P
			High Speed - (approx. 45.8 r.p.s.)					
.504	.002321	20.84	45.77	46.52	10.097	.152	.1181	.0537
1.800	.002316	39.42	45.71	40.94	10.336	.287	.1044	.0552
2.079	.002312	42.41	45.83	40.05	10.416	.308	.1018	.0554
2.493	.002310	46.46	45.75	38.61	10.394	.339	.0986	.0556
3.717	.002309	56.74	45.87	35.12	10.314	.412	.0892	.0549
5.040	.002303	66.16	46.24	32.03	10.192	.477	.0803	.0535
6.444	.002300	74.85	45.89	27.98	9.612	.544	.0713	.0513
8.127	.002298	84.10	45.86	23.80	9.034	.611	.0608	.0483
9.216	.002293	89.65	45.69	21.09	8.521	.654	.0544	.0460
			Intermediate Speed - (approx. 39.5 r.p.s.)					
.369	.002321	17.83	39.58	34.89	7.617	.150	.1184	.0541
1.683	.002317	38.11	39.35	29.07	7.689	.323	.1000	.0554
1.971	.002312	41.29	39.51	28.52	7.754	.348	.0979	.0555
2.367	.002310	45.27	39.74	27.56	7.820	.380	.0933	.0554
3.645	.002309	56.19	39.47	23.61	7.502	.475	.0810	.0539
4.986	.002303	65.80	39.61	20.23	7.176	.554	.0691	.0513
6.309	.002300	74.07	39.20	16.82	6.466	.630	.0588	.0473
7.992	.002294	83.47	39.38	13.26	5.808	.707	.0460	.0422
9.072	.002293	88.84	39.57	11.07	5.309	.749	.0381	.0382
			Low Speed - (approx. 32.6 r.p.s.)					
.270	.002321	15.25	32.50	23.26	5.013	.156	.1171	.0529
1.557	.002317	36.66	32.64	18.82	5.266	.374	.0941	.0551
1.845	.002311	39.96	32.85	18.25	5.316	.406	.0904	.0551
2.259	.002310	44.22	32.91	17.21	5.237	.448	.0849	.0541
3.573	.002309	55.63	32.59	13.47	4.832	.569	.0678	.0509
4.824	.002303	64.72	32.57	10.51	4.267	.662	.0531	.0452
6.138	.002300	73.05	32.36	7.60	3.646	.753	.0390	.0391
7.839	.002294	82.67	32.55	4.37	2.835	.847	.0222	.0302
8.937	.002293	88.29	32.58	2.05	2.228	.904	.0104	.0237

Table IV.

C. W. Hall Model Propeller

2-Blade

Model VE-7

Observed Data

$\rho V^2/2$	ρ	V	n	R_a	R_o	A	T	T-A	Q	V/nD	C_T	C_P	η
					October 6, 1925								
3.138	.002322	51.99	18.41	2.89	2.82	.07	.00	-.07	.672	.941	-.0011	.0221	-.047
3.181	.002322	52.34	20.45	3.07	2.85	.22	1.40	1.18	1.164	.853	.0151	.0310	.414
3.199	.002317	52.55	22.38	3.30	2.87	.43	3.14	2.71	1.750	.783	.0288	.0390	.579
3.225	.002317	52.76	22.43	3.37	2.89	.48	3.14	2.66	1.743	.784	.0283	.0387	.573
3.243	.002317	52.90	24.91	3.56	2.91	.65	5.58	4.93	2.459	.708	.0424	.0442	.679
3.269	.002313	53.16	27.75	3.92	2.93	.99	8.72	7.73	3.298	.639	.0536	.0479	.715
3.321	.002313	53.59	30.90	4.36	2.98	1.38	12.56	11.18	4.332	.578	.0625	.0507	.712
3.339	.002312	53.74	33.89	4.81	2.99	1.82	17.10	15.28	5.511	.529	.0710	.0536	.700
3.400	.002312	54.23	37.36	5.37	3.04	2.33	22.33	20.00	6.837	.484	.0764	.0547	.676
3.549	.002307	55.46	41.08	6.07	3.17	2.90	28.27	25.37	8.356	.450	.0804	.0555	.652
3.618	.002303	56.05	44.35	6.73	3.23	3.50	34.90	31.40	9.910	.421	.0855	.0565	.637
2.482	.002303	46.42	42.72	5.67	2.25	3.42	34.90	31.48	9.300	.362	.0924	.0572	.585
1.329	.002310	33.92	40.93	4.61	1.22	3.39	34.90	31.51	8.440	.276	.1004	.0564	.492
.218	.002311	13.73	38.81	3.57	.20	3.37	34.90	31.53	6.986	.118	.1118	.0519	.254

Table IV

C. W. Hall Model Propeller

3-Blade

Model VE-7

Observed Data

$\rho V^3/2$	ρ	V	n	R_a	R_o	A	T	T-A	Q	V/nD	C_T	C_P	η
October 6, 1925.													
3.234	.002303	52.99	18.84	2.98	2.90	.08	.00	-0.08	1.099	.938	-.0012	.0348	-.032
3.243	.002303	53.07	20.13	3.16	2.91	.25	1.40	1.15	1.569	.879	.0152	.0435	.307
3.243	.002303	53.07	21.65	3.36	2.91	.45	3.14	2.69	2.119	.817	.0308	.0507	.496
3.269	.002303	53.28	23.59	3.64	2.93	.71	5.58	4.87	2.900	.753	.0469	.0585	.604
3.269	.002303	53.28	25.71	3.97	2.93	1.04	8.72	7.68	3.833	.691	.0623	.0651	.661
3.330	.002303	53.78	28.03	4.37	3.03	1.34	12.56	11.22	4.925	.640	.0765	.0704	.696
3.374	.002303	54.13	30.78	4.85	3.02	1.83	17.10	15.27	6.227	.586	.0864	.0738	.686
3.427	.002303	54.55	33.47	5.32	3.07	2.35	22.33	20.08	7.644	.543	.0961	.0766	.681
3.435	.002303	54.61	36.28	5.85	3.07	2.78	28.27	25.49	9.301	.502	.1038	.0793	.657
3.627	.002303	56.12	39.49	6.69	3.24	3.45	34.90	31.45	11.220	.474	.1081	.0808	.634
3.750	.002303	57.06	43.81	7.87	3.34	4.53	46.53	42.00	14.120	.434	.1173	.0826	.616
2.596	.002303	47.48	42.16	6.74	2.34	4.40	46.53	42.23	13.340	.375	.1271	.0842	.566
1.311	.002306	33.72	40.04	5.50	1.20	4.30	46.53	42.23	12.160	.281	.1410	.0850	.456
.306	.002306	16.29	37.91	4.41	.28	4.13	46.53	42.40	10.570	.143	.1579	.0824	.274

Table IV.

Model Pressed Steel Propeller

Complete Fairing

Model VE-7

October 2, 1925.

$\rho V^2/2$	ρ	V	n	R_a	R_o	A	T	T-A	Q	V/nD	C_T	C_P	η
3.042	.002309	51.33	18.64	2.80	2.73	.07	.00	-.07	.217	.918	-.0011	.0071	-.139
3.059	.002308	51.48	20.44	2.92	2.75	.17	1.40	1.23	.731	.839	.0157	.0196	.674
3.094	.002306	51.79	22.53	3.15	2.78	.37	3.14	2.77	1.324	.766	.0292	.0292	.766
3.151	.002306	52.27	25.27	3.44	2.83	.61	5.58	4.97	2.134	.690	.0417	.0375	.767
3.216	.002305	52.82	28.31	3.80	2.89	.81	8.72	7.91	3.139	.622	.0528	.0439	.748
3.243	.002300	53.10	31.53	4.09	2.91	1.18	12.56	11.38	4.340	.561	.0614	.0491	.702
3.299	.002300	53.56	34.70	4.56	2.96	1.50	17.10	15.60	5.598	.514	.0695	.0523	.683
3.452	.002300	54.79	38.35	5.17	3.09	2.08	23.33	20.25	7.096	.476	.0739	.0542	.649
3.478	.002300	54.99	41.59	5.74	3.11	2.63	28.27	25.64	8.688	.441	.0796	.0565	.621
3.531	.002299	55.42	45.36	6.42	3.16	3.26	34.90	31.64	10.680	.407	.0826	.0584	.576
2.390	.002300	45.59	44.28	5.40	2.17	3.23	34.90	31.67	10.630	.343	.0867	.0609	.488
.328	.002300	16.89	42.25	3.67	.30	3.37	34.90	31.53	12.150	.133	.0948	.0765	.165

Table IV.

