NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 195

STANDARDIZATION TESTS OF N. A. C. A. No. 1 WIND TUNNEL

By ELLIOTT G. REID

WASHINGTON
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1924

AERONAUTICAL SYMBOLS.

1. FUNDAMENTAL AND DERIVED UNITS.

	Symbol.	Metric.		English.	
		Unit.	Symbol.	Unit.	Symbol.
Length	l	meter	m.	foot (or mile)	ft. (or mi.).
Time	t	second	sec.	second (or hour)	sec. (or hr.).
Force	F	weight of one kilogram	kg.	weight of one pound	lb.
Power	P	kg.m/sec		horsepower	HP
Speed		m/sec	m. p. s.	mi/hr	M. P. H.

2. GENERAL SYMBOLS, ETC.

Weight, $W=mg$.

Standard acceleration of gravity, $g=9.806\text{m/sec.}^2=32.172\text{ft/sec.}^2$

Mass, $m=\dfrac{W}{g}$

Density (mass per unit volume), ρ

Standard density of dry air, 0.1247 (kg.-m.-sec.) at 15.6°C. and 760 mm. = 0.00237 (lb.-ft.-sec.)

Specific weight of "standard" air, 1.223 kg/m.^{3} = 0.07635 lb/ft.^{3}

Moment of inertia, mk^2 (indicate axis of the radius of gyration, k, by proper subscript).

Area, S; wing area, S_w, etc.

Gap, G

Span, b; chord length, c.

Aspect ratio $=b/c$

Distance from $c.\ g.$ to elevator hinge, f.

Coefficient of viscosity, μ.

3. AERODYNAMICAL SYMBOLS.

True airspeed, V

Dynamic (or impact) pressure, $q=\frac{1}{2}\rho V^2$

Lift, L; absolute coefficient $C_L=\dfrac{L}{qS}$

Drag, D; absolute coefficient $C_D=\dfrac{D}{qS}$.

Cross-wind force, C; absolute coefficient $C_c=\dfrac{C}{qS}$.

Resultant force, R

(Note that these coefficients are twice as large as the old coefficients L_c, D_c.)

Angle of setting of wings (relative to thrust line), i_w

Angle of stabilizer setting with reference to thrust line i_t

Dihedral angle, γ

Reynolds Number $=\rho\dfrac{Vl}{\mu}$, where l is a linear dimension.

e. g., for a model airfoil 3 in. chord, 100 mi/hr., normal pressure, 0°C: 255,000 and at 15.6°C, 230,000;

or for a model of 10 cm. chord, 40 m/sec., corresponding numbers are 299,000 and 270,000.

Center of pressure coefficient (ratio of distance of C. P. from leading edge to chord length), C_p.

Angle of stabilizer setting with reference to lower wing. $(i_t - i_w)=\beta$

Angle of attack, α

Angle of downwash, ϵ

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By ELLIOTT G. REID
Langley Memorial Aeronautical Laboratory

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REPORT No. 195.

STANDARDIZATION TESTS OF N. A. C. A. No. 1 WIND TUNNEL.

By Elliott G. Reid.

SUMMARY.

The tests described in this report were made in the 5-foot atmospheric wind tunnel of the National Advisory Committee for Aeronautics, at Langley Field, with the primary object of collecting data on the characteristics of this tunnel for comparison with those of others throughout the world, in order that, in the future, the results of tests made in all the principal laboratories may be interpreted, compared, and coordinated on a basis of scientifically established relationships, a process hitherto impossible due to the lack of comparable data.

The work includes tests of a disk, spheres, cylinders, and airfoils, explorations of the test section for static pressure and velocity distribution, and determination of the variations of air-flow direction throughout the operating range of the tunnel.

INTRODUCTION.

Although tests similar to the ones described herein have been carried out at nearly all large laboratories, the systematic exchange of a comprehensive series of models for test under standard operating conditions, with the object of standardization, has never been accomplished and so reference to truly contemporary work is impossible.

The "Standardization Tests" of this report consist in drag determinations on a disk, spheres, cylinders (axes perpendicular to air flow) and similitude studies on a series of four U. S. A. 16 airfoils. All these tests were made under standard operating conditions.

With spheres, considerable additional work was done to ascertain the effects of turbulence, method of support, etc. This last division of the data, being extraneous to the present report, is available in N. A. C. A. Technical Report No. 185.[1]

DESCRIPTION OF THE TUNNEL.

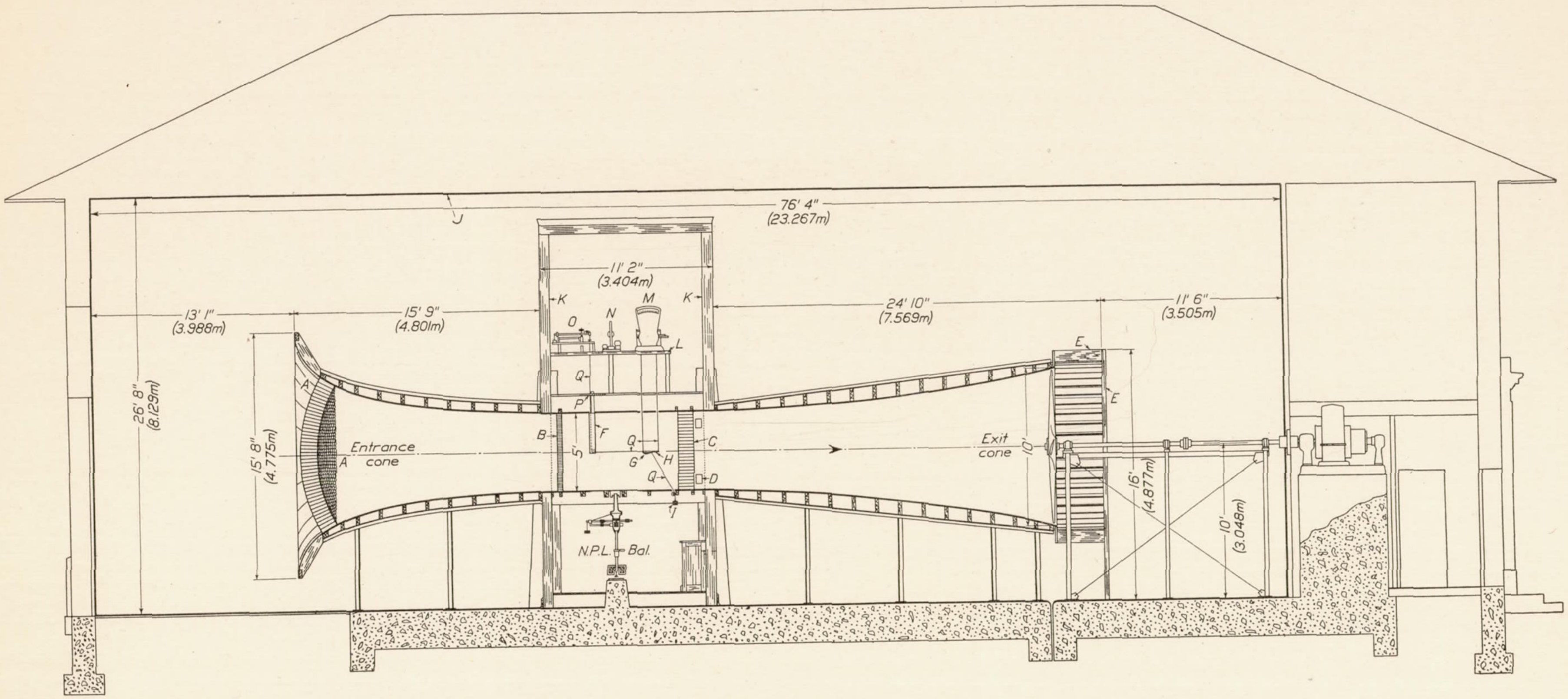
The atmospheric tunnel at Langley Field is of the open circuit, closed throat type. It is shown in longitudinal section, with its housing, in Figure 1. The tunnel itself will be seen to consist of portions of two parabolic cones connected by a cylinder. The over-all length of the tunnel is approximately 50 feet (15.2 m.) and of the cylinder, 11 feet (3.3 m.). The cross-section is everywhere circular, the diameter of the throat being 5 feet (1.52 m.).

In plan view, the tunnel is symmetrically located in a room 40 by 76 feet 2 inches (12.2 by 23.27 m.), but reference to Figure 1 shows the center line closer to the floor than to the ceiling.

The balance room is entirely closed but, as it is not absolutely air-tight, four "bleeder" openings of about 200 square inches (0.13 m^2.) total area have been cut in the tunnel walls just within the downstream wall of the test chamber (see Fig. 1) for the purpose of reducing to a minimum the pressure difference between throat and balance room. In this way leakage through the inevitable openings in the throat section is made negligible and the air-flow direction is rendered immune to the influences of changes of leakage into the balance room.

The devices used for air-flow damping and correction are:

[1] See also National Advisory Committee for Aeronautics Technical Note No. 130—"Model Supports and Their Effect on the Results of Wind Tunnel Tests"—1923.



A-Spherical honeycomb (12"x2½"±conical tubes), bell mouth of beaver board
B-Honeycomb-fine (3"x⅜"-7.62x0.95 cm tubes)
C-Rear honeycomb (12"x2½"-30.48x6.35 cm tubes)
D-Bleeding holes-four (10"x5"-25.40x12.70 cm)
E-Squirrel cage of 48 radial vanes (3'x9"x⅞") and deflector of beaver board on 2x4^s
F-Streamlined strut
G-Airfoil, 6" chord, inverted
H-Skids 12" long
I-Counterweight
J-Ceiling
K-Experiment chamber wall
L-Bench for instruments
M-Lift balance, angle of attack and center of pressure indicator
N-Micro-manometer
O-Drag balance
P-Cast-iron plate for supporting strut
Q-Wire

FIG. 1.—N. A. C. A. atmospheric No. 1 wind tunnel.

A honeycomb, in the mouth of the entrance cone, made of 2½ by 12 inch (6.35 by 30.48 cm.) conical sheet-metal tubes whose ends define portions of two concentric spherical surfaces.

A very fine honeycomb of ⅜ by 3 inch (0.95 by 7.62 cm.) tubes which is mounted on two pairs of sliding trunnions at the front of the throat section, thus providing for a small range of universal angular adjustment.

A honeycomb of 2½ by 12 inch (6.35 by 30.48 cm.) cylindrical tubes at the back of test section.

A "squirrel cage" torque reactor and flat plate deflector at the end of the exit cone. (See Figs. 1 and 2.) The squirrel cage, in which the vanes are obliquely set with respect to radii so as to neutralize the rotation of the air caused by the propeller, is partially closed, and nonsymmetrically so, to correct for the dissymmetries of the whole installation.

These devices combine their effects in such a way that the air flow through the test section is very smooth and constant. A velocity exploration across the horizontal diameter showed that while there were small variations from point to point (± 1.5 per cent from the mean being a maximum) these irregularities are constant with respect to time. It was also found that the drag strut of the wire balance produced a wake of about 2 inches width in which the velocity was low but within the limit given above.

Static pressure was found to have a linear gradient over most of the length of the test section, as shown in Figure 3, and the value of this gradient is a linear function of dynamic pressure. (See Fig. 4.)

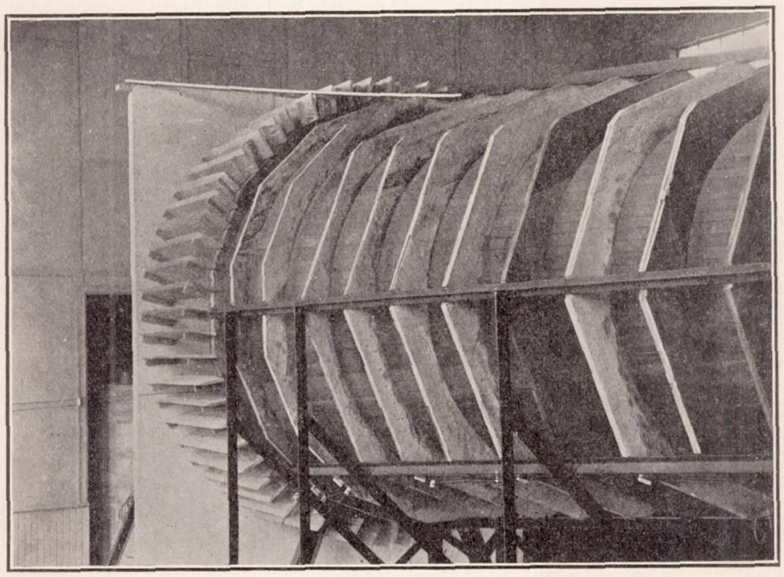


FIG. 2.—End of exit cone.

POWER EQUIPMENT.

Power for operating the four-bladed, 10-foot (3.05 m.) propeller is furnished by a 200-HP. D. C. motor. A specially designed system of electrical regulation operates on both the drive motor and the motor-generator set which supplies the current and serves to keep the propeller speed constant. This regulating mechanism is quite complex and will not be discussed here as a complete description may be found in N. A. C. A. Technical Note No. 81. The regulators will maintain any speed between 7 (22 ft.) and 40 meters (131 ft.) per second within approximately ± 0.1 per cent. For speeds below 7 meters per second, a potentiometer circuit is cut in and with the voltage regulator in operation, air speeds may be held constant within the limits of measurement stated in the following section.

AIRSPEED MEASURING APPARATUS.

