REPORT No. 113

TESTS ON AIR PROPELLERS IN YAW

By W. F. DURAND and E. P. LESLEY
Leland Stanford Junior University

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This report was prepared by W. F. Durand and E. P. Lesley, for the National Advisory Committee for Aeronautics and contains the results of tests to determine the thrust (pull) and torque characteristics of air propellers in movement relative to the air in a line oblique to the line of the shaft, and specifically when such angle of obliquity is large, as in the case of helicopter flight with the propeller serving for both sustentation and traction.

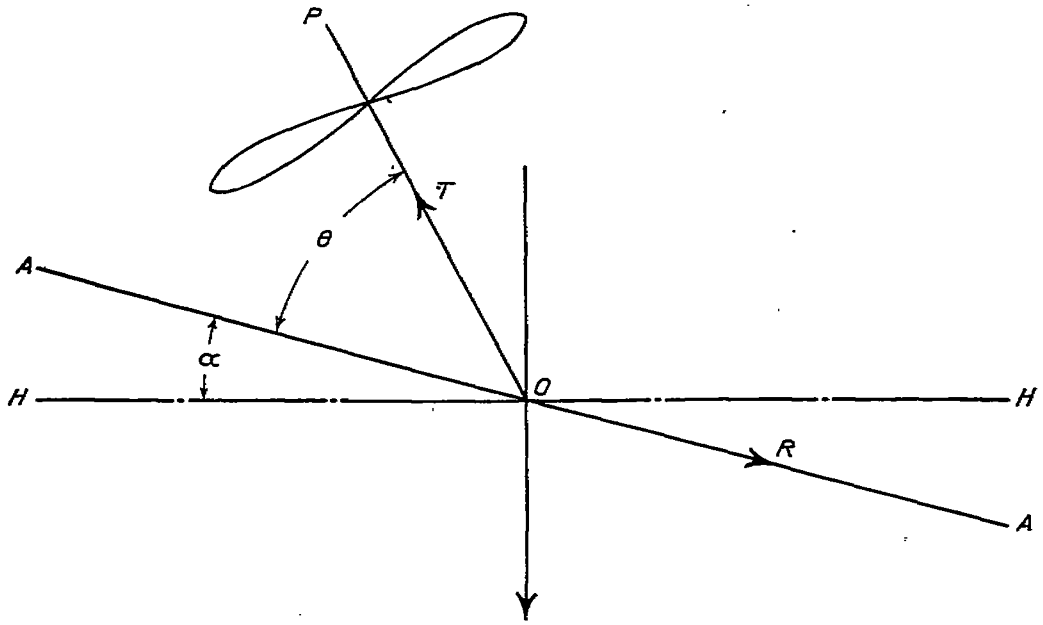

Fig. 1

Diagramatically let figure 1 represent such a propeller attached to an aircraft of some form with shaft OP inclined at angle θ to the line of motion AA, which is itself inclined at angle α to the horizontal HH.

Let T denote the traction on the shaft. Let R denote the traction resistance in the line of motion. Then assuming that T is the only force reaction of the propeller on the structure and assuming likewise conditions of right line nonaccelerated motion, we shall have

$$T \sin (\alpha + \theta) = W \quad (1)$$

$$T \cos \theta = R \quad (2)$$

The resistance R will be given by an equation of the form—

$$gR = k \Delta L^2 v^2 \quad (3)$$

Where k = coefficient depending on the geometrical form of the aircraft in question.

Δ = density of air.

L = Some standard or type lineal dimension of the aircraft.

v = velocity.

It will be noted that a coefficient k thus defined will be independent of the particular units employed so long as they form a homogeneous system (foot, pound, and second, or meter, kilogram, and second.)

We have then:

$$\frac{\sin(\alpha+\theta)}{\cos\theta}=\frac{W}{R}=\frac{g\,W}{k\Delta L^2v^2} \tag{4}$$

or—

$$g\,W=k\Delta L^2v^2\frac{\sin(\alpha+\theta)}{\cos\theta} \tag{5}$$

From these equations a number of elementary problems involving such motion may be solved, once we have the means of relating the force T to the general conditions of the problem.

The present investigation has then for its primary purpose the development of the relations between T and the operating conditions, including at the same time the similar relations for the torque Q.

With these relations established and suitable data known or assumed, the solution of problems arising in flight of this character and involving power, speed, etc., will be reduced to the same general program as in the usual case of airplane flight.

No further discussion of these phases of the problem will be given in the present report, the primary purpose of which is to furnish the data for the investigation of flight conditions of the character outlined.

LIMITATION IN SIGNIFICANCE OF RESULTS OBTAINED.

As noted in the preceding paragraph, the purpose of the investigation has been the determination of the thrust and torque characteristics of air propellers under conditions of movement sharply oblique to the line of the shaft.

These forces, however, do not represent the entire force reaction between the propeller and the aircraft. The latter will involve additional forces arising from two sources.

(1) A lateral or side thrust acting from the shaft to its bearings and due to the lack of symmetry of the air stream relative to the propeller shaft and the resulting lack of symmetry between the two opposite blades of the propeller in their relation to the air stream.

(2) A distortion of the lines of airflow relative to the aircraft, and due to the action of the propeller, thus modifying the free resistance of the aircraft moving with the attitude and speed assumed.

It is to be hoped that the character and significance of these secondary forces may be made the subject of a later study. It may, however, be noted in this connection that certain experimental difficulties are foreseen in such a study in connection with the elimination and determination of the lateral force (1) independent of (2) the effect due to distorted wind streams. These are, however, matters which are only incidental to the present report and are mentioned only to indicate the fact that the investigations reported on herein have been restricted to a study of the direct thrust and torque characteristics as noted.

MODELS SELECTED FOR TEST.

Twelve models, numbered 5, 6, 7, 8, 9, 10, 11, 12, 139, 144, 145, and 146 were selected. The principal characteristics of these models are shown in Table I. In the above table, blade shape No. 1 is shown in Report No. 14, N. A. C. A., figure 14, blade shape No. 2 in figure 15, while the various blade sections applicable to these forms are shown in figures 16, 18, 20, and 22, all of the same report. Models Nos. 5 to 12, inclusive, are among those tested in 1917, to determine performance coefficients under conditions of flight, and again in 1918, when standing thrust and power coefficients were derived.

TABLE I.—*Characteristics of model propellers.*

No.	Diameter (inches).	Pitch (inches).	Pitch ratio.	Mean blade width.	Shape of blade.	Blade section.
5	36	25.2	0.7	0.15r	1	1
6	36	25.2	.7	.20r	1	1
7	36	25.2	.7	.15r	2	1
8	36	25.2	.7	.20r	2	1
9	36	18.0	.5	.15r	1	1
10	36	18.0	.5	.20r	1	1
11	36	18.0	.5	.15r	2	1
12	36	18.0	.5	.20r	2	1
139	36	10.8	.3	.15r	2	1
144	36	10.8	.3	.20r	2	1
145	36	10.8	.3	.15r	1	1
146	36	10.8	.3	.20r	1	1

All of the above numbered propellers are, as shown in Table I, 3 feet in diameter, with uniform nominal pitch of driving face and are noncambered. There are thus represented among the models tested two forms, straight and curved; three pitch ratios, 0.7, 0.5 and 0.3; and two blade areas corresponding to mean blade width ratios of 0.15 and 0.20.

METHOD OF TEST.

The 0.3 pitch ratio models, Nos. 139, 144, 145, and 146, were first tested in the usual manner (described in Report No. 30, N. A. C. A.) to determine standing thrust and power coefficients. Tests to check those made in 1918 (Report No. 30) were also made on the other models. The dynamometer, after slight alterations, was then turned through an angle of 90° so that the propeller shaft was at a right angle to the wind stream through the experiment chamber. The following program was then conducted with each model. A wind velocity of about 30 feet per second was set up with the tunnel fan. The model was then rotated at various speeds from 10 to 50 revolutions per second and simultaneous observations of thrust, torque, or turning moment, revolutions, and wind velocity were made and recorded. Seven to ten observations, representing the same number of angular velocities, were made for each propeller. These tests were repeated with a wind velocity of about 45 feet per second and finally with one of about 60 feet per second. During a single series of observations the wind velocity was maintained approximately constant only. Because of the effect of the model itself in drawing air out of the stream and forcing it into the experiment chamber, there developed some increase in the experiment chamber pressure and a corresponding reduction in the velocity of the wind stream, especially at the higher angular velocities of the model.

Following the observations at an angle of 90°, the dynamometer was then set so that the propeller shaft and the axis of the tunnel formed an angle of 85° and the same program of tests, with the three wind velocities of about 30, 45, and 60 feet per second and seven to ten rotative speeds for each propeller, was carried out. This was repeated with angles of 80°, 70°, and 60°. The whole lot of experimental data thus represents, aside from the experiments to determine standing thrust and power coefficients, about 1,500 simultaneous observations of thrust, turning moment, angular velocity, and wind velocity, distributed about equally over five angles of approach, 90°, 85°, 80°, 70°, and 60°. For each turning moment or torque determination, an observation of torque zero was made.

REDUCTION OF DATA.

The data were reduced to the coefficients—

$$\frac{V}{ND},\quad C_t=\frac{g\times \text{thrust}}{\Delta N^2D^4},$$

$$\text{and } C_q=\frac{g\times \text{torque}}{\Delta N^2D^5}.$$

In $\frac{V}{ND}$, V is the wind velocity, N the rate of revolution, and D the diameter. In C_t and C_q, N and D have the same values as in $\frac{V}{ND}$ and Δ is the weight per unit volume of the medium. It may be noted that these coefficients are independent of the units used provided the latter are homogeneous.

The coefficient C_t and ten times the coefficient C_q were plotted as ordinates, upon $\frac{V}{ND}$ as abscissæ, for each angle of approach. The result for propeller No. 8 at 80° is shown on Plate I. As may be noted, there is some dispersion of the plotted data from a single smooth curve, and the data for one wind speed indicate, in general, values of the coefficients somewhat different from those shown by the tests at the other wind speeds. Plate I is representative of the dispersion of the data from a fair curve in the average case. With some propellers it is somewhat greater and with others somewhat less. As an experiment the data on Plate I were changed in form and plotted as shown on Plate II. In this instance—

$$C'_t=\frac{g\times \text{thrust}}{\Delta V^2D^2}$$

$$\text{and } C'_q=\frac{g\times \text{torque}}{\Delta V^2D^3}.$$

As may be seen, these coefficients are of the form used previously in plotting data for tests of models under the condition of flight or of axial wind, and are derived from the coefficients shown on Plate I by dividing the values of C_t and C_q there indicated by the square of the corresponding $\frac{V}{ND}$. It is interesting to note that although mathematically the data as shown on Plates I and II are the same, the appearances are in the two cases very different.

The form as shown on Plate I was selected for presentation since coefficients without the factor V in the denominator are necessary in order to permit of graphic representation at $\frac{V}{ND}=0$.

In Plates III to XIV are shown the results as determined for the twelve propellers. Each curve as shown represents an average of points plotted. The actual marking of the spots is omitted in order to avoid confusion. The original observations, reduced to the coefficients C_t and C_q, are, however, given in Table II against the various values of $\frac{V}{ND}$ as resulting from the three different wind speeds employed. The curves of Plates III to XIV are in some instances slightly different from those at first drawn through the plotted data. These modifications were the result of drawing cross curves as shown on Plates XV to XXVI. For these latter plates the ordinates are as before, C_t and C_q, but the abscissæ are values of angle of approach.

DISCUSSION OF RESULTS.

Thrust.—As may be seen by reference to Plates III to XXVI, the effect of side wind at any angle of approach greater than a certain value for any one propeller is to increase the thrust developed at a fixed tip speed. For the propellers of 0.7 pitch ratio (propellers 5, 6, 7, and 8) the angle at which there is no change in thrust with change in wind speed is about 70°. For angles less than this the thrust varies inversely with wind velocity. For the 0.5 pitch ratio (propellers, 9, 10, 11, and 12) the angle of approach for approximately constant thrust with constant tip speed but variable wind velocity is between 72° and 74°. Not only is there greater variation in this angle for the 0.5 pitch ratio propellers than for those of 0.7 pitch ratio, but also the angle is, for a given propeller, usually less definite. For the 0.3 pitch ratio (propellers 139, 144, 145, and 146) the constant thrust angle lies between 73° and 78°, showing a wider variation than for the 0.5 pitch ratio as well as, in some cases, a more pronounced lack of definition.

For a constant value of $\frac{V}{ND}$ the thrust coefficient C_t varies directly with the angle of approach.

Torque.—The changes in torque with variation of side wind velocity are less marked than those in thrust. They appear to be in general somewhat less consistent. For the 90° angle of approach it appears that the torque at first generally decreases with increase of wind velocity and later increases. An exception to this general rule is noted in the propeller No. 139 (Pl. XI) where the trend of the torque coefficient curve is slightly downward throughout its length. It may be noted, however, that for 85° and 80° the previously stated general rule appears to be followed. For the angle of 60° the torque coefficient curves on abscissæ of $\frac{V}{ND}$ are generally convex upward instead of downward as with 90°. For other angles the torque coefficient curves on abscissæ of $\frac{V}{ND}$ have a generally rising characteristic except at small values of $\frac{V}{ND}$ where in some cases they have very similar characteristics to the 90° curve.

An examination of Plates XIV to XXVI shows that with few exceptions there is an angle of approach for which the torque is practically constant for varying wind velocity. This angle is generally from 6° to 10° less than the angle for constant thrust. It may be also noted that while the torque coefficient curves of Plates III to XIV appear in some instances inconsistent, the cross curves on Plates XV to XXVI show in general similar characteristics. With few exceptions they are convex upward and show, with decreasing angle of approach, at first a rise and later a fall in the value of C_q.

PROPELLER No. 5.

60° yaw.			70° yaw.			80° yaw.			85° yaw.			90° yaw.		
$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.
0.620	0.1195	0.01146	1.76	0.1345	0.01434	1.15	0.1715	0.0130	1.58	0.2145	0.0150	0.000	0.151	0.01105
.413	.1290	.01092	1.27	.1445	.01366	.820	.1666	.01145	1.09	.1945	.01155	.527	.159	.0096
.352	.1394	.01122	1.06	.1467	.01311	.605	.1611	.01111	.954	.1834	.01155	.373	.151	.0105
.314	.1421	.01118	.830	.149	.01255	.484	.160	.01105	.745	.1734	.01133	.250	.150	.0105
.277	.1450	.01150	.770	.1522	.01245	.433	.1589	.01133	.650	.169	.01155	.181	.153	.0105
.250	.1471	.01172	.674	.1545	.01222	.424	.1589	.01133	.565	.1655	.01155	.159	.157	.01095
.240	.1490	.01172	.595	.1545	.01222	.390	.1577	.01145	.561	.1645	.01166	.145	.1735	.014
1.508	.0866	.01145	.572	.1323	.0120	.553	.1455	.01111	.543	.1556	.01072	1.05	.196	.0107
1.133	.1069	.01211	.411	.1378	.01145	.402	.1466	.01033	.414	.1534	.01061	.720	.173	.01065
.95	.1154	.01200	.325	.1434	.01122	.275	.1472	.0107	.252	.1511	.0105	.537	.1635	.01042
.776	.1271	.01200	.234	.1511	.01133	.212	.1495	.01038	.215	.1556	.01078	.447	.159	.01095
.665	.1311	.01345	.204	.1500	.01133	.191	.1545	.0111	.1915	.1495	.01031	.398	.158	.01093
.57	.1353	.01279	.178	.1489	.01145	.160	.1578	.01095	.186	.1561	.01078	.356	.157	.0112
.5525	.1384	.01245	.159	.1522	.01166	.138	.159	.01145	.153	.1578	.01122	.313	.157	.0112
1.027	.1038	.01180	1.278	.1328	.01366	1.95	.201	.01565	.173	.1528	.01116	1.91	.261	.01495
.7545	.1204	.01171	.882	.1406	.01250	1.38	.187	.01368	1.194	.1866	.01355	1.28	.209	.0125
.623	.1261	.01156	.690	.1455	.01212	1.08	.179	.01268	.827	.1745	.01139	.935	.189	.0113
.508	.1340	.01171	.597	.1466	.01172	.853	.171	.01168	.605	.1655	.01061	.772	.1745	.0112
.429	.1396	.01144	.471	.1490	.01122	.750	.168	.01142	.473	.1590	.01067	.672	.172	.01118
.3935	.1419	.01156	.430	.1566	.01145	.665	.167	.01178	.431	.1590	.01081	.613	.171	.01145
.371	.1455	.01195	.407	.1522	.01155	.572	.1645	.01178	.421	.1590	.0111	.531	.169	.01145
									.372	.1611	.01122			

PROPELLER No. 6.

0.572	0.1368	0.0129	1.277	0.1485	0.01346	0.548	0.1735	0.0121	1.694	0.2502	0.01659	0.605	0.1920	0.01155
.409	.1480	.01252	.894	.1570	.01324	.384	.1701	.01172	1.30	.222	.01445	.609	.1916	.0120
.365	.1500	.01239	.724	.1605	.01311	.278	.1695	.01184	.990	.211	.01341	.369	.1765	.01122
.311	.1532	.01232	.548	.1622	.01248	.218	.1673	.01200	.808	.200	.0130	.373	.1732	.01180
.2976	.1562	.01210	.477	.1636	.01227	.1375	.1682	.01222	.703	.191	.01266	.378	.1769	.01146
.270	.1585	.01218	.449	.1628	.01211	.1675	.170	.01245	.624	.187	.01279	.378	.1754	.01162
.262	.1596	.01262	.419	.1646	.01265	.1495	.1712	.0125	.540	.1845	.01273	.257	.1715	.01121
1.47	.0948	.01000	1.744	.1616	.01490	1.187	.1995	.01440	.537	.1777	.01181	.256	.1722	01153
1.117	.1142	.01135	1.26	.1600	.01370	.838	.1884	.01305	.421	.1752	.01141	.209	.1710	.01190
.955	.1234	.01222	1.028	.1616	.01350	.673	.1810	.01240	.292	.1678	.01160	.209	.1720	.01198
.77	.1335	.01245	.904	.1623	.01331	.544	.1780	.01230	.221	.1690	.01168	.178	.1731	.01215
.704	.1391	.01270	.799	.1635	.01322	.490	.1758	.01240	.188	.1697	.01204	.178	.1728	.01199
.611	.1441	.01276	.696	.1878	.01326	.445	.1755	.01242	.178	.169	.01212	.162	.1733	.01191
.566	.1471	.01261	.607	.1655	.01316	.402	.1752	.01256	.165	.1699	.01226	.156	.1731	.01212
1.037	.1117	.0124	.569	.1568	.01275	1.998	.248	.01704	1.240	.226	.01410	1.120	.2366	.01415
.755	.1332	.01242	.418	.1535	.01217	1.31	.209	.01476	.838	.202	.01345	1.140	.2405	.01492
.605	.1392	.01249	.331	.158	.01219	1.118	.204	.01423	.6195	.1842	.0120	.760	.2069	.0130
.4685	.1494	.01257	.258	.1621	.01225	.874	.194	.01320	.476	.179	.01180	.755	.2056	.01293
.417	.1518	.01257	.226	.1649	.01244	.781	.189	.01313	.4445	.1785	.01210	.539	.1879	.01245
.3925	.1528	.01248	.198	.1666	.01257	.677	.184	.01303	.417	.1734	.01239	.543	.1890	.01261
.387	.1542	.0127	.175	.1679	.01262	.589	.181	.01253	.388	.177	.01237	.461	.1828	.01229
												.453	.1828	.01229
												.361	.1792	.01206
												.348	.1735	.01187
												.293	.1770	.01203

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PROPELLER NO. 7.