Model Pressed Steel Propeller
Complete Fairing
Model VE-7

$\rho V^2/2$	ρ	V	n	R_a	R_o	A	T	T-A	Q	V/nD	C_T	C_P	η
					October 13, 1925.								
2.989	.002323	50.73	18.34	2.71	2.69	.02	.00	-.02	.210	.922	-.0003	.0069	-.042
3.007	.002323	50.88	20.20	2.85	2.70	.15	1.40	1.25	.760	.840	.0163	.0207	.661
3.015	.002319	50.99	22.29	3.06	2.71	.35	3.14	2.79	1.367	.763	.0299	.0307	.743
3.094	.002317	51.67	24.98	3.34	2.78	.56	5.58	5.02	2.134	.690	.0429	.0382	.774
3.138	.002317	52.04	28.06	3.69	2.81	.88	8.72	7.84	3.132	.618	.0530	.0444	.738
3.208	.002313	52.66	31.23	4.13	2.88	1.25	12.56	11.31	4.311	.562	.0619	.0494	.704
3.321	.002313	53.59	34.70	4.63	2.98	1.65	17.10	15.45	5.613	.515	.0685	.0521	.677
3.347	.002313	53.79	38.03	5.15	3.00	2.15	22.33	20.18	6.972	.472	.0745	.0539	.653
3.417	.002312	54.36	41.45	5.70	3.06	2.64	28.27	25.63	8.622	.437	.0796	.0561	.621
3.461	.002311	54.73	45.11	6.37	3.09	3.28	34.90	31.62	10.540	.404	.0830	.0579	.579
					October 20, 1925.								
3.103	.002292	52.03	18.85	2.90	2.79	.11	.00	-.11	.231	.920	-.0017	.0073	-.210
3.164	.002287	52.60	20.76	3.03	2.84	.19	1.40	1.21	.760	.845	.0152	.0199	.644
3.208	.002287	52.96	22.92	3.21	2.87	.34	3.14	2.80	1.360	.770	.0288	.0293	.756
3.557	.002286	55.78	45.55	6.53	3.17	3.36	34.90	31.54	10.630	.408	.0821	.0579	.578
2.395	.002286	45.77	44.42	5.50	2.17	3.33	34.90	31.57	10.550	.344	.0864	.0605	.491
1.119	.002287	31.28	43.16	4.43	1.03	3.40	34.90	31.50	11.050	.242	.0913	.0668	.331
.315	.002287	16.60	42.09	3.73	.29	3.44	34.90	31.46	11.930	.131	.0959	.0761	.165

Table IV.

Pressed Steel Propeller
Partial Fairing
Model VE-7

$1/2\rho V^2$	ρ	V	n	R_a	R_o	A	T	T-A	Q	V/nD	C_T	C_P	η
					November 5, 1925.								
2.727	.002394	47.73	16.74	2.42	2.46	-.04	.00	.04	.282	.950	.0007	.0109	.064
2.736	.002394	47.81	17.69	2.47	2.47	.00	.70	.70	.506	.901	.0115	.0175	.594
2.753	.002390	48.00	18.67	2.57	2.48	.09	1.40	1.31	.731	.857	.0194	.0227	.732
2.762	.002390	48.08	19.65	2.69	2.49	.20	2.21	2.01	1.027	.816	.0269	.0288	.761
2.806	.002390	48.46	20.67	2.80	2.53	.27	3.14	2.87	1.360	.782	.0347	.0344	.788
2.849	.002385	48.88	21.82	2.96	2.57	.39	4.30	3.91	1.722	.747	.0425	.0392	.810
2.867	.002385	49.03	23.10	3.07	2.58	.49	5.58	5.09	2.120	.708	.0494	.0431	.811
2.876	.002380	49.16	24.63	3.26	2.59	.67	7.21	6.54	2.655	.665	.0559	.0475	.783
2.884	.002378	49.25	25.93	3.39	2.60	.79	8.72	7.93	3.104	.633	.0612	.0502	.772
2.911	.002378	49.48	27.52	3.60	2.62	.98	10.70	9.72	3.733	.599	.0666	.0536	.745
3.050	.002374	50.69	29.08	3.89	2.74	1.15	12.56	11.41	4.291	.581	.0702	.0553	.731
3.251	.002374	52.33	32.39	4.44	2.92	1.52	17.10	15.58	5.665	.539	.0772	.0588	.708
3.295	.002373	52.69	35.70	4.94	2.95	1.99	22.33	20.34	7.082	.492	.0830	.0605	.675
3.321	.002373	52.90	38.91	5.50	2.98	2.52	28.27	25.75	8.782	.453	.0885	.0632	.634
3.374	.002373	53.31	42.11	6.10	3.02	3.08	34.90	31.82	10.650	.422	.0934	.0654	.603
2.272	.002374	43.75	41.28	5.15	2.04	3.11	34.90	31.79	10.670	.353	.0970	.0682	.502
					November 3, 1925.								
.961	.002351	28.59	40.45	4.19	.88	3.31	34.90	31.59	11.180	.236	.1014	.0751	.319
.332	.002352	16.80	39.49	3.63	.31	3.32	34.90	31.58	11.860	.142	.1063	.0836	.181

Table IV.

Pressed Steel Propeller
No Fairing
Model VE-7

November 12, 1925.

$\rho V^2/2$	ρ	V	n	R_a	R_o	A	T	T-A	Q	V/nD	C_T	C_P	η
3.217	.002352	52.30	18.12	2.89	2.89	.00	.00	.00	.362	.962	.0000	.0121	.000
3.221	.002352	52.33	19.00	2.95	2.89	.06	.70	.64	.600	.918	.0093	.0183	.467
3.217	.002351	52.31	19.78	3.03	2.89	.14	1.40	1.26	.825	.882	.0169	.0232	.643
3.212	.002351	52.27	20.78	3.12	2.88	.24	2.21	1.97	1.085	.839	.0240	.0276	.728
3.225	.002348	52.41	21.62	3.21	2.89	.32	3.14	2.82	1.403	.808	.0317	.0331	.774
3.221	.002346	52.40	22.85	3.30	2.89	.41	4.30	3.89	1.794	.764	.0392	.0379	.790
3.247	.002346	52.61	23.98	3.46	2.91	.55	5.58	5.03	2.198	.731	.0460	.0421	.799
3.286	.002346	52.93	25.27	3.63	2.94	.69	6.98	6.29	2.669	.698	.0518	.0461	.785
3.321	.002346	53.21	26.78	3.84	2.98	.86	8.72	7.86	3.211	.662	.0577	.0494	.773
3.334	.002346	53.32	28.00	3.98	2.99	.99	10.47	9.48	3.725	.635	.0636	.0524	.771
3.321	.002346	53.21	29.47	4.20	2.98	1.22	12.56	11.34	4.362	.602	.0687	.0554	.747
3.431	.002345	54.09	32.70	4.75	3.07	1.68	17.10	15.42	5.685	.551	.0759	.0586	.714
3.496	.002346	54.60	35.87	5.25	3.13	2.12	22.33	20.21	7.110	.507	.0827	.0609	.688
3.496	.002346	54.60	39.07	5.85	3.13	2.72	28.27	25.55	8.810	.466	.0881	.0636	.645
3.527	.002351	54.78	42.29	6.44	3.15	3.29	34.90	31.61	10.730	.432	.0928	.0660	.607
2.434	.002352	45.49	41.43	5.53	2.20	3.33	34.90	31.57	10.640	.366	.0965	.0681	.519
1.036	.002353	29.67	40.36	4.54	.95	3.59	34.90	31.31	11.100	.245	.1008	.0749	.330