The speed of the air stream is measured by a standard N. P. L. Pitot tube connected to a special micro-manometer. Details of the latter instrument may be found in N. A. C. A. Technical Note No. 81. With it, the Pitot head may thus be accurately read to 0.1 mm. of alcohol. The Pitot tube is mounted 1 foot (0.31 m.) upstream from the fine honeycomb and the orifices are approximately 15 inches (0.38 m.) from the tunnel wall. The head it indicates is not the true impact-static difference at the center of experimental section, and this is taken into consideration by a calibration of the "Service Pitot" against an identical tube mounted there. This installation is peculiarly advantageous for very close work since the location of the Pitot is so remote as to be entirely unaffected by any disturbance around a model under test.

BALANCES.

In the course of the tests, three balances were used. The work on cylinders, the disk, and spheres was done on the N. P. L. type balance. A complete description of this instrument will be found in Technical Report No. 72. The accuracy and sensitivity have been somewhat improved over those of the original installation through the use of an improved main pivot. This now consists of a single steel ball riding on three smaller balls which are supported in a hemispherical cup.

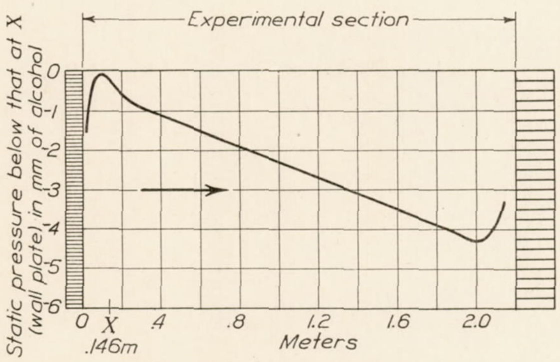


FIG. 3.—Static pressure gradient.

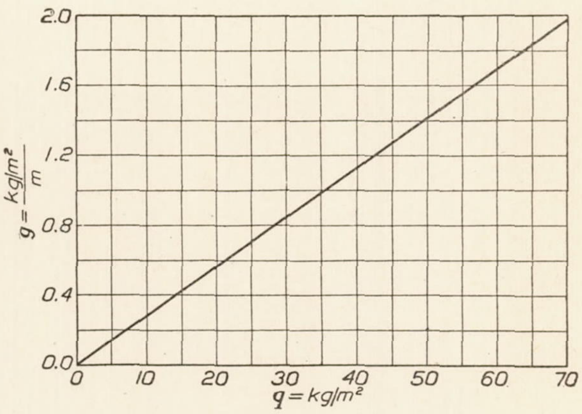


FIG. 4.—Variation of static pressure gradient with dynamic pressure.

In the airfoil tests use was made of the "wire balance." This apparatus, schematically shown in Figure 1, will be seen to consist of two independent balances, each of which measure one component of the air reaction. The lift balance is simply a special Toledo scale in which a platform deflection of 0.050 inch (1.27 mm.) corresponds to a force of 10 kg. (22 pounds). Its minimum reading is 0.005 kg. (0.011 pound). The drag balance is a simple beam on knife edges; its stability and damping are adjustable and it will consistently check readings to within ± 0.0002 kg. (0.0004 lb.).

The method of transmitting the lift to the Toledo balance warrants no comment as it is accomplished through four vertical wires in tension. The drag forces, however, are transmitted to their balance at 90° to the direction of application. A very rigid hollow strut, extending down to the center line of the tunnel directly below the drag balance, carries a flat grooved pulley at its lower extremity (see Figure 1). The ends of the pulley shaft are conical and ride in polished instrument sockets. Instead of carrying the drag wire around the pulley, a narrow strip of 0.002 inch (0.05 mm.) shim steel is spliced in to avoid stiffness at the section of contact and the friction of this system is imperceptible for any loads thus far encountered.

PROCEDURE AND RESULTS.

TEST OF DISK.

Drag determinations were made on a 15 cm. (5.91 inches) steel disk of 1.59 mm. (0.06 inch) thickness. The back was chamfered at 45° to give a knife edge periphery. The disk was supported on a right angle spindle attached to the downstream face. The vertical section of the spindle was shielded in a fairing; the horizontal arm was 20 cm. (7.87 inches) in length.

Drag was measured on the N. P. L. balance and the observations cover the entire speed range of the tunnel.

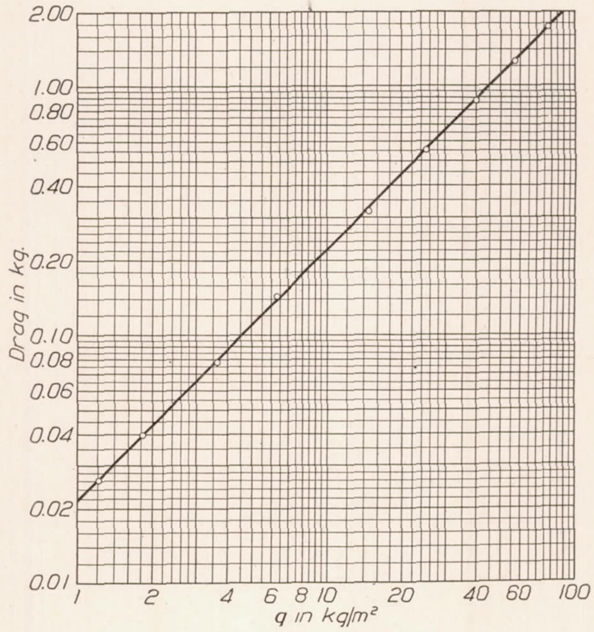


FIG. 7.—Resistance of disk.

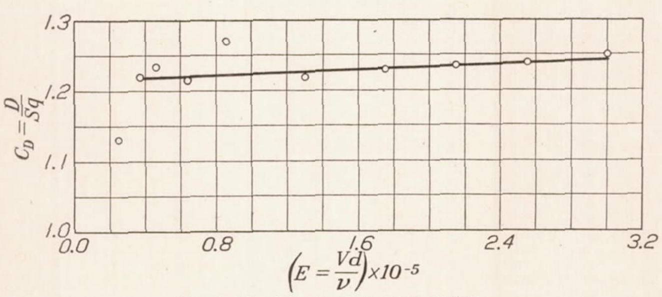


FIG. 8.—Resistance coefficients of disk.

DISCUSSION.

Table I contains both test data and calculated coefficents for the disk; the values of drag and C_D are plotted in Figures 7 and 8.

No unusual results were found in this test; the coefficients agree very well with those found previously in several laboratories.

TESTS OF SPHERES.

Two wooden spheres, 15 and 20 cm. (5.91 and 7.87 inches) in diameter were tested throughout the speed range of the tunnel to determine the behavior of the drag coefficients under the standard testing conditions. The spheres were of laminated wooden construction, gauged to very close limits of sphericity, and finished by rubbing down several coats of spar varnish on the surface of each one. Brass plugs, threaded to receive a spindle, were built in, the plugs being filed smooth and flush with the surfaces.

Measurements were made on the N. P. L. balance; the set-up is shown in Figure 5. Two spindles were provided, each having a horizontal arm of such length as to separate the sphere and the vertical portion of the spindle by one sphere diameter.

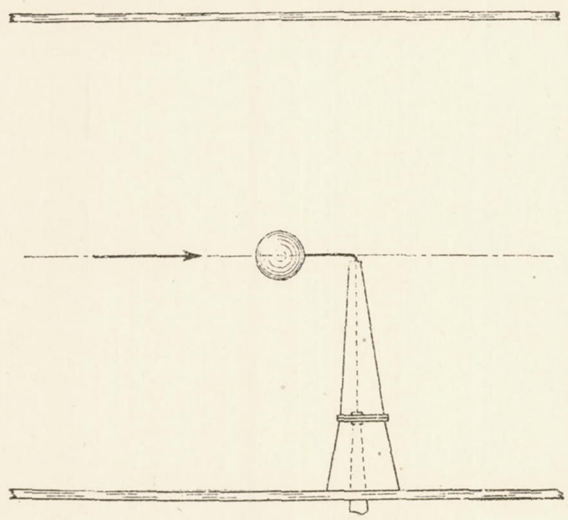


FIG. 5.—Sphere set up in wind tunnel.

Considerable difficulty was experienced with the stability conditions while the airflow passed through the transitional regime but repetition of the tests gave excellent checks of the results. Experiments with a dummy set-up showed the support drag to be negligible so the drag coefficients are calculated directly from balance readings.

DISCUSSION.

Tables II and III contain the data obtained from these tests. Actual drag forces have been plotted against Reynolds number in Figure 9 to show the magnitude of the unstable region of

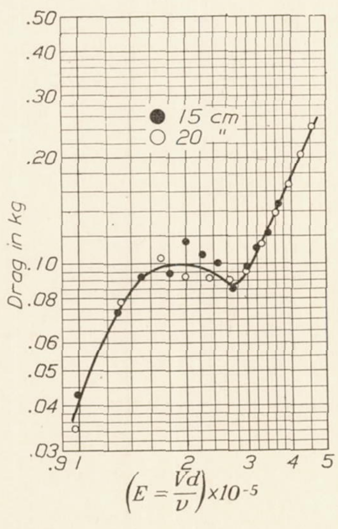


FIG. 9.—Resistance of spheres.

flow and to demonstrate the change in slope of the resistance curves at that stage. The resistance coefficients $C_D=\frac{D}{qd^2}$ (d being the sphere diameter), are plotted in Figure 10.

Two points of great interest stand out among the results of these tests. The agreement of the two sets of coefficients constitutes a remarkable confirmation of Reynolds law. The discrepancy existing through the transitional stage is attributed to the "scale effect of turbulance." Also, the texture of the airflow is shown to be quite unusual by the occurrence of the critical flow régime at a very high value of Reynolds number.

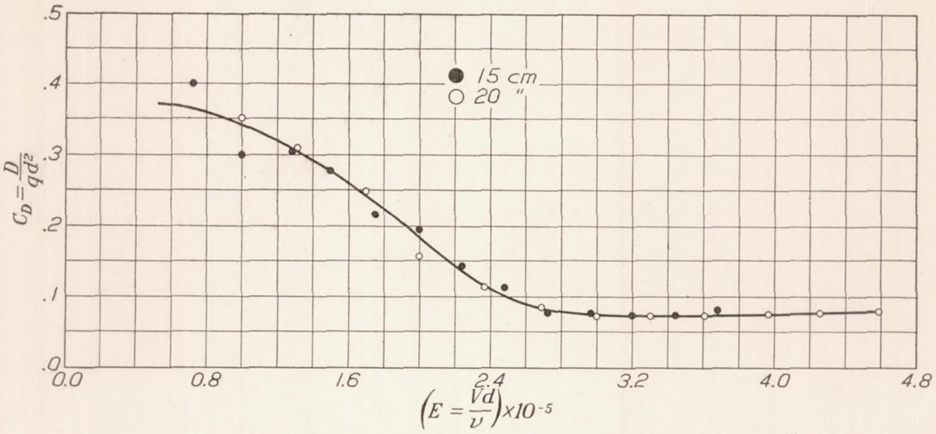


FIG. 10.—Resistance coefficients of spheres.

It will be remarked that the values of drag coefficients are extraordinarily low as compared with those obtained by previous investigators, but this seems quite logical in view of the effects of turbulance and support found in later tests and described in N. A. C. A. Technical Report No. 185.

TESTS OF CYLINDERS.

A series of tests was made on right circular cylinders with axes perpendicular to the airflow direction. The cylinders were of length: diameter ratio 5, and made of steel. Their surfaces were brought to the final polish with crocus cloth.

The drag measurements were made on the N. P. L. balance. Each cylinder was supported for test by two means, i. e., on an axial spindle and on a bent spindle which entered from downstream. In the latter case the cylinder axis was horizontal.

A pair of spindles was made for each cylinder, each bearing a constant relation to the cylinder diameter. The spindle diameter was, in each case, 0.125 that of the cylinder it supported; lengths of unshielded spindle were also proportional to the cylinder sizes. The vertical portions of all the bent spindles were enclosed in a fairing and the horizontal arms were 3.5 cylinder diameters in length; straight spindles were unshielded for a distance of two cylinder diameters below the model.

For the tests with bent spindles, the same spindle housing was used throughout. This was a tapered, hollow form, made of laminated paper and varnished. The open, upper end was of streamline form and about $\frac{5}{8}$ by $1\frac{3}{8}$ inches (15.88 by 34.93 mm.). To obtain proportional interference effects when testing on straight spindles, a conical streamlined form was made up and successively truncated for each increase of cylinder size. The fairing was so made that its upper end had the dimensions 0.75 by 1.8 cylinder diameters in each case.

In the tests with bent spindles it was found necessary to attach a wire to the spindle, midway along the horizontal arm. To eliminate any possible constraint by this device, the wire was taken off in such a direction that, if prolonged, it would pass through the balance pivot. Using fine wires, the additional drag was found negligible.

Vibration also became excessive during the test of the largest cylinder on the straight spindle. Here, again, an auxiliary wire was used. In this case, however, one turn was made around the middle of the cylinder and the two ends were attached to the walls of the balance room, each approximately 8 feet (2.4 m.) from the cylinder. Care was taken to introduce no drag component with the attachment of this support and, as before, the additional drag of the wire was found to be negligible.

Spindle drag was neglected in the tests with bent spindles because, with the cylinder otherwise supported, the drag of the spindle behind it was found to be always less than 2 per cent of the total. To determine support drag for the tests with end spindles, dummy wooden cylinders were made with an elliptical hole in one end so that they could be supported to give the same general flow around the "supported" end and yet allow the spindle enough freedom to permit the measurement of its drag.

DISCUSSION.

Tables IV–IX present the test data. The drag coefficients, shown in Figures 11 and 12, were calculated as $C_D = \frac{D}{Sq}$, wherein S is the cylinder's projected area. Horizontal buoyancy is neglected.