60° yaw.			70° yaw.			80° yaw.			85° yaw.			90° yaw.		
$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.
0.580	0.1260	0.01149	0.552	0.137	0.0110	1.138	0.1700	0.01209	1.174	0.1879	0.01132	1.77	0.2455	0.01256
.399	.1354	.01092	.403	.1425	.0106	.798	.1640	.01080	.816	.1731	.01028	1.19	.1992	.01140
.3567	.1382	.01079	.3032	.145	.0105	.625	.1600	.01041	.593	.1620	.00972	.935	.1871	.01037
.294	.1394	.01055	.2362	.146	.0104	.484	.1548	.01015	.490	.1603	.00970	.757	.1743	.01020
.2733	.1418	.01061	.1999	.147	.0103	.435	.1548	.01021	.424	.1550	.00976	.606	.1702	.01034
.2595	.1428	.01012	.1790	.147	.01025	.415	.1540	.01035	.394	.1527	.00978	.612	.1673	.01013
.2285	.1404	.01072	.1528	.147	.0105	.374	.1533	.01083	.353	.1517	.00996	.544	.1615	.00999
1.49	.0921	.01151	1.710	.1455	.0143	1.872	.213	.01440	.532	.1567	.00984	.475	.1580	.01008
1.12	.1000	.01192	1.230	.1435	.0126	1.345	.185	.01240	.399	.1532	.00973	1.23	.2050	.01160
.951	.1178	.01167	.995	.1460	.0123	1.052	.173	.01142	.270	.1512	.00975	.868	.1802	.01074
.78	.1266	.01165	.845	.1480	.0118	.851	.167	.01085	.214	.1490	.00964	.636	.1732	.01007
.666	.1366	.01145	.722	.1480	.0115	.723	.163	.01060	.187	.1508	.00906	.547	.1024	.00992
.584	.1345	.01140	.625	.1480	.0112	.612	.159	.01065	.169	.1495	.00994	.433	.1558	.00992
.557	.1375	.01151	.553	.1480	.0112	.530	.160	.01060	.146	.1505	.00967	.399	.1544	.00998
1.024	.1038	.01202	1.279	.1377	.01285	.561	.152	.01065				.360	.1532	.00998
.742	.1233	.01160	.856	.1430	.01133	.373	.148	.00983				.287	.1522	.00909
.605	.1298	.01128	1.342	.1389	.0133	.271	.147	.00983				.562	.1190	.01007
.4405	.136	.0110	.908	.1420	.01202	.207	.146	.00898				.375	.1497	.01010
.398	.1383	.01111	.738	.1462	.0117	.177	.147	.00975				.276	.1493	.00982
.3675	.1379	.01091	.632	.1458	.01124	.155	.149	.0101				.214	.1503	.00962
.3585	.1399	.01100	.512	.1458	.0107	.139	.151	.0103				.179	.1500	.00980
			.431	.1440	.01047							.1585	.1502	.00990
			.399	.1460	.01041							.146	.1511	.00990
			.398	.1465	.01054							.000	.1434	.01009

PROPELLER NO. 8.

1.619	0.0882	0.00988	1.784	0.162	0.01468	2.04	0.2450	0.0159	1.625	0.244	0.01535	0.	0.1598	0.0114
1.18	.1186	.01092	1.293	.157	.01406	1.452	.212	.0148	1.155	.221	.0137	.544	.1781	.01012
1.007	.1184	.01155	1.072	.1592	.0137	1.066	.1995	.0134	.858	.203	.01255	.373	.1738	.01088
.885	.1260	.01200	.907	.1595	.0134	.889	.1925	.0128	.712	.1915	.0119	.207	.1675	.01120
.718	.1340	.01189	.792	.163	.0132	.755	.1820	.0122	.625	.186	.01155	.221	.1671	.01144
.636	.1387	.01205	.707	.162	.0130	.645	.1810	.0121	.529	.1805	.0114	.134	.1675	.01130
.592	.1409	.01219	.609	.1623	.0127	.542	.1765	.01175	.491	.180	.0116	.176	.1681	.01132
1.068	.1173	.01198	1.305	.153	.0141	1.203	.200	.0143	1.260	.2241	.01389	.167	.1690	.01138
.765	.1294	.01182	.910	.159	.0131	.840	.187	.0128	.849	.1955	.01239	1.020	.2300	.01239
.624	.1372	.01183	.735	.157	.01245	.651	.178	.0116	.611	.1828	.01112	.719	.2020	.01153
.506	.1440	.01185	.628	.158	.0122	.558	.1695	.0114	.467	.1731	.01117	.528	.1821	.01078
.430	.1465	.01189	.500	.161	.01175	.455	.168	.0112	.433	.1753	.01121	.443	.1754	.01093
.393	.1487	.01182	.450	.162	.0117	.433	.169	.0113	.410	.1732	.01132	.380	.1703	.01093
.396	.1582	.01264	.422	.162	.01195	.392	.1685	.0114	.376	.1720	.01130	.327	.1720	.01098
.747	.1290	.01175	.554	.1615	.0128				.538	.1799	.0120	.297	.1711	.0111
.482	.1442	.01190	.419	.157	.01205				.404	.1733	.01109	1.707	.2725	.01417
.3915	.1475	.01181	.305	.157	.01170				.281	.1062	.01120	1.182	.2300	.01360
.3500	.1495	.01192	.238	.161	.01180				.219	.1654	.01140	.871	.2125	.01220
.3170	.1476	.01179	.2175	.161	.01190				.190	.1660	.01158	.701	.1978	.01179
.2781	.1550	.01190	.1878	.162	.01180				.168	.1647	.01152	.013	.1932	.01138
.254	.1562	.01220	.161	.164	.01210				.157	.1665	.01172	.545	.1864	.01113
												.512	.1853	.01117

PROPELLER NO. 9.

1.393	0.0438	0.00650	1.553	0.0894	0.00875	1.720	0.1490	0.00955	1.355	0.167	0.0088	0	0.1180	0.00718
1.058	.0676	.00689	1.138	.1005	.00814	1.230	.1410	.00825	.978	.1536	.00734	.472	.1262	.00670
.886	.0786	.00728	.880	.1056	.00805	.937	.1370	.00787	.743	.142	.00694	.337	.1225	.00686
.710	.0876	.00748	.730	.1161	.00783	.748	.131	.00725	.596	.1365	.00689	.257	.1219	.00683
.609	.0935	.00733	.622	.1132	.00778	.599	.131	.00718	.505	.1325	.00695	.2025	.1211	.00682
.531	.0984	.00738	.535	.1158	.00773	.519	.130	.00712	.447	.131	.00698	.183	.1202	.00677
.465	.1025	.00748	.514	.1170	.00788	.432	.129	.00730	.404	.1295	.00718	.158	.1217	.00694
.932	.0716	.0074	1.110	.0978	.00792	1.022	.132	.00805	1.116	.1591	.00776	.144	.1227	.00710
.675	.0875	.00707	.795	.106	.00940	.729	.129	.00738	.746	.1401	.00702	.131	.123	.00727
.523	.097	.00744	.603	.1115	.00777	.549	.1255	.00700	.551	.1309	.00694	.872	.1557	.00760
.4295	.103	.00722	.481	.113	.00713	.440	.123	.00693	.442	.1268	.00672	.541	.1367	.00719
.397	.1038	.00732	.389	.1165	.00724	.378	.123	.00695	.394	.1262	.00673	.413	.1290	.00685
.344	.1078	.00728	.359	.1180	.00726	.347	.125	.00708	.366	.1275	.00696	.330	.1273	.00671
.321	.1087	.00684	.332	.1175	.0075	.326	.125	.00723	.320	.1256	.00718	.281	.1273	.00699
.315	.1101	.00738	.516	.104	.00798	.471	.118	.00746	.491	.1270	.00802	.260	.1271	.00706
.511	.0901	.00739	.368	.109	.00738	.349	.117	.00702	.356	.1214	.00720	.238	.1272	.00725
.362	.0998	.00699	.306	.112	.00748	.255	.115	.00733	.255	.1191	.00709	.451	.1347	.00716
.315	.1003	.00719	.219	.114	.00738	.184	.118	.00710	.206	.1195	.00709	1.301	.1842	.00779
.288	.1070	.00727	.174	.1165	.00727	.157	.118	.00710	.159	.1206	.00716	.921	.1623	.00690
.249	.1090	.00731	.156	.119	.00738	.135	.121	.00724	.140	.1228	.00731	.701	.1480	.00810
.2185	.1100	.00736	.129	.119	.00754	.117	.122	.0075	.126	.1222	.00744	.614	.1440	.00692
.2105	.1152	.0077										.461	.1348	.00690
												.391	.1322	.00688

PROPELLER No. 10.

60° yaw.			70° yaw.			80° yaw.			85° yaw.			90° yaw.		
$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.
1.346	0.0417	0.00564	1.510	0.098	0.00871	0.512	0.1345	0.00720	1.410	0.193	0.0101	1.503	0.2215	0.00861
1.03	.0652	.00680	1.135	.1075	.00861	.368	.1133	.00687	1.015	.1755	.00868	1.056	.1992	.00839
.815	.0815	.00713	.882	.1150	.00863	.250	.130	.00772	.7725	.1600	.00810	.865	.1820	.00795
.688	.0915	.00760	.710	.1180	.00841	.220	.130	.00790	.636	.1525	.00778	.703	.1671	.00771
.614	.0988	.00760	.611	.1225	.00844	.162	.1311	.00788	.565	.150	.00778	.621	.1618	.00756
.537	.1030	.00775	.535	.1245	.00838	.144	.1322	.00813	.4725	.1470	.00782	.528	.1570	.00772
.483	.1078	.00792	.475	.1260	.00850	.130	.1333	.00842	.422	.1445	.00780	.421	.1513	.00802
.925	.0733	.00708	1.115	.1045	.00873	.1020	.1510	.00847	1.04	.176	.00930	.481	.1552	.00783
.690	.0915	.00746	.805	.1145	.00820	.732	.1435	.00764	.728	.157	.00801	1.116	.2010	.00910
.531	.1015	.00783	.608	.1190	.00824	.556	.1385	.00768	.550	.1450	.00791	.770	.1732	.00846
.435	.1085	.00778	.486	.1230	.00818	.446	.1365	.00773	.443	.1425	.00785	.573	.1558	.00771
.378	.1125	.00779	.400	.1240	.00796	.388	.1355	.00779	.401	.1400	.00780	.441	.1455	.00763
.342	.1170	.00791	.378	.1255	.00822	.376	.1365	.00795	.343	.141	.00803	.376	.1490	.00749
.325	.1190	.00817	.356	.1270	.00871	.343	.1355	.00810	.340	.141	.00825	.334	.1432	.00764
.532	.1005	.00791	.528	.1185	.00819	1.783	.1765	.01065	.507	.1450	.0075	.273	.1412	.00803
.372	.1100	.00778	.583	.1210	.00814	1.275	.1585	.0094	.359	.1370	.00742	.507	.1516	.00773
.324	.1125	.00791	.293	.1220	.00805	.970	.1540	.00893	.277	.1320	.00780	.361	.1432	.00796
.290	.1155	.00782	.224	.1255	.00805	.757	.1490	.00825	.208	.1315	.00775	.258	.1350	.00776
.2155	.1195	.00750	.180	.1280	.00804	.605	.1450	.00797	.183	.1320	.00798	.201	.1342	.00778
.2185	.1230	.00801	.1596	.1295	.00821	.516	.1415	.00800	.1513	.1335	.00814	.169	.1343	.00782
.1970	.1230	.00817	.1368	.1300	.00812	.443	.1420	.00840	.134	.1335	.00825	.153	.1340	.00806
												.133	.1363	.00817
												0	.1268	.00817

PROPELLER No. 11.

1.379	0.0551	0.00697	1.442	0.1031	0.00839	1.56	0.159	0.00973	1.434	0.1698	0.00871	0	0.117	0.00685
1.024	.0735	.00749	1.129	.1072	.00824	1.104	.1434	.00792	1.071	.161	.00756	0	.1175	.00710
.807	.0849	.00768	.877	.1104	.00792	.852	.140	.00742	.909	.1500	.00709	.472	.1318	.00682
.672	.0932	.00762	.728	.1142	.00779	.694	.135	.00706	.676	.1422	.00689	.315	.1250	.00691
.597	.0972	.00757	.641	.1149	.00773	.677	.131	.00682	.573	.137	.00662	.217	.1214	.00662
.503	.1028	.00740	.549	.1175	.00762	.494	.1257	.00693	.491	.1339	.00672	.170	.1205	.00652
.460	.1047	.00737	.465	.1182	.00769	.426	.1258	.00696	.443	.1316	.00684	.1467	.1200	.00672
.908	.0791	.00834	1.125	.1019	.00572	1.07	.142	.00934	.952	.1565	.00778	.137	.1213	.00698
.677	.0919	.00793	.826	.110	.00814	.739	.132	.00762	.667	.1421	.0070	.1256	.1209	.00703
.516	.0990	.00755	.589	.1127	.00723	.356	.128	.00724	.534	.1342	.00678	.992	.1708	.00720
.394	.1052	.00746	.456	.1142	.00765	.444	.1268	.00702	.436	.1289	.00658	.742	.1540	.00658
.344	.1079	.00726	.384	.1140	.00741	.387	.1244	.00398	.392	.1268	.00678	.558	.1397	.00607
.323	.109	.00742	.381	.1150	.00735	.361	.1244	.00399	.349	.1142	.00676	.451	.1335	.00640
.308	.1092	.00736	.362	.1160	.00744	.322	.1244	.00712	.313	.1255	.00726	.382	.1295	.00654
.527	.0958	.00769	.332	.1166	.00735	.481	.123	.00727	.456	.1300	.0072	.350	.1254	.00648
.366	.1037	.0074	.526	.1108	.00794	.358	.1205	.00668	.364	.1263	.0068	.293	.1250	.00680
.317	.1051	.00720	.380	.1124	.00746	.245	.1182	.00666	.258	.1214	.00672	1.495	.200	.00687
.271	.1053	.00713	.299	.1139	.00736	.182	.1175	.00674	.202	.1198	.00692	1.103	.1779	.00730
.219	.1111	.00715	.219	.1149	.0069	.154	.1176	.00681	.1615	.1199	.00699	.836	.1615	.00680
.213	.1120	.00725	.182	.1161	.00702	.1356	.1189	.00693	.1386	.1192	.00698	.646	.1470	.00650
.190	.1123	.00738	.152	.1170	.00739	.121	.1198	.00722	.1208	.1198	.00718	.582	.1438	.00635
			.1286	.1172	.00682							.520	.1263	.00640
												.442	.1340	.00667

PROPELLER No. 12.

1.30	0.0478	0.00605	1.54	0.1045	0.00834	1.52	0.1732	0.00989	1.453	0.200	0.0101	1.66	0.2435	0.0102
1.01	.0698	.00678	1.145	.111	.0084	1.18	.160	.00922	1.012	.1752	.00936	1.165	.2095	.00914
.806	.0847	.00755	.894	.1155	.0088	.865	.1510	.00855	.82	.165	.00792	.852	.1830	.00811
.674	.0920	.00760	.739	.119	.00817	.705	.1432	.00804	.682	.1542	.00758	.700	.1705	.00732
.566	.1000	.00763	.627	.120	.00812	.595	.1405	.00811	.57	.1432	.00639	.614	.1622	.00703
.504	.1044	.00755	.553	.1211	.00812	.518	.1379	.00784	.511	.1415	.00749	.536	.1555	.00711
.455	.1069	.00784	.493	.1222	.0080	.448	.1332	.00777	.45	.139	.00765	.460	.1522	.00731
.884	.0799	.00761	1.035	.1104	.00878	1.09	.160	.01028	1.02	.179	.00872	1.105	.2053	.00837
.668	.0944	.0078	.785	.1157	.00874	.76	.159	.00840	.713	.158	.00775	.757	.1745	.00792
.519	.1049	.00788	.600	.1211	.00845	.572	.138	.00820	.542	.1432	.00753	.585	.1545	.00722
.395	.1078	.00767	.479	.1220	.00811	.452	.1345	.00789	.421	.1366	.00735	.459	.1477	.00715
.352	.1105	.0077	.399	.1222	.00739	.395	.1342	.00768	.399	.1343	.00739	.403	.1445	.00715
.328	.1122	.00776	.370	.1211	.00733	.358	.1325	.00772	.357	.1332	.00748	.362	.1490	.00763
.318	.1128	.00786	.336	.1222	.00794	.319	.1320	.00786	.3325	.1321	.00784	.289	.1333	.00752
.52	.1030	.00839	.530	.1159	.00839	.455	.1389	.00833	.463	.1428	.00759	.493	.1510	.00750
.365	.1112	.0080	.397	.1222	.00811	.371	.1344	.00793	.367	.1372	.00765	.332	.1345	.00731
.318	.1122	.00789	.311	.1245	.00794	.254	.1255	.00761	.252	.1306	.00775	.260	.1322	.00755
.274	.1133	.00785	.221	.1220	.00781	.196	.1256	.00762	.190	.1283	.00760	.190	.1311	.00744
.251	.1144	.00761	.189	.1277	.00725	.1595	.1232	.00760	.1574	.1272	.00775	.1725	.1311	.00748
.218	.1168	.00783	.157	.1314	.00395	.1395	.1222	.00755	.1366	.1279	.00770	.149	.1311	.00765
.186	.1179	.00795	.140	.1273	.00383	.1251	.1244	.00772	.1277	.1259	.00785	.138	.1300	.00770
												0	.1255	.00784

PROPELLER No. 139.