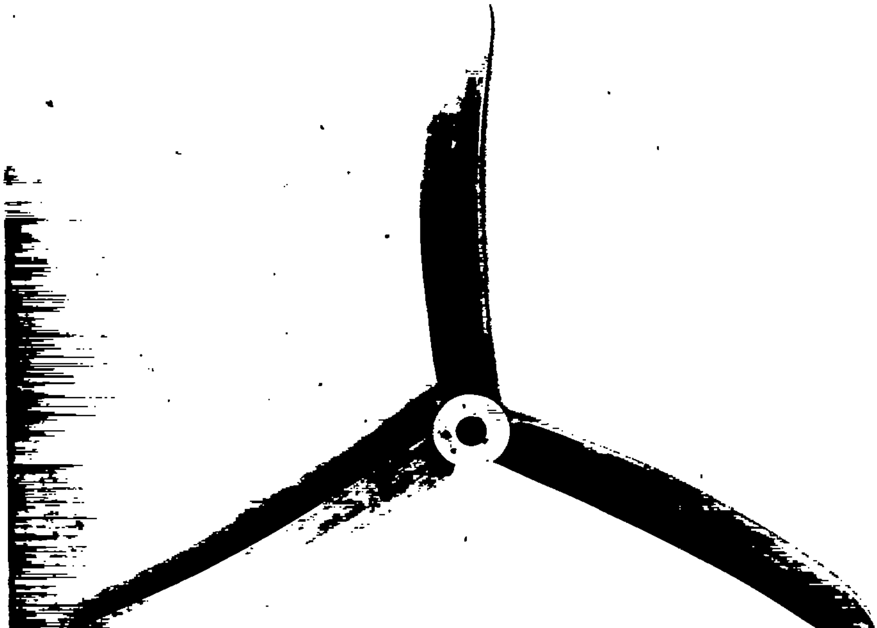


Fig. 2

Fig. 1

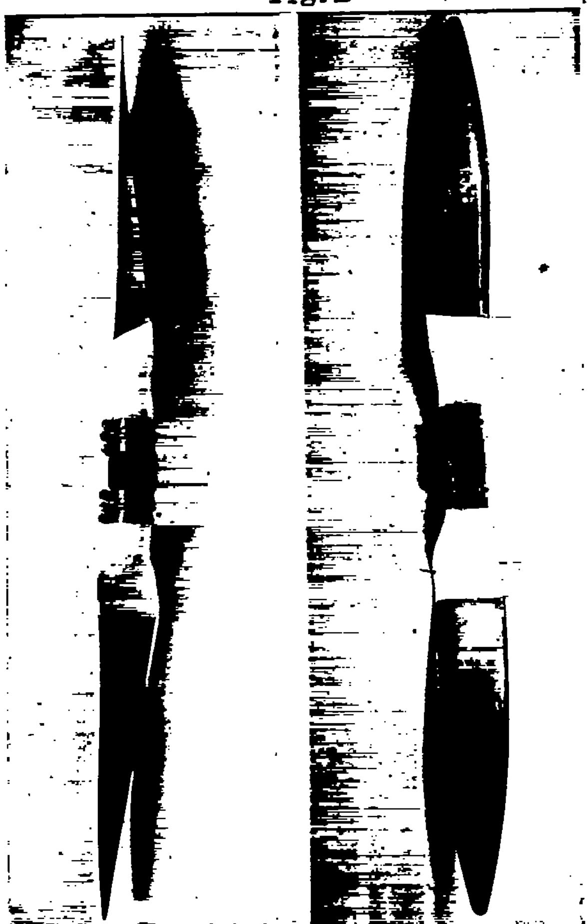


Fig. 3

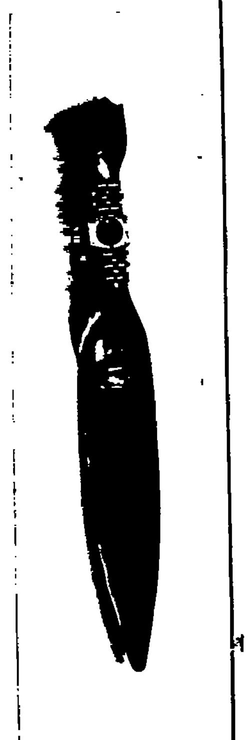


Fig. 18

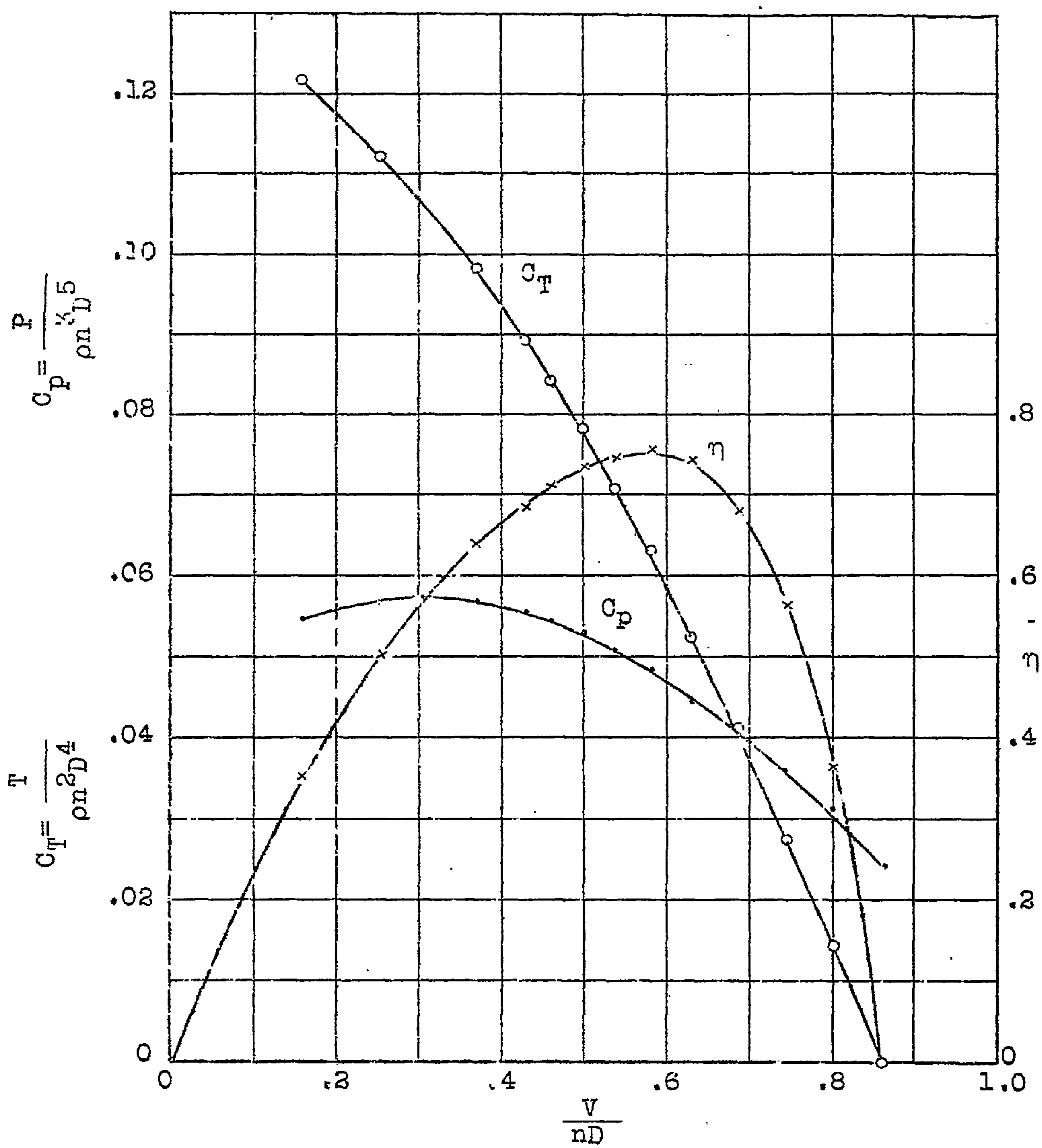


Fig.4 C.W.Hall model propeller. Two blade. Free wind stream.

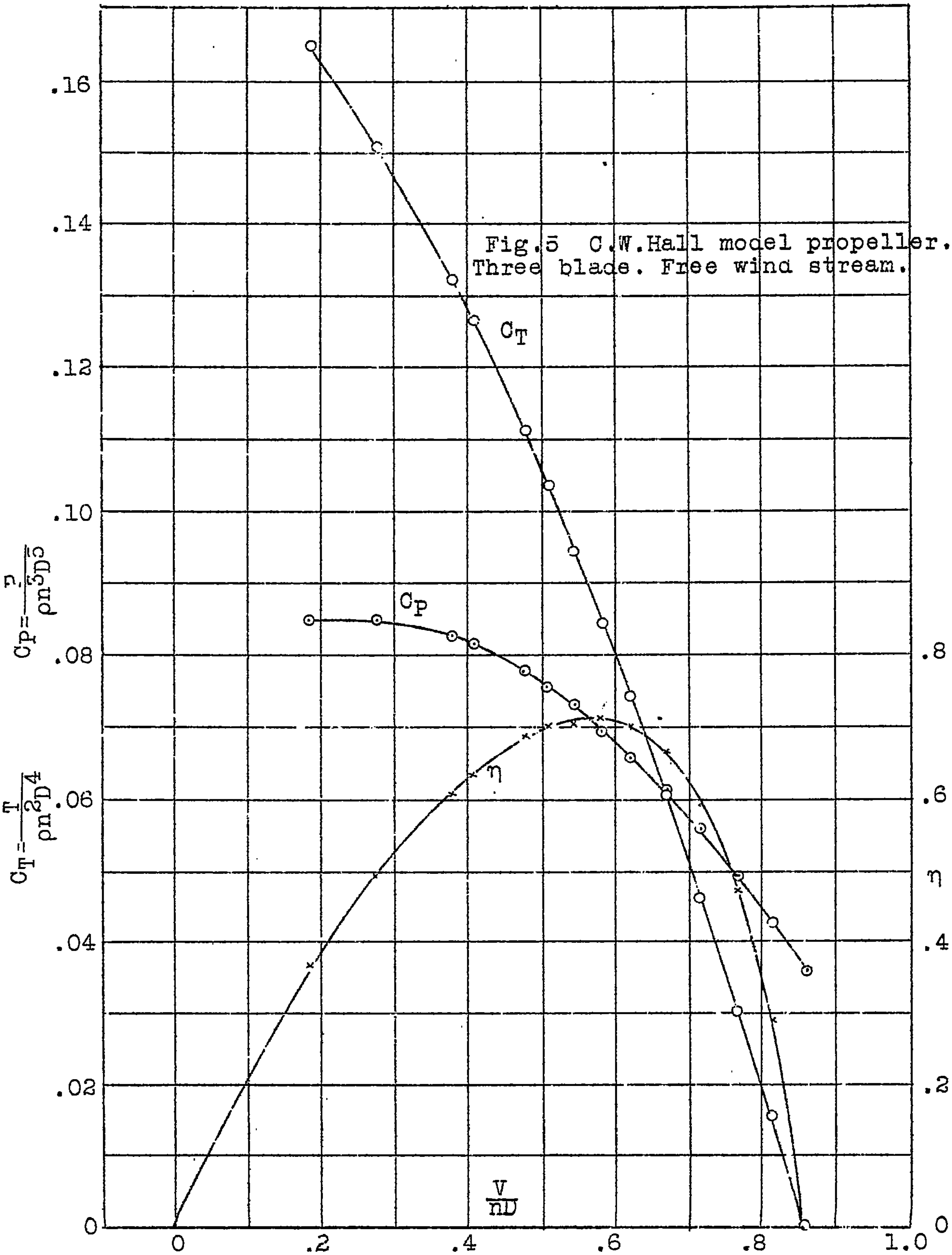


Fig.5 C.W.Hall model propeller.
Three blade. Free wind stream.
C_T
C_P
η
$C_P = \frac{P}{\rho n^3 D^5}$
$C_T = \frac{T}{\rho n^2 D^4}$
$\frac{V}{nD}$
.16
.14
.12
.10
.08
.06
.04
.02
0
.2
.4
.6
.8
1.0
η