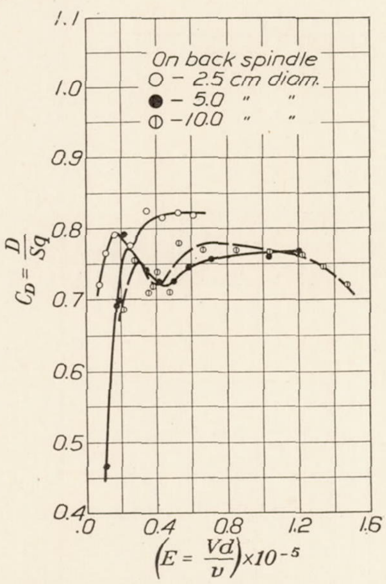


FIG. 11.—Resistance coefficients of cylinders.

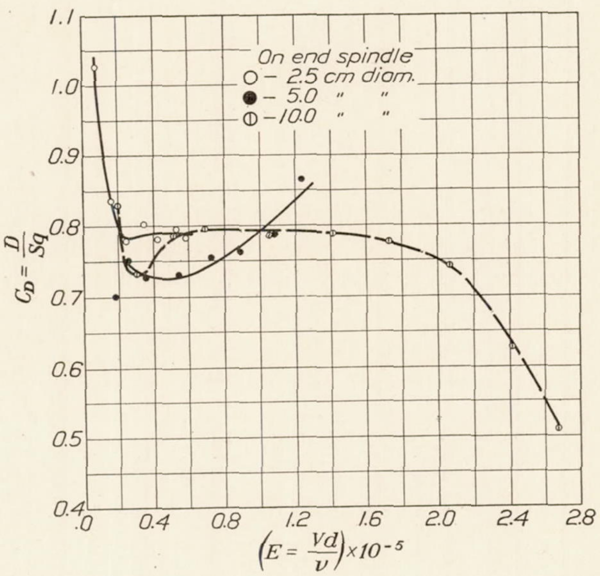


FIG. 12.

It is of interest to note the apparent modifications of flow introduced by an end spindle and the fact that even with back spindles the agreement of coefficients along the Reynolds base is not good. It seems quite probable that the scale of turbulence may be an important factor here as in the case of the spheres. As the interference of the support has not been studied extensively, a complete explanation of the discrepancies is impossible. It would seem from these tests, however, that the cylinder of finite length-diameter ratio behaves so erratically as to be of little use for comparison between tunnels.

SIMILITUDE TESTS OF AIRFOILS.

Four steel airfoils, U. S. A. 16 profile, of aspect ratio 6 and spans 45, 60, 75, and 90 cm. (17.71, 23.62, 29.52, and 35.43 inches), respectively, were tested throughout the useful range of angle of attack, lift and drag being measured at a series of airspeeds. Figure 6 is a photograph of the 15 by 90 cm. (5.9 by 35.43 inches) airfoil on the wire balance; the general scheme of the apparatus is shown in Figure 1.

All the airfoils were tested twice at each speed—first erect, then inverted—so that when a polar is drawn through the points which divide, equally, the distances between corresponding points of the polars calculated from the two sets of data, the effect of misalignment of the balance, with respect to the airstream, disappears. These pairs of runs also furnish the data necessary for the calculation of true direction of airflow by the method of maximum L/D ratios.

Careful determinations of wire drag were made by successive substitutions of two "spacers" of small steel rod for the airfoil. The variation of D_0 with angle of attack was taken into account only in the case of the largest airfoil; for the other three the effect was so small that accurate determinations could not be made. A polar (C_L vs. C_D) was plotted for each pair of tests.

To get at the more basic airfoil characteristics, the parabola of induced drag for the aspect ratio 6 was added to each polar and, from these curves, a series of plots was made to show, on a Reynolds number (E) base, the variations of profile drag coefficients (C_{DP}) for several lift coefficients.

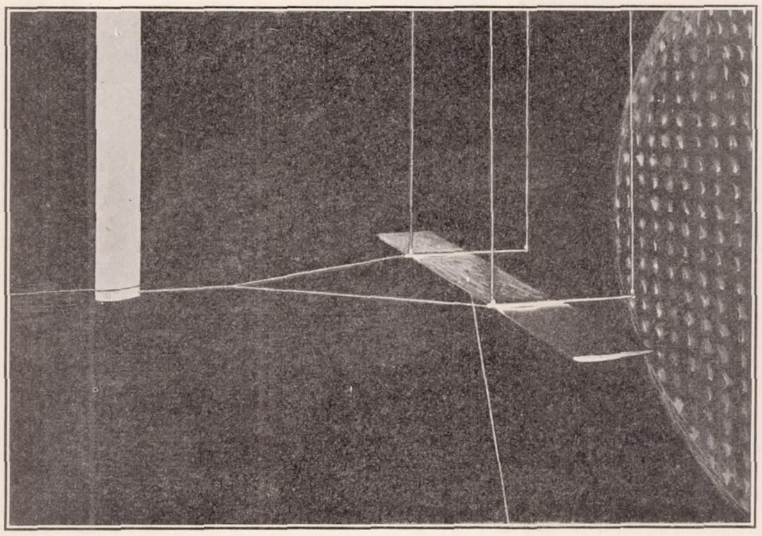


FIG. 6.—15×90 cm. airfoil on wire balance.

DISCUSSION.

The data from these tests is presented in Tables XI–XXIX and the Figures 13–30 give the resulting polars. The coordinates of these mean polars are tabulated in Table XXX. The parabolas of induced drag on these plots include the Prandtl correction for tunnel interference.[2] When the original C_{DP} vs. E plots were made, using the uncorrected C_{Di} parabolas, the curves were considerably separated vertically; application of the correction grouped them as they appear in Figures 31–35.[3] The interference corrections are shown in Figure 36.

The variations of airflow direction throughout the speed range are shown in Figure 37; the data are tabulated in Table XXXI. The angles were calculated from the formula:

$$\beta = \frac{\cot^{-1}\left(\frac{L}{D}\right)_1 - \cot^{-1}\left(\frac{L}{D}\right)_2}{2}$$

wherein $\frac{(L)}{(D)_1}$ and $\frac{(L)}{(D)_2}$ are the maximum values found for the erect and inverted tests, respectively.

[2] N. A. C. A. Technical Report No. 116, equation (72a), "Application of Modern Hydrodynamics to Aeronautics," 1921.

[3] Kumbruch (Gottingen) "Similitude Tests on Wing Sections" (N. A. C. A. Technical Note No. 53), 1921. It should be noted that some of these tests were made on wings of infinite aspect ratio and, therefore, have an exceptionally large range of Reynolds number.

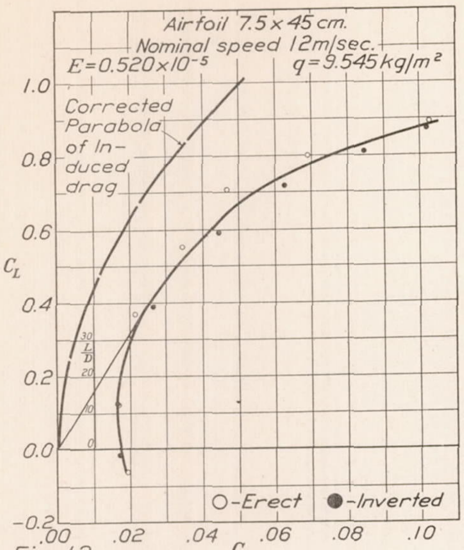


Fig. 13.

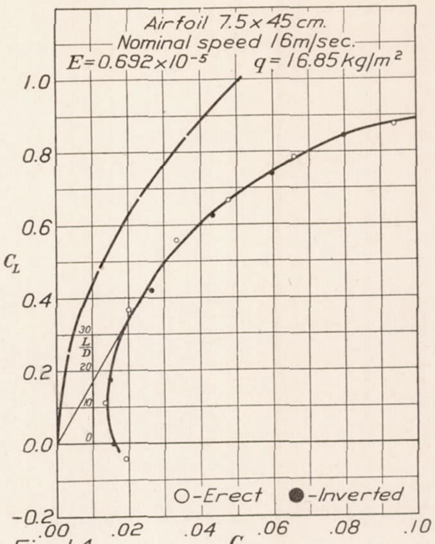


Fig. 14.

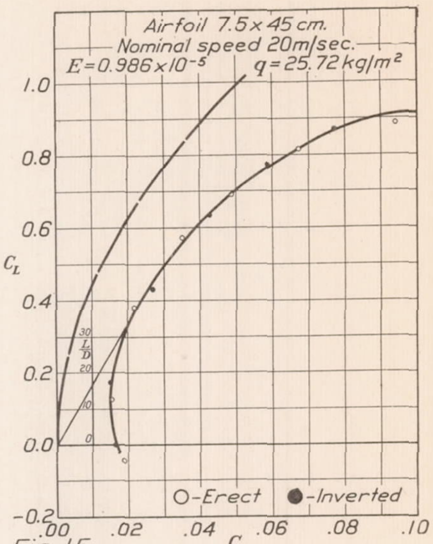


Fig. 15.

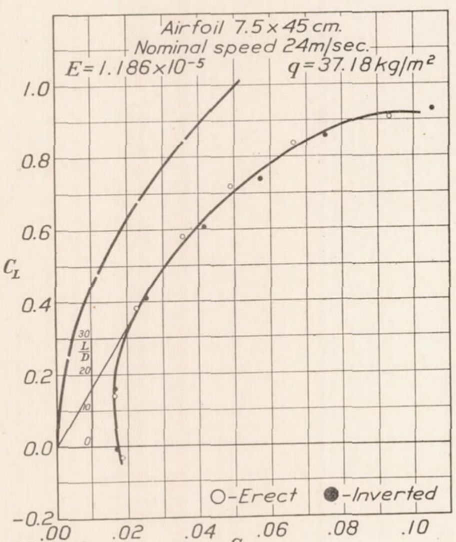


Fig. 16.

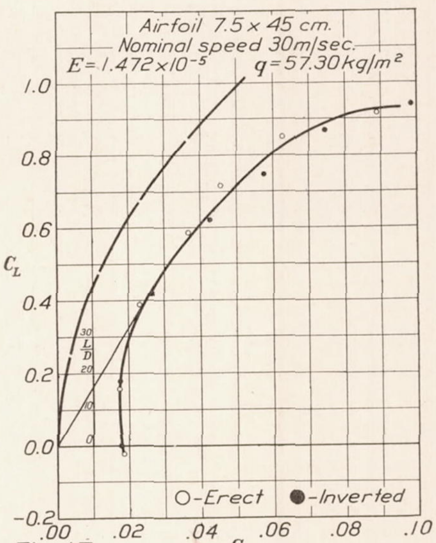


Fig. 17

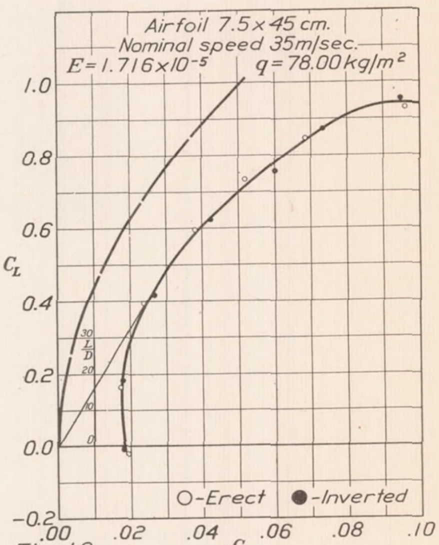


Fig. 18.

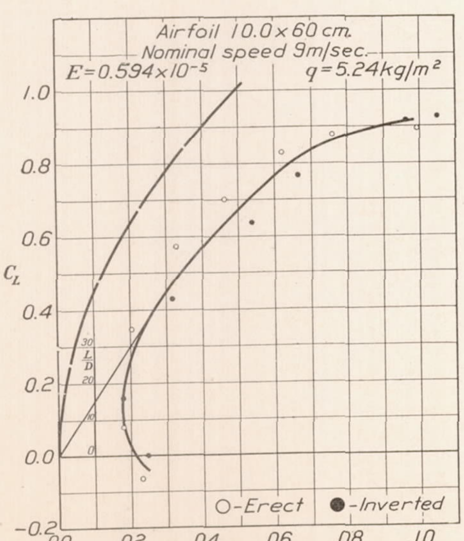


Fig. 19.

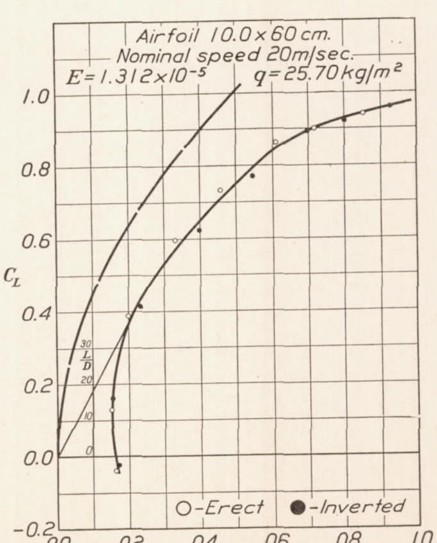


Fig. 20.

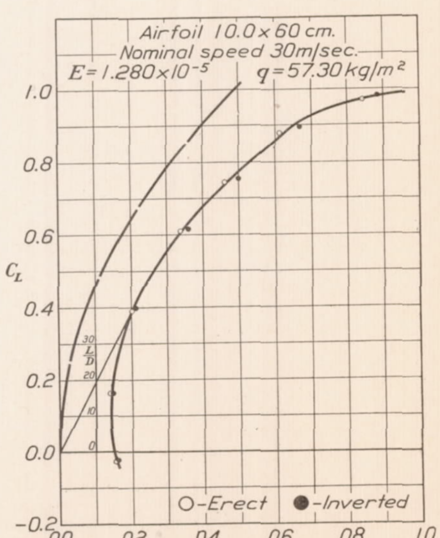


Fig. 21.