60° yaw.			70° yaw.			80° yaw.			85° yaw.			90° yaw.		
$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.
1.163	0.00532	0.00403	1.64	0.0454	0.00454	1.55	0.0958	0.00504	1.16	0.115	0.00473	0	0.0738	0.00414
.890	.0263	.00374	.984	.0572	.00423	.956	.0915	.00422	.865	.107	.00391	0	.0772	.00407
.719	.0402	.00388	.787	.0630	.00427	.727	.0789	.00362	.684	.0985	.00346	0	.0748	.00401
.594	.0486	.00408	.661	.0665	.00412	.635	.0846	.00402	.564	.0932	.00355	0	.0738	.00363
.532	.0529	.00396	.548	.0699	.00412	.543	.0827	.00394	.513	.0909	.00373	0	.0750	.00378
.484	.0562	.00414	.492	.0705	.00412	.485	.0815	.00393	.474	.0878	.00377	0	.0754	.00387
.408	.0600	.00416	.455	.0719	.00413	.419	.0800	.00420	.421	.0848	.00375	0	.0753	.00386
.796	.0364	.00441	.936	.0568	.00454	.926	.0931	.00503	.465	.092	.00383	0	.0747	.00397
.602	.0494	.00412	.693	.0653	.00444	.669	.0818	.00435	.308	.0845	.0039	.423	.0936	.00346
.479	.0571	.00412	.538	.0687	.00421	.514	.0806	.00404	.268	.0821	.00362	.315	.0873	.00397
.386	.0622	.00406	.436	.0700	.00412	.408	.0802	.00388	.194	.0779	.0036	.238	.0821	.00353
.333	.0645	.00400	.372	.0738	.00364	.360	.0786	.00378	.157	.0767	.00364	.185	.0804	.00357
.301	.0662	.00416	.318	.0745	.00401	.319	.0768	.00376	.139	.0761	.00389	.155	.0796	.00372
.236	.0668	.00407	.292	.0748	.00404	.291	.0758	.00388	.121	.0758	.00406	.131	.0791	.00382
.458	.059	.00489	.469	.0702	.00447	.418	.083	.0041	.912	.1085	.00475	.112	.0792	.00393
.324	.0648	.00428	.318	.0700	.00396	.297	.0783	.00378	.656	.0988	.00373	.933	.1251	.00333
.259	.0734	.00410	.278	.072	.00375	.241	.0768	.00368	.489	.0905	.0037	.673	.1102	.00359
.242	.0688	.00406	.216	.0712	.00366	.201	.0755	.00383	.368	.08355	.00368	.522	.1003	.00336
.210	.0698	.00407	.1706	.0712	.00372	.1515	.0718	.00382	.325	.08105	.00373	.430	.0936	.00334
.191	.0700	.00408	.1482	.0713	.00372	.136	.0738	.00382	.305	.0795	.00388	.359	.0878	.00342
.172	.0692	.00404	.1262	.0711	.00392	.1182	.0725	.00389	.288	.07905	.00400	.317	.0860	.00353
												.286	.0829	.00369

PROPELLER No. 144.

0.964	0.00293	0.0033	1.273	0.033	0.003615	1.261	0.0959	0.00468	0.517	0.0948	0.00402	0.913	0.1332	0.00379
.778	.02345	.003499	.975	.0468	.003670	.937	.0932	.00493	.332	.0841	.00382	.665	.1153	.00351
.623	.0385	.00354	.791	.0615	.003722	.766	.0909	.00416	.288	.0810	.00368	.514	.1027	.0033
.558	.0452	.003639	.691	.0613	.00377	.663	.0888	.00409	.227	.0800	.00334	.456	.0956	.00331
.526	.0482	.00366	.565	.0663	.00394	.584	.0880	.00404	.168	.0780	.00371	.340	.0913	.00352
.496	.0504	.003702	.515	.0688	.00390	.508	.0858	.00390	.144	.0780	.00402	.322	.0887	.00348
.467	.0531	.003815	.449	.0706	.00391	.429	.0848	.00410	.122	.0786	.00399	.292	.0878	.00361
.417	.0567	.00387	1.007	.0464	.00449	.931	.0926	.00503	1.209	.1201	.00465	1.258	.1413	.00384
.786	.0242	.00389	.732	.0504	.00387	.680	.0890	.00432	.892	.1114	.00399	.943	.1332	.00303
.602	.0411	.00357	.553	.0653	.00387	.521	.0856	.00420	.701	.1033	.00373	.747	.1197	.00360
.481	.0514	.00372	.467	.0653	.00383	.415	.0829	.00414	.572	.0978	.00361	.617	.1123	.00349
.386	.0577	.00383	.397	.0707	.00381	.350	.0811	.00408	.519	.0955	.00373	.524	.1038	.00334
.340	.0616	.00388	.326	.0722	.0038	.821	.0812	.00418	.471	.0936	.00388	.465	.1002	.00347
.299	.0643	.00388	.296	.0733	.0043	.299	.0812	.00395	.413	.0906	.00396	.411	.0962	.00366
.265	.0664	.00386	.471	.0673	.00431	.509	.0868	.00470	.843	.1110	.00488	.423	.0971	.00407
.466	.0524	.00446	.315	.0717	.00369	.318	.0807	.00392	.589	.0976	.00391	.309	.0970	.00357
.331	.0615	.00394	.281	.0714	.00371	.242	.0784	.0035	.448	.0918	.00368	.237	.0821	.0038
.266	.0656	.00385	.227	.0720	.00376	.179	.0769	.0036	.343	.0849	.00369	.181	.0804	.00377
.234	.0661	.00382	.171	.0732	.0038	.149	.0769	.0036	.310	.0835	.00370	.151	.0806	.00381
.214	.0681	.00381	.150	.0745	.00386	.132	.0779	.00390	.296	.0835	.00389	.132	.0799	.00399
.196	.0695	.00399	.123	.0748	.00387	.112	.0782	.0040	.282	.0834	.00395	.113	.0797	.00396
.167	.0710	.00384				.264	.0766	.00400						
						.204	.0775	.00383						
						.138	.0771	.00372						

PROPELLER No. 145.

1.02	0.0157	0.00149	1.334	0.0376	0.00447	1.278	0.0918	0.00515	1.193	0.1134	0.00518	1.331	0.1412	0.00428
.807	.0347	.0043	1.009	.0465	.00448	.963	.0912	.00474	.887	.1071	.00431	.950	.1266	.00365
.668	.0458	.00412	.813	.0630	.00459	.775	.0914	.00446	.700	.1014	.00390	.757	.1159	.00363
.564	.0543	.00437	.657	.0652	.00440	.671	.0911	.00436	.570	.0983	.00387	.627	.1081	.00349
.513	.0578	.0044	.577	.0720	.00439	.568	.0901	.00427	.508	.0965	.00396	.530	.1033	.00356
.483	.0597	.00434	.516	.0742	.00431	.491	.0889	.00419	.473	.0957	.00406	.458	.1005	.00371
.419	.0641	.00427	.442	.0758	.00428	.422	.0882	.00417	.422	.0935	.00423	.413	.0985	.00383
.800	.0343	.00469	.979	.0536	.00481	.942	.0897	.00492	.448	.0899	.00394	.901	.1213	.00341
.610	.0499	.00452	.718	.0645	.00446	.687	.0892	.00439	.309	.0844	.00356	.653	.1101	.00358
.481	.0585	.00441	.559	.0703	.00448	.524	.0886	.00422	.275	.0837	.00395	.518	.1019	.00361
.391	.0640	.00433	.468	.0729	.00431	.418	.0858	.00416	.209	.0829	.00397	.422	.0969	.00322
.341	.0676	.00438	.371	.0756	.00429	.361	.0849	.00417	.159	.0826	.00405	.344	.0930	.00365
.293	.0701	.00439	.330	.0768	.00423	.322	.0845	.00410	.141	.0829	.00418	.308	.0912	.00334
.267	.0725	.00446	.295	.0775	.00432	.304	.0852	.00419	.128	.0825	.00432	.290	.0924	.00100
.468	.0583	.00478	.479	.0692	.00467	.454	.0847	.00452	.805	.1047	.00455	.431	.0950	.00147
.338	.0667	.00437	.322	.0729	.00406	.306	.0811	.00395	.578	.0969	.00393	.310	.0881	.00414
.269	.0694	.00428	.283	.0746	.00408	.249	.0806	.00395	.445	.0920	.00388	.233	.0850	.00408
.243	.0716	.00429	.226	.0763	.00409	.201	.0807	.00402	.343	.0881	.00399	.175	.0843	.00402
.215	.0730	.00434	.165	.0777	.00405	.151	.0815	.00398	.313	.0674	.00391	.153	.0843	.00409
.183	.0750	.00427	.149	.0798	.00423	.137	.0817	.00416	.301	.0882	.00412	.137	.0849	.00418
.169	.0766	.00435	.125	.0807	.00444	.112	.0834	.00424	.278	.0876	.00411	.120	.0843	.00337

PROPELLER No. 146.

60° yaw.			70° yaw.			80° yaw.			85° yaw.			90° yaw.		
$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.	$\frac{V}{ND}$.	C_t.	C_q.
0.939	0.00653	0.00372	1.262	0.0339	0.00402	0.452	0.0884	0.00453	0.825	0.1126	0.00436	1.333	0.1540	0.00455
.776	.02555	.00395	.972	.0495	.00415	.307	.0844	.00426	.586	.1023	.00417	.958	.1395	.00385
.663	.0376	.00411	.774	.0690	.00424	.246	.0821	.00434	.450	.0964	.00407	.761	.1268	.00382
.582	.0458	.00425	.654	.0691	.00428	.176	.0832	.00433	.345	.0915	.00414	.615	.1125	.00360
.528	.0514	.00397	.553	.0713	.00443	.149	.0842	.00444	.318	.0914	.00432	.543	.1121	.00395
.495	.0545	.00400	.504	.0765	.00440	.126	.0855	.00447	.304	.0927	.00457	.552	.1152	.00406
.422	.0610	.00422	.442	.0764	.00440	.109	.0868	.00460	.282	.0924	.00465	.508	.1117	.00408
.766	.0281	.00368	.930	.0509	.00442	1.267	.0977	.00496	1.201	.1240	.00539	.520	.1129	.00404
.596	.0446	.00356	.700	.0532	.00418	.953	.0955	.00446	.891	.1162	.00469	.456	.1088	.00412
.473	.0551	.00396	.550	.0697	.00417	.774	.0956	.00446	.697	.1090	.00402	.395	.1040	.00449
.384	.0622	.00406	.436	.0728	.00420	.651	.0942	.00440	.569	.1035	.00413	.906	.1335	.00399
.327	.0671	.00423	.385	.0758	.00422	.561	.0944	.00447	.504	.1022	.00436	.650	.1182	.00369
.290	.0698	.00428	.334	.0772	.00423	.509	.0935	.00444	.460	.1016	.00444	.509	.1068	.00374
.267	.0724	.00440	.300	.0788	.00442	.432	.0931	.00459	.406	.0989	.00459	.405	.0994	.00386
.459	.0556	.00474	.292	.0723	.00387	.931	.0956	.00530	.449	.0958	.00416	.340	.0969	.00414
.330	.0646	.00431	.446	.0708	.00438	.676	.0922	.00464	.319	.0884	.00398	.329	.0974	.00430
.262	.0690	.00423	.318	.0743	.00401	.522	.0900	.00455	.271	.0872	.00419	.279	.0968	.00458
.237	.0707	.00416	.270	.0746	.00411	.413	.0884	.00439	.203	.0856	.00418	.433	.1084	.00410
.218	.0725	.00417	.209	.0778	.00414	.354	.0881	.00437	.163	.0861	.00438	.314	.0906	.00402
.185	.0756	.00433	.168	.0795	.00419	.323	.0889	.00443	.135	.0871	.00453	.242	.0850	.00418
.168	.0776	.00435	.148	.0810	.00426	.301	.0892	.00452	.121	.0873	.00473	.190	.0858	.00419
			.124	.0828	.00443							.158	.0864	.00426
												.136	.0873	.00450
												.122	.0888	.00464

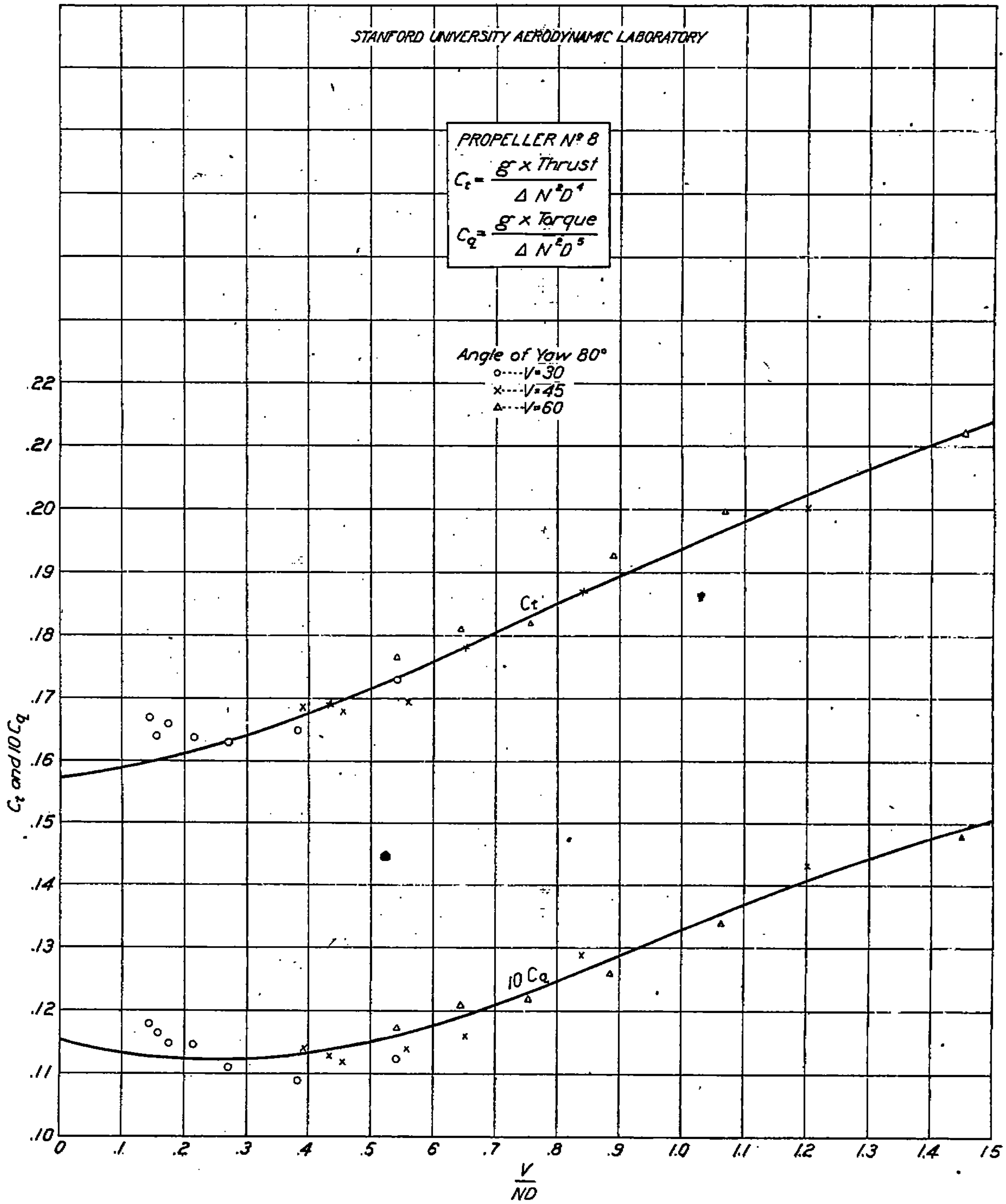

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER Nº 8
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
Angle of Yaw 80°
○----V=30
×----V=45
△----V=60
Ct
10 Cq
C_t and $10 C_q$
.22
.21
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
V/ND

PLATE 1.

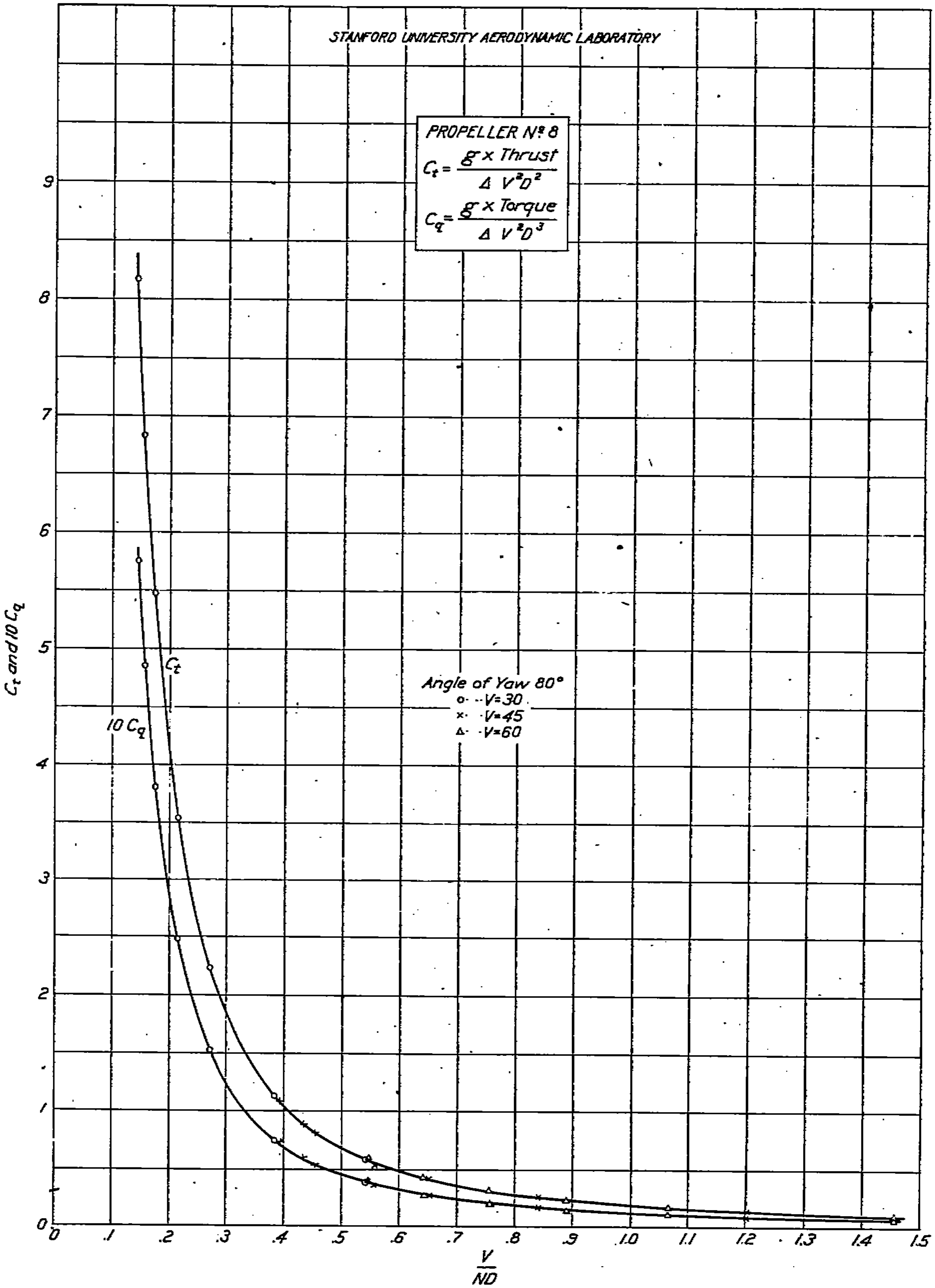

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER No 8
$C_t = \frac{g \times Thrust}{\Delta V^2 D^2}$
$C_q = \frac{g \times Torque}{\Delta V^2 D^3}$
Angle of Yaw 80°
o V=30
× V=45
Δ V=60
C_t
$10 C_q$
C_t and $10 C_q$
$\frac{V}{ND}$

PLATE II.