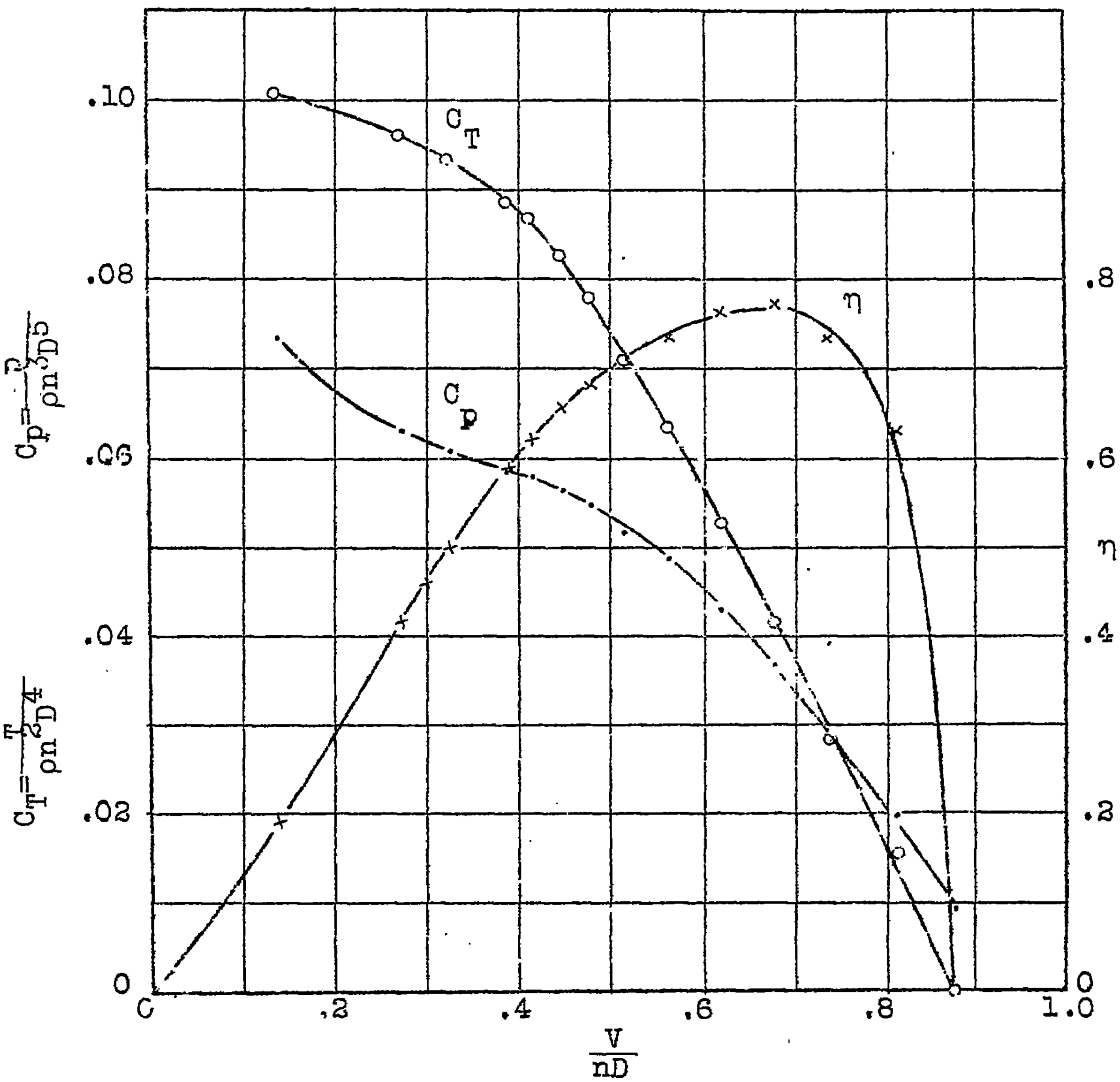


Fig.6 Model pressed steel propeller. Complete fairing. Free wind stream.

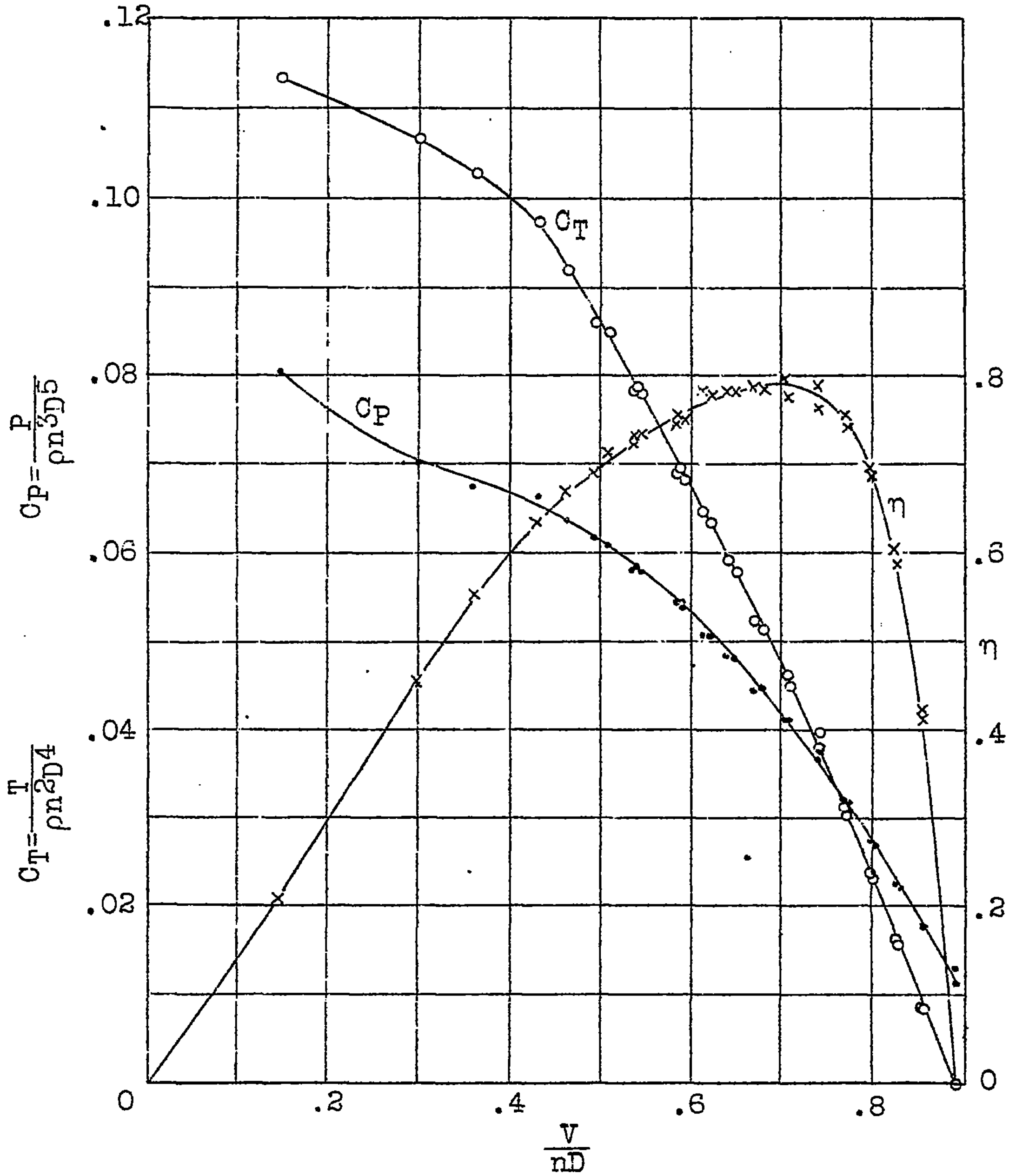


Fig.7 Model pressed steel propeller.
Partial fairing. Free wind stream.