Polars for U. S. A. 16 airfoils.

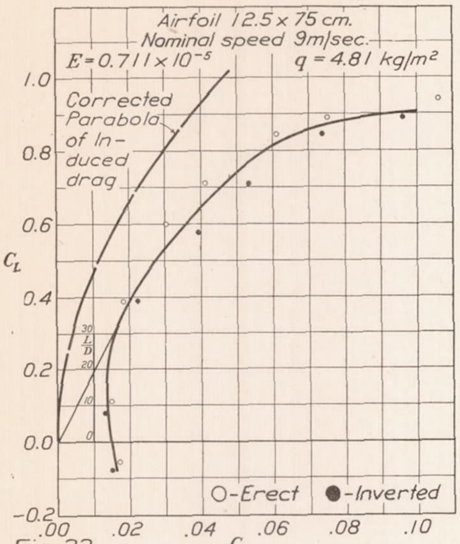


Fig. 22.

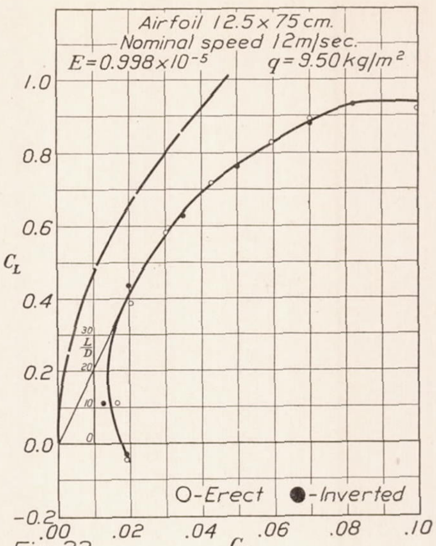


Fig. 23.

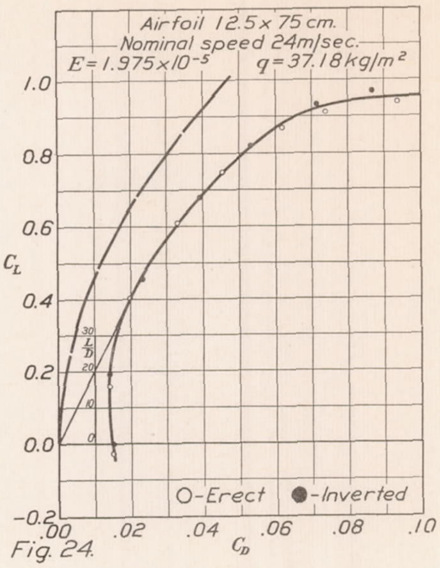


Fig. 24.

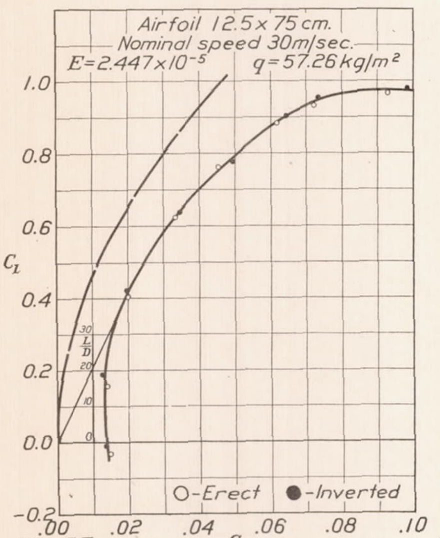


Fig. 25.

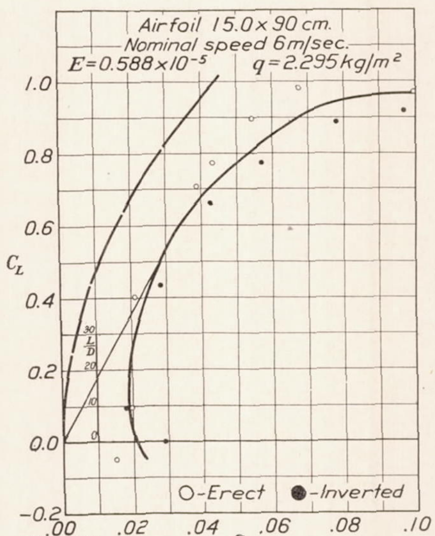


Fig. 26.

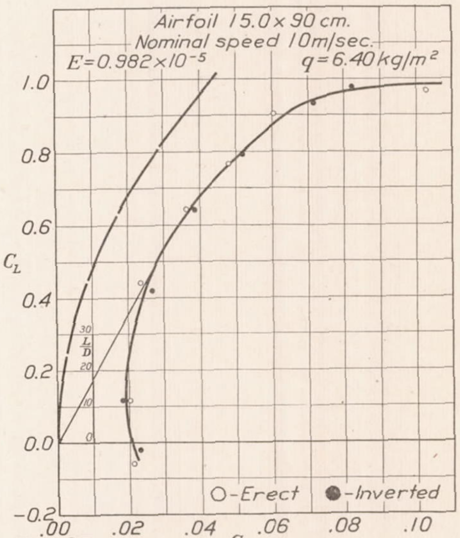


Fig. 27.

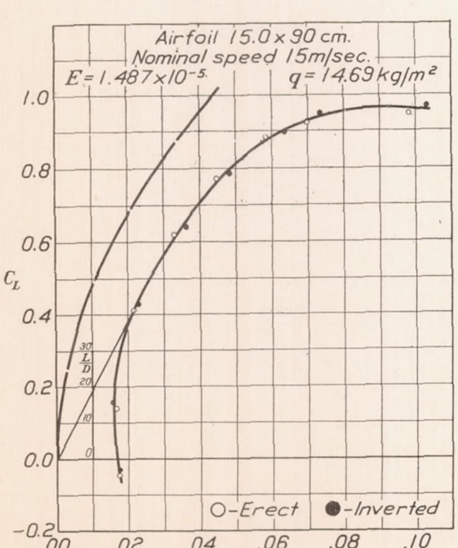


Fig. 28.

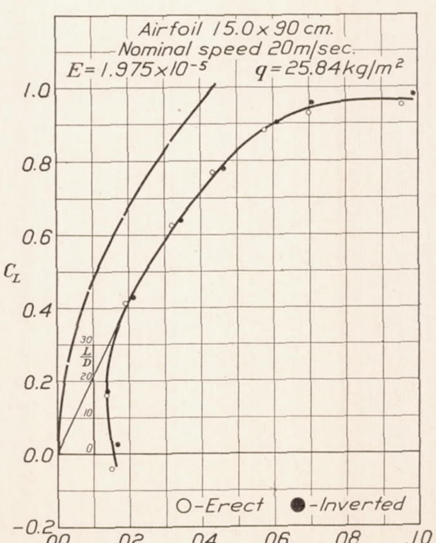


Fig. 29.

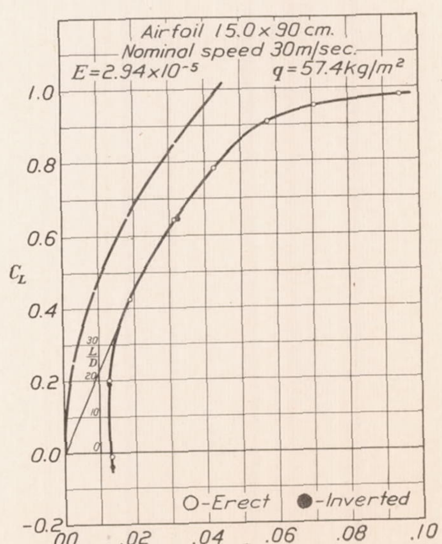
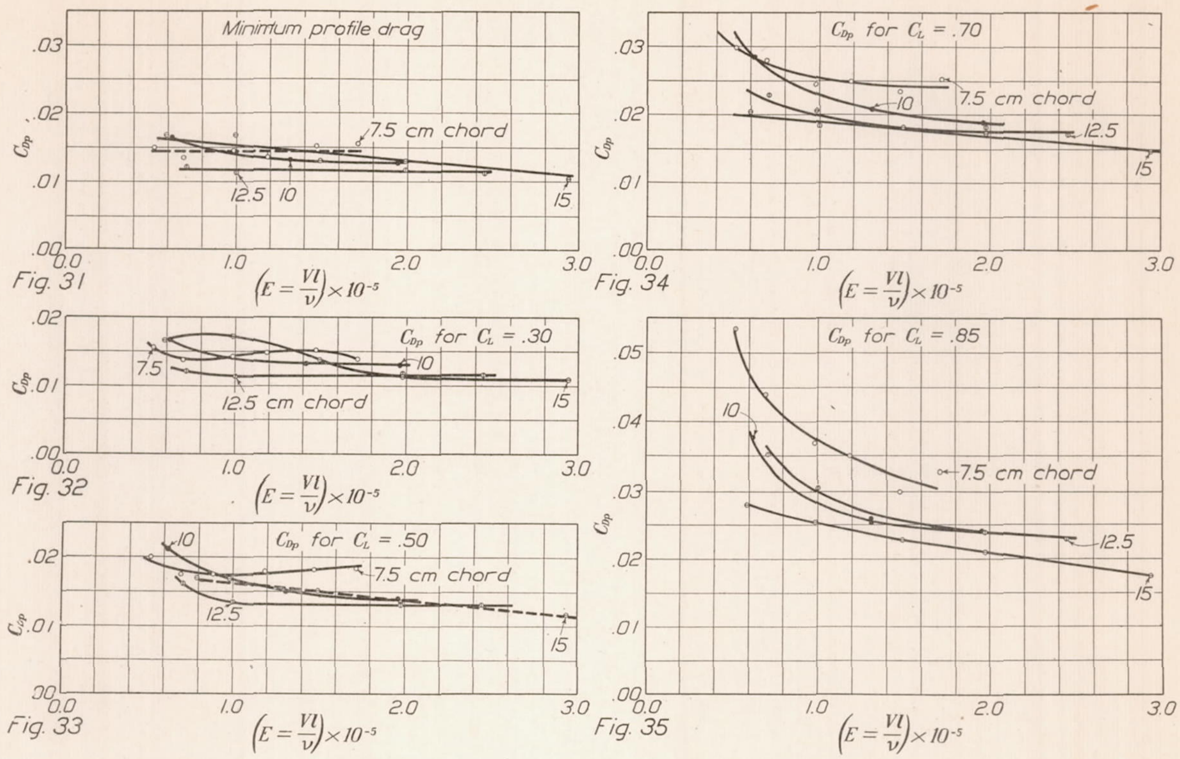


Fig. 30.

Polars for U. S. A. 16 airfoils.



Profile drag of U. S. A. 16 airfoil.

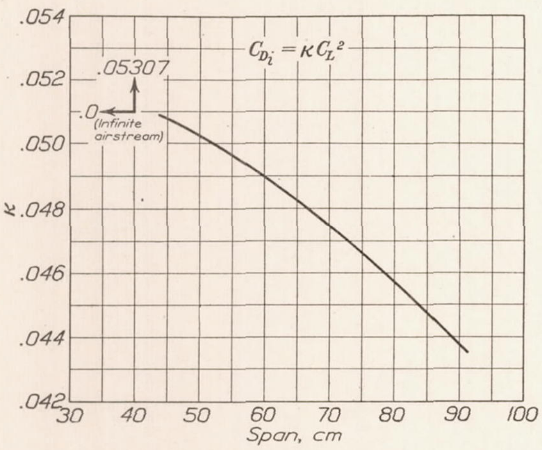


FIG. 36.—Tunnel interference correction (Prandtl) for airfoils of aspect ratio 6 in 5-foot closed airstream.

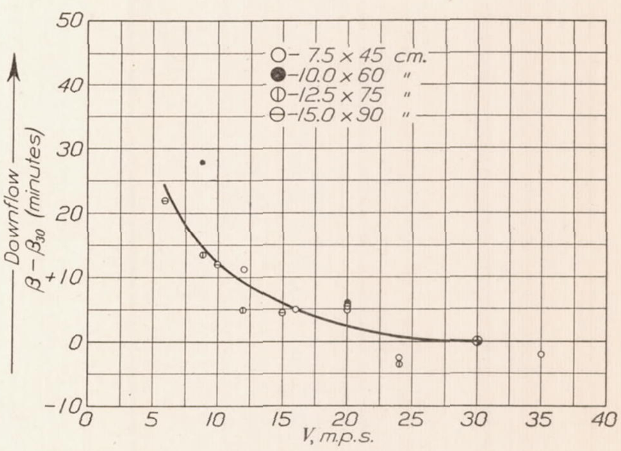


FIG. 37.—Variation of airflow direction in vertical plane.

GENERAL COMMENT.

The data collected here must be considered, primarily, as data concerning the tunnel, and not the models tested there. The maximum possible accuracy has been maintained throughout the tests but the coefficients derived are not intended to be interpreted as *the correct absolute values* applying to the bodies tested; they are the values derived from tests made under the conditions, and according to the procedure considered as standard at this laboratory. As such, our results are collected and submitted for comparison with those from other laboratories.

The actual process of standardization still lies in the future. Even when such tests as the series above have been completed by all the laboratories concerned, an enormous amount of work will have to be done before any real state of standardization is attained. Since the different tunnel characteristics affect the apparent aerodynamic properties of different bodies in a seemingly nonrelated manner, it would not appear plausible to attempt the derivation of a series of empirical "Standardization Constants," with which to coordinate results obtained under diverse conditions, but rather to adjust tunnel characteristics until all laboratories can arrive at the same experimental results from tests of a series of standard models.