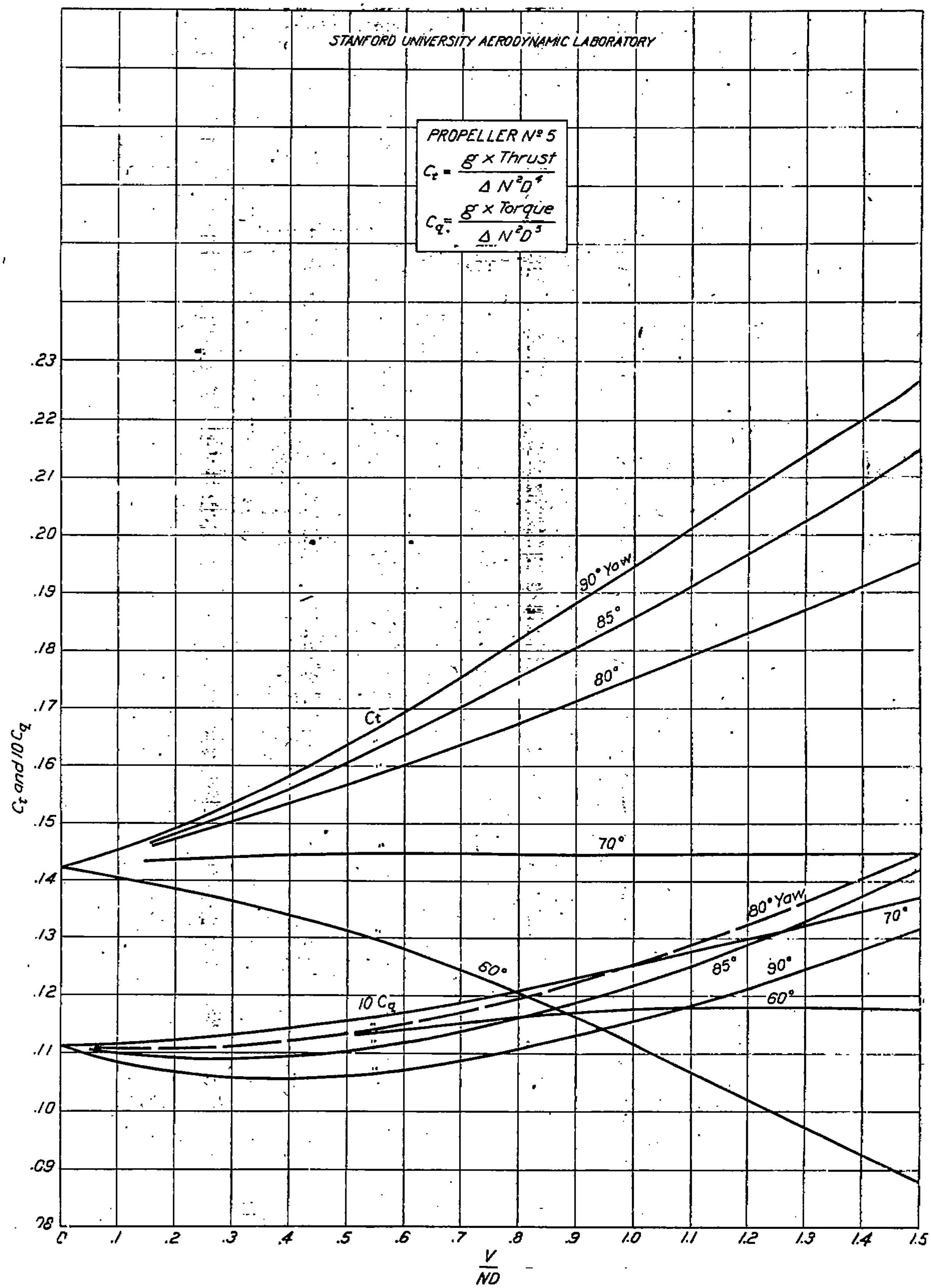

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER Nº 5
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
90° Yaw
85°
80°
70°
60°
Ct
10 Cq
80° Yaw
85°
90°
70°
60°
Ct and 10 Cq
.23
.22
.21
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
V/ND

PLATE III.

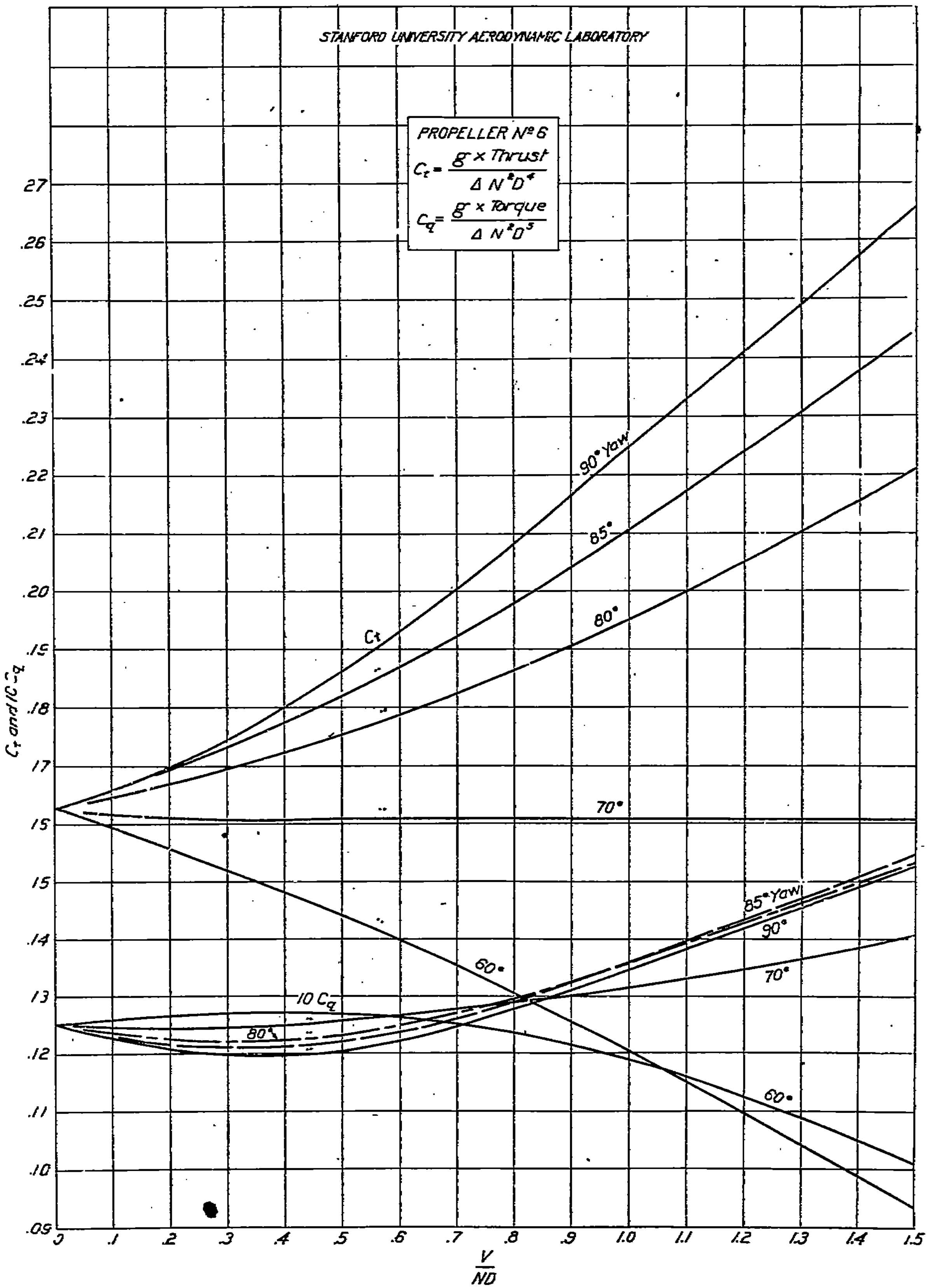

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER No 6
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
90° Yaw
85°
80°
70°
60°
Ct
10 Cq
85° Yaw
90°
70°
80°
60°
C_t and $10 C_q$
$\frac{V}{ND}$

PLATE IV

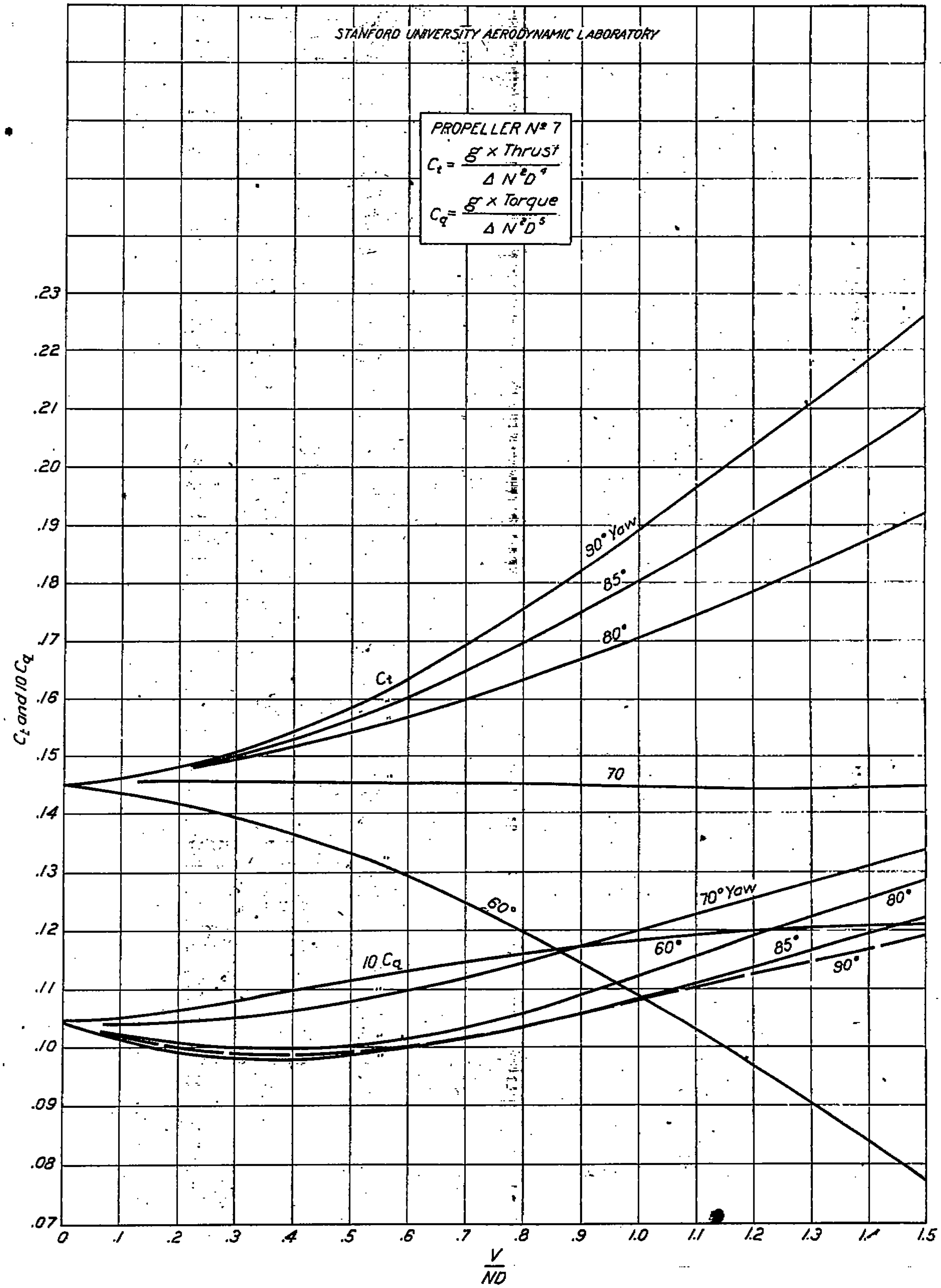

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER No 7
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
Ct and 10 Cq
Ct
90° Yaw
85°
80°
70
60°
10 Cq
70° Yaw
60°
80°
85°
90°
V/ND
.23
.22
.21
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5

PLATE V.

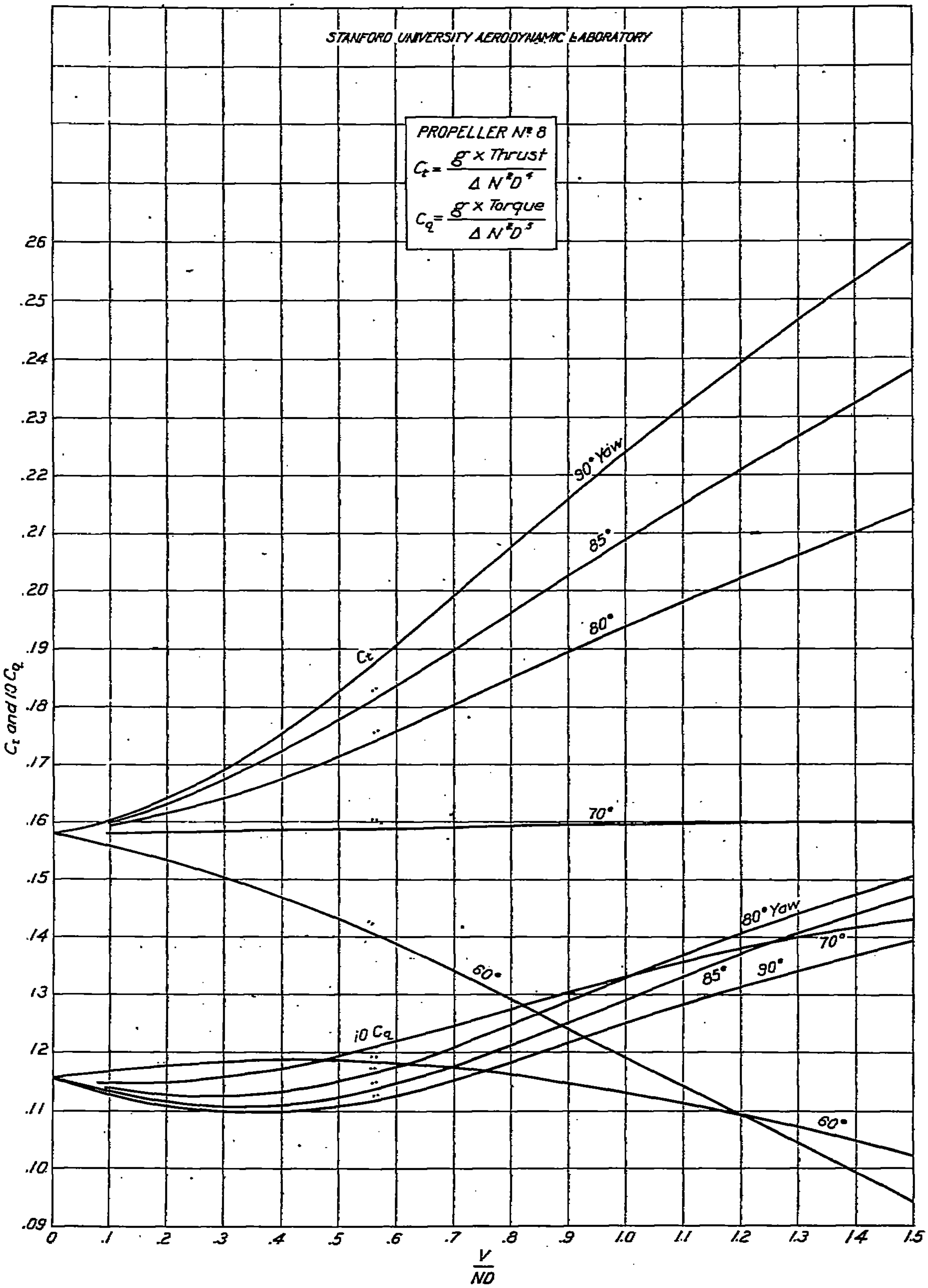

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER Nº 8
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
C_t and $10\,C_q$
90° Yaw
85°
80°
70°
60°
Ct
10 Cq
80° Yaw
70°
85°
90°
60°
V / ND
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
.09
.10
.11
.12
.13
.14
.15
.16
.17
.18
.19
.20
.21
.22
.23
.24
.25
.26

PLATE VI.

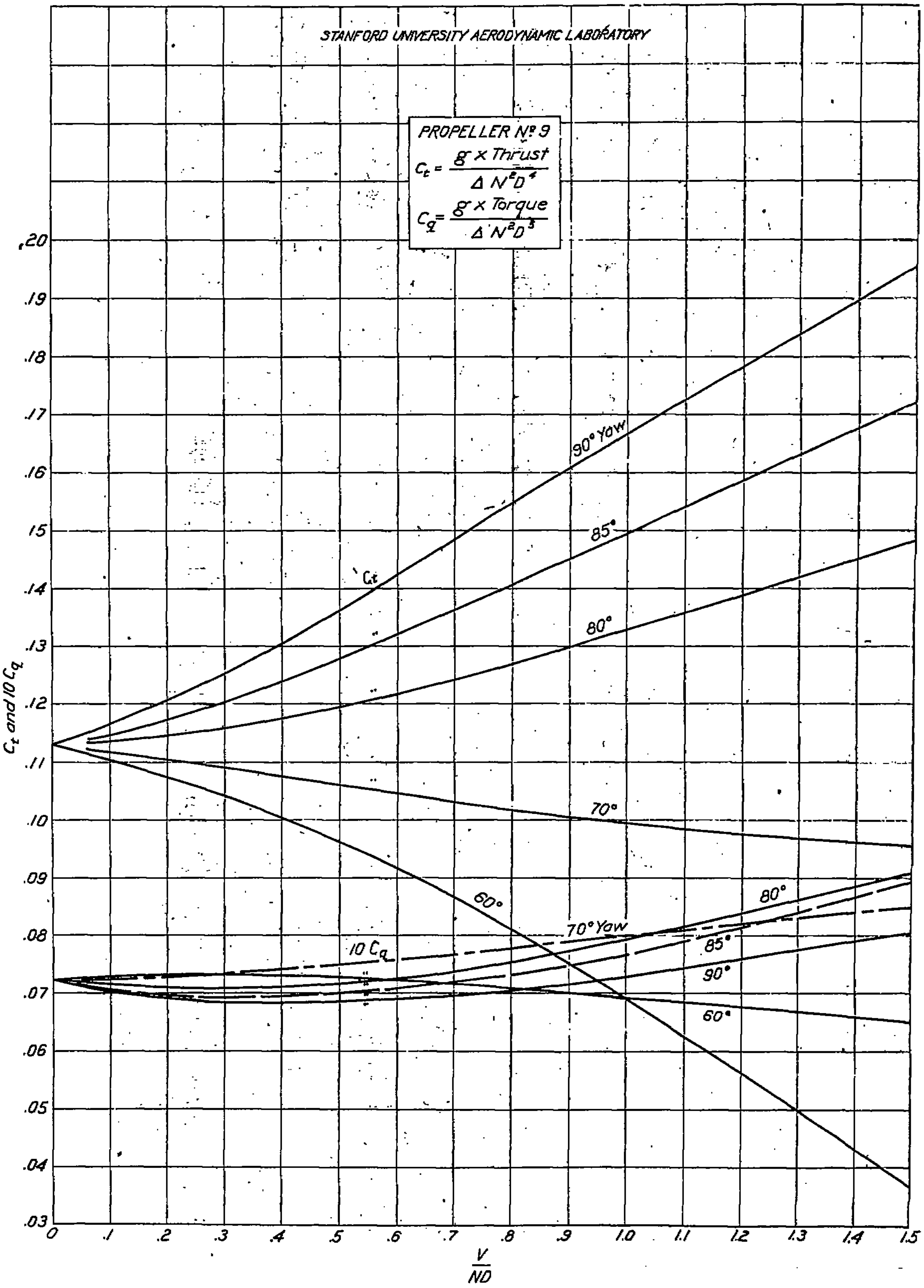

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER No 9
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
C_t and 10 C_q
90° Yaw
85°
80°
70°
60°
Ct
10 Cq
70° Yaw
80°
85°
90°
60°
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
V/ND

PLATE VII.