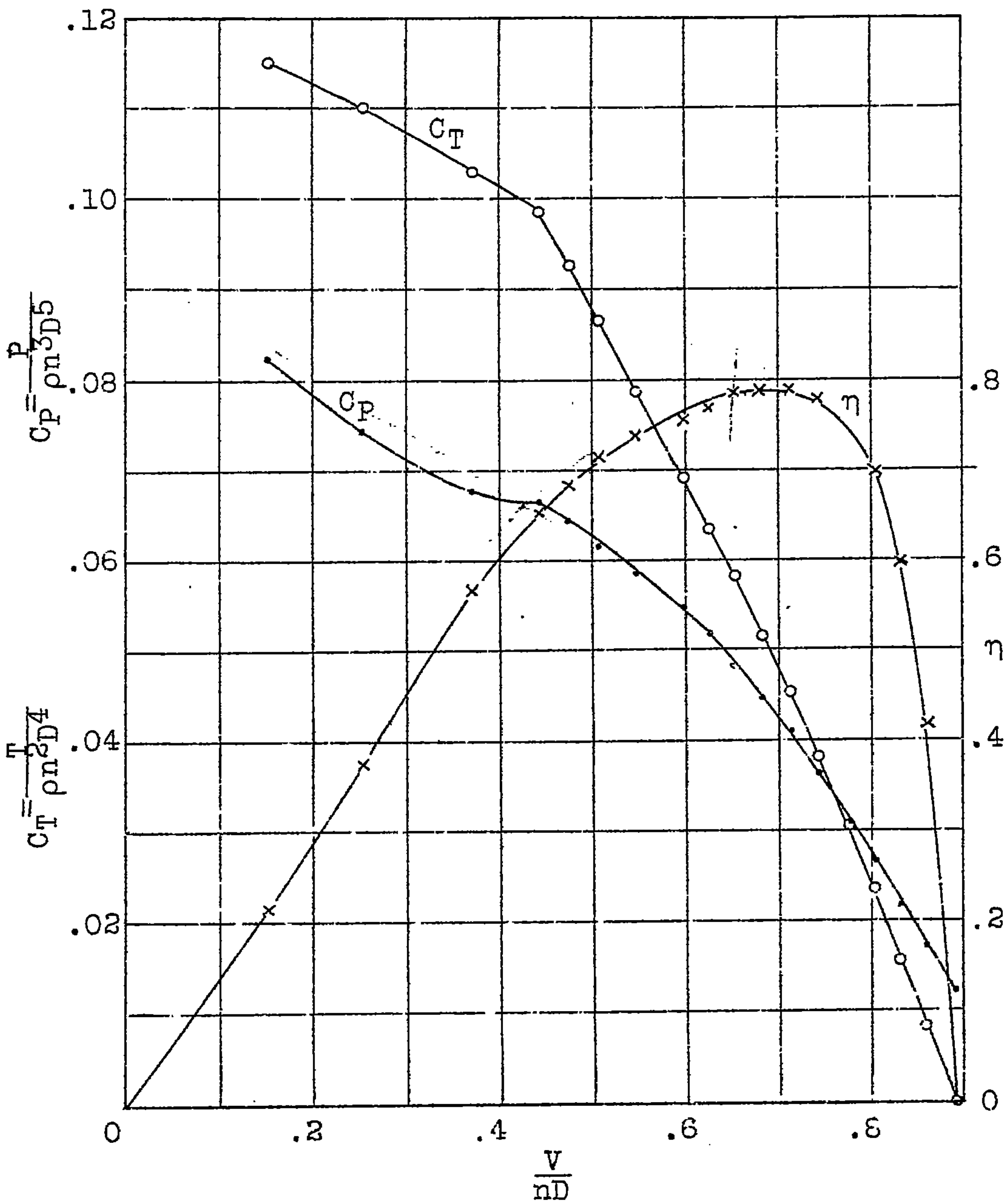


Fig.8 Model pressed steel propeller.
No fairing. Free wind stream.

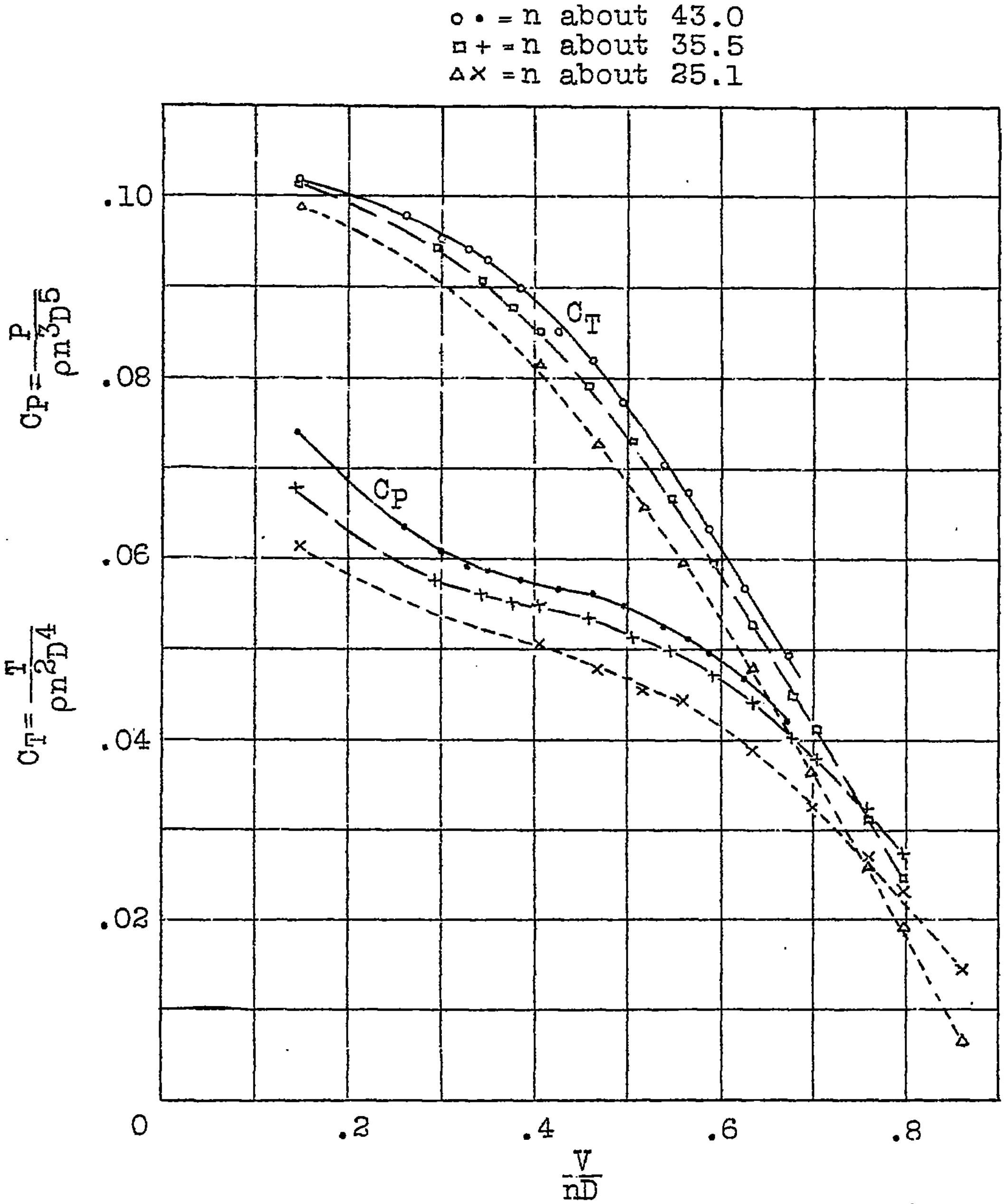


Fig.9 Model pressed steel propeller.
Complete fairing. Free wind stream.