From a general survey of these tests it would appear that, of the simple geometrical bodies, the sphere has the greatest value as a means of comparison. It was our experience that tests of disks furnish little information other than a check on the speed-measuring apparatus and that, with the use of equally good testing technique, sphere tests furnish much more consistent data than can be obtained from cylinders.

These remarks are necessarily confined to the geometric bodies, as the work on airfoils can not be intelligently discussed without comparative data from the other laboratories, inasmuch as the airfoil characteristics are very sensitive to small differences in form—which may exist in the set tested—and to tunnel interference.

TABLE I.

RESISTANCE OF 15 cm. DISK.

(45° beveled edge; 1.59 mm. (0.0625 inch) thickness.)

h (cm)	h^1 (cm)	q (kg/m²)	D_0 (kg)	D_1 (kg)	D (kg)	V (m/s)	C_D	$E \times 10^{-5}$
0.06	0.066	0.541	0.0440	0.0548	0.0108	2.91	1.130	0.256
.13	.147	1.208	----------	.0701	.0261	4.34	1.221	.371
.20	.223	1.83	----------	.0839	.0399	5.34	1.232	.457
.40	.444	3.64	----------	.1222	.0782	7.54	1.215	.646
.70	.771	6.33	----------	.1857	.1417	9.96	1.268	.852
1.60	1.80	14.78	----------	.3632	.3192	15.20	1.222	1.301
2.80	3.12	25.60	----------	.6015	.5575	19.98	1.231	1.760
4.40	4.88	40.05	----------	.920	.876	25.13	1.235	2.151
6.30	6.97	57.2	----------	1.298	1.254	29.89	1.240	2.558
8.70	9.57	78.5	----------	1.784	1.740	35.01	1.252	2.996

Temperature=8° C.

Sp. gr. of alcohol=0.821

$\rho=0.1281.$

$\mu=0.1753\times10^{-7}.$

$E=\frac{Vd}{\nu}.\ \left(\nu=\frac{\mu}{\rho}.\right)$

Spindle drag neglected.

TABLE II.

RESISTANCE OF 20 cm. SPHERE.

q (kg/m²)	D (kg)	C_D	E ($\times10^{-5}$)	q (kg/m²)	D (kg)	C_D	E ($\times10^{-5}$)
3.53	0.0488	0.346	0.98	32.75	0.0962	0.0735	2.99
6.38	.0784	.309	1.32	39.9	.1145	.0718	3.30
10.68	.1042	.244	1.71	48.1	.1399	.0725	3.62
14.73	.0926	.157	2.00	57.0	.1693	.0743	3.94
20.40	.0918	.112	2.36	66.8	.2045	.0766	4.26
26.45	.0904	.0853	2.68	77.3	.2464	.0798	4.59

$C_D=\frac{D}{q^{d2}}$ $\quad E=\frac{Vd}{\nu}$ $\quad \nu=\frac{\mu}{\rho}$

TABLE III.

RESISTANCE OF 15 cm. SPHERE.

q (kg/m^2)	D (kg)	C_D	E ($\times 10^{-5}$)	q (kg/m^2)	D (kg)	C_D	E ($\times 10^{-5}$)
3.53	0.0316	0.398	0.735	39.9	0.1008	0.112	2.48
6.38	.0430	.300	.99	48.1	.0858	.0793	2.72
10.68	.0735	.306	1.28	57.0	.0988	.0770	2.96
14.73	.0921	.278	1.50	66.8	.1122	.0745	3.20
20.40	.0944	.216	1.77	77.3	.1295	.0745	3.44
26.45	.1169	.196	2.01	82.4	.1495	.0807	3.68
32.75	.1070	.145	2.24				

Both spheres tested 0.4 m. downstream from fine honeycomb tubes 0.9525×7.620 cm. ($\frac{3}{8}$×3″).

$$C_D=\frac{D}{q^{d^2}} \qquad E=\frac{Vd}{\nu} \qquad \nu=\frac{\mu}{\rho}$$

TABLE IV.

DRAG OF 2.5 cm. CYLINDER.

(On back spindle.)

q	D_0	D_1	D	C_D	$E\times 10^{-5}$
1.65	0.0020	0.0057	0.0037	0.718	0.0901
3.64	----------	.0107	.0087	.765	.1341
6.40	----------	.0179	.0159	.795	.1778
14.80	----------	.0378	.0358	.774	.2702
26.58	----------	.0683	.0663	.826	.3625
40.08	----------	.1030	.1010	.808	.4451
57.26	----------	.1491	.1471	.822	.5312
77.70	----------	.2003	.1983	.818	.6199

Throat temperature=14.1° C.
Manometer temperature=19.0° C.
Sp. gr. alcohol=0.8180.
$\rho=0.1245$.
$\mu=0.1780\times 10^{-7}$.
q=dynamic pressure (kg/m^2).
D=cylinder drag (kg).

$C_D=\frac{D}{Sq}$ (S=projected area of cylinder in m^2).

$E=\frac{Vd}{\nu} \quad \nu=\frac{\mu}{\rho}$.

TABLE V.

DRAG OF 5 cm. CYLINDER.

(On back spindle.)

q	D_0	D_1	D	C_D	$E\times 10^{-5}$
0.548	0.0051	0.0083	0.0032	0.468	0.1015
1.65	----------	.0182	.0131	.690	.1769
2.29	----------	.0250	.0199	.695	.1976
3.27	----------	.0375	.0324	.793	.2474
6.33	----------	.0636	.0585	.739	.3455
9.25	----------	.0890	.0839	.726	.4175
13.84	----------	.1304	.1253	.725	.5105
18.34	----------	.1758	.1707	.744	.5880
27.33	----------	.2625	.2574	.754	.7178
36.42	----------	.3489	.3438	.754	.8280
57.30	----------	.5505	.5453	.762	1.039
77.75	----------	.7520	.7469	.769	1.208

Throat temperature=19.6° C.
Manometer temperature=16.8° C.
Sp. gr. alcohol=0.8187.
$\rho=0.1230$.
$\mu=0.1806\times 10^{-7}$.
q=dynamic pressure (kg/m^2).
D=cylinder drag (kg).

$C_D=\frac{D}{Sq}$ (S=projected area of cylinder in m^2)

$E=\frac{Vd}{\nu} \quad \nu=\frac{\mu}{\rho}$.

TABLE VI.

DRAG OF 10 cm. CYLINDER.

(On back spindle.)

q	D_o	D_1	D	C_D	$E\times10^{-5}$
0. 54	0. 0050	0. 0235	0. 0185	0. 685	0. 208
1. 11	----------	. 0468	. 0418	. 754	. 298
1. 65	----------	. 0632	. 0582	. 706	. 363
1. 84	----------	. 0710	. 0660	. 718	. 383
2. 11	----------	. 0828	. 0778	. 738	. 407
2. 37	----------	. 0821	. 0771	. 652	. 435
2. 92	----------	. 1086	. 1036	. 710	. 483
3. 64	----------	. 1477	. 1427	. 783	. 539
5. 44	----------	. 2147	. 2090	. 770	. 663
9. 25	----------	. 3617	. 3567	. 772	. 860
13. 83	----------	. 5330	. 5280	. 764	1. 052
18. 41	----------	. 7085	. 7035	. 763	1. 214
22. 90	----------	. 8560	. 8510	. 749	1. 352
27. 41	----------	. 9900	. 9850	. 719	1. 480

Throat temperature=13.3° C.
Manometer temperature=16.5° C.
Sp. gr. alcohol=0.8188.
ρ=0.1257.
$\mu=1775\times10^{-7}$.
q=dynamic pressure (kg/m²).
D=cylinder drag (kg).
$C_D=\frac{D}{Sq}$ (S=projected area of cylinder in m²).
$E=\frac{Vd}{\nu}$ $\nu=\frac{\mu}{\rho}$.

TABLE VII.

DRAG OF 2.5 cm. CYLINDER.

(On end spindle.)

q	D_T	D_s	D	C_D	$E\times10^{-5}$
1. 65	0. 0053	----------	0. 0053	1. 028	0. 087
6. 41	. 0177	0. 0010	. 0167	. 833	. 170
14. 81	. 0380	. 0019	. 0361	. 780	. 254
26. 59	. 0698	. 0030	. 0668	. 805	. 348
40. 10	. 1046	. 0059	. 0987	. 787	. 427
57. 28	. 1507	. 0085	. 1422	. 795	. 510
77. 52	. 2050	. 0149	. 1901	. 785	. 594

Throat temperature=23.5° C.
Manometer temperature=18.0° C.
Sp. gr. alcohol=0.8183.
ρ=0.1214.
$\mu=1826\times10^{-7}$.
q=dynamic pressure (kg/m²).
D_T=drag of cylinder and spindle (kg).
D_s=spindle drag (kg).
D=cylinder drag (kg).
$C_D=\frac{D}{Sq}$ (S=projected area of cyiinder in m²)
$E=\frac{Vd}{\nu}$ $\nu=\frac{\mu}{\rho}$.

TABLE VIII.

DRAG OF 5 cm. CYLINDER.

(On end spindle.)

q	D_T	D_s	D	C_D	$E\times10^{-5}$
1. 65	0. 0161	0. 0016	0. 0145	0. 703	0. 181
3. 64	. 0361	. 0029	. 0342	. 752	. 269
6. 41	. 0628	. 0045	. 0583	. 727	. 357
14. 83	. 1450	. 0094	. 1356	. 730	. 542
26. 59	. 2683	. 0167	. 2516	. 757	. 726
40. 10	. 4077	. 0250	. 3827	. 763	. 892
57. 30	. 6010	. 0358	. 5652	. 789	1. 065
77. 75	. 9136	. 0487	. 8649	. 869	1. 242

Throat temperature=13.8° C.
Manometer temperature=16.8° C.
Sp. gr. alcohol=0.8187.
ρ=0.1255.
$\mu=1779\times10^{-7}$.
q=dynamic pressure (kg/m²).
D_T=drag of cylinder and spindle (kg).
D_s=spindle drag (kg).
D=cylinder drag (kg).
$C_D=\frac{D}{Sq}$ (S=projected area of cylinder in m²).
$E=\frac{Vd}{\nu}$ $\nu=\frac{\mu}{\rho}$.

TABLE IX.

DRAG OF 10 cm. CYLINDER.

(On end spindle.)

q	D_T	D_s	D	C_D	$E\times 10^{-5}$
0.54	0.0234	0.0010	0.0224	0.830	0.202
1.65	.0671	.0066	.0605	.734	.352
3.64	.1514	.0122	.1392	.787	.522
6.40	.2721	.0169	.2552	.798	.694
14.79	.6141	.0337	.5804	.786	1.054
26.65	1.1060	.0532	1.0528	.790	1.414
40.05	1.6372	.0819	1.5553	.776	1.735
57.20	2.2372	.1153	2.1219	.743	2.075
77.65	2.5872	.1553	2.4319	.626	2.418
92.65	2.642	.181	2.461	.510	2.682

Throat temperature=19.8° C.
Manometer temperature=22.0° C.
Sp. gr. alcohol=0.8171.
$\rho=0.1230$.
$\mu=1808\times10^{-7}$.
q=dynamic pressure (kg/m²).
D_T=drag of cylinder and spindle (kg).
D_s=spindle drag (kg).
D=cylinder drag (kg).
$C_D=\frac{D}{Sq}$ (S=projected area of cylinder in m²).

$E=\frac{Vd}{\nu}$ $\nu=\frac{\mu}{\rho}$.

TABLE X

STATIC PRESSURE GRADIENT IN NO. 1 WIND TUNNEL

P_s=Static press. at wall plate (X=0.146m.)—static press. on tunnel axis.
X=Distance behind No. 3 honeycomb.
q=57.4 kg/m².
Temperature=10° C.

Tabular data

X (meters).	Ps (kg/m²).	X (meters).	Ps (kg/m²).	X (meters).	Ps (kg/m²).
0.025	+1.2	0.229	+0.5	1.37	+2.5
.037	0.8	.305	.7	1.52	2.7
.051	.3	.457	.9	1.68	3.0
.063	.1	.610	1.2	1.83	3.2
.076	.1	.762	1.5	1.98	3.5
.118	.0	.914	1.7	2.06	3.4
.127	+.2	1.07	2.0	2.13	2.7
.153	.2	1.22	2.2		

VARIATION OF STATIC PRESSURE DIFFERENCE BETWEEN TWO POINTS, WITH CHANGE IN DYNAMIC PRESSURE

(1) Dynamic head (mm. alcohol).	(2) Difference in static pressure (mm. alcohol).	$\frac{(2)}{(1)}$
7.1	0.10	0.0014
16.0	.20	.0013
29.2	.40	.00137
44.2	.60	.00135
63.4	.90	.00142
86.6	1.20	.00139

TABLE XI.

TEST OF 7.5×45 cm. U. S. A. 16 AIRFOIL.

Nominal speed 12 m/s.

Erect.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0444	0.0640	+0.0063	1.00	0.98	−0.02	+0.0194	−0.062	−3.18
0	0.0000	.0187	.0054	"	1.04	+0.04	.0166	+0.123	+7.40
+3	"	.0203	.0070	"	1.12	.12	.0215	.370	17.15
6	"	.0245	.0112	"	1.18	.18	.0345	.554	16.07
8	0.0438	.0722	.0152	"	1.23	.23	.0468	.709	15.23
10	"	.0795	.0224	"	1.26	.26	.0690	.801	11.60
12	"	.0904	.0333	"	1.29	.29	.1026	.893	8.71

q=9.59 kg/m².
D_w=0.0133 kg. (Wire drag.)
Temperature=11.7° C.
Sq=0.3247 kg.