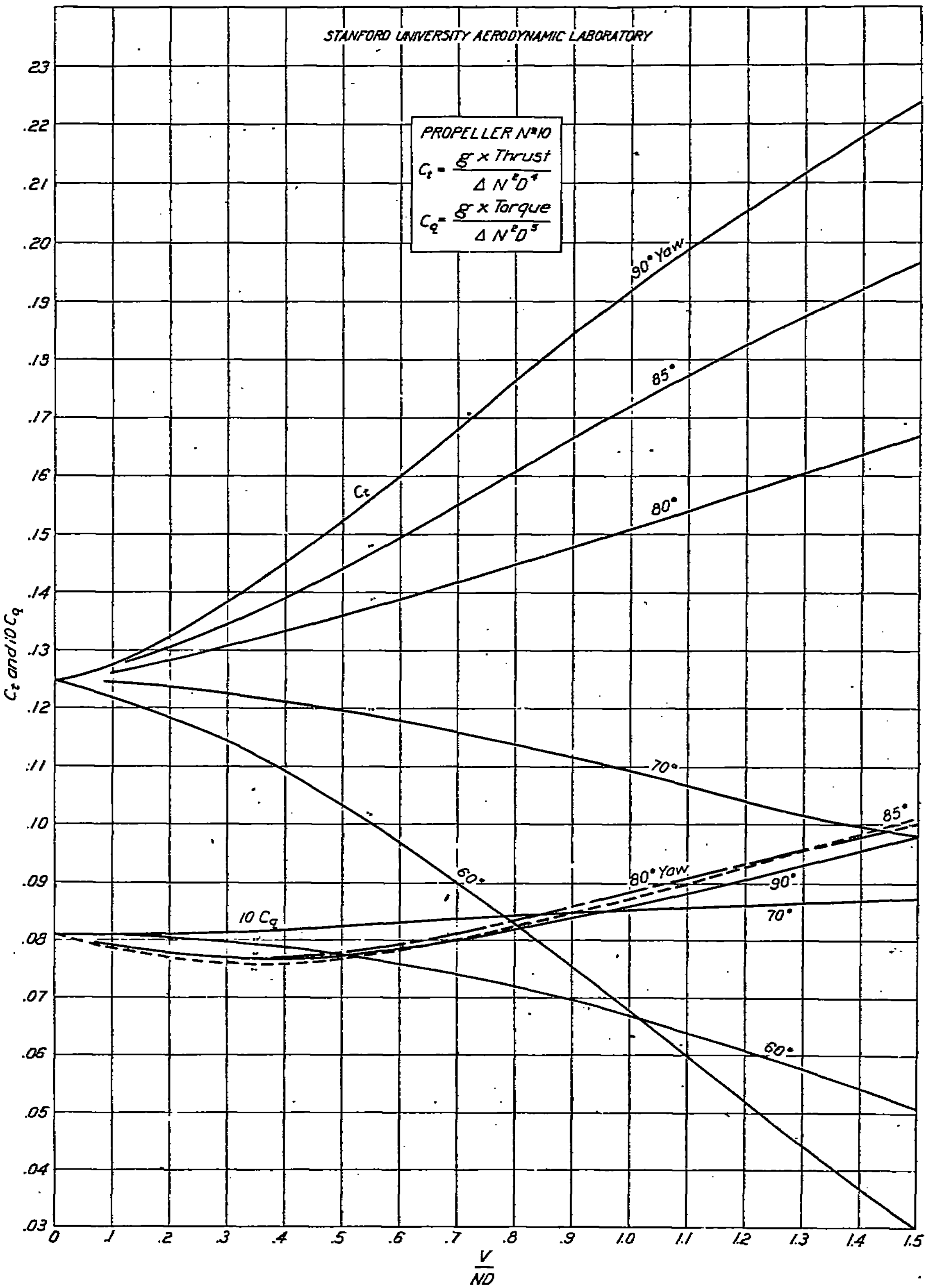
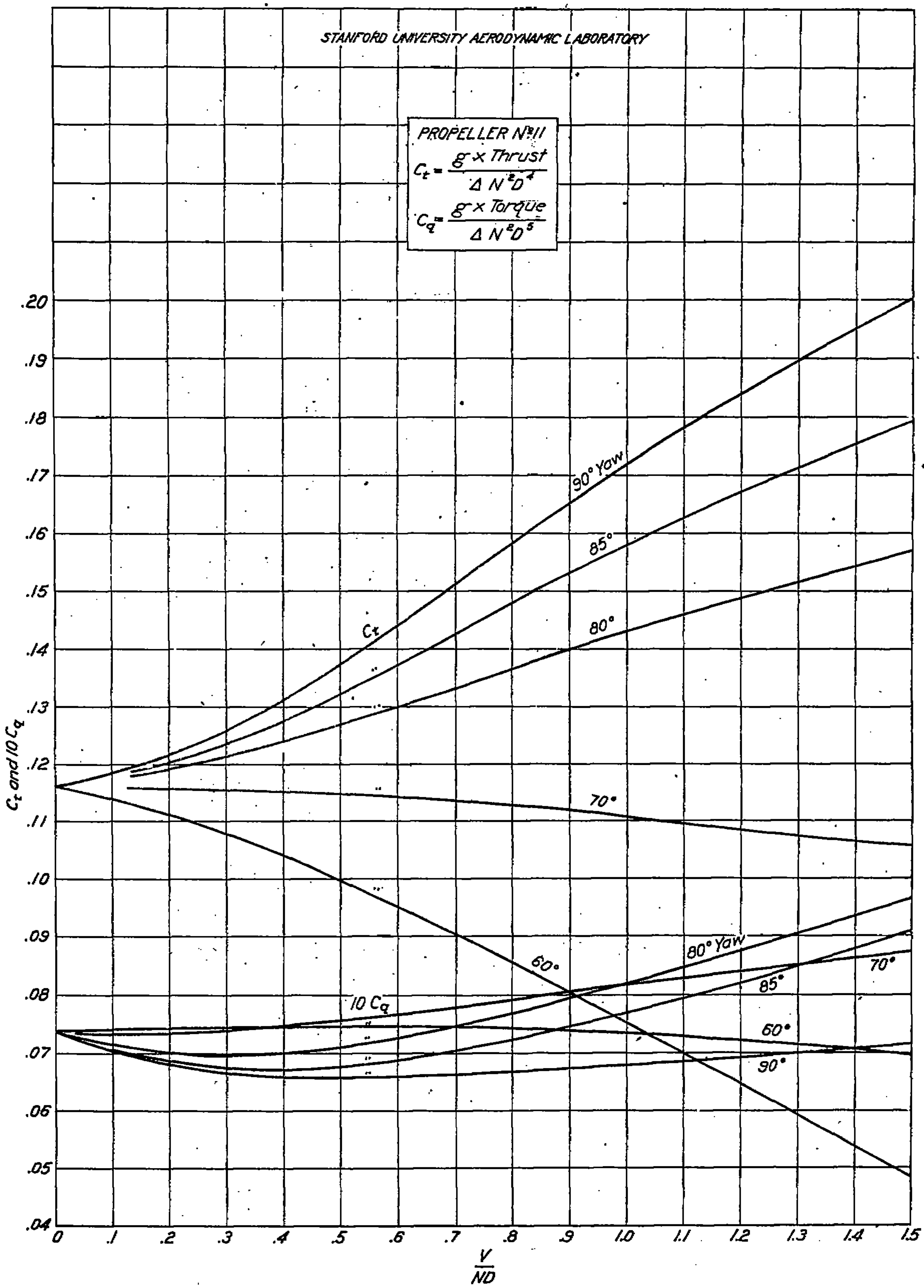

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER Nº10
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
90° Yaw
85°
80°
Ct
70°
60°
80° Yaw
90°
70°
60°
85°
10 Cq
Ct and 10 Cq
V/ND
.23
.22
.21
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5

PLATE VIII.



STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER No. 11
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
C_t and 10 C_q
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
$\frac{V}{ND}$
C_t
90° Yaw
85°
80°
70°
60°
10 C_q
80° Yaw
70°
85°
60°
90°

PLATE IX.

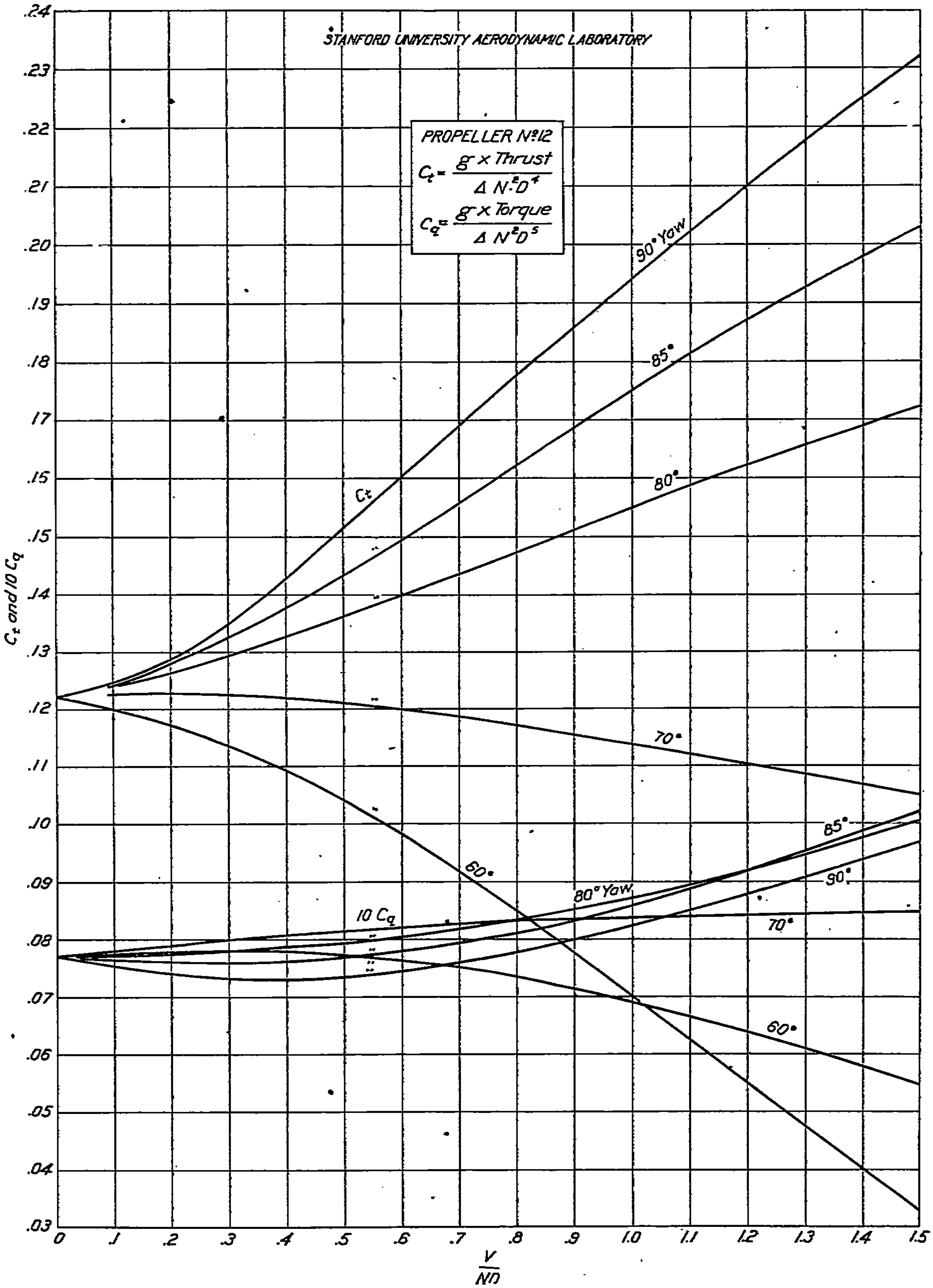

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER No. 12
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
90° Yaw
85°
80°
Ct
70°
60°
10 Cq
80° Yaw
85°
90°
70°
60°
Ct and 10 Cq
V / ND
.24
.23
.22
.21
.20
.19
.18
.17
.15
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5

PLATE X.

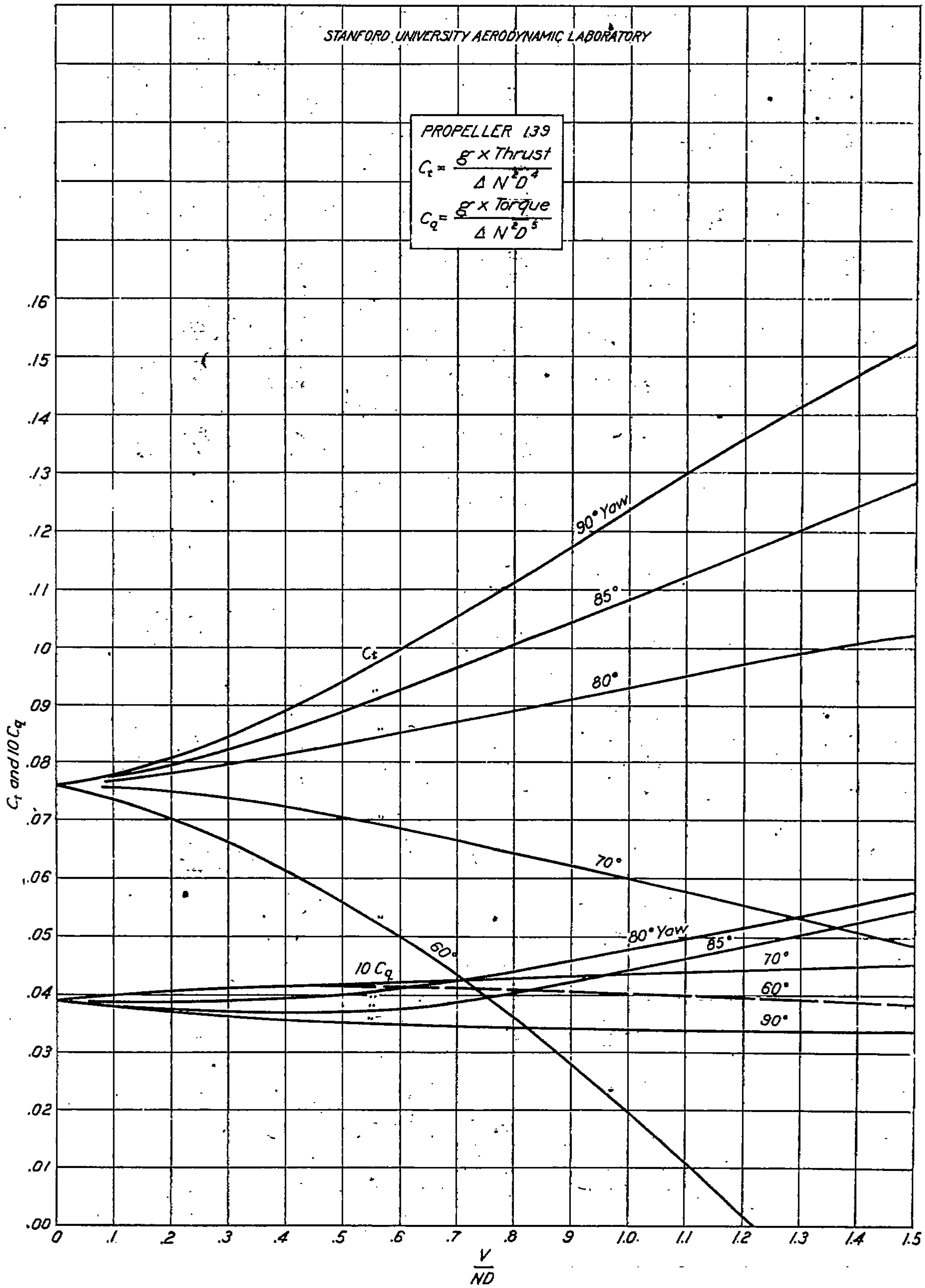

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 139
Ct = g x Thrust / Δ N²D⁴
Cq = g x Torque / Δ N²D⁵
Ct and 10 Cq
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
.00
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
90° Yaw
85°
80°
70°
60°
Ct
10 Cq
80° Yaw
85°
70°
60°
90°
V/ND

PLATE XI.