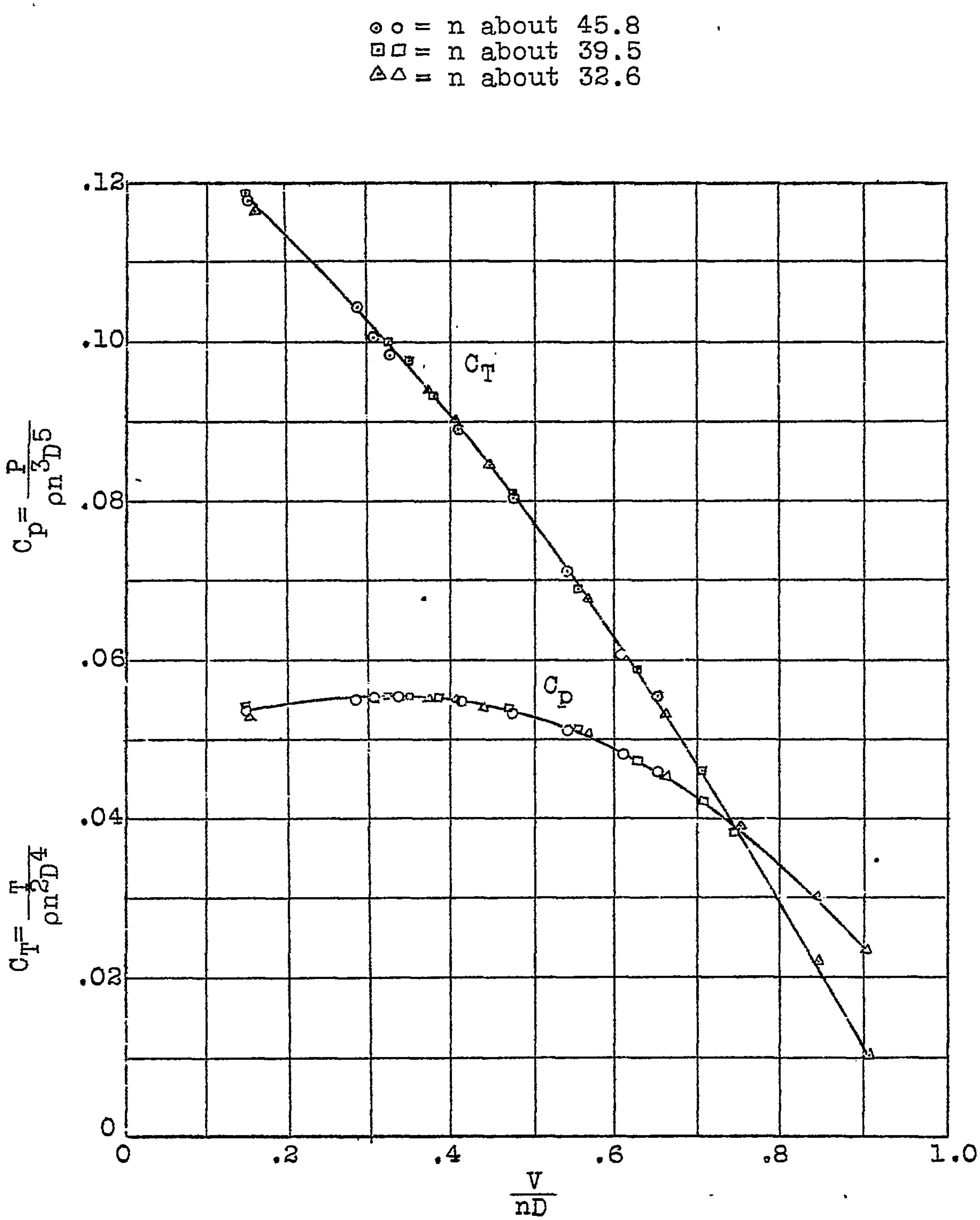


Fig.10 Model propeller I-178.

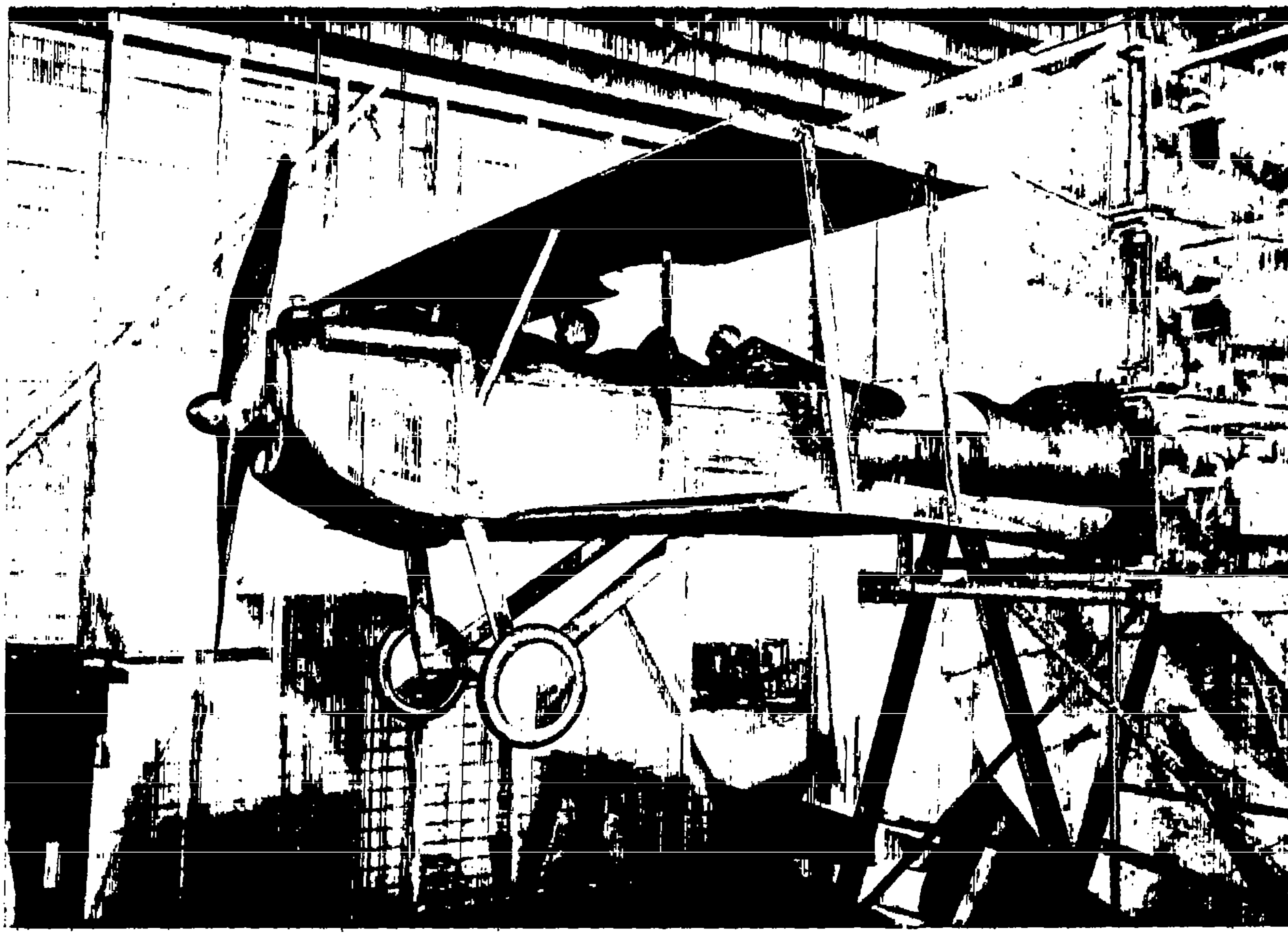


Fig. 11

2798 A.S.

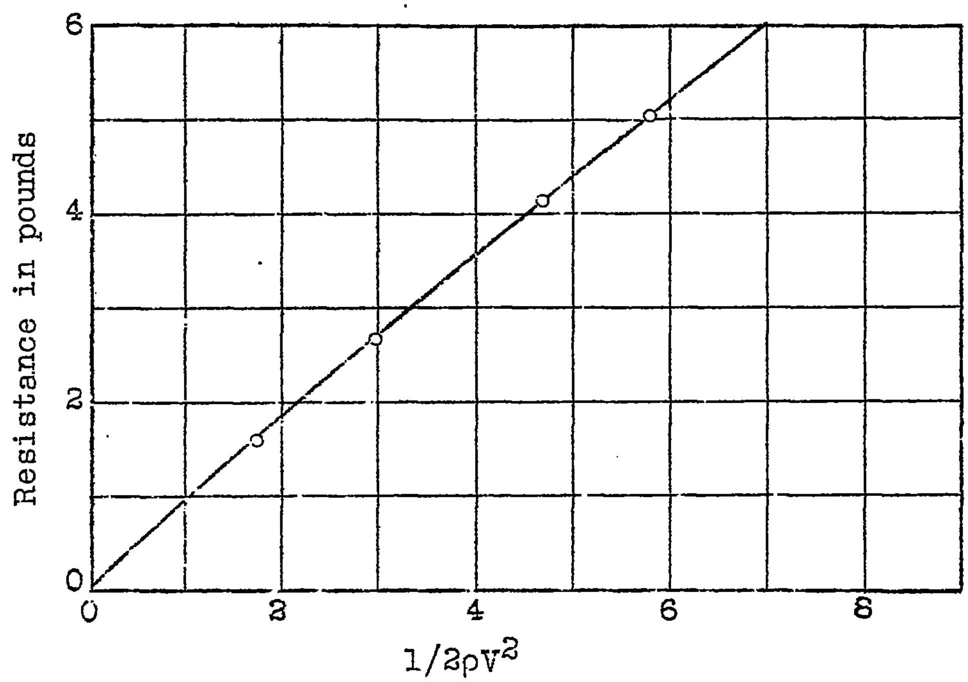


Fig.12 Resistance of model V.E.7.

