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The Resistance of the Airship Models
Measured in the Wind
Tunnels of Japan.*

BY

THE WIND TUNNEL COMMITTEE
SPECIALY APPOINTED BY
THE AERONAUTICAL COUNCIL OF JAPAN.

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Corrections.

Page	Line	Misprint	Correction
157	3	$-(\frac{3}{16} - \frac{1}{8}\sigma)$	$-(\frac{1}{16} - \frac{1}{8}\sigma)$
177	Table 3	Elo gation	<u>Elongation</u>
193	21	fix d	<u>fixed</u>
Pl. 8	Fig. 11	Surfae	<u>Surface</u>

CHAPTER I.

GENERAL DESCRIPTION.

1. *Object of the Investigation.*

The principal object of the present investigation, which has been initiated by the proposal of the National Physical Laboratory, Teddington England, is to compare the resistance or the resistance coefficient, as the case may be, of airship models measured at different wind tunnels and by different methods, to deduce thereby some properties, if any, peculiar to the wind tunnels and the aerodynamical balances employed.

As a slight dissimilarity, in the strict geometrical sense, in the material and construction of the models may result in no small discrepancy of their aerodynamical properties, models specially prepared for this purpose have been passed round to various institutes to be tested in their wind tunnels.

2. *Description of the Models.*

For this purpose two airship models have been prepared by the National Physical Laboratory. These are made of light alloy and have the shape shown in Fig. 1.

Their exact dimensions, which were measured at the Aeronautical Research Institute of Tôkyô Imperial University, are given in the Appendix.

The principal particulars of the models as supplied by the National Physical Laboratory and those taken from our measurement are compared in Table I. The two models, differing only in the length of the parallel portion, are hereafter for convenience sake called the *Long* and the *Short* model respectively.

Each model is made of three sections and a tail piece, and is made adaptable to different forms of aerodynamic balances. It is also

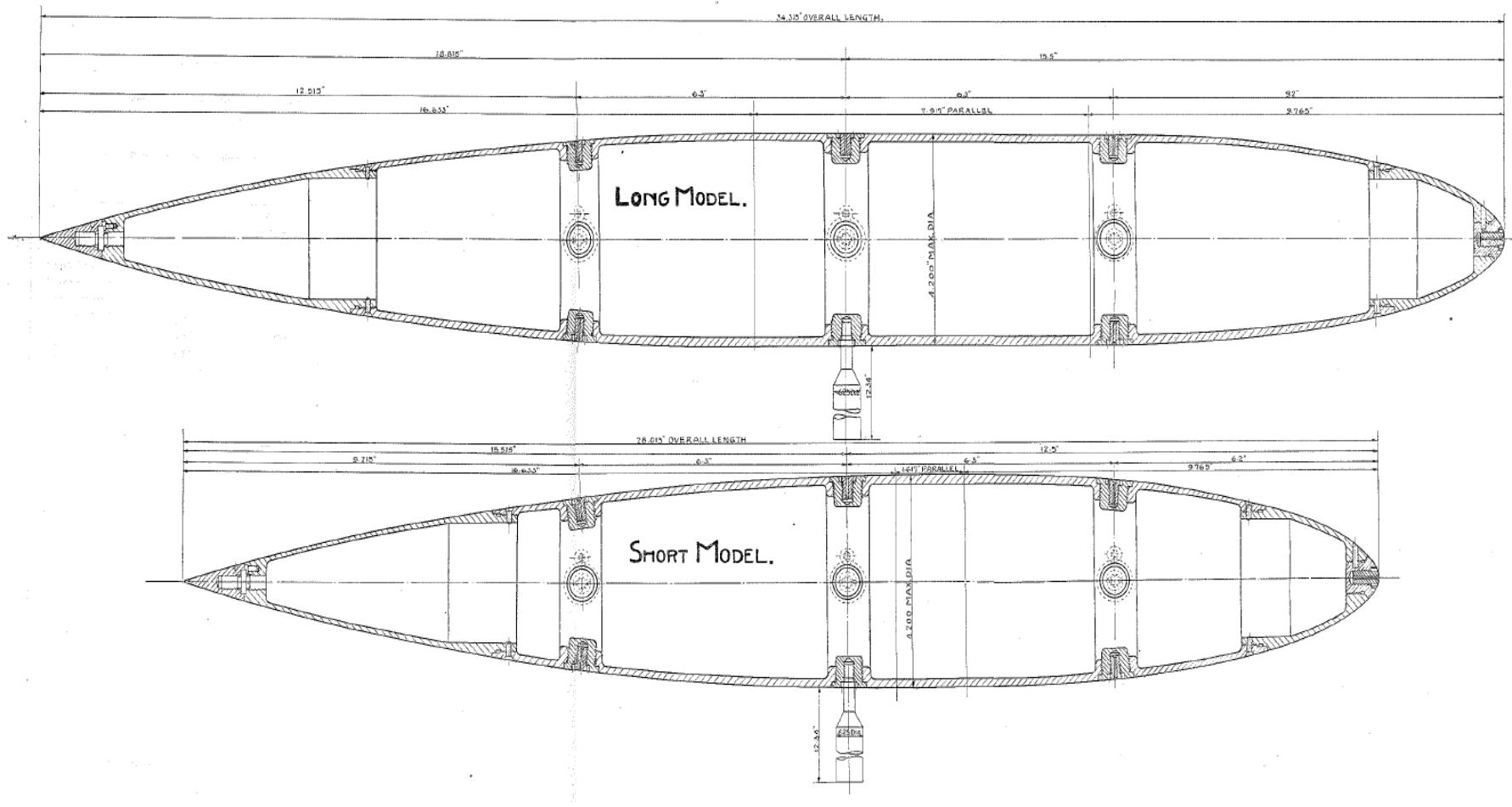


Fig. I.

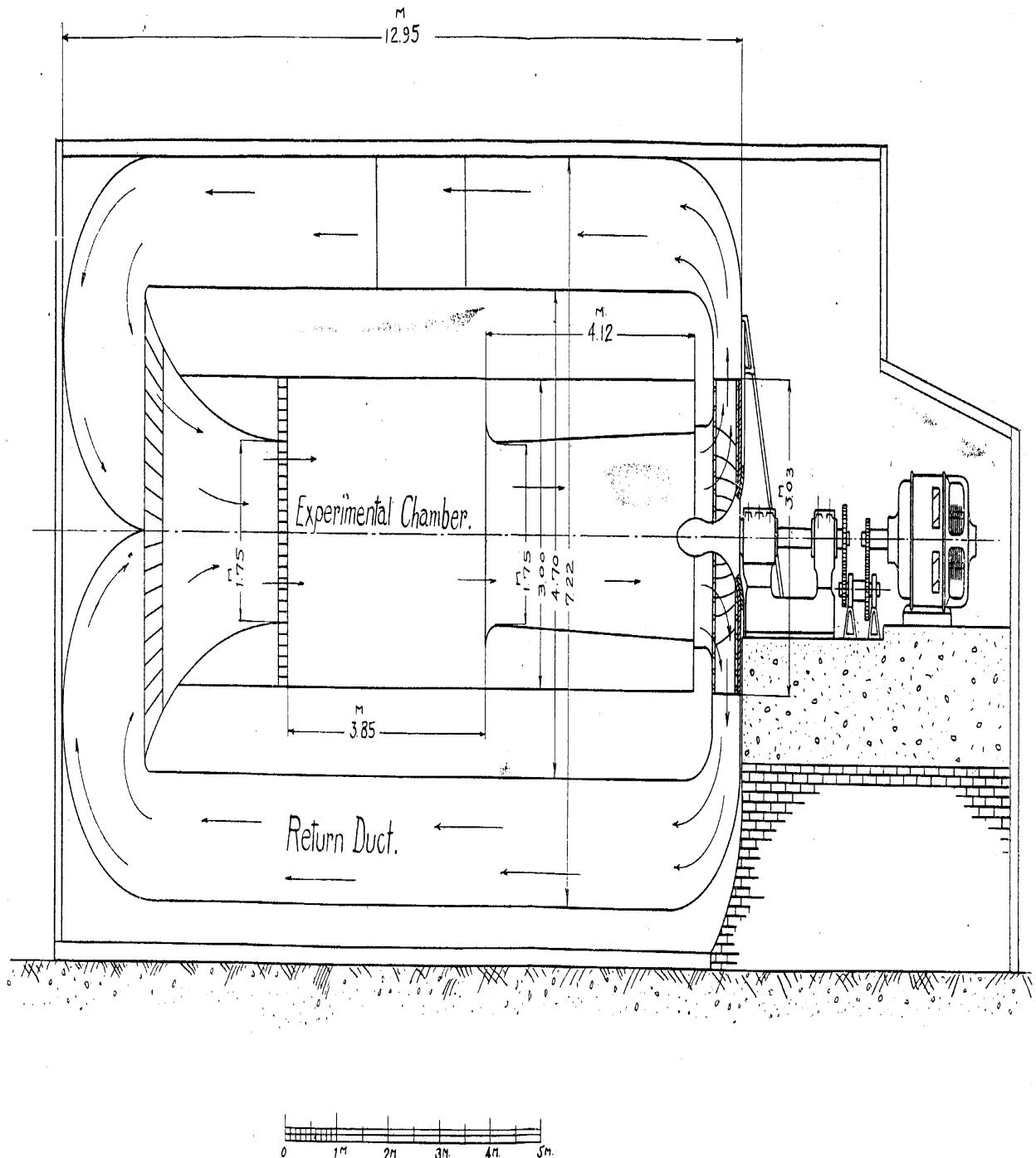


Fig. 2. The Wind Tunnel of the Technical Department of Board of Military Air Service. (Elevation).

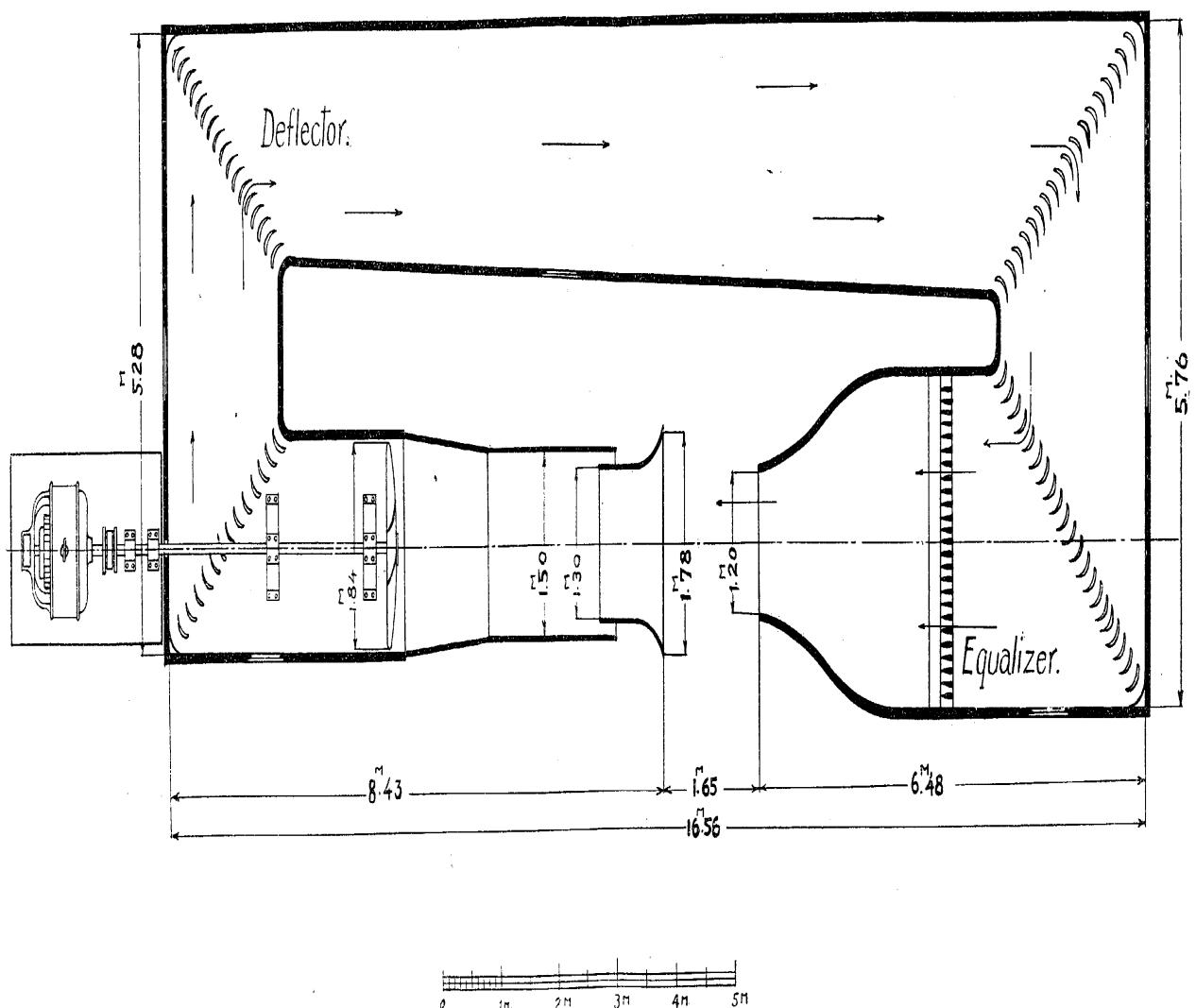


Fig. 3. The Wind Tunnel of the Aeronautical Research Institute, Tôkyô Imperial University. (Plan).

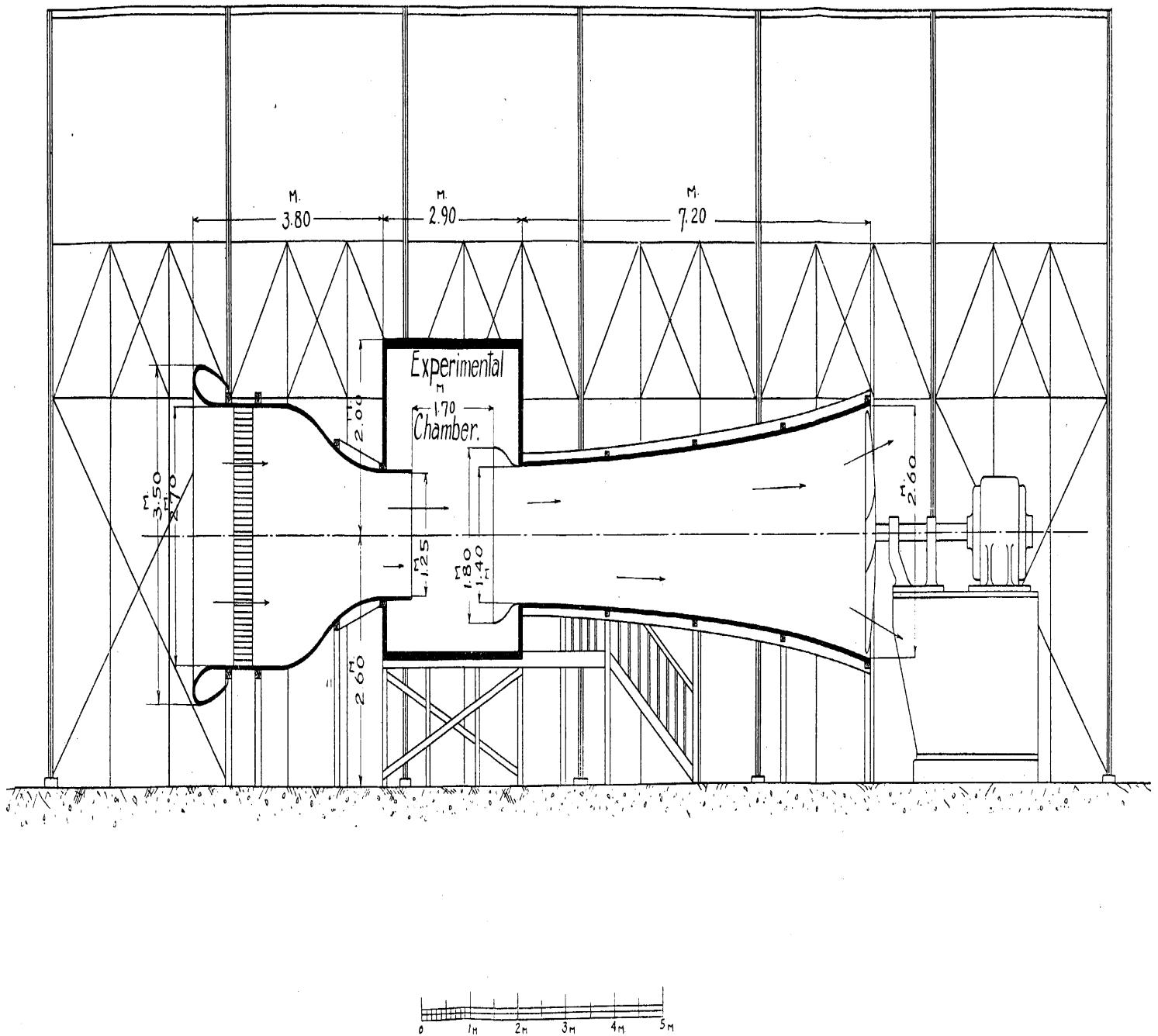


Fig. 4. The Wind Tunnel of the Aeronautical Research Laboratories, Imperial Japanese Navy. (Elevation).

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provided with special metal lugs for fixing suspending wires, as shown in Fig. 1.

Table I.—Particulars of the Models.

Long Model

	Measured at :	
	National Physical Laboratory	Aeronautical Research Institute, Tôkyô Imperial University
Overall Length	34.314 inches	0.871337 m. 0.106650 m.
Maximum Diameter	4.200 inches	34.305 inches 4.199 inches
Fineness Ratio	8.17	8.16
Length of Parallel Body	7.92 inches	
Volume	0.1890 cub. ft. (Volume) $^{\frac{1}{3}}$	0.00534796 m ³ . 0.17488 m. 0.5738 ft.

Short Model

	Measured at :	
	National Physical Laboratory	Aeronautical Research Institute, Tôkyô Imperial University
Overall Length	28.010 inches	0.711272 m. 0.106630 m.
Maximum Diameter	4.199 inches	28.003 inches 4.198 inches
Fineness Ratio	6.67	6.68
Length of Parallel Body	1.62 inches	
Volume	0.1383 cub. ft. (Volume) $^{\frac{1}{3}}$	0.00390652 m ³ . 0.15749 m. 0.5166 ft.

Remark. The temperature varied during the measurements of the Long Model from 12.3° to 14.7° C. and during those of the Short Model from 12.2° to 14.1° C.

3. Measurements carried out in Japan.

The wind tunnels in Japan available after the devastation caused by the Great Earthquake of 1923 are as given in Table II. Further details will be found under the chapter of each wind tunnel.

Table II.—Wind Tunnels in Japan.

Rikugun Kôkûhonbu Gizyutubu.

(Technical Department of Board of Military Air Service)

Diameter	1.75 m.
Wind velocity	10 m/s—25 m/s
Power of motor	100 H. P.

Tôkyô Teikoku-Daigaku Kôkû-Kenkyûzyo.

(Aeronautical Research Institute, Tôkyô Imperial University)

Diameter	1.20 m.
Wind velocity	4 m/s—24 m/s
Power of motor	20 H. P.

Kaigun Gizyutu-Kenkyûsyo Kôkû-Kenkyûbu.

(Aeronautical Research Laboratories, Imperial Japanese Navy)

Diameter	1.25 m.
Wind velocity	3 m/s—50 m/s
Power of motor	100 H. P.

The measurements were carried out—
at the Technical Department of Board of Military Air Service,
from May to December, 1924;
at the Aeronautical Research Institute, Tôkyô Imperial University,
from January to March, 1925;
at the Aeronautical Research Laboratories, Imperial Japanese Navy,
from April to May, 1925.

Dimensions and general forms can be seen from the diagrammatical sketches given in Figs. 2, 3 and 4.

The models, after the completion of the measurements, were sent back to the National Physical Laboratory in July and duly received in August 1925.

4. Characteristics of the Wind Tunnels.

In order to know the degree of deviation from uniformity of the air flow in the wind tunnels, the distribution of the velocity and the direction of air flow were determined in the neighbourhood of the place where the actual measurement was to take place.

The gradient of the static pressure along the axis of the wind tunnel is very difficult to nullify completely. It is necessary to determine its amount, as its effect, acting as horizontal buoyancy and affecting the results of the measurement of the resistance, can not be neglected in the present case.

The distribution of static pressure along the axis of the wind tunnel, as indicated by the static hole of a Pitot-static tube, was compared with that of the standard Pitot-static tube fixed at a definite point of the wind tunnel and the correction for the horizontal buoyancy was obtained by means of mechanical integration.

5. Measurement of Total Resistance.

The model was suspended from fixed points with two pairs of piano wires, of about 0.2 mm. diameter, in V form. The wires of each pair of the V were made to coincide as nearly as possible with a line perpendicular to and passing through the axis of the model, so as to avoid undesirable strain at the points of attachment to the model. A pair of wires were fixed at the lower pair of lugs at the middle part of the model and ran backward and downward over a roller and weighted at its end to afford sufficient tension to the drag wire, as well as to prevent the rotational motion of the model about its longitudinal axis. The drag wire ran horizontally from the nose of the model to a point about one meter upwind, where it was fixed to two wires, one running thence vertically upwards to the arm of the drag balance and the other obliquely downwards at nearly 45° degrees to the wall of the wind tunnel where it was fixed. Thus the model was definitely fixed in position leaving only one degree of freedom in the direction of the

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resistance. The sketch given in Fig. 5 will show the general principle of the suspension.

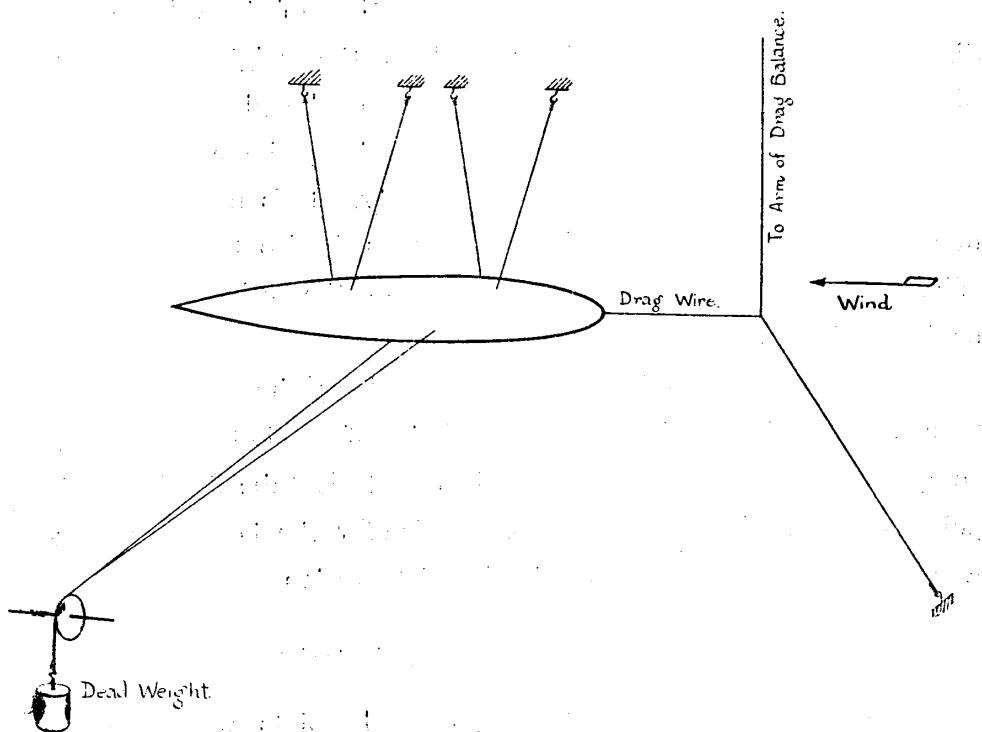


Fig. 5. Sketch showing Mode of Suspension of the Model in Wind Tunnel.

Care was taken in fixing the wires to the model, so as to offer as small disturbance as can be desired to the flow of air over the surface of the models.

After the model was thus fixed in position ready for the resistance measurement, the drag balance was calibrated against a known horizontal pull of the model, caused by means of a string, a pulley and a dead weight.

As the resistance coefficient of such a shape as an airship model is not a constant and, as generally considered, a function of Reynolds' number, while the velocity of the air flow in the wind tunnel is the only variable quantity at our disposal, the measurements were taken at as many different values of the air velocity as possible.

6. Measurement of Wire Resistance.

As can be seen from the results of the measurements, the resistance of the suspension system covers a large portion of the total resistance. Hence, to obtain an accurate value of the resistance of such a model, the determination of the resistance of the suspension system must be made with an equal accuracy. As the presence of the model may affect the flow of the air around it and in consequence the resistance of the wire, it is desirable to measure the resistance of the suspension system with the model in position. For this purpose a hollow model of the same size and the same external form as the given model was made of wood and held, independently of the original suspension wire, in the same position in which the total resistance was measured. The original suspension wires passed through the holes in the wooden model and fixed to a metal rod inside, so as the suspension wires and the rod, to which they were fixed, were held separately of the wooden model. As it is possible that the tension of the suspension wire may affect its resistance, the weight of the metal rod was made as nearly equal to the original model as possible. The holes on the hull of the wooden model keep the inside in free communication with the outside and give rise to a pressure difference, which may cause an air current within the hollow model. As such a current will act on the weighted rod and affect the reading of the wire resistance, it is necessary to shut off their mutual communication, at least, where the said pressure difference is appreciable. As is well known, in such a model the gradient of pressure on its surface is considerable near its nose while it is fairly small on the other parts of the body. Therefore it was considered sufficient to put a mercury sealing at the nose of the model. The details can be seen from Fig. 6.

The calibration of the balance was carried out in exactly the same manner as in the case of the total resistance measurement against known pull of the drag wire. The measurement of the wire resistance was made in as many different values of the air velocity as in those

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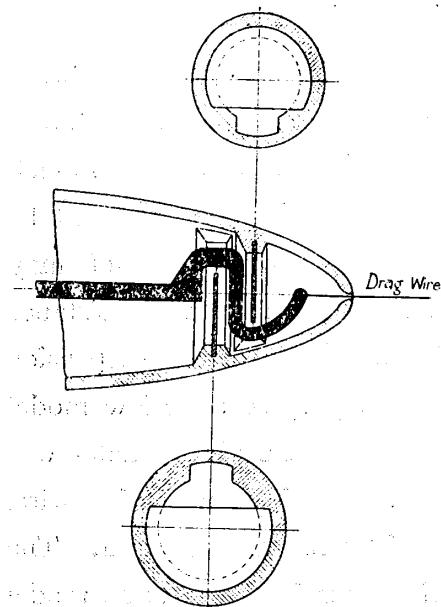


Fig. 6. Mercury Sealing at the Head of the Wooden Model.

number is the same.

Reynolds' number is defined by

$$R = \frac{Lv\rho}{\mu}, \quad (1)$$

where L is the linear dimension of the body in meters,

v the velocity of air in m/s,

ρ the density of air in kg/m³,

μ the coefficient of viscosity of air in m.-kg.-s. absolute.

Accepting this, we have to compare the results of the measurement of the total and wire resistances for the same Reynolds' number.

From the dimensional consideration we can write generally

$$F = qSf(R), \quad (2)$$

where F is the resistance of body in kg.-weight;

$q = \frac{1}{2} \frac{\rho}{g} v^2$, the dynamic pressure in kg.-weight/m² (mm. of water column), g , acceleration due to gravity, being in m/sec²;

S , square of the linear dimension in m² and

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$f(R)$, a function of Reynolds' number.

We denote by $F^{(T)}$ and $F^{(W)}$ the total resistance and wire resistance respectively, while F without index denotes the resistance of the model only. A suffix denotes the condition under which the model was put; T and W for the conditions at which the total resistance and the wire resistance were measured respectively, while S denotes a standard condition. For example, $F_S^{(T)}$ means the total resistance in the standard condition, and $F_T^{(W)}$ the wire resistance in the condition under which the total resistance was measured. Further, we denote with S_1, L_1 and S_2, L_2 the values of S and L , and with f_1 and f_2 the function f , for the model and wire respectively.

Then we have for the body resistance F_S of the model in the standard condition

$$F_S = F_S^{(T)} - F_S^{(W)} \quad (3)$$

Actually measured quantities are $F_T^{(T)}$ and $F_W^{(W)}$ which can be written as follows—

$$F_T^{(T)} = q_T S_1 f_1 \left(\frac{L_1 v_T \rho_T}{\mu_T} \right) + q_T S_2 f_2 \left(\frac{L_2 v_T \rho_T}{\mu_T} \right), \quad (4)$$

$$F_W^{(W)} = q_W S_2 f_2 \left(\frac{L_2 v_W \rho_W}{\mu_W} \right). \quad (5)$$

The required quantities $F_S^{(T)}$ and $F_S^{(W)}$ can also be written

$$F_S^{(T)} = q_S S_1 f_1 \left(\frac{L_1 v_S \rho_S}{\mu_S} \right) + q_S S_2 f_2 \left(\frac{L_2 v_S \rho_S}{\mu_S} \right) \quad (6)$$

$$F_S^{(W)} = q_S S_2 f_2 \left(\frac{L_2 v_S \rho_S}{\mu_S} \right). \quad (7)$$

In order to have the same values of Reynolds' number in the three conditions denoted by T, W and S for the model as well as for the wire, we have to take, since L_1 and L_2 are constant for all cases,

$$\frac{v_S \rho_S}{\mu_S} = \frac{v_T \rho_T}{\mu_T} = \frac{v_W \rho_W}{\mu_W}. \quad (8)$$

Expressed in terms of q , these relations give

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$$q_s = q_T \left(\frac{\mu_s}{\mu_T} \right)^2 \frac{\rho_T}{\rho_s} = q_w \left(\frac{\mu_s}{\mu_w} \right)^2 \frac{\rho_w}{\rho_s}. \quad (9)$$

Putting these values into the right hand member of (6) and (7),

$$\begin{aligned} F_s^{(T)} &= \left(\frac{\mu_s}{\mu_T} \right)^2 \frac{\rho_T}{\rho_s} \left\{ q_T S_1 f_1 \left(\frac{L_1 v_T \rho_T}{\mu_T} \right) + q_T S_2 f_2 \left(\frac{L_2 v_T \rho_T}{\mu_T} \right) \right\} \\ &= \left(\frac{\mu_s}{\mu_T} \right)^2 \frac{\rho_T}{\rho_s} F_T^{(T)}, \end{aligned} \quad (10)$$

$$F_s^{(W)} = \left(\frac{\mu_s}{\mu_w} \right)^2 \frac{\rho_w}{\rho_s} q_w S_2 f_2 \left(\frac{L_2 v_w \rho_w}{\mu_w} \right) = \left(\frac{\mu_s}{\mu_w} \right)^2 \frac{\rho_w}{\rho_s} F_w^{(W)}. \quad (11)$$

We may denote by K the coefficient $\left(\frac{\mu_s}{\mu} \right)^2 \frac{\rho}{\rho_s}$ for any condition of air, so that

$$K_T = \left(\frac{\mu_s}{\mu_T} \right)^2 \frac{\rho_T}{\rho_s}, \quad K_w = \left(\frac{\mu_s}{\mu_w} \right)^2 \frac{\rho_w}{\rho_s}. \quad (12)$$

We see that the multiplication of $F_T^{(T)}$ by K_T reduces it into $F_s^{(T)}$, which is the value of $F^{(T)}$ in the standard pressure and temperature when the air velocity is

$$v_s = \frac{\mu_s}{\mu_T} \frac{\rho_T}{\rho_s} v_T. \quad (13)$$

Similarly for other cases. Note that v_s corresponds to

$$q_s = \frac{1}{2} \frac{\rho_s}{g} v_s^2 = K_T q_T = K_w q_w. \quad (14)$$

Thus, we get from (3) for the body resistance of the model in the standard condition

$$F_s = K_T F_T^{(T)} - K_w F_w^{(W)}. \quad (15)$$

For the standard condition we have taken:

Atmospheric pressure 760 mm. in Hg.

Atmospheric temperature 15°C.

Then we have

$$\rho_s = 1.225 \text{ kg/m}^3$$

$$\mu_s = 0.00001785 \text{ m.-kg.-sec. absolute units.}$$

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The value of K for $t^{\circ}\text{C}$. and H mm. Hg. of barometric pressure is, since

$$\rho = \rho_s \frac{288}{273+t} \cdot \frac{H}{760}, \quad \mu = \mu_s \left\{ 1 + 0.00276(t - 15) \right\},$$

$$K = \frac{H}{760} \left\{ 1 - 0.00899(t - 15) \right\}. \quad (16)$$

The measured values $F_T^{(T)}$ and $F_W^{(W)}$ were corrected to the standard condition and the results were plotted against the standard dynamic pressure, namely

$$q_s = \frac{1}{2} \frac{\rho_s}{g} v_s^2. \quad (17)$$

F_s was then obtained as the difference of the ordinates of two curves $F_S^{(T)}$ and $F_S^{(W)}$ for the same standard dynamic pressure q_s .

F_s was then corrected for the horizontal buoyancy.

8. Representation of Results.

The result of our measurements is expressed in two relations:—

Firstly we have expressed F_s , i.e. the resistance of the model reduced to the standard temperature and pressure for such a velocity v_s that the value of R is the same as in any actual measurement, against q_s , the dynamic pressure of the said standard air flow.

Secondly we have expressed the resistance coefficient C_x , defined by

$$C_x = \frac{F_s}{\frac{1}{2} \frac{\rho_s}{g} v_s^2 V^{\frac{2}{3}}}, \quad (18)$$

where V denotes the total volume of the model, as a function of Reynolds' number R , which is

$$R = \frac{\rho v V^{\frac{1}{3}}}{\mu}, \quad (19)$$

$\frac{\rho v}{\mu}$ being the same in the actual experiment and in the reduced standard state.

CHAPTER II.

MEASUREMENT AT THE WIND TUNNEL OF THE TECHNICAL DEPARTMENT OF BOARD OF MILITARY AIR SERVICE.

1. Description of the Wind Tunnel and the Aerodynamic Balance.

The wind tunnel, which was erected in Tokorozawa in 1917 consists, as can be seen from Fig. 2, of three coaxial cylinders, the innermost of which is the experimental chamber and is provided with simple equalizers at both ends. There is a fine adjustable equalizer at the nozzle. It is constructed of hollow square cylinders, 5 cm. square and 20 cm. long, made of zinc plate 0.4 mm. thick. The diameter of the air current within the experimental chamber is about 1.57 m. and the length of the free stream is about 4 m. A centrifugal fan, driven by a 100 H. P., D. C. compound electric motor, gives wind velocities from 10 m/s to 25 m/s. The diameter of the fan is 3.03 m. with 36 fixed and 37 moving vanes. The number of revolutions of the motor and that of the fan make a ratio of 750/200. The reduction is effected by means of a mechanical gearing.

A diagrammatical sketch of the aerodynamic balance, which was specially installed for the present investigation, is shown in Fig. 7. The seats of knife edges are placed on balls so that a slight error in alignment may be adjusted automatically. Special magnifying device is provided by which readings up to 0.1 gramme can be taken.

2. Characteristics of the Wind Tunnel.

a) Distribution of Air Velocity.

The dynamic pressures as indicated by a standard Pitot-static tube and a portable one were compared. The standard Pitot-static tube, which is of the standard N.P.L. type, was placed at about 60 cm. from the nozzle. The portable Pitot-static tube is of Prof. Prandtl's type and was supported by a pillar of stream line form. The mano-

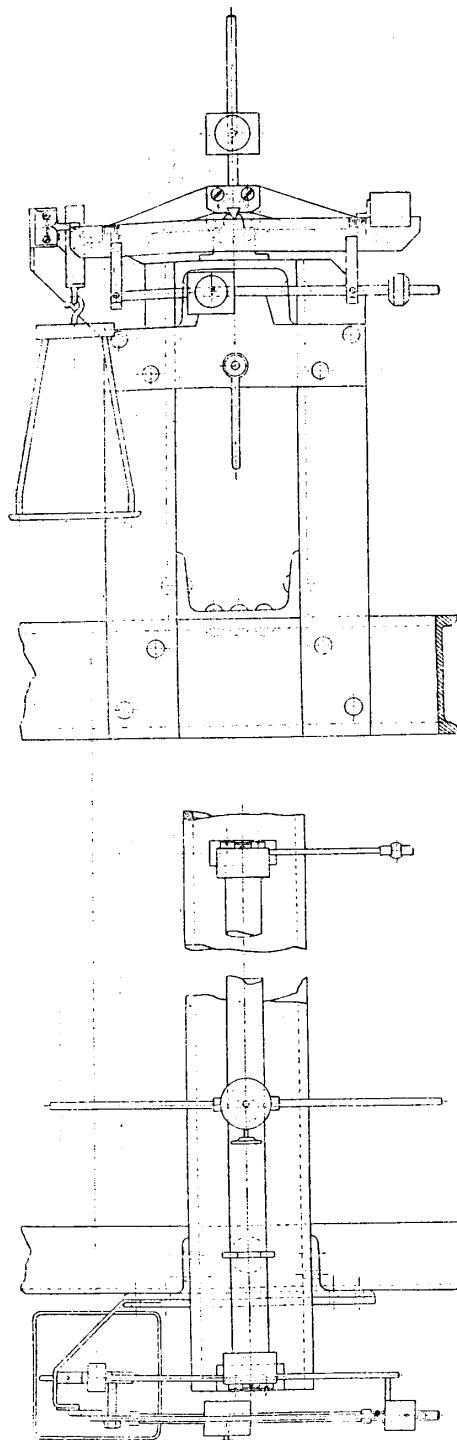


Fig. 7.

meter employed was an inclined differential water manometer of small bore (about 2 mm. inner diameter) with a big reservoir. The inclination of the glass tube of the manometer, which could be read to one minute with a sensitive level, was kept at 10 degrees throughout the experiment. The manometer reading, which could be taken to 0.05 mm. of water column, was calibrated against Chattock tilting manometer with maximum possible error of 0.05 mm. at an inclination of 10 degrees.

The measurements were made at 27 points, which are shown in Fig. 8. The readings were taken with two different indications of the dynamic pressure q_0 at the position No. 25, namely for $q_0 = 9$ mm. and $q_0 = 25$ mm. of water column. From them were calculated the values of

$$\left(\frac{q - q_0}{q_0} \right) \times 100, \quad (1)$$

where q is the dynamic pressure of the portable Pitot-static tube. The result is tabulated in Table III.

The result shows some velocity drop from the nozzle to the diffuser.

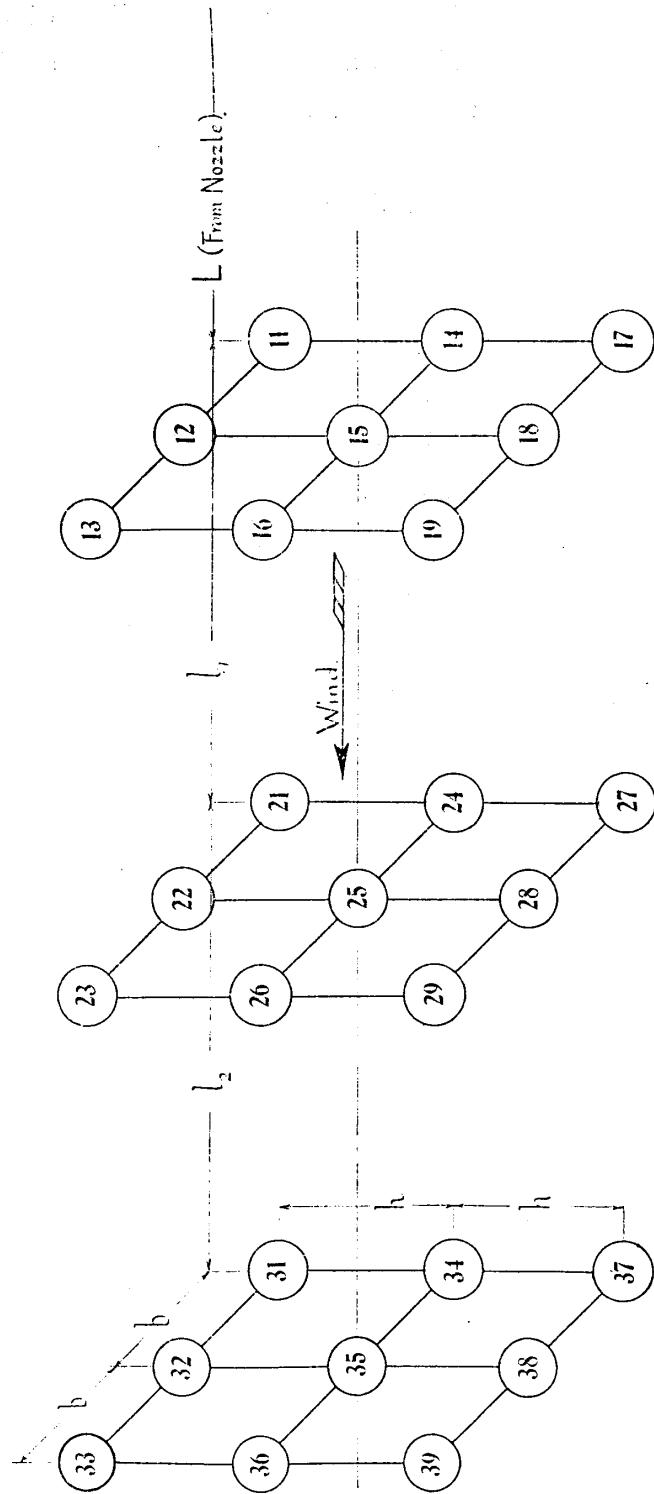
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Fig. 8.

L , cm.	l_1 , cm.	l_2 , cm.	h , cm.	h , cm.
1348	962	940	300	300
174	439	436	200	200
0	600	650	300	300

The Technical Department of Board of Military Air Services.
The Aeronaut. Research Inst., Tôkyô Imp. Univ.
The Aeronaut. Research Labors, I. J. N.

Table III.—Velocity Distribution.
The Technical Department of Board of Military Air Service

Position number.	$\frac{q-q_0}{q_0} \times 100$		Position number.	$\frac{q-q_0}{q_0} \times 100$		Position number.	$\frac{q-q_0}{q_0} \times 100$	
	$q_0 = 25$ mm. water.	$q_0 = 9$ mm. water.		$q_0 = 25$ mm. water.	$q_0 = 9$ mm. water.		$q_0 = 25$ mm. water.	$q_0 = 9$ mm. water.
11	+3.0	0	21	-0.5	-2.0	31	-5.5	-6.0
12	+3.5	+2.0	22	0	-1.0	32	-3.0	-4.0
13	+1.5	0	23	-2.0	-2.0	33	-8.5	-8.0
14	-0.5	-4.0	24	-2.0	0	34	-6.5	-8.0
15	-0.5	-4.0	25	0	0	35	-1.5	0
16	+3.5	0	26	+0.5	0	36	-3.5	-8.0
17	+3.0	0	27	-0.5	0	37	-6.5	-8.0
18	+1.5	0	28	0	+1.0	38	-1.5	0
19	+3.5	+2.0	29	+0.5	0	39	-3.0	-4.0

b) Direction of Air Flow.

Prof. Tamaru's yawmeter⁽¹⁾, in conjunction with the inclined differential water manometer at 10 degrees, was employed for the determination of the deviation of the air flow from the vertical and horizontal plane parallel to the axis of the wind tunnel. A special supporting frame was constructed to facilitate the setting of the instrument. The deviation angles were calculated from the following formula⁽²⁾, where P_1 and P_2 denote the pressure differences between consecutive rows of pressure holes of the yawmeter, and θ the deviation angle,

$$\theta = \frac{1}{2} \tan^{-1} \left[0.578 \left(\frac{P_2 + P_1}{P_2 - P_1} \right) \right]. \quad (2)$$

The measurements were taken at the same positions as in the case of the velocity distribution, shown in Fig. 8, and at the air velocities 12 m/s, 15 m/s and 20 m/s. The results are shown in Table IV giving the actual angles of deviation in degrees. There the upward deviation

(1) For full description, see Report of the Aeronautical Research Institute, Tôkyô Imperial University. No. 1.

(2) For full description, see *Hûtôkiyô* (Tokorozawa) No. 9. The same will be published in *Kôkû-Kenkyûzô Zaturoku*. The other formula $\rho v^2 = 1.941 \sqrt{(P_1 + P_2)^2 - P_1 P_2}$, there given, showed a good agreement with values found by the Pitot-static tube.

from the horizontal plane and the deviation towards the right from the vertical plane facing the wind are taken positive.

Table IV.—Direction of Air Flow.

The Technical Department of Board of Military Air Service.

Position number.	Deviation angle in degrees					
	from the horizontal plane.			from the vertical plane		
	20 m/s	15 m/s	12 m/s	20 m/s	15 m/s	12 m/s
11	+0.75	+2.37	+1.08	+0.12	+0.15	-0.10
12	+1.33	+1.03	+1.85	+0.52	+0.77	+0.30
13	+1.85		+1.55	+0.23	+1.00	-1.00
14	+3.05	+0.60	+3.37	-0.37	-0.15	-0.28
15	+0.55	+1.27	+0.53	-0.33	-0.28	-0.33
16	+0.75	+2.10	+0.62	-0.25	-0.47	-0.53
17	+1.60	+3.02	+1.48	-0.30	-0.22	-0.23
18	+2.08	+0.48	+2.25	+0.50	+0.75	+0.77
19	+1.43	+0.77	+1.67	-0.05	+0.07	+0.17
21	+0.60	+0.75	+0.07	+0.38	+0.28	+0.07
22	+0.67	-1.02	+0.85	+0.40	+0.75	+0.70
23	+1.37	-1.90	+1.73	+1.50	+1.25	+1.33
24	+2.15	+1.83	+1.82	-0.72	-0.98	-0.88
25	+0.95	+1.47	+1.75	-0.57	-0.60	-0.45
26	+0.30	-0.38	+0.52	-0.50	-0.30	-0.18
27	+1.38	+1.25	+1.12	-0.92	-0.73	-0.42
28	+1.67	+1.78	+1.72	-0.05	-0.12	-0.13
29	+0.80	-0.78	+0.77	-0.38	+0.02	+0.12
31	+0.77	+0.93	+0.68	-0.08	+0.02	-0.18
32	+0.15	+0.35	+0.47	-0.07	+0.12	+0.28
33	+0.88	+1.28	+1.43	+0.97	+0.53	+0.58
34	+0.77	+0.92	+1.12	-0.70	-0.60	-0.45
35	+0.63	+0.85	+0.65	-0.45	-0.63	-0.78
36	+0.25	+0.35	+0.03	+0.10	-0.10	-0.02
37	+0.83	+0.58	+0.65	-1.50	-1.62	-1.90
38	+0.80	+0.93	+0.73	+0.12	0	-0.07
39	+0.60	+0.65	+1.18	-0.53	0	+0.52

c) Gradient of Static Pressure.

The difference of the pressures of the static holes of the standard Pitot-static tube (ρ_{ss}) and the portable one (ρ_s) was determined along

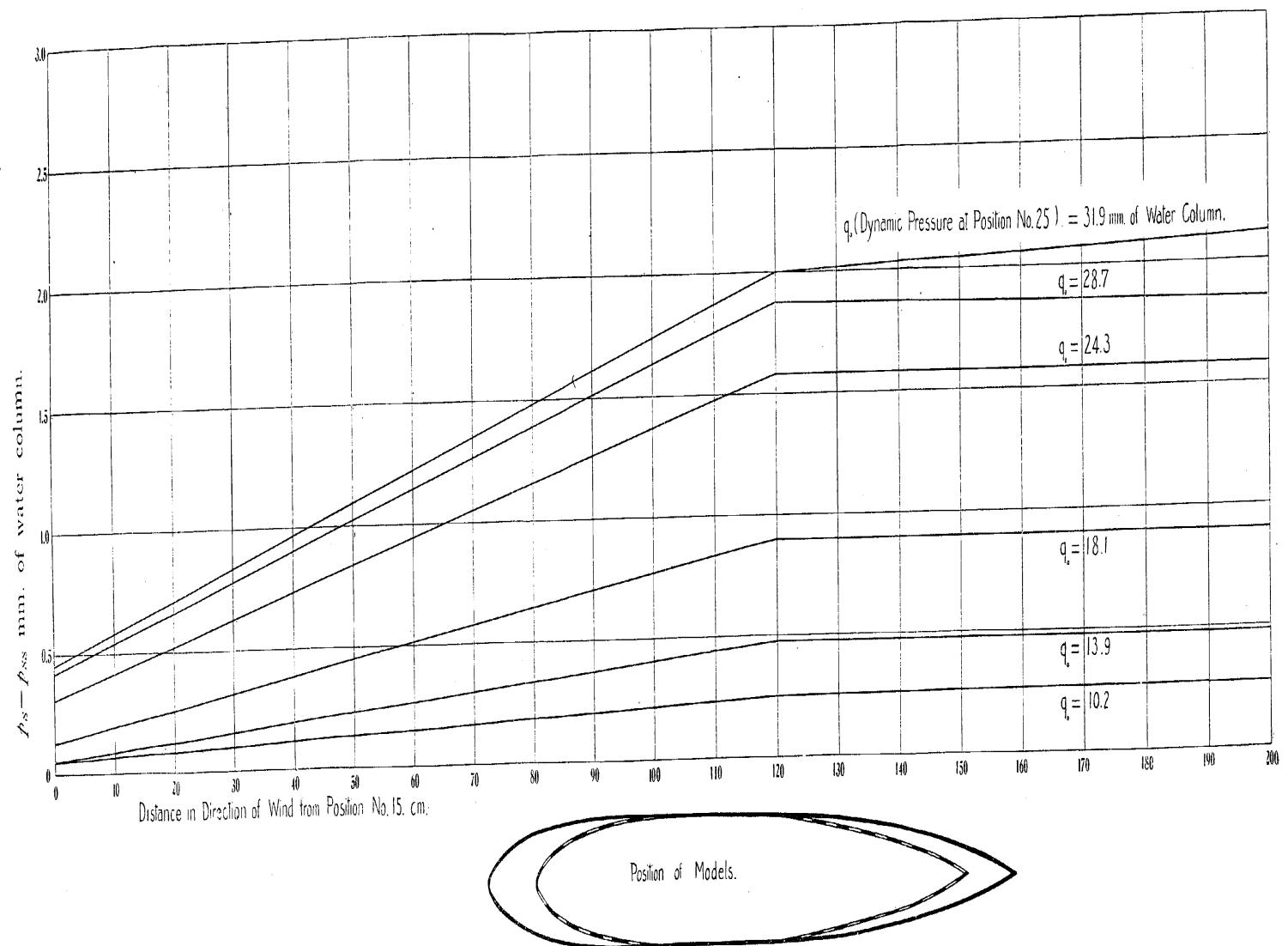


Fig. 9.—Static Pressure Distribution of the Wind Tunnel. The Technical Department of Board of Military Air Service.

the longitudinal axis of the wind tunnel with an inclined differential water manometer at 3° inclination. As can be seen from the Fig. 9, the static pressure increases proportionally to the distance from the position No. 15 up to 1.20m. from it, beyond which it is nearly constant.

3. Measurement of Resistance.

The model, kept in position as explained in Art. 5, Chapter I and shown in Fig. 5, was placed at 1.42° to the axis of the wind tunnel in the horizontal plane so that the direction of its axis and that of air flow at the position No. 25 coincided. For suspension was used piano wire of 0.3 mm. diameter. The distance of the knife edges of the balance from the axis of the model was 0.615 m. for the long model and 0.691 m. for the short model respectively. The method of connection of the suspension wires to the model was as shown in Fig. 10.

The results of the measurement of the total resistance including that of the suspension system are given in Tables V, VI and Figs. 11, 12.

The measurement of the wire resistance is the same as described in Art. 6, Chapter I. The results are given in Tables VII, VIII and Figs. 11, 12.

4. Resistance and Resistance Coefficient.

The body resistance as obtained by the method described in Art. 7, Chapter I, and corrected for static pressure gradient is given in Tables IX, X and Figs. 11, 12. The correction for the static pressure gradient was calculated from the data shown in Fig. 9, the result being a relation between q for the position No. 25 and the horizontal buoyancy,

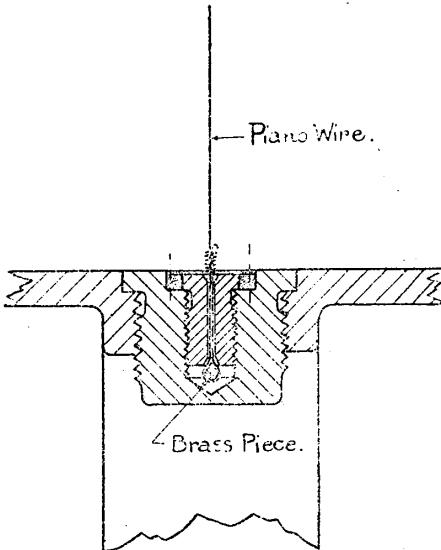


Fig. 10. The Method of Connection of Suspension Wire.

which is tabulated in Table XI.

The resistance coefficients are given in Tables IX, X and Figs. 13, 14.

Table V.—Total Resistance. *Long Model.*

The Technical Department of Board of Military Air Service.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Density of air, half saturated, kg/m³.	Coefficient of viscosity of air, kg/m.s. (absolute)	Coefficient K	Reduction to standard condition of air. (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Total resistance, kg. weight.
7·5	0·0179	11·0	743·1	1·212	0·0000177	1·002	7·5	0·0179
9·2	0·0215	"		"	"	"	9·2	0·0215
10·6	0·0252	11·2		1·211	"	"	10·6	0·0252
13·0	0·0303	"		"	"	"	13·0	0·0304
15·8	0·0353	11·5		1·210	"	"	15·8	0·0354
17·8	0·0392	"		"	"	"	17·8	0·0393
20·8	0·0446	11·7		1·209	"	"	20·8	0·0447
23·6	0·0503	12·0		1·208	"	1·000	23·6	0·0503
27·2	0·0566	12·3		1·206	"	0·998	27·2	0·0564
29·5	0·0609	12·5		1·205	"	"	29·4	0·0607
31·8	0·0649	13·0		1·203	0·0000178	0·984	31·3	0·0638
39·4	0·0793	13·2		1·202	"	0·982	38·7	0·0778
37·0	0·0742	13·5		1·201	"	"	36·4	0·0728
33·8	0·0688	14·0		1·199	"	0·980	33·1	0·0674
6·0	0·0143	7·7	752·0	1·242	0·0000175	1·051	6·3	0·0147
7·3	0·0174	8·0		1·241	"	"	7·7	0·0183
9·1	0·0219	8·2		1·240	"	1·048	9·5	0·0230
11·5	0·0271	8·5		1·239	"	"	12·1	0·0284
13·7	0·0310	9·0		1·236	0·0000176	1·033	14·2	0·0320
15·7	0·0348	9·3		1·235	"	"	16·2	0·0360
18·6	0·0408	9·7		1·233	"	1·031	19·2	0·0421
21·4	0·0462	10·2		1·230	"	1·028	22·0	0·0475
24·7	0·0529	10·5		1·229	"	"	25·4	0·0544
27·6	0·0576	11·0		1·227	0·0000177	1·015	28·0	0·0585
29·5	0·0615	11·5		1·225	"	1·013	29·9	0·0624
36·5	0·0744	12·0		1·222	"	"	37·0	0·0754
33·8	0·0705	12·5		1·220	"	1·010	34·2	0·0712
31·1	0·0636	13·0		1·218	0·0000178	0·995	31·0	0·0632

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Table VI.—Total Resistance. Short Model.

The Technical Department of Board of Military Air Service.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Density of air, half saturated. kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coefficient <i>K</i>	Reduction to standard condition of air. (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Total resistance, kg. weight.
4.95	0.0105	7.5	757.3	1.251	0.0000175	1.059	5.2	0.0111
5.9	0.0140	7.8		1.250	"	1.057	6.2	0.0148
7.7	0.0179	8.0		1.249	"	"	8.1	0.0189
10.2	0.0232	8.2		1.248	"	"	10.8	0.0245
12.8	0.0288	8.5		1.247	"	"	13.5	0.0305
15.4	0.0337	9.0		1.244	0.0000176	1.041	16.1	0.0351
18.1	0.0379	9.5		1.242	"	1.039	18.8	0.0394
21.3	0.0438	10.0		1.240	"	1.036	22.1	0.0454
25.2	0.0505	10.5		1.238	"	"	26.1	0.0523
28.0	0.0553	11.0		1.235	0.0000177	1.023	28.7	0.0566
29.2	0.0588	11.5		1.233	"	1.020	29.8	0.0600
35.3	0.0670	13.0		1.226	0.0000178	1.002	35.4	0.0672
32.7	0.0626	13.5		1.224	"	1.000	32.7	0.0626
6.25	0.0144	7.0	752.6	1.247	0.0000175	1.054	6.6	0.0106
7.6	0.0175	"		"	"	"	8.0	0.0132
9.5	0.0216	7.2		1.246	"	"	10.0	0.0167
11.9	0.0268	"		"	"	"	12.1	0.0200
14.7	0.0319	7.5		1.245	"	"	15.5	0.0250
17.3	0.0368	7.7		1.244	"	"	18.3	0.0294
19.9	0.0416	8.0		1.242	"	1.051	20.9	0.0331
23.0	0.0471	8.2		1.241	"	1.048	24.1	0.0373
24.3	0.0496	10.0		1.233	0.0000176	1.031	25.0	0.0387
27.2	0.0548	10.3		1.232	"	1.028	28.0	0.0428
28.8	0.0574	10.5		1.231	"	"	29.6	0.0450
38.8	0.0748	"		"	"	"	39.9	0.0590
35.9	0.0708	11.0		1.229	0.0000177	1.018	36.6	0.0545
32.8	0.0644	11.5		1.226	"	1.015	33.3	0.0500
6.34	0.0138	5.0		1.260	0.0000174	1.076	6.8	0.0110
7.7	0.0177	5.4		1.258	"	1.075	8.3	0.0137
9.6	0.0215	5.7		1.256	"	"	10.3	0.0172
11.6	0.0265	6.0		1.255	"	1.072	12.4	0.0204

*The Resistance of the Airship Models.*Table VI.—*Continued.*

Dynamic pressure, mm. water.	Total resistance, kg. weight	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Density of air, half-satu- rated, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coeffi- cient <i>K</i>	Reduction to standard condition of air. (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Total resistance, kg. weight
13.5	0.0297	6.3		1.253	0.0000174	1.072	14.5	0.0235
15.5	0.0342	6.5		"	"	"	16.6	0.0268
18.2	0.0391	7.0		1.250	0.0000175	1.059	19.3	0.0307
21.1	0.0440	7.5		1.248	"	1.056	22.3	0.0350
23.8	0.0485	8.0		1.246	"	1.054	25.1	0.0389
26.1	0.0531	8.3		1.244	"	"	27.5	0.0421
28.5	0.0564	8.7		1.242	"	1.050	29.9	0.0454
37.4	0.0744	10.0		1.236	0.0000176	1.033	38.7	0.0574
35.1	0.0692	10.5		1.234	"	1.031	36.2	0.0540
32.6	0.0636	10.8		1.232	"	"	33.6	0.0504

Table VII.—Wire Resistance. *Long Model.*

The Technical Department of Board of Military Air Service.

Dynamic pressure, mm. water.	Wire resistance, kg. weight	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Density of air, half-satu- rated, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coeffi- cient <i>K</i>	Reduction to standard condition of air. (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Wire resistance, kg. weight
6.16	0.0093	6.5		1.248	0.0000174	1.066	6.6	0.0099
7.5	0.0120	6.8		1.246	"	1.064	8.0	0.0128
9.1	0.0153	7.2		1.244	0.0000175	1.054	9.6	0.0161
11.5	0.0190	7.5		1.243	"	1.051	12.1	0.0200
15.4	0.0248	8.0		1.241	"	"	16.2	0.0261
17.5	0.0282	8.5		1.238	"	1.049	18.4	0.0296
20.5	0.0321	9.0		1.236	0.0000176	1.033	21.2	0.0332
23.0	0.0363	9.5		1.234	"	1.031	23.7	0.0375
25.9	0.0398	10.0		1.231	"	1.028	26.7	0.0410
28.7	0.0442	10.5		1.229	"	"	29.5	0.0455
30.9	0.0468	11.0		1.227	0.0000177	1.015	31.4	0.0475
37.4	0.0563	12.0		1.222	"	1.010	37.8	0.0569
35.3	0.0526	12.5		1.220	"	"	35.7	0.0532
32.2	0.0484	13.0		1.218	0.0000178	1.007	32.5	0.0488

Table VIII.—Wire Resistance. Short Model.
The Technical Department of Board of Military Air Service.

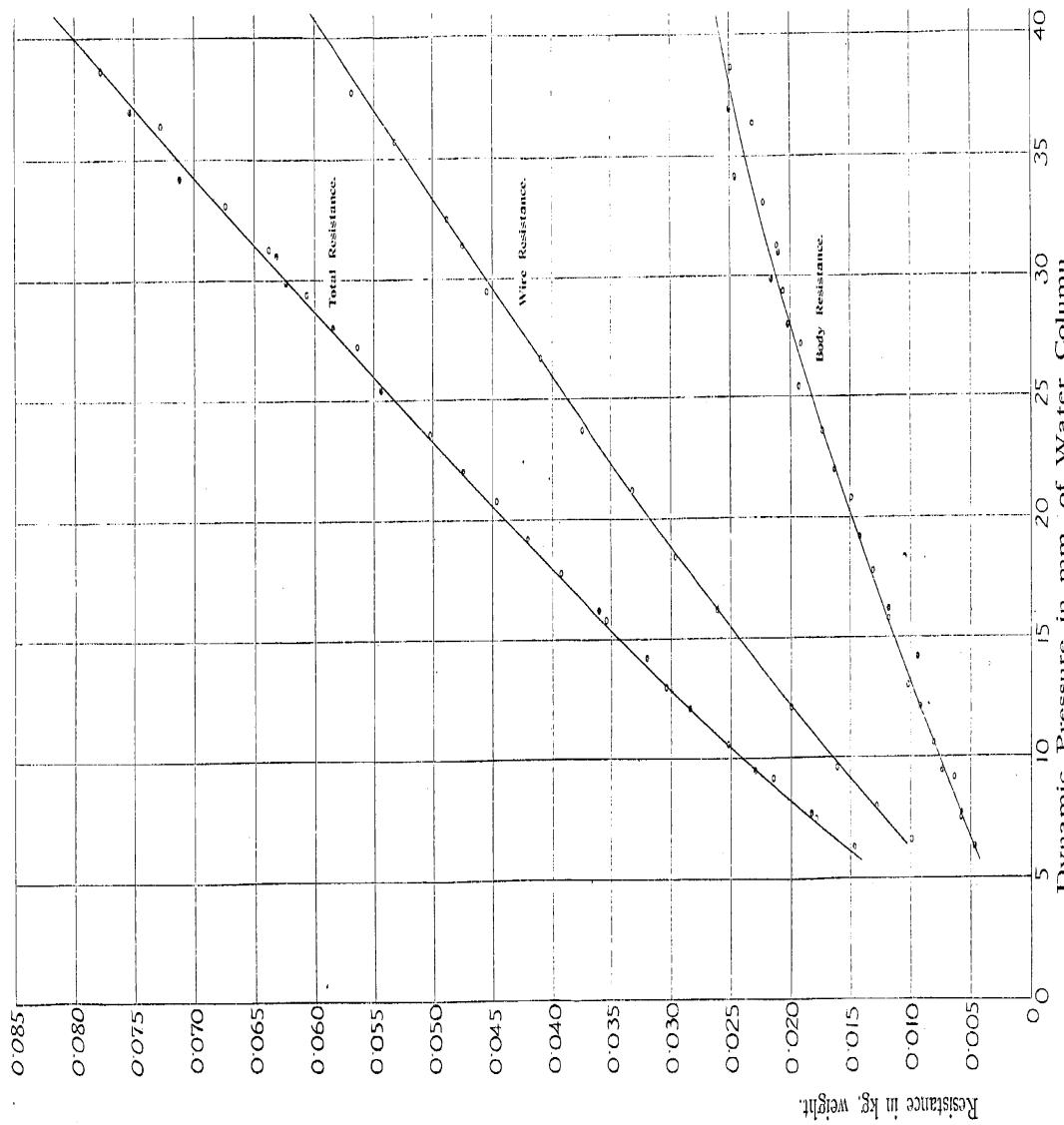
Dynamic pressure, mm. water.	Wire resistance, kg. weight.	Atmos- pheric tem- perature, °C.	Atmos- pheric pressure, mm. Hg.	Density of air, half sat- urated, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coeffi- cient <i>K</i>	Reduction to standard condition of air. (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Wire resistance, kg. weight.
5.9	0.0099	2.5	1.271	0.0000172	1.110	6.6	0.0110	
7.1	0.0119	"	"	"	"	7.9	0.0132	
8.9	0.0147	2.8	1.270	"	"	9.9	0.0163	
11.5	0.0189	3.0	1.269	0.0000173	1.098	12.6	0.0208	
13.9	0.0225	3.5	1.267	"	1.095	15.2	0.0246	
16.5	0.0265	4.0	1.264	"	1.093	18.1	0.0290	
19.4	0.0308	4.5	1.262	"	1.090	21.2	0.0336	
22.3	0.0350	5.0	1.260	0.0000174	1.076	24.0	0.0377	
25.4	0.0389	5.5	1.257	"	1.074	27.3	0.0418	
28.5	0.0433	6.0	1.255	"	1.071	30.5	0.0464	
30.5	0.0461	6.5	1.253	"	1.069	32.6	0.0493	
42.4	0.0614	8.5	1.243	0.0000175	1.051	44.6	0.0646	
39.2	0.0566	10.0	1.236	0.0000176	1.033	40.5	0.0585	
35.3	0.0521	10.5	1.234	"	1.031	36.4	0.0538	
32.0	0.0489	10.8	1.233	"	"	33.0	0.0495	
<hr/>								
5.73	0.0087	5.0	1.261	0.0000174	1.076	6.2	0.0096	
6.94	0.0114	5.4	1.259	"	1.075	7.5	0.0123	
8.7	0.0146	5.7	1.258	"	"	9.4	0.0157	
11.4	0.0185	6.0	1.257	"	"	12.3	0.0199	
13.6	0.0222	6.3	1.255	"	1.072	14.6	0.0238	
15.8	0.0258	6.6	1.254	"	"	16.9	0.0277	
18.2	0.0290	7.0	1.252	0.0000175	1.059	19.3	0.0307	
21.5	0.0338	7.4	1.250	"	"	22.8	0.0358	
24.1	0.0370	8.0	1.247	"	1.056	25.4	0.0390	
26.9	0.0410	8.5	1.245	"	1.054	28.4	0.0432	
29.2	0.0441	9.0	1.243	0.0000176	1.038	30.3	0.0458	
36.2	0.0539	9.5	1.240	"	1.035	37.5	0.0558	
34.4	0.0508	10.0	1.238	"	1.033	35.5	0.0526	
31.5	0.0466	10.5	1.236	"	"	32.6	0.0481	

Table IX.—Resistance and Resistance Coefficient reduced to
the Standard Condition of Air. (Atmospheric temperature 15°C.
(Atmospheric pressure 760 mm. Hg.)

Long Model.

The Technical Department of Board of Military Air Service.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Wire resistance, kg. weight.	Difference of total resistance and wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient.	Reynolds' number.
7.5	0.0179	0.0122	0.0057	0.0001	0.0058	0.0251	1.31 × 10 ⁵
9.2	0.0215	0.0153	0.0062	0.0002	0.0064	0.0231	1.46 "
10.6	0.0252	0.0176	0.0076	0.0005	0.0081	0.0253	1.56 "
13.0	0.0304	0.0214	0.0090	0.0012	0.0102	0.0258	1.72 "
15.8	0.0354	0.0255	0.0099	0.0019	0.0118	0.0247	1.92 "
17.8	0.0393	0.0286	0.0107	0.0024	0.0131	0.0244	2.02 "
20.8	0.0447	0.0330	0.0117	0.0032	0.0149	0.0236	2.19 "
23.6	0.0503	0.0368	0.0135	0.0038	0.0173	0.0242	2.33 "
27.2	0.0564	0.0417	0.0147	0.0044	0.0191	0.0231	2.49 "
29.4	0.0607	0.0447	0.0160	0.0046	0.0206	"	2.59 "
31.3	0.0638	0.0473	0.0165	"	0.0211	0.0222	2.68 "
28.7	0.0778	0.0574	0.0204	0.0045	0.0249	0.0212	2.98 "
36.4	0.0728	0.0542	0.0186	"	0.0231	0.0210	2.89 "
33.1	0.0674	0.0497	0.0177	"	0.0222	0.0222	2.77 "
6.3	0.0147	0.0100	0.0047	0	0.0047	0.0246	1.20 × 10 ⁵
7.7	0.0183	0.0126	0.0057	0.0001	0.0058	0.0244	1.32 "
9.5	0.0230	0.0158	0.0072	0.0002	0.0074	0.0258	1.48 "
12.1	0.0284	0.0200	0.0084	0.0008	0.0092	0.0251	1.67 "
14.2	0.0320	0.0241	0.0079	0.0015	0.0094	0.0217	1.81 "
16.2	0.0360	0.0262	0.0098	0.0020	0.0118	0.0240	1.93 "
19.2	0.0421	0.0306	0.0115	0.0027	0.0142	0.0245	2.09 "
22.0	0.0475	0.0346	0.0129	0.0034	0.0163	"	2.25 "
25.4	0.0544	0.0392	0.0152	0.0041	0.0193	0.0250	2.42 "
28.0	0.0585	0.0428	0.0157	0.0045	0.0202	0.0238	2.54 "
29.9	0.0624	0.0454	0.0170	0.0046	0.0216	0.0239	2.61 "
37.0	0.0754	0.0550	0.0204	"	0.0250	0.0233	2.91 "
34.2	0.0712	0.0512	0.0200	"	0.0246	0.0239	2.80 "
31.0	0.0632	0.0468	0.0164	"	0.0210	0.0224	2.66 "



Resistance in kg. weight.
Dynamic Pressure in mm. of Water Column.
Fig. 11. Total, Wire and Body Resistances of the Long Model.
The Technical Department of Board of Military Air Service.