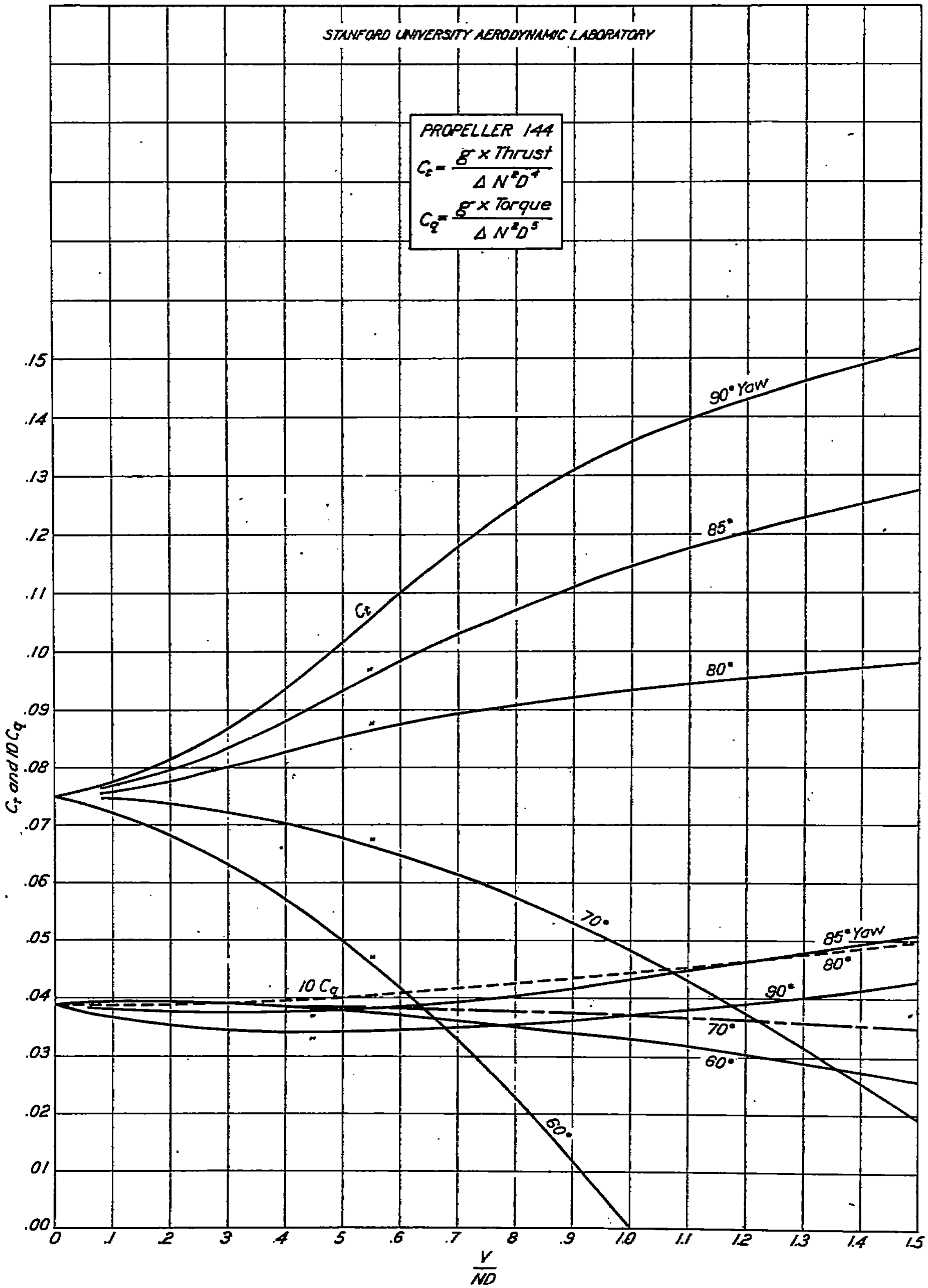

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 144
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
90° Yaw
85°
80°
70°
60°
Ct
10 Cq
85° Yaw
80°
90°
70°
60°
Ct and 10 Cq
V/ND

PLATE XII.

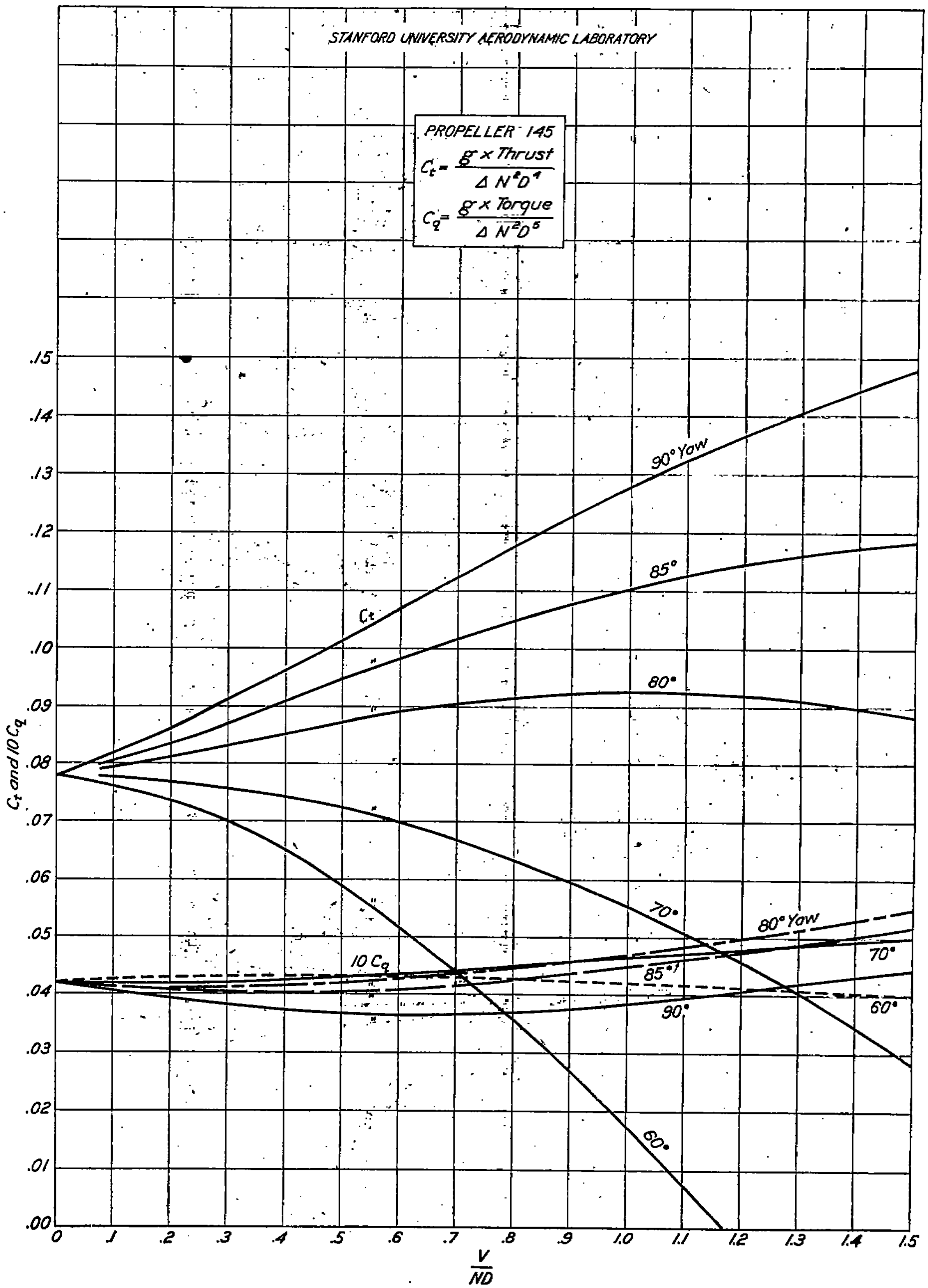

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 145
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
90° Yaw
85°
80°
70°
60°
C_t
$10\,C_q$
80° Yaw
70°
85°
90°
60°
C_t and $10\,C_q$
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
.00
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
$\frac{V}{ND}$

PLATE XIII.

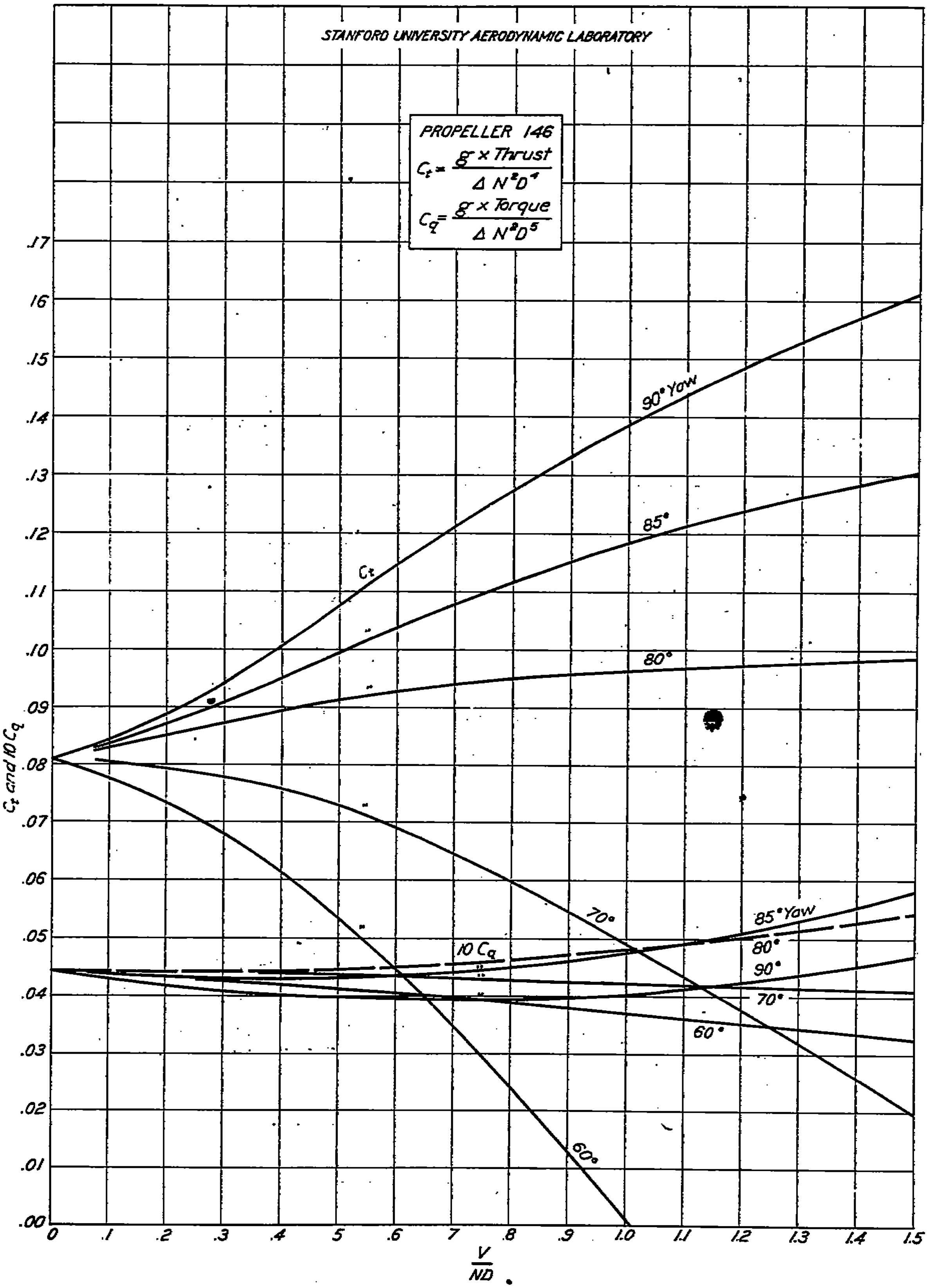

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 146
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
90° Yaw
85°
80°
70°
60°
C_t
10 C_q
85° Yaw
80°
90°
70°
60°
C_t and 10 C_q
.00
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
.11
.12
.13
.14
.15
.16
.17
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
$\frac{V}{ND}$

PLATE XIV.

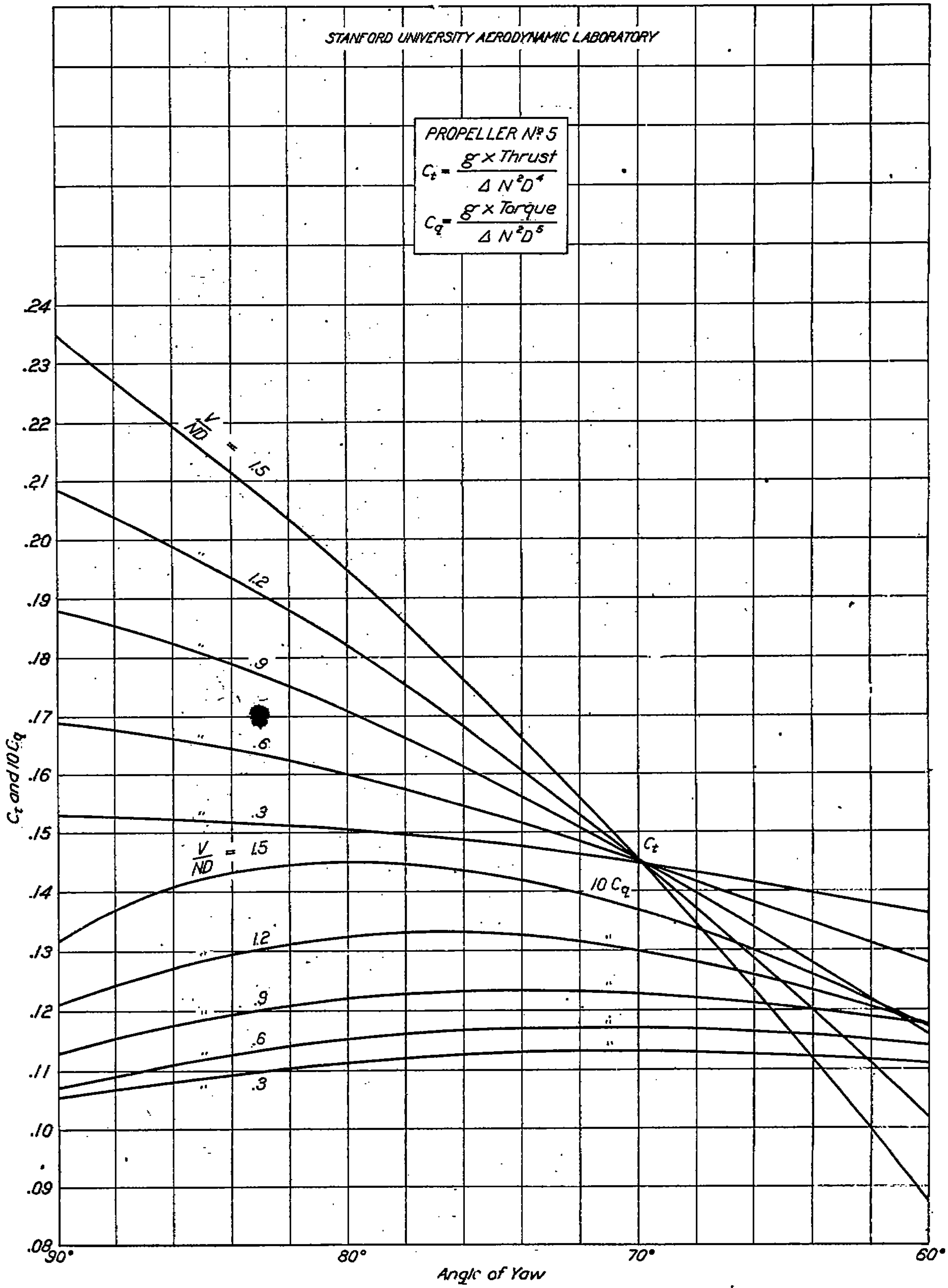

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER No. 5
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
$\frac{V}{ND}$ = 1.5
1.2
.9
.6
.3
$\frac{V}{ND}$ = 1.5
1.2
.9
.6
.3
C_t
10 C_q
C_t and 10 C_q
.24
.23
.22
.21
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
90°
80°
70°
60°
Angle of Yaw

PLATE XV.

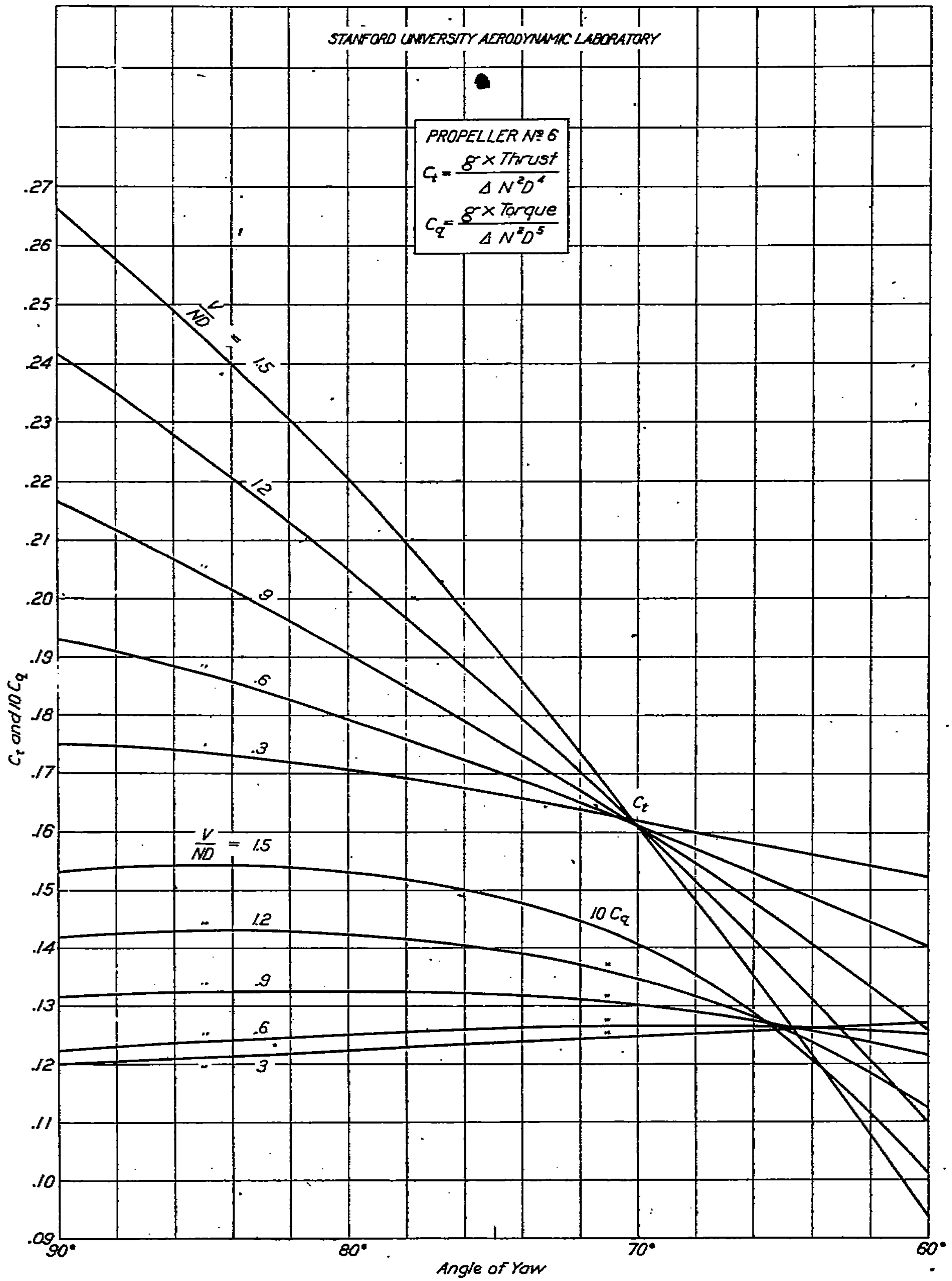

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER No 6
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
$\frac{V}{ND}$ = 1.5
1.2
.9
.6
.3
C_t
$\frac{V}{ND}$ = 1.5
1.2
.9
.6
.3
10 C_q
.27
.26
.25
.24
.23
.22
.21
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
C_t and 10 C_q
90°
80°
70°
60°
Angle of Yaw

PLATE XVI.