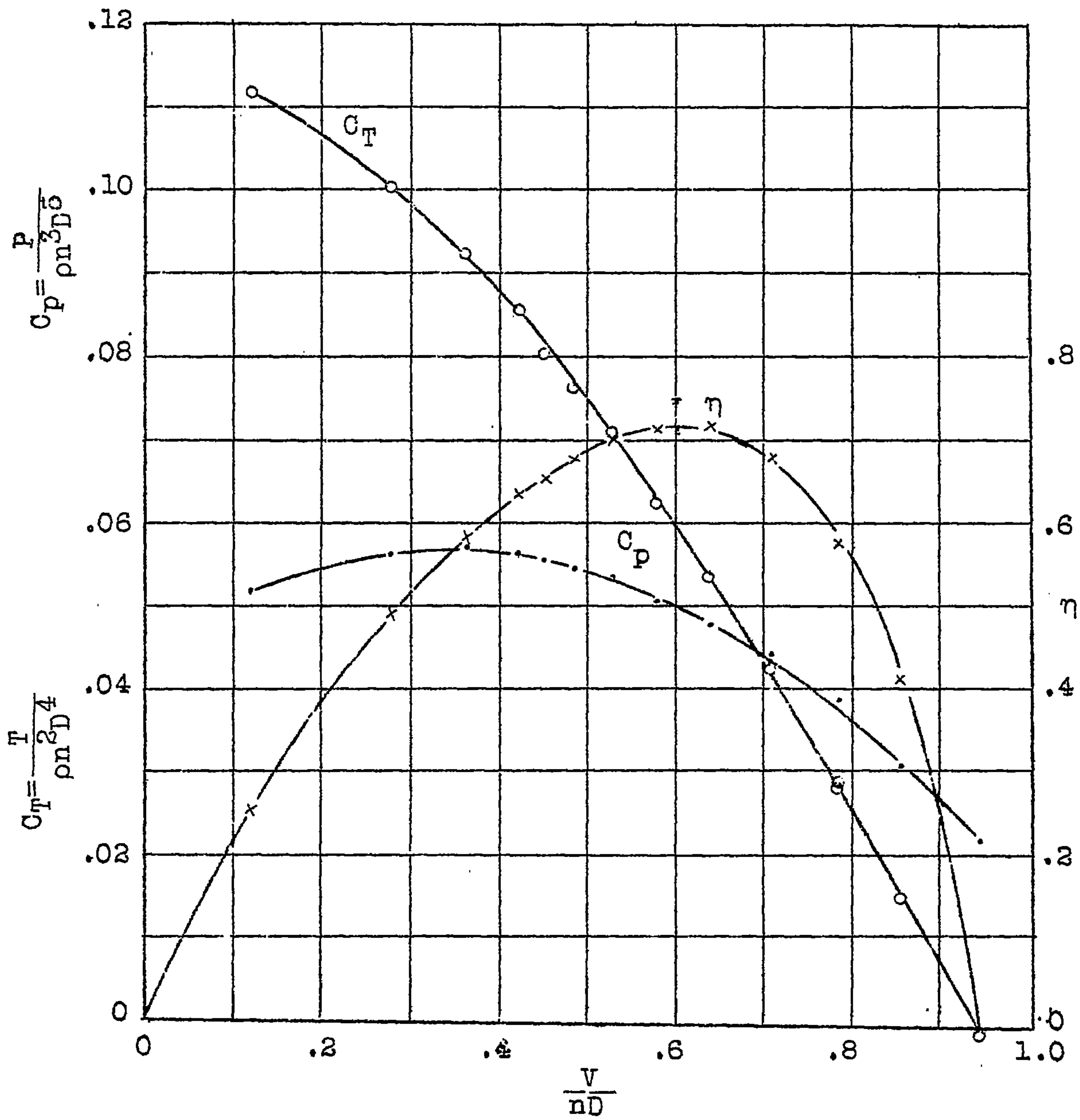
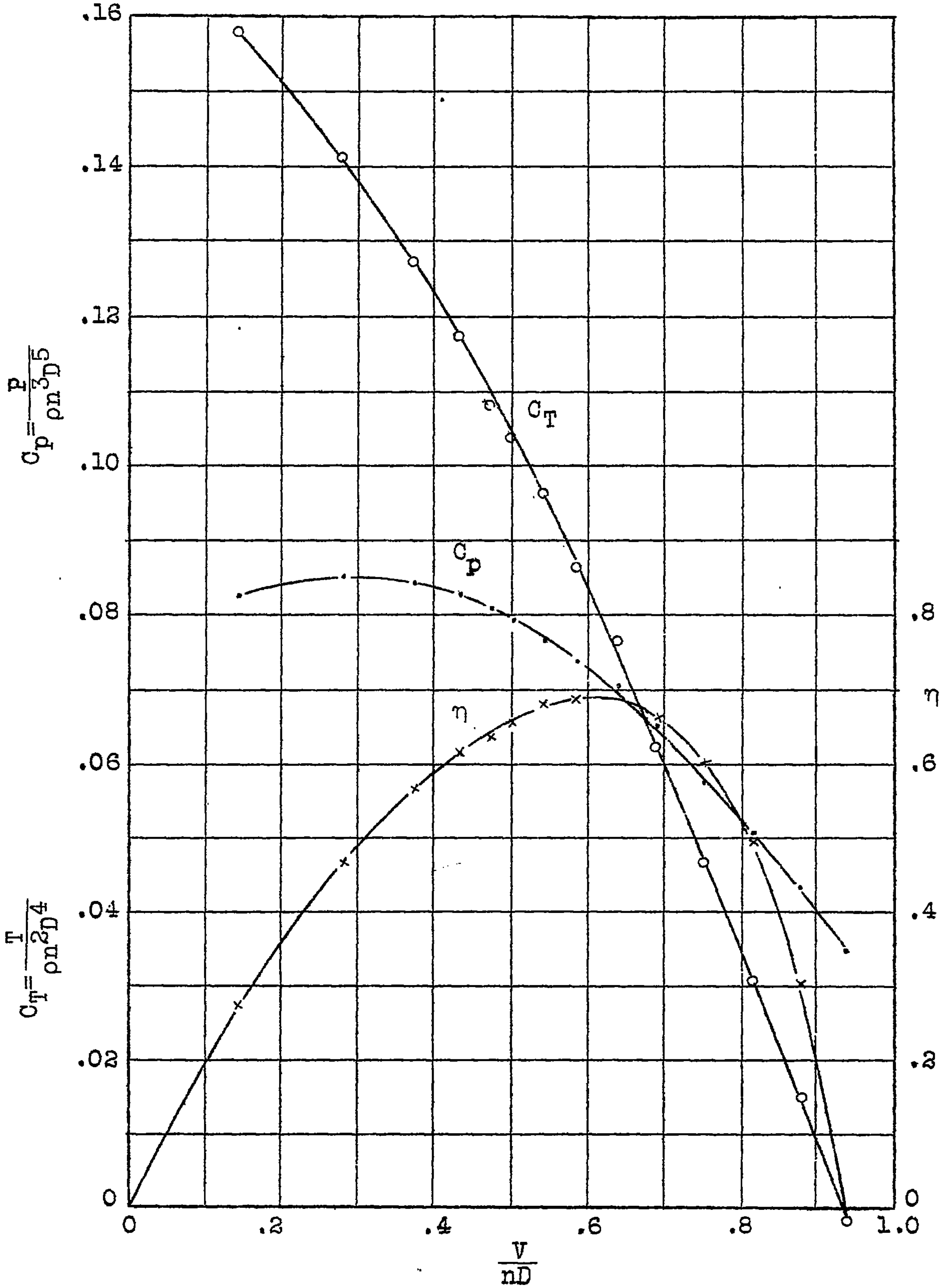


Fig.13 C.W.Hall model propeller. Two blade. With model V.E.7.



V.E.7.

Fig.14 C.W.Hall model propeller. Three blade. With model

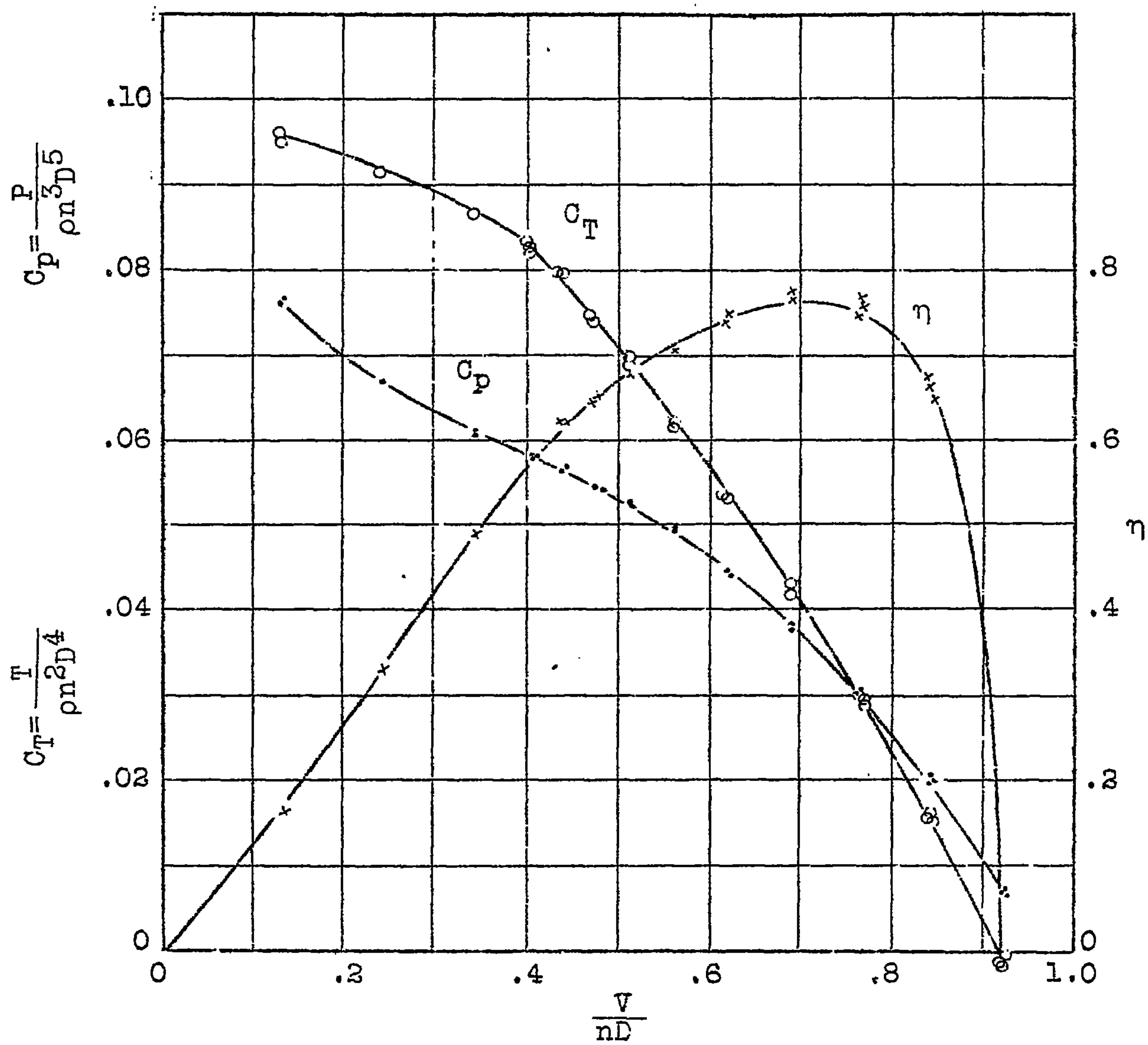


Fig.15 Model pressed steel propeller. Complete fairing. With model V.E.7.