Inverted.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0025	0.0212	+0.0055	3.00	3.005	−0.005	+0.0172	−0.015	−0.91
0	"	.0208	.0051	"	2.960	+0.04	.0159	+0.125	+7.48
+3	"	.0242	.0085	"	2.875	.125	.0265	.390	14.72
6	"	.0300	.0143	"	2.81	.190	.0446	.593	13.29
8	"	.0358	.0201	"	2.77	.230	.0627	.718	11.44
10	"	.0428	.0271	"	2.74	.260	.0846	.811	9.50
12	"	.8591	.0334	"	2.72	.280	.1042	.874	8.39

q=9.50 kg/m².
D_w=0.0132 kg.
Temperature=17.0° C.
Sq=0.3205 kg.
V=12.29 m/s.
E=0.520×10⁻⁵.

TABLE XII.

TEST OF 7.5×45 cm. U. S. A. 16 AIRFOIL.

Nominal speed 16 m/s.

Erect.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0444	0.0778	+0.0109	1.00	0.975	−0.025	+0.0191	−0.044	−2.29
0	0.0000	.0302	.0077	"	1.065	+0.065	.0135	+0.114	+8.45
+3	"	.0340	.0115	"	1.210	.210	.0201	.368	18.27
6	"	.0416	.0191	"	1.320	.320	.0334	.561	16.74
8	0.0438	.0934	.0271	"	1.380	.380	.0475	.666	14.03
10	"	.1038	.0375	"	1.450	.450	.0657	.788	12.00
12	"	.1198	.0535	"	1.500	.500	.0937	.876	9.35

q=16.90 kg/m².
D_w=0.0225 kg.
Temperature=11.8° C.
Sq=0.571 kg.

Inverted

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0025	0.0338	+0.0089	3.00	3.000	0.000	+0.0157	0.000	0.00
0	"	.0333	.0084	"	2.900	+0.100	.0148	+0.176	+11.90
+3	"	.0398	.0149	"	2.760	.240	.0263	.423	16.10
6	"	.0494	.0245	"	2.645	.355	.0432	.626	14.48
8	"	.0587	.0338	"	2.580	.420	.0596	.741	12.42
10	"	.0700	.0451	"	2.520	.480	.0796	.846	10.64
12	"	.0961	.0712	"	2.480	.520	.1256	.917	7.31

q=16.80 kg/m².
D_w=0.0224 kg.
Temperature=17.0° C.
Sq=0.567 kg.
V=16.35 m/s.
E=0.692×10⁻⁵.

TABLE XIII.

TEST OF 7.5×45 cm. U. S. A. 16 AIRFOIL.

Nominal speed 20 m/s.

Erect.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0444	0.0933	+0.0165	1.00	+0.965	−0.035	+0.0190	−0.040	−2.12
0	0.0000	.0458	.0134	"	1.11	+.11	.0154	+0.127	+8.21
+3	"	.0513	.0189	"	1.33	.33	.0217	.380	17.47
6	"	.0629	.0304	"	1.50	.50	.0350	.575	16.44
8	0.0438	.1185	.0423	"	1.60	.60	.0487	.691	14.18
10	"	.1345	.0583	"	1.71	.71	.0671	.817	12.19
12	"	.1580	.0818	"	1.78	.78	.0941	.898	9.54

q=25.75 kg/m².
D_w=0.0324 kg.
Temperature=11.8° C.
Sq=0.869 kg.

Inverted.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0025	0.0490	+0.0141	3.00	3.00	0.000	+0.0163	0.000	0.00
0	"	.0480	.0131	"	2.85	+0.15	.0151	+0.173	+11.45
+3	"	.0582	.0233	"	2.625	.375	.0269	.432	16.08
6	"	.0718	.0369	"	2.45	.55	.0426	.634	14.90
8	"	.0856	.0507	"	2.33	.67	.0585	.773	13.21
10	"	.1018	.0669	"	2.245	.755	.0772	.871	11.28
12	"	.1384	.1035	"	2.20	.80	.1194	.923	7.73

q=25.70 kg/m².
D_w=0.0324 kg.
Temperature=17.0° C.
Sq=0.867 kg.
V=20.18 m/s.
E=0.986×10⁻⁶.

TABLE XIV.

TEST OF 7.5×45 cm. U. S. A. 16 AIRFOIL.

Nominal speed 24 m/s.

Erect.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0444	0.1116	+0.0230	1.00	0.96	−0.04	+0.0183	−0.031	−1.74
0	0.0000	.0644	.0202	"	1.175	+.175	.0161	+0.140	+8.76
+3	"	.0726	.0284	"	1.48	.48	.0226	.383	16.90
6	"	.0890	.0448	"	1.73	.73	.0357	.582	16.29
8	0.0438	.1494	.0614	"	1.90	.90	.0490	.718	14.67
10	"	.1714	.0834	"	2.05	1.05	.0665	.837	12.60
12	"	.2049	.1169	"	2.14	1.14	.0932	.909	9.76

q=37.18 kg/m².
D_w=0.0442 kg.
Temperature=12.1° C.
Sq=1.254 kg.

Inverted.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0149	0.0803	+0.0212	3.00	3.01	−0.010	+0.0169	−0.008	−0.47
0	"	.0795	.0204	"	2.80	+0.200	.0163	+0.159	+9.81
+3	"	.0908	.0317	"	2.485	.515	.0253	.411	16.24
6	"	.1114	.0523	"	2.24	.760	.0417	.606	14.53
8	"	.1311	.0720	"	2.075	.925	.0574	.738	12.84
10	"	.1532	.0941	"	1.925	1.075	.0754	.857	11.42
12	"	.1912	.1321	"	1.830	1.170	.1054	.933	8.86

q=37.18 kg/m².
D_w=0.0442 kg.
Temperature=13.6° C.
Sq=1.254 kg.
V=24.27 m/s.
E=1.186×10⁻⁶.

TABLE XV.

TEST OF 7.5×45 cm. U. S. A. 16 AIRFOIL.

Nominal speed 30 m/s.

Erect.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0444	0.1438	+0.0361	1.00	0.955	−0.045	+0.0187	−0.023	−1.25
0	0.0000	.0968	.0335	"	1.300	+0.300	.0173	+0.155	+8.95
+3	"	.1077	.0444	"	1.750	.750	.0230	.388	16.90
6	"	.1339	.0706	"	2.135	1.135	.0365	.587	16.09
8	0.0438	.2053	.0880	"	2.39	1.39	.0454	.717	15.80
10	"	.2384	.1211	"	2.67	1.67	.0625	.852	13.79
12	"	.2896	.1723	"	2.78	1.78	.0889	.918	10.31

Temp.=10.1° C.
q=57.45 kg/m².
Dw=0.0635 kg.
Sq=1.940 kg.

q=57.30 kg/m².
Dw=0.0633 kg.
Temperature=12.0° C.
Sq=1.934 kg.

Inverted.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0149	0.1127	+0.0345	2.99	2.99	0.00	+0.0178	0.000	0.00
0	"	.1120	.0338	"	2.65	+0.34	.0175	+0.176	+10.06
+3	"	.1295	.0513	"	2.18	.81	.0265	.419	15.78
6	"	.1603	.0821	"	1.79	1.20	.0425	.621	14.62
8	"	.1889	.1107	"	1.545	1.445	.0573	.747	13.07
10	"	.2220	.1438	"	1.31	1.68	.0744	.869	11.68
12	"	.2684	.1902	"	1.17	1.82	.0984	.941	9.57

q=57.30 kg/m².
Dw=0.0633 kg.
Temperature=12.9° C.
Sq=1.934 kg.
V=30.12 m/s.
$E=1.472\times10^{-5}$.

TABLE XVI.

TEST OF 7.5×45 cm. U. S. A. 16 AIRFOIL.

Nominal speed 35 m/s.

Erect.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0444	0.1770	0.0509	1.00	0.95	−0.05	+0.0193	−0.019	−0.98
0	0.0000	.1273	.0456	"	1.43	+0.43	.0173	+0.163	+9.42
+3	"	.1448	.0631	"	2.04	1.04	.0240	.395	16.50
6	"	.1816	.0999	"	2.57	1.57	.0380	.597	15.71
8	0.0438	.2614	.1367	"	2.93	1.93	.0519	.734	14.12
10	"	.3046	.1799	"	3.23	2.23	.0683	.847	12.40
12	"	.3775	.2528	"	3.46	2.46	.0960	.931	9.72

Temp.=10.4° C.
q=78 kg/m².
Dw=0.0809 kg.
Sq=2.635 kg.

q=78.00 kg/m².
Dw=0.0817 kg.
Temperature=12.0° C.
Sq=2.632 kg.

Inverted.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0161	0.1458	+0.0480	3.00	2.975	+0.025	+0.0182	+0.009	+0.52
0	"	.1449	.0471	"	2.52	.48	.0179	.182	10.18
+3	"	.1680	.0702	"	1.90	1.10	.0267	.418	15.66
6	"	.2090	.1112	"	1.36	1.64	.0422	.623	14.76
8	"	.2495	.1581	"	1.01	1.99	.0601	.756	13.44
10	"	.2898	.1920	"	0.70	2.30	.0730	.874	11.98
12	"	.3475	.2497	"	.48	2.52	.0948	.957	10.09

q=78.00 kg/m².
Dw=0.0817 kg.
Temperature=12.1° C.
Sq=2.632 kg.
V=35.14 m/s.
$E=1.716\times10^{-5}$.

TABLE XVII.

TEST OF 10×60 cm. U. S. A. 16 AIRFOIL.

Nominal speed 9 m/s.

Erect.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0. 0144	0. 0288	+0. 0072	2. 00	1. 98	−0. 02	+0. 0230	−0. 064	−2. 78
0	"	. 0272	. 0056	"	2. 025	+0. 025	. 0179	+0. 080	+4. 46
+3	"	. 0280	. 0064	"	2. 11	. 11	. 0204	. 351	17. 20
6	"	. 0318	. 0102	"	2. 18	. 18	. 0326	. 575	17. 63
8	"	. 0360	. 0144	"	2. 22	. 22	. 0460	. 702	15. 28
10	"	. 0410	. 0194	"	2. 26	. 26	. 0619	. 830	13. 40
11	"	. 0453	. 0237	"	2. 275	. 275	. 0756	. 878	11. 60
12	"	. 0527	. 0311	"	2. 28	. 28	. 0993	. 894	9. 00

q=5.24 kg/m².
D_w=0.0072 kg.
Temperature=15.5° C.
Sq=0.3134 kg.

Inverted.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0. 0081	0. 0230	+0. 0077	3. 00	3. 00	0. 00	+0. 0246	0. 000	0. 00
0	"	. 0209	. 0056	"	2. 95	+0. 05	. 0179	+0. 159	+8. 93
+3	"	. 0252	. 0099	"	2. 865	. 135	. 0316	. 431	13. 63
6	"	. 0321	. 0168	"	2. 80	. 20	. 0536	. 639	11. 90
8	"	. 0361	. 0208	"	2. 76	. 24	. 0664	. 766	11. 54
10	"	. 0454	. 0301	"	2. 715	. 285	. 0961	. 910	9. 48
11	"	. 0482	. 0329	"	2. 71	. 290	. 1050	. 926	8. 82
12	"	. 0593	. 0440	"	2. 70	. 300	. 1404	. 958	6. 81

q=5.24 kg/m².
D_w=0.0072 kg.
Temperature 15.2° C.
Sq=0.3134 kg.
V=9.12 m/s.
E=0.594×10⁻⁵.

TABLE XVIII.

TEST OF 10×60 cm. U. S. A. 16 AIRFOIL.

Nominal speed 20 m/s.

Erect.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0. 0145	0. 0719	+0. 0252	2. 00	1. 94	−0. 06	+0. 0163	−0. 039	−2. 38
0	"	. 0699	. 0232	"	2. 20	+0. 20	. 0150	+0. 130	+8. 62
+3	"	. 0772	. 0305	"	2. 60	. 60	. 0198	. 389	19. 67
6	"	. 0976	. 0509	"	2. 92	. 92	. 0330	. 597	18. 06
8	"	. 1169	. 0702	"	3. 13	1. 13	. 0455	. 733	16. 10
10	"	. 1408	. 0941	"	3. 32	1. 32	. 0610	. 866	14. 03
11	"	. 1568	. 1101	"	3. 39	1. 39	. 0714	. 902	12. 62
12	"	. 1778	. 1311	"	3. 45	1. 45	. 0851	. 941	11. 06

q=25.70 kg/m².
D_w=0.0322 kg.
Temperature=16.0° C.
Sq=1.542 kg.

Inverted.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0. 0080	0. 0668	+0. 0266	3. 00	3. 03	−0. 03	+0. 0172	−0. 019	−1. 13
0	"	. 0640	. 0238	"	2. 75	+0. 25	. 0154	+0. 162	+10. 50
+3	"	. 0762	. 0360	"	2. 36	. 64	. 0233	. 415	17. 77
6	"	. 1015	. 0613	"	2. 04	. 96	. 0397	. 623	15. 66
8	"	. 1240	. 0838	"	1. 81	1. 19	. 0544	. 772	14. 20
10	"	. 1475	. 1073	"	1. 62	1. 38	. 0696	. 895	12. 86
11	"	. 1632	. 1230	"	1. 58	1. 42	. 0798	. 921	11. 55
12	"	. 1829	. 1427	"	1. 52	1. 48	. 0926	. 960	10. 37

q=25.70 kg/m².
D_w=0.0322 kg.
Temperature=16.3° C.
Sq=1.542 kg.
V=20.17 m/s.
E=1.312×10⁻⁵.

TABLE XIX.

TEST OF 10×60 cm. U. S. A. 16 AIRFOIL.

Nominal speed 30 m/s.

Erect.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
0	0.0070	0.1218	+0.0515	1.000	1.59	+0.59	0.0150	+0.171	+11.46
−2	"	.1260	.0557	"	0.96	−0.04	.0162	−0.011	−0.78
−1	"	.1231	.0528	"	1.245	+0.245	.0153	+0.071	+4.64
0	"	.1220	.0517	"	1.60	.60	.0150	.174	11.61
+1	"	.1257	.0554	"	1.87	.87	.0161	.253	15.70
2	"	.1323	.0620	"	2.14	1.14	.0181	.332	18.38
3	"	.1440	.0737	"	2.39	1.39	.0214	.404	18.87
4	"	.1565	.0862	"	2.63	1.63	.0250	.474	18.92
6	"	.1908	.1205	"	3.12	2.12	.0349	.616	17.60
8	"	.2346	.1643	"	3.61	2.61	.0478	.759	15.88
10	"	.2887	.2184	"	4.04	3.04	.0635	.884	13.92
12	"	.3755	.3054	"	4.35	3.35	.0888	.974	10.62
14	"	.5980	.5277	"	4.45	3.45	.1532	1.003	6.54
16	"	.8950	.8247	"	4.27	3.27	.2398	.951	3.97

q=57.3 kg/m².
D_u=0.0633 kg.
Temperature=15.0° C.
Sq=3.440 kg.

Inverted.

α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
0	0.0042	0.1187	+0.0512	3.000	2.40	+0.60	+0.0152	+0.174	+11.72
+1	"	.1229	.0554	"	2.11	.89	.0161	.259	16.06
2	"	.1300	.0625	"	1.87	1.13	.0182	.327	18.08
3	"	.1429	.0754	"	1.58	1.42	.0219	.413	18.86
4	"	.1573	.0898	"	1.34	1.66	.0261	.483	18.48
5	"	.1741	.1066	"	1.09	1.91	.0310	.555	17.92

q=57.3 kg/m².
D_w=0.0633 kg.
Temperature=15.0° C.
Sq=3.440 kg.
V=30.22 m/s.
$E=1.280\times10^{-5}$.

TABLE XX.

TEST OF 12.5×75.0 cm. U. S. A. 16 AIRFOIL.

Nominal speed 8.7 m/s.

Erect.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0038	0.0180	+0.0077	2.000	1.975	−0.025	+0.0171	−0.055	−0.325
0	"	.0170	.0067	"	2.05	+0.050	.0149	+0.111	+7.47
+3	"	.0186	.0083	"	2.175	.175	.0184	.388	21.10
6	"	.0239	.0136	"	2.27	.270	.0302	.599	19.85
8	"	.0288	.0185	"	2.325	.325	.0411	.711	17.58
10	"	.0379	.0276	"	2.38	.380	.0610	.844	13.78
11	"	.0441	.0338	"	2.40	.400	.0750	.888	11.82
12	"	.0580	.0477	"	2.425	.425	.1058	.943	8.91

q=4.81 kg/m².
D_w=0.0065 kg.
Temperature=13.0° C.
Sq=0.4507 kg.

Inverted.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0597	0.0730	+0.0068	8.000	8.035	−0.035	0.0151	−0.078	−5.15
0	"	.0721	.0059	"	7.965	+0.035	.0131	+0.078	+5.93
+3	"	.0763	.0101	"	7.825	.175	.0224	.388	17.32
6	"	.0839	.0177	"	7.740	.260	.0393	.577	14.70
8	"	.0902	.0240	"	7.680	.320	.0533	.710	13.32
10	"	.0994	.0332	"	7.620	.380	.0737	.844	11.44
11	"	.1095	.0433	"	7.600	.400	.0961	.888	9.24
12	"	.1253	.0591	"	7.600	.400	.1312	.888	6.78

q=4.81 kg/m².
D_w=0.0065 kg.
Temperature=12.7° C.
Sq=0.4507 kg.
V=8.72 m/s.
E=0.711×10⁻⁵.

TABLE XXI.

TEST OF 12.5×75 cm. U. S. A. 16 AIRFOIL.

Nominal speed 12 m/s.

Erect.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0090	0.0392	+0.0169	4.00	3.96	−0.04	+0.0190	−0.045	−2.37
0	"	.0370	.0147	"	4.10	+0.10	.0165	+0.112	+6.81
+3	"	.0405	.0182	"	4.345	.345	.0204	.388	18.95
6	"	.0492	.0269	"	4.52	.52	.0302	.584	19.30
8	"	.0603	.0380	"	4.64	.64	.0427	.719	16.84
10	"	.0750	.0527	"	4.74	.74	.0592	.832	14.04
11	"	.0846	.0623	"	4.795	.795	.0700	.893	12.75
12	"	.1111	.0888	"	4.82	.82	.0999	.921	9.24

q=9.50 kg/m².
D_w=0.0133 kg.
Temperature=14.0° C.
Sq=0.890 kg.

Inverted.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0042	0.0344	+0.0169	3.00	3.025	−0.025	0.0190	−0.028	−1.48
0	"	.0286	.0111	"	2.90	+0.10	.0125	+0.112	+9.01
+3	"	.0351	.0176	"	2.61	.39	.0198	.438	22.15
6	"	.0486	.0311	"	2.44	.56	.0349	.629	18.00
8	"	.0621	.0445	"	2.32	.68	.0500	.764	15.28
10	"	.0798	.0623	"	2.215	.785	.0700	.882	12.60
11	"	.0902	.0727	"	2.17	.83	.0817	.933	11.42
12	"	.1210	.1035	"	2.15	.85	.1163	.955	8.22

q=9.50 kg/m².
D_w=0.0133 kg.
Temperature=15.5° C.
Sq=0.890 kg.
V=12.27 m/s.
E=0.998×10⁻⁵.

TABLE XXII.

TEST OF 12.5×75 cm. U. S. A. 16 AIRFOIL.

Nominal speed 24 m/s.

Erect.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0090	0.1048	+0.0516	4.00	3.91	−0.09	+0.0148	−0.026	−1.74
0	"	.1025	.0493	"	4.56	+0.56	.0142	+0.161	+11.36
+3	"	.1217	.0685	"	5.41	1.41	.0197	.405	20.58
6	"	.1684	.1152	"	6.13	2.13	.0330	.612	18.50
8	"	.2110	.1578	"	6.61	2.61	.0453	.750	16.53
10	"	.2680	.2148	"	7.03	3.03	.0617	.870	14.12
11	"	.3095	.2563	"	7.18	3.18	.0736	.913	12.40
12	"	.3790	.3258	"	7.28	3.28	.0936	.942	10.06

q=37.18 kg/m².
D_w=0.0442 kg.
Temperature=11.5° C.
Sq=3.482 kg.

Inverted.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0031	0.0995	+0.0522	4.00	4.00	0.00	+0.0150	0.000	0.00
0	"	.0963	.0490	"	3.32	+0.68	.0141	+0.195	+1.38
+3	"	.1281	.0808	"	2.40	1.60	.0232	.459	19.80
6	"	.1837	.1364	"	1.63	2.37	.0392	.681	17.50
8	"	.2323	.1850	"	1.14	2.86	.0531	.822	15.47
10	"	.2950	.2477	"	0.75	3.25	.0711	.934	13.12
11	"	.3490	.3017	"	0.62	3.38	.0866	.971	11.21
12	"	.5050	.4577	"	0.65	3.35	.1314	.962	7.32

q=37.18 kg/m².
D_w=0.0442 kg.
Temperature=11.0° C.
Sq=3.482 kg.
V=24.22 m/s.
$E=1.975\times10^{-5}$.

TABLE XXIII.

TEST OF 12.5×75 cm. U. S. A. 16 AIRFOIL.

Nominal speed 30 m/s.

Erect.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0076	0.1502	+0.0794	1.00	0.80	−0.20	+0.0148	−0.037	−2.52
0	"	.1461	.0753	"	1.84	+0.84	.0140	.156	+11.16
+3	"	.1787	.1079	"	3.18	2.18	.0201	.406	20.11
6	"	.2496	.1788	"	4.36	3.36	.0333	.626	18.80
8	"	.3145	.2437	"	5.10	4.10	.0453	.764	16.82
10	"	.4020	.3312	"	5.75	4.75	.0618	.885	14.34
11	"	.4670	.3862	"	6.00	5.00	.0720	.932	12.93
12	"	.5680	.4972	"	6.17	5.17	.0927	.964	10.39

$=57.23$ kg/m².
$D_w=0.0632$ kg.
Temperature=15.0° C.
$Sq=5.365$ kg.

Inverted.									
α	D_o	D_1	D	L_o	L_1	L	C_D	C_L	L/D
°									
−2	0.0648	0.2016	+0.0724	8.00	8.04	−0.06	+0.0135	−0.011	−0.83
0	"	.1978	.0696	"	6.99	+1.01	.0128	+0.188	+14.51
+3	"	.2352	.1070	"	5.73	2.27	.0197	.423	20.60
6	"	.3136	.1854	"	4.55	3.45	.0345	.642	18.61
8	"	.3940	.2658	"	3.82	4.18	.0495	.778	15.75
10	"	.4736	.3454	"	3.14	4.86	.0643	.905	14.06
11	"	.5270	.3988	"	2.88	5.12	.0732	.953	12.72
12	"	.6570	.5288	"	2.74	5.26	.0985	.980	9.95

$q=57.30$ kg/m².
$D_w=0.0634$ kg.
Temperature=11.6° C.
$Sq=5.370$ kg.
$V=30.07$ m/s.
$E=2.447\times10^{-5}$.

TABLE XXIV.

TEST OF 15×90 cm. U. S. A. 16 AIRFOIL.

Nominal speed 6 m/s.

Erect.										
α	D_o	D_1	D^1	D	L_o	L_1	L	C_D	C_L	L/D
°										
−2	0.0096	0.0189	0.0093	+0.0047	2.00	1.985	−0.015	+0.0151	−0.048	−3.19
0	.0062	.0169	.0107	.0061	"	2.030	+0.030	.0197	+0.097	+4.92
+3	.0043	.0155	.0112	.0066	"	2.125	.125	.0212	.403	18.94
6	.0011	.0177	.0166	.0120	"	2.220	.220	.0387	.710	18.33
8	.0010	.0190	.0180	.0134	"	2.24	.240	.0433	.775	17.91
10	.0028	.0242	.0214	.0168	"	2.275	.275	.0542	.898	16.36
11	.0038	.0293	.0255	.0209	"	2.305	.305	.0674	.984	14.59
12	.0044	.0398	.0354	.0308	"	2.30	.300	.0994	.968	9.75

$q=2.995$ kg/m².
$D_w=0.0046$ kg.
Temperature=12.0° C.
$Sq=0.310$ kg.

Inverted.										
α	D_o	D_1	D^1	D	L_o	L_1	L	C_D	C_L	L/D
°										
−2	0.0027	0.0163	0.0136	+0.0090	8.00	8.00	0.00	+0.0290	0.000	0.00
0	.0037	.0139	.0102	.0056	"	7.97	+0.03	.0181	+0.097	+5.36
+3	.0052	.0186	.0134	.0088	"	7.865	.135	.0284	.436	15.34
6	.0078	.0256	.0178	.0132	"	7.795	.205	.0426	.662	15.52
8	.0101	.0323	.0222	.0176	"	7.76	.24	.0568	.774	13.64
10	.0126	.0413	.0287	.0241	"	7.725	.275	.0778	.888	11.41
11	.0140	.0486	.0346	.0300	"	7.715	.285	.0968	.920	9.51
12	.0153	.0634	.0481	.0435	"	7.71	.29	.1404	.936	6.67

$q=2.298$ kg/m².
$D_w=0.0046$ kg.
Temperature=10.4° C.
$Sq=0.310$ kg.
$V=6.02$ m/s.
$E=0.588\times10^{-5}$.

TABLE XXV.

TEST OF 15×90 cm. U. S. A. 16 AIRFOIL.

Nominal speed 10 m/s.

Erect.

α	D_o	D_1	D^1	D	L_o	L_1	L	C_D	C_L	L/D
°										
−2	0.0319	0.0606	0.0287	+0.0182	2.00	1.95	−0.05	+0.0212	−0.059	−2.74
0	.0285	.0562	.0277	.0172	"	2.10	+0.10	.0201	+0.117	+5.82
+3	.0266	.0572	.0306	.0201	"	2.36	.36	.0235	.422	17.90
6	.0234	.0648	.0414	.0309	"	2.55	.55	.0362	.644	17.79
8	.0233	.0747	.0514	.0409	"	2.655	.655	.0479	.767	16.01
10	.0251	.0871	.0620	.0515	"	2.77	.77	.0603	.902	14.94
11	.0261	.0978	.0717	.0612	"	2.80	.80	.0717	.937	13.07
12	.0267	.1248	.0981	.0876	"	2.825	.825	.1026	.966	9.42

q=6.40 kg/m².
D_w=0.0104 kg.
Temperature=10.8° C.
Sq=0.854 kg.

Inverted.

α	D_o	D_1	D^1	D	L_o	L_1	L	C_D	C_L	L/D
°										
−2	0.0027	0.0328	0.0301	+0.0196	8.00	8.02	−0.02	+0.0228	−0.023	−1.02
0	.0037	.0297	.0260	.0155	"	7.90	+0.10	.0181	+0.117	+6.46
+3	.0052	.0385	.0333	.0228	"	7.64	.36	.0267	.420	15.78
6	.0078	.0513	.0435	.0330	"	7.45	.55	.0385	.643	16.67
8	.0101	.0649	.0548	.0443	"	7.32	.68	.0517	.794	15.34
10	.0125	.0843	.0718	.0613	"	7.20	.80	.0716	.935	13.05
11	.0140	.0949	.0809	.0704	"	7.165	.835	.0822	.976	11.85
12	.0153	.1295	.1142	.1037	"	7.16	.840	.1211	.981	8.10

q=6.41 kg/m².
D_w=0.0105 kg.
Temperature=9.5° C.
Sq=0.856 kg.
V=10.04 m/s.
E=0.982×10⁻⁵.

TABLE XXVI.

TEST OF 15×90 cm. U. S. A. 16 AIRFOIL.

Nominal speed 15 m/s.

Erect.

α	D_o	D_1	D^1	D	L_o	L_1	L	C_D	C_L	L/D
°										
−2	0.0319	0.0890	0.0571	+0.0345	2.00	1.91	−0.09	+0.0174	−0.045	−2.61
0	.0285	.0841	.0556	.0330	"	2.28	+0.28	.0166	+0.141	+8.49
+3	.0266	.0920	.0654	.0428	"	2.82	.82	.0216	.413	19.15
6	.0234	.1110	.0876	.0650	"	3.23	1.23	.0328	.620	18.93
8	.0233	.1335	.1102	.0876	"	3.55	1.55	.0447	.782	17.70
10	.0251	.1634	.1383	.1157	"	3.75	1.75	.0583	.883	16.57
11	.0261	.1872	.1611	.1385	"	3.83	1.83	.0699	.923	13.22
12	.0267	.2435	.2168	.1942	"	3.88	1.88	.0980	.948	9.68

q=14.69 kg/m².
D_w=0.0226 kg.
Temperature=10.5° C.
Sq=1.983 kg.

Inverted.

α	D_o	D_1	D^1	D	L_o	L_1	L	C_D	C_L	L/D
°										
−2	0.0026	0.0600	0.0574	+0.0348	8.00	8.06	−0.06	+0.0175	−0.030	−1.72
0	.0036	.0573	.0537	.0311	"	7.69	+0.31	.0157	+0.156	+9.98
+3	.0051	.0730	.0679	.0453	"	7.15	.85	.0229	.428	18.75
6	.0077	.1022	.0945	.0719	"	6.73	1.27	.0362	.640	17.66
8	.0100	.1282	.1182	.0956	"	6.45	1.55	.0482	.784	16.22
10	.0124	.1610	.1486	.1260	"	6.22	1.78	.0635	.898	14.13
11	.0139	.1820	.1681	.1455	"	6.12	1.88	.0734	.948	12.92
12	.0152	.2475	.2323	.2097	"	6.08	1.92	.1056	.968	9.16

q=14.695 kg/m²
D_w=0.0226 kg
Temperature=9 3° C
Sq=1.984 kg.
V=15.21 m/s.
E=1.487×10⁻⁵.

TABLE XXVII.

TEST OF 15×90 cm. U. S. A. 16 AIRFOIL.

Nominal speed 20 m/s.

Erect.										
α	D_o	D_1	D^1	D	L_o	L_1	L	C_D	C_L	L/D
°										
−2	0.0314	0.1235	0.0921	+0.0525	2.00	1.86	−0.14	+0.0150	−0.040	−2.67
0	.0280	.1158	.0878	.0482	“	2.57	+0.57	.0138	+0.163	+11.82
+3	.0261	.1327	.1066	.0670	“	3.44	1.44	.0192	.413	21.50
6	.0229	.1739	.1510	.1114	“	4.18	2.18	.0319	.625	18.67
8	.0228	.2135	.1907	.1511	“	4.68	2.68	.0433	.769	17.73
10	.0246	.2650	.2404	.2008	“	5.08	3.08	.0576	.883	15.34
11	.0256	.3083	.2827	.2431	“	5.24	3.24	.0698	.930	13.31
12	.0262	.3987	.3725	.3329	“	5.35	3.35	.0955	.951	10.06

q=25.83 kg/m².
Dw=0.0396 kg.
Temperature 10.5° C.
Sq=3.488 kg.

Inverted.										
α	D_o	D_1	D^1	D	L_o	L_1	L	C_D	C_L	L/D
°										
−2	0.0028	0.0999	0.0971	+0.0575	8.00	8.09	−0.09	+0.0165	−0.026	−1.56
0	.0038	.0919	.0881	.0485	“	7.40	+0.60	.0139	+0.172	+12.37
+3	.0053	.1192	.1139	.0743	“	6.50	1.50	.0213	.430	20.19
6	.0079	.1678	.1599	.1203	“	5.77	2.23	.0345	.639	18.52
8	.0102	.2112	.2010	.1614	“	5.28	2.72	.0462	.780	16.85
10	.0127	.2653	.2526	.2130	“	4.84	3.16	.0610	.906	14.83
11	.0141	.3002	.2861	.2465	“	4.66	3.34	.0706	.957	13.55
12	.0154	.4035	.3881	.3485	“	4.58	3.42	.0989	.980	9.82

q=25.85 kg/m².
Dw=0.0396 kg.
Temperature=9° C.
Sq=3.49 kg.
V=20.02 m/s.
$E=1.975\times10^{-5}$.

TABLE XXVIII.

TEST OF 15×90 cm. U. S. A. 16 AIRFOIL.

Nominal speed 30 m/s.

Erect.										
α	D_o	D_1	D^1	D	L_o	L_1	L	C_D	C_L	L/D
°										
−2	0.0889	0.2779	0.1890	+0.1030	1.00	0.99	−0.01	+0.0133	−0.001	− 0.97
0	.0855	.2700	.1845	.0995	“	2.55	+1.55	.0129	+0.200	+15.58
+3	.0836	.3157	.2323	.1463	“	4.30	3.30	.0189	.426	22.55
6	.0804	.4096	.3292	.2432	“	5.98	4.98	.0314	.643	20.47
8	.0803	.4955	.4152	.3292	“	7.06	6.06	.0425	.782	18.41
10	.0821	.6155	.5334	.4474	“	8.05	7.05	.0577	.910	15.75
11	.0831	.716	.6329	.5469	“	8.38	7.38	.0706	.952	13.48
12	.0837	.903	.8193	.7333	“	8.67	7.67	.0946	.980	10.46

q=57.40 kg/m.²
Dw=0.0860 kg.
Temperature=12.5° C
Sq=7.75 kg.

Inverted.										
α	D_o	D_1	D^1	D	L_o	L_1	L	C_D	C_L	L/D
°										
−2	0.0114	0.2018	0.1884	+0.1024	8.00	8.03	−0.03	+0.0132	−0.004	− 0.29
0	.0124	.1967	.1843	.0983	“	6.52	+1.48	.0127	+.191	+15.06
+3	.0141	.2480	.2341	.1481	“	4.70	3.30	.0191	.425	22.27
6	.0153	.3527	.3362	.2502	“	2.99	5.01	.0323	.646	20.01

q=57.45 kg/m².
Dw=0.0860 kg.
Temperature=9.0° C.
Sq=7.755 kg.
V=30.09 m/s.
$E=2.94\times10^{-5}$.

TABLE XXIX.

VARIATION OF D_o WITH α.

15×90 cm. model.

α	Erect.		Inverted.	
	D_o	D_o^1	D_o	D_o^1
−2	+0.0100	+0.0034	+0.0661	−0.0010
0	.0064	0.0000	.0671	0.0000
+3	.0045	−0.0019	.0688	+0.0017
6	.0013	.0051	.0700	.0029
8	−0.0012	.0052	.0737	.0066
10	.0030	.0034	.0758	.0087
11	.0040	.0024	.0778	.0107
12	.0046	.0018	.0786	.0115

Counterweight, erect, 3 kg. Counterweight, inverted, 5 kg.

TABLE XXX

COORDINATES OF MEAN POLARS

7.5×45 cm. airfoil

Airspeed C_L	12 m/s C_D	16 C_D	20 C_D	24 C_D	30 C_D	35 C_D
0.0	0.0175	0.0163	0.0168	0.0172	.0182	0.0186
.1	.0165	.0142	.0152	.0162	.0173	.0176
.2	.0173	.0152	.0160	.0166	.0177	.0180
.3	.0202	.0183	.0190	.0194	.0200	.0205
.4	.0253	.0235	.0237	.0242	.0246	.0250
.5	.0327	.0302	.0303	.0308	.0310	.0312
.6	.0422	.0393	.0385	.0393	.0390	.0394
.7	.0547	.0528	.0495	.0497	.0484	.0500
.8	.0755	.0695	.0645	.0630	.0590	.0630
.85	.0910	.0808	.0738	.0717	.0665	.0700

10×60 cm. airfoil

Airspeed C_L	9 m/s C_D	20 C_D	30 C_D
0.0	0.0214	0.0162	0.0152
.1	.0180	.0153	.0141
.2	.0184	.0157	.0150
.3	.0213	.0177	.0175
.4	.0266	.0216	.0210
.5	.0337	.0275	.0262
.6	.0425	.0354	.0335
.7	.0525	.0448	.0428
.8	.0642	.0553	.0535
.85	.0730	.0615	.0593

12.5×75 cm. airfoil

Airspeed C_L	9 m/s C_D	12 C_D	24 C_D	30 C_D
0.0	0.0150	0.0175	0.0148	0.0140
.1	.0140	.0147	.0140	.0134
.2	.0141	.0140	.0143	.0136
.3	.0162	.0155	.0160	.0155
.4	.0209	.0194	.0198	.0193
.5	.0276	.0252	.0253	.0247
.6	.0361	.0321	.0325	.0313
.7	.0458	.0412	.0410	.0400
.8	.0580	.0555	.0512	.0505
.85	.0690	.0643	.0575	.0565

15×90 cm. airfoil

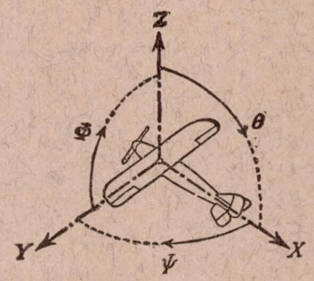
Airspeed C_L	6 m/s C_D	10 C_D	15 C_D	20 C_D	30 C_D
0.0	0.0210	0.0207	0.0168	0.0156	0.0130
.1	.0188	.0192	.0160	.0142	.0125
.2	.0192	.0197	.0164	.0138	.0128
.3	.0212	.0214	.0180	.0155	.0145
.5	.0240	.0241	.0212	.0192	.0176
.5	.0280	.0280	.0262	.0245	.0225
.6	.0337	.0340	.0324	.0311	.0288
.7	.0420	.0420	.0396	.0387	.0360
.8	.0532	.0517	.0487	.0472	.0440
.85	.0598	.0572	.0548	.0530	.0490

TABLE XXXI.

VARIATION IN DIRECTION OF AIRFLOW (IN VERTICAL PLANE).

V (m/s) (approx.).	Erect.	Inverted.	β	$\beta-\beta_{30}$
	L/D (max.).			
7.5×45 cm. AIRFOIL.				
12	17.5	14.7	+0°19′	+0°11½′
16	18.2	16.0	12½′	05′
20	18.0	15.9	12½′	05′
24	17.0	16.2	05′	−0°02½′
30	17.0	15.8	07½′	------
35	16.5	15.7	05½′	−0°02½′
10.0×60 cm. AIRFOIL.				
9	18.5	13.7	+0°32′	+0°28′
20	19.5	17.5	10′	06′
30	19.7	18.9	04′	------
12.5×75 cm. AIRFOIL.				
9	21.5	17.6	+0°17½′	+0°14′
12	22.2	20.0	08½′	05′
24	20.2	20.2	------	−0°03½′
30	21.3	20.4	03½′	------
15.0×90 cm. AIRFOIL.				
6	19.8	15.8	+0°22′	+0°22′
10	19.0	16.7	12′	12′
15	19.7	18.7	04½′	04½′
20	21.5	20.1	05½′	05½′
30	22.8	22.8	------	------

$$\beta=\frac{\operatorname{cotan}^{-1}\left(\frac{L}{D}\right)_1-\operatorname{cotan}^{-1}\left(\frac{L}{D}\right)_2}{2}$$



Positive directions of axes and angles (forces and moments) are shown by arrows.

Axis.		Force (parallel to axis) symbol.	Moment about axis.			Angle.		Velocities.	
Designation.	Sym-bol.		Designa-tion.	Sym-bol.	Positive direc-tion.	Designa-tion.	Sym-bol.	Linear (compo-nent along axis).	Angular.
Longitudinal	X	X	rolling	L	$Y \longrightarrow Z$	roll	Φ	u	p
Lateral	Y	Y	pitching	M	$Z \longrightarrow X$	pitch	Θ	v	q
Normal	Z	Z	yawing	N	$X \longrightarrow Y$	yaw	Ψ	w	r

Absolute coefficients of moment

$$C_l=\frac{L}{q\,b\,S} \quad C_m=\frac{M}{q\,c\,S} \quad C_n=\frac{N}{q\,f\,S}$$

Angle of set of control surface (relative to neutral position), δ. (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS.

Diameter, D
Pitch (a) Aerodynamic pitch, p_a
(b) Effective pitch, p_e
(c) Mean geometric pitch, p_g
(d) Virtual pitch, p_v
(e) Standard pitch, p_s
Pitch ratio, p/D
Inflow velocity, V'
Slipstream velocity, V_s

Thrust, T
Torque, Q
Power, P
(If "coefficients" are introduced all units used must be consistent.)
Efficiency $\eta = T\,V/P$
Revolutions per sec., n; per min., N
Effective helix angle $\Phi = \tan^{-1}\left(\frac{V}{2\pi rn}\right)$

5. NUMERICAL RELATIONS.

1 HP = 76.04 kg. m/sec. = 550 lb. ft/sec.
1 kg. m/sec. = 0.01315 HP
1 mi/hr. = 0.44704 m/sec.
1 m/sec. = 2.23693 mi/hr.

1 lb. = 0.45359 kg.
1 kg. = 2.20462 lb.
1 mi. = 1609.35 m. = 5280 ft.
1 m. = 3.28083 ft.