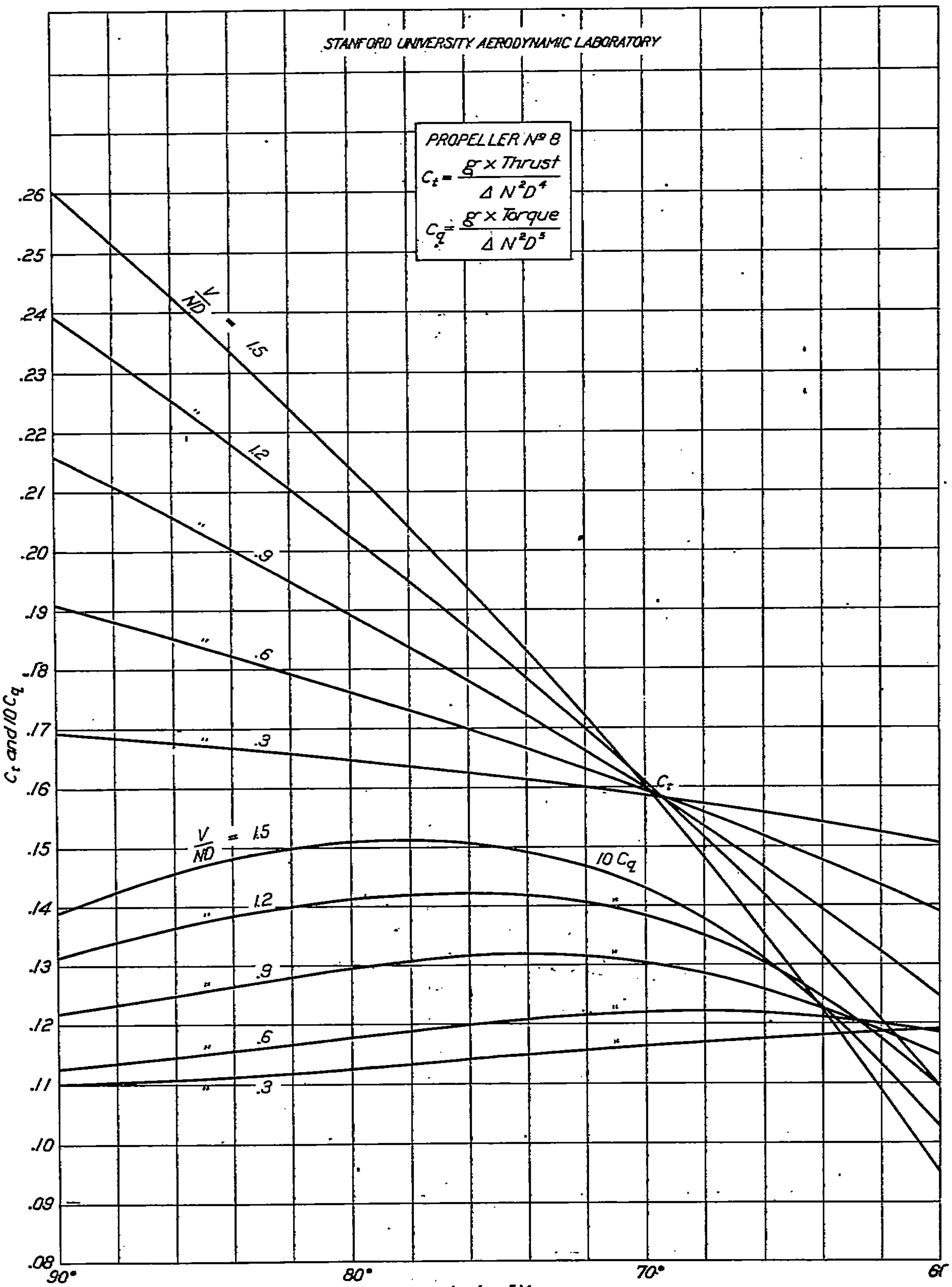

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER Nº 8
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
$\frac{V}{ND}$ = 1.5
1.2
.9
.6
.3
C_t
$\frac{V}{ND}$ = 1.5
1.2
.9
.6
.3
10 C_q
.26
.25
.24
.23
.22
.21
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
C_t and 10 C_q
90°
80°
70°
60°
Angle of Yaw

PLATE XVIII.

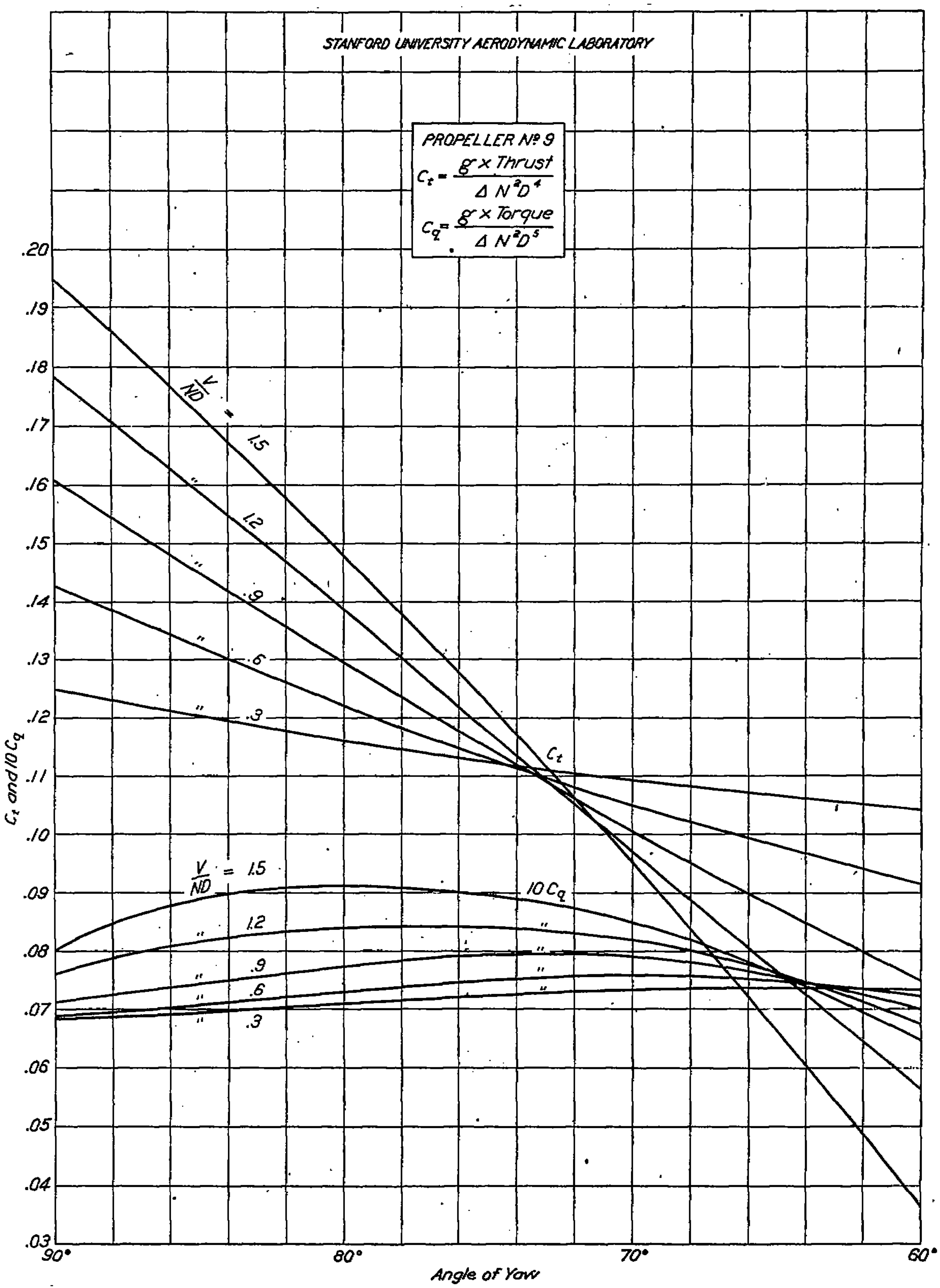

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER No 9
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
$\frac{V}{ND}$ = 1.5
" 1.2
" .9
" .6
" .3
C_t
$\frac{V}{ND}$ = 1.5
$10 C_q$
" 1.2
" .9
" .6
" .3
C_t and $10 C_q$
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
90°
80°
70°
60°
Angle of Yaw

PLATE XIX.

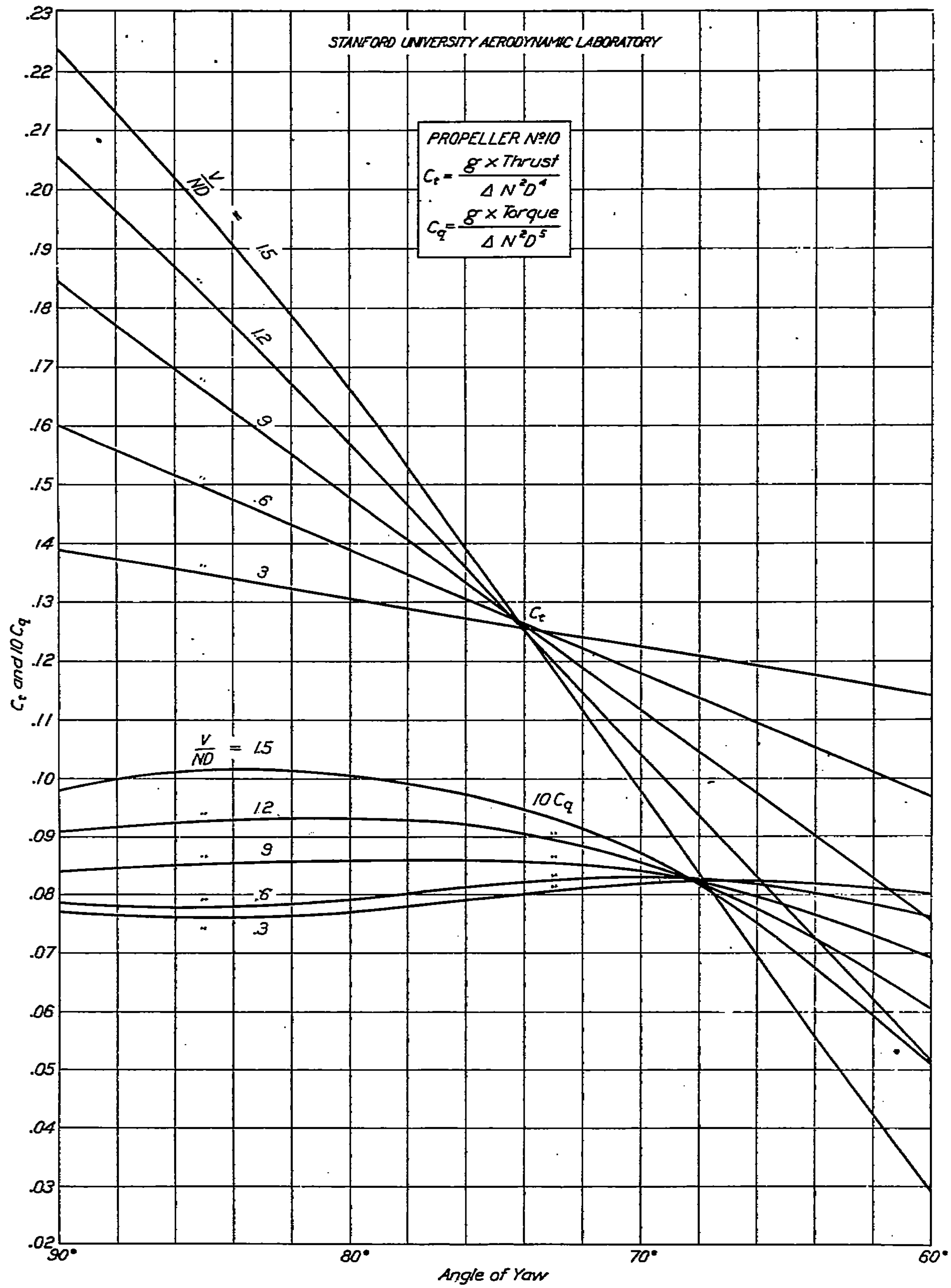

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER No. 10
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
$\frac{V}{ND}$ = 1.5
1.2
.9
.6
.3
C_t
$\frac{V}{ND}$ = 1.5
1.2
.9
.6
.3
$10 C_q$
C_t and $10 C_q$
.23
.22
.21
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
90°
80°
70°
60°
Angle of Yaw

PLATE XX.

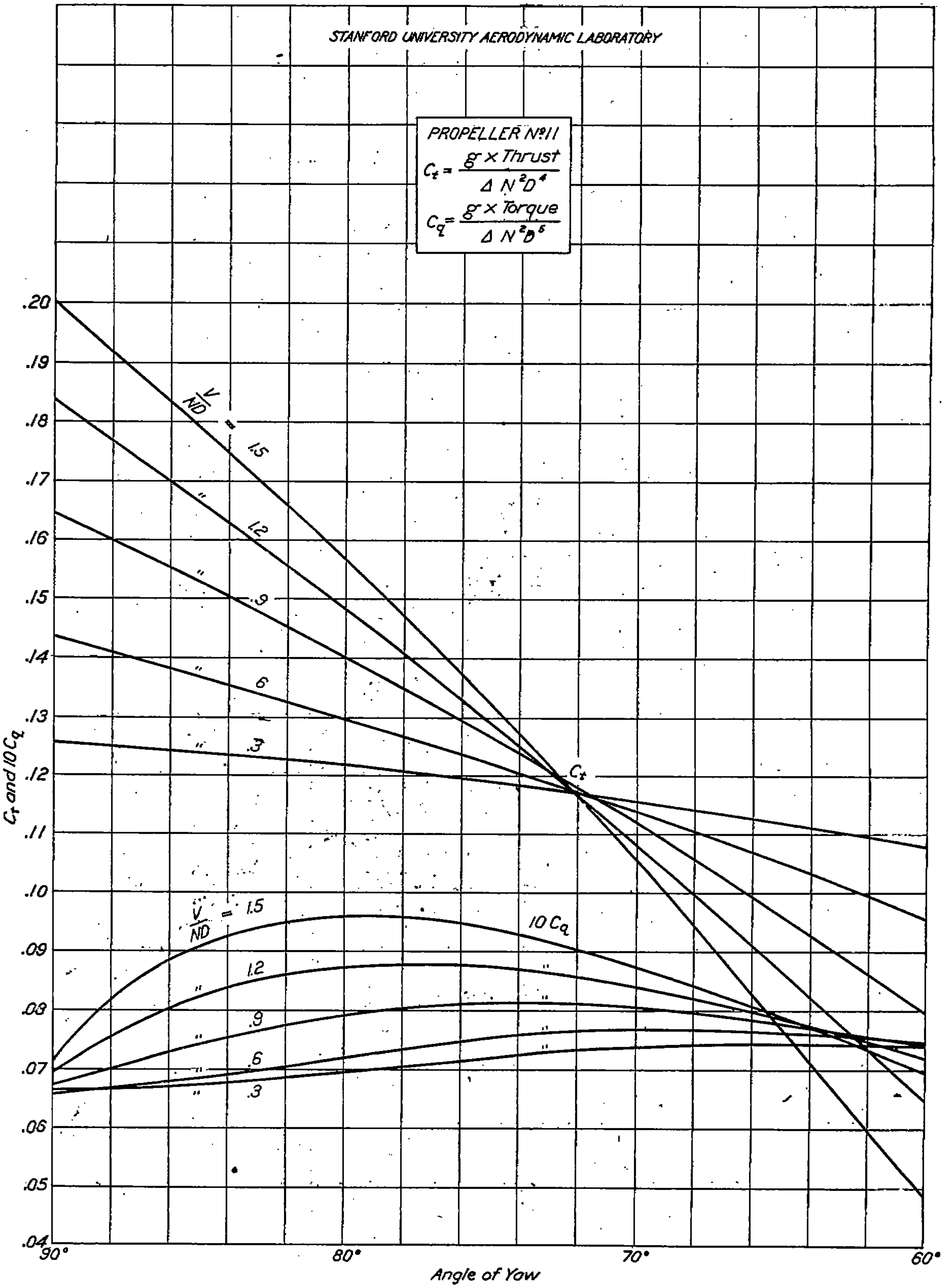

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER Nº 11
Ct = g × Thrust / Δ N²D⁴
Cq = g × Torque / Δ N²D⁵
V/ND = 1.5
" 1.2
" .9
" .6
" .3
Ct
10 Cq
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
Ct and 10 Cq
90°
80°
70°
60°
Angle of Yaw

PLATE XXI.

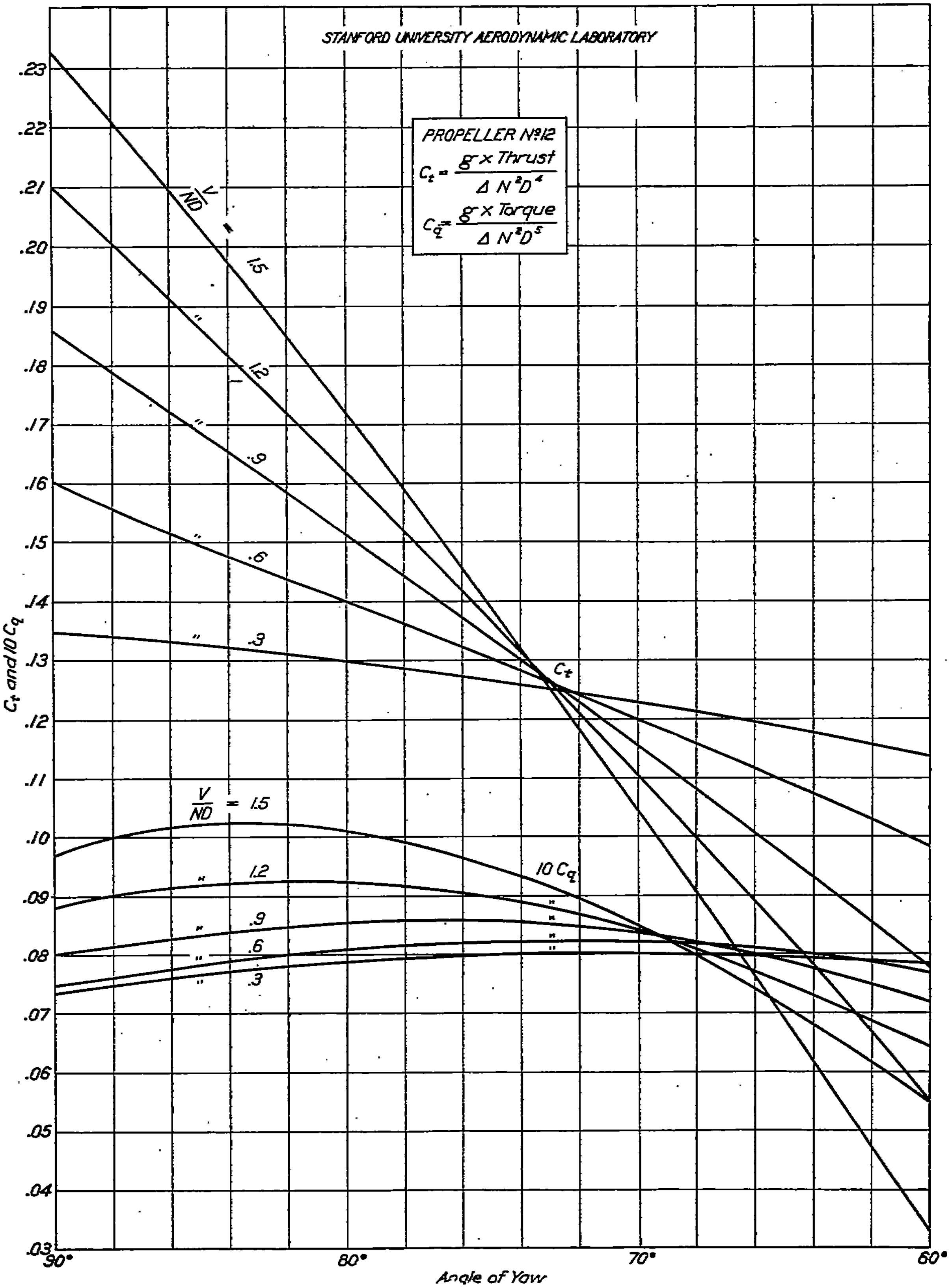
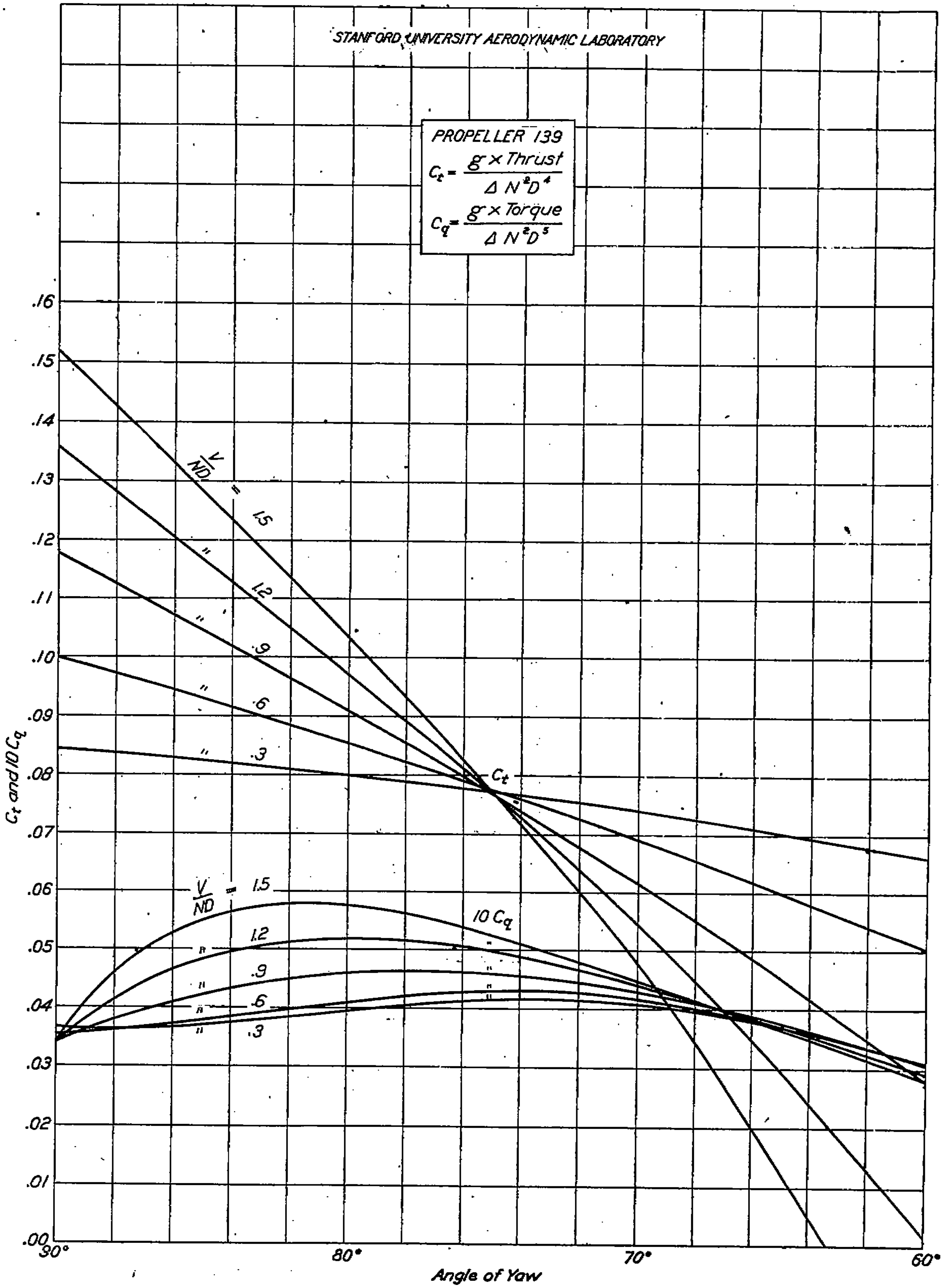

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER Nº12
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
V/ND = 1.5
" 1.2
" .9
" .6
" .3
C_t
$10\,C_q$
C_t and $10\,C_q$
.23
.22
.21
.20
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
90°
80°
70°
60°
Angle of Yaw

PLATE XXII.



STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 139
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
$\frac{V}{ND}$ = 1.5
" 1.2
" .9
" .6
" .3
C_t
$\frac{V}{ND}$ = 1.5
" 1.2
" .9
" .6
" .3
10 C_q
C_t and 10 C_q
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
.00
90°
80°
70°
60°
Angle of Yaw

PLATE XXIII.

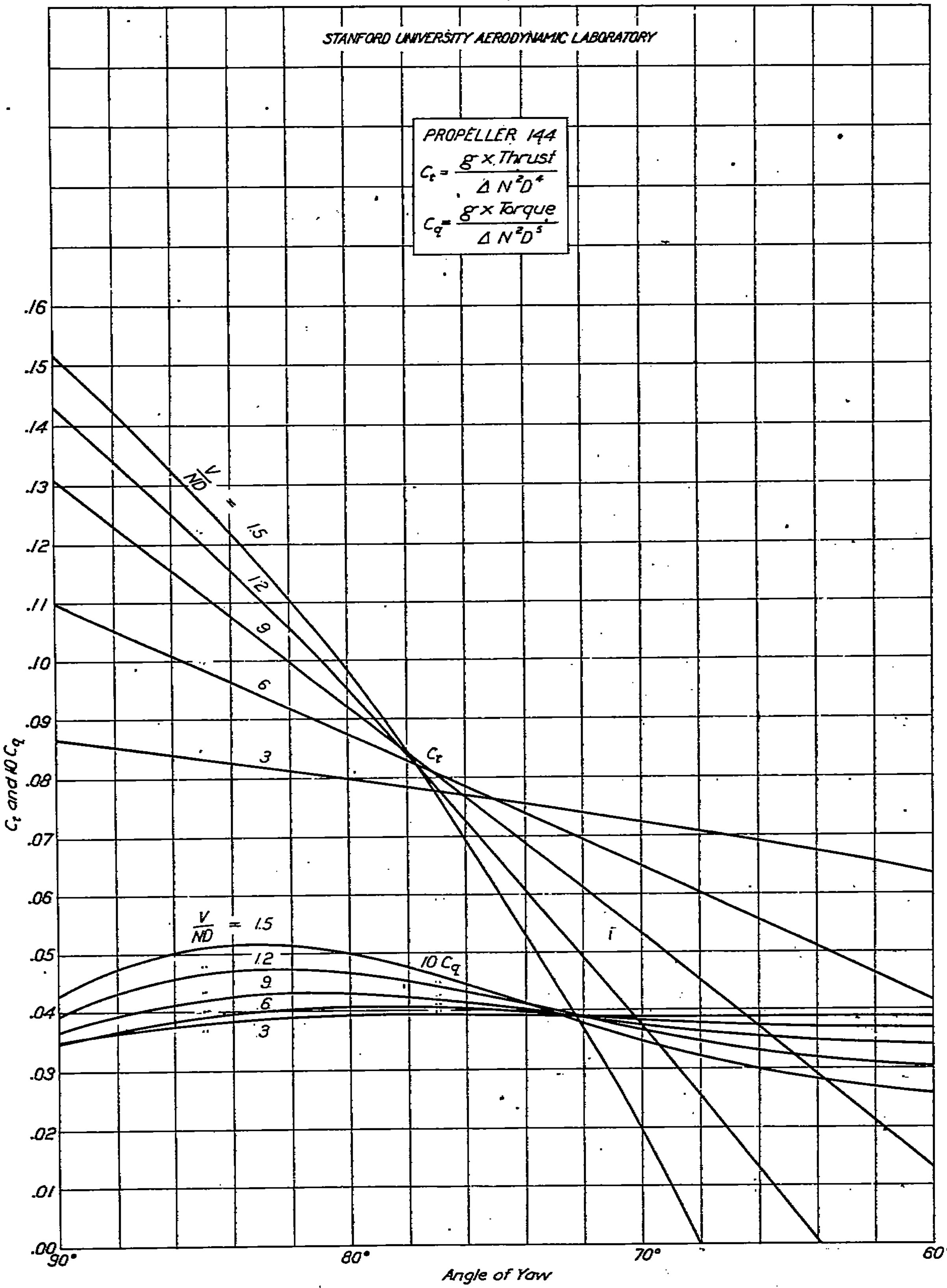

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 144
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
C_t and $10\,C_q$
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
.00
V/ND = 1.5
1.2
.9
.6
.3
C_t
$10\,C_q$
90°
80°
70°
60°
Angle of Yaw

PLATE XXIV.

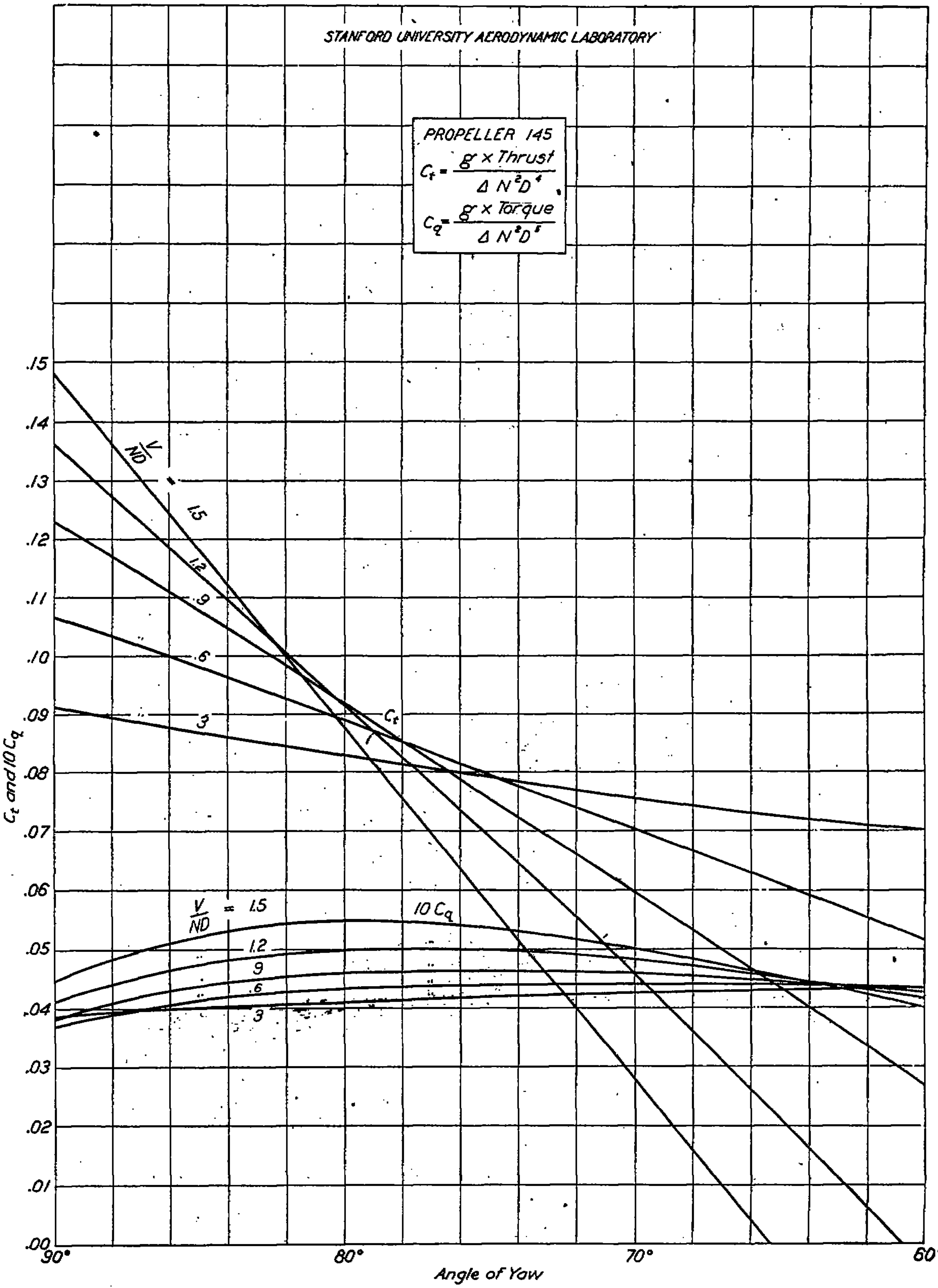

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 145
Ct = g x Thrust / Δ N²D⁴
Cq = g x Torque / Δ N²D⁵
V/ND = 1.5
1.2
.9
.6
.3
Ct
10 Cq
Ct and 10 Cq
.00
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
.11
.12
.13
.14
.15
90°
80°
70°
60°
Angle of Yaw

PLATE XXV.

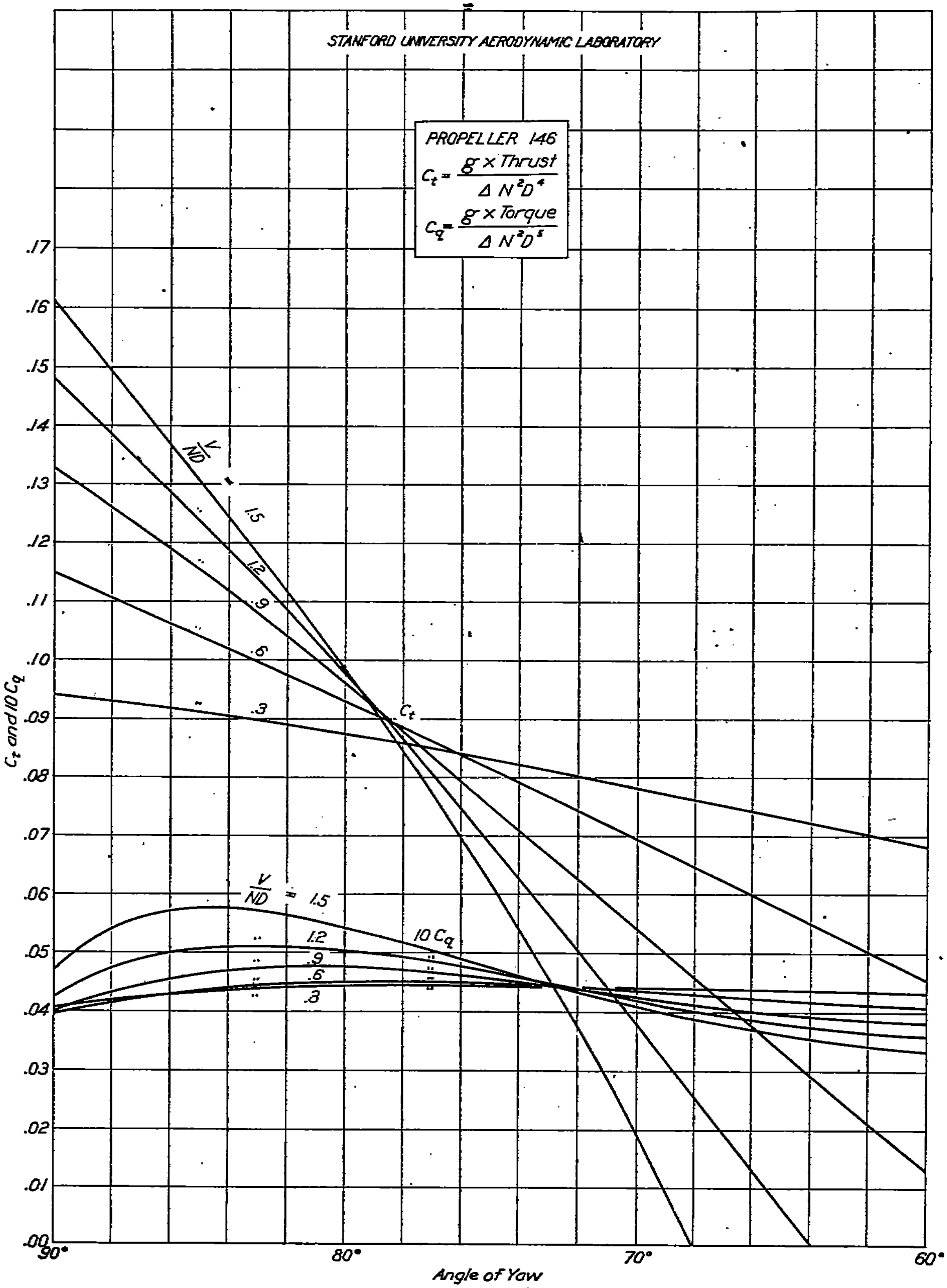

STANFORD UNIVERSITY AERODYNAMIC LABORATORY
PROPELLER 146
$C_t = \frac{g \times Thrust}{\Delta N^2 D^4}$
$C_q = \frac{g \times Torque}{\Delta N^2 D^5}$
$\frac{V}{ND}$ = 1.5
1.2
.9
.6
.3
C_t
$\frac{V}{ND}$ = 1.5
1.2
.9
.6
.3
10 C_q
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
.00
C_t and 10 C_q
90°
80°
70°
60°
Angle of Yaw

PLATE XXVI.