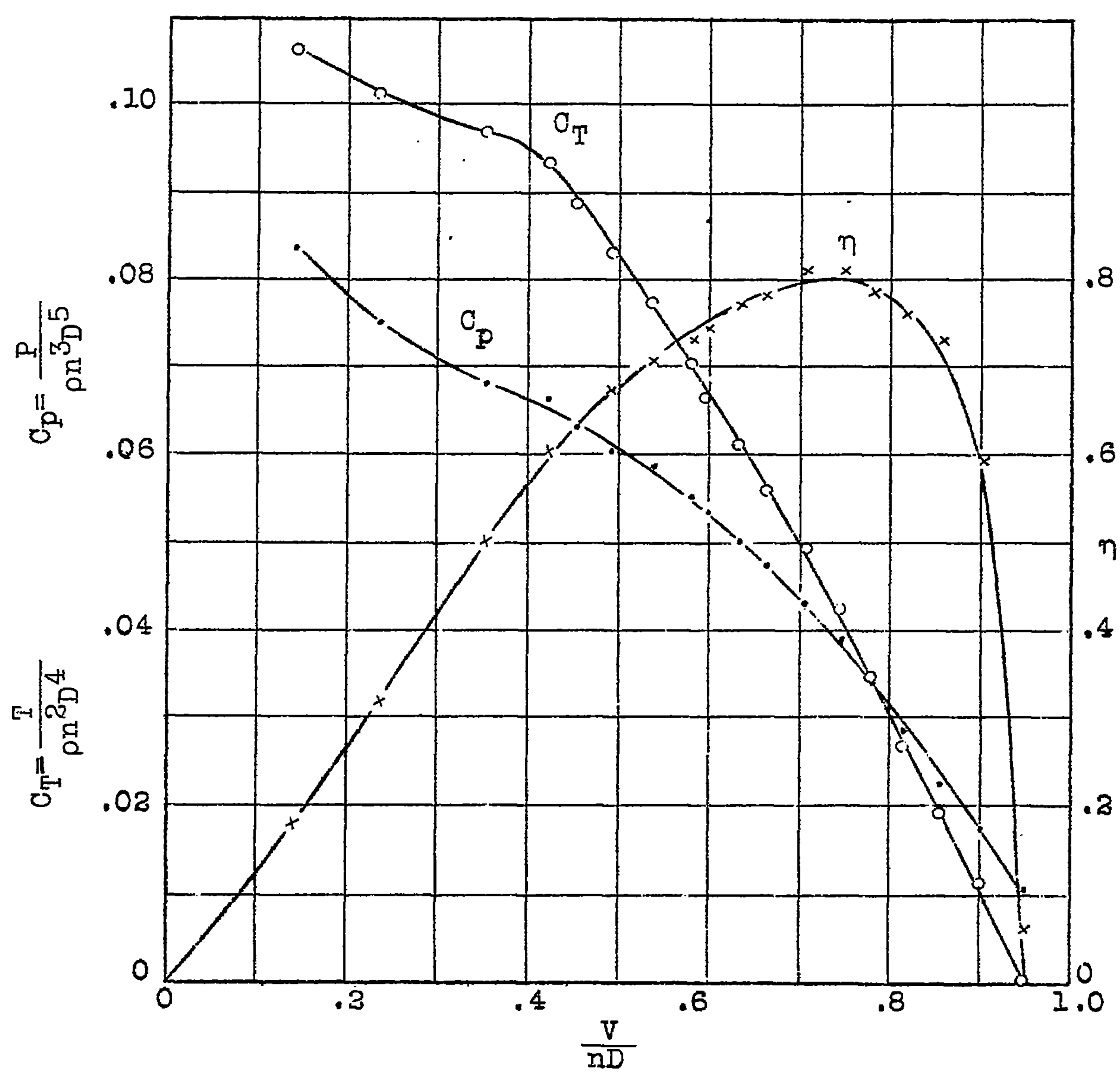


Fig.16 Model pressed steel propeller. Partial fairing. With model V.E.7.

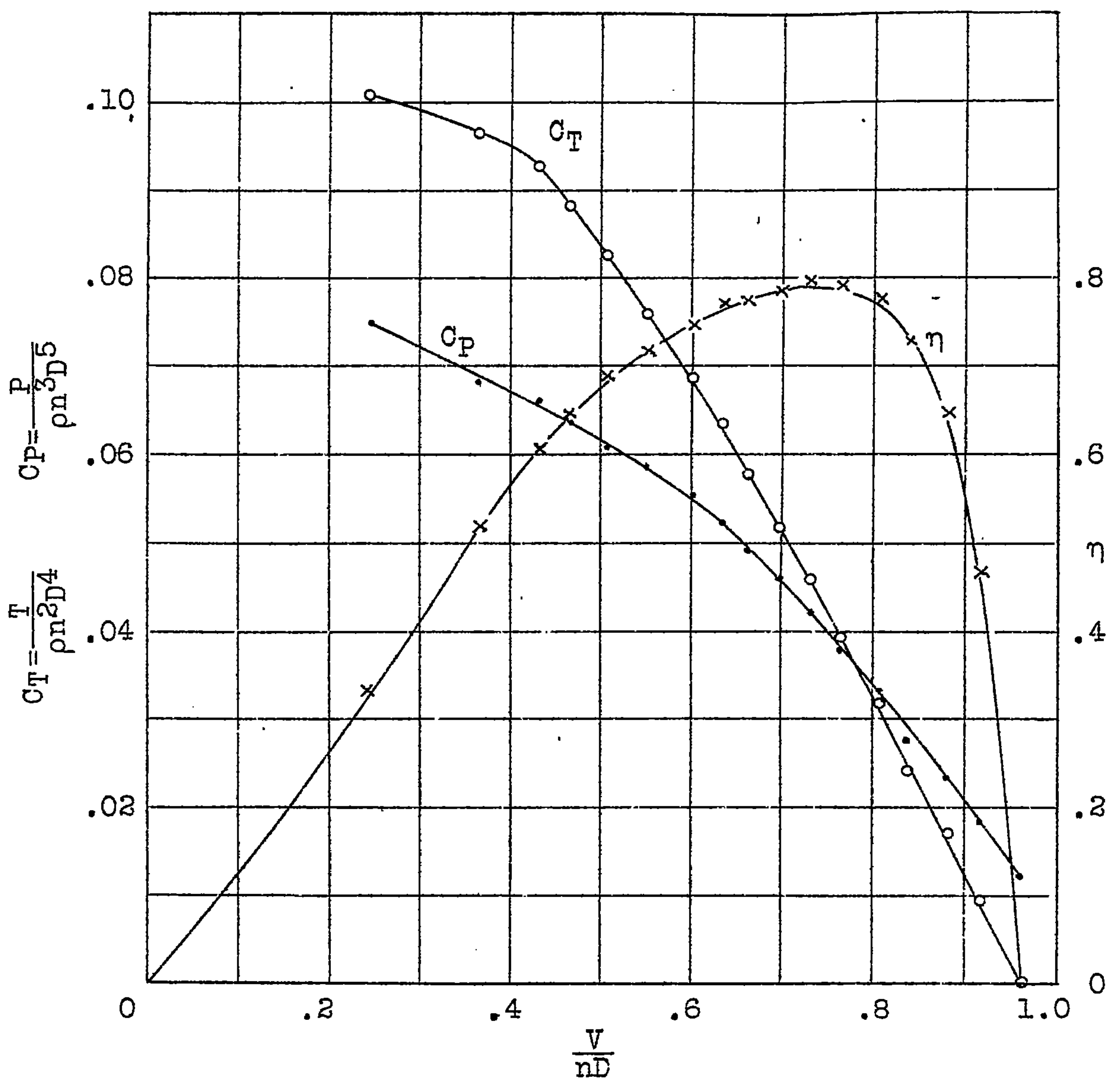


Fig.17 Model pressed steel propeller.
No fairing. With model V.E.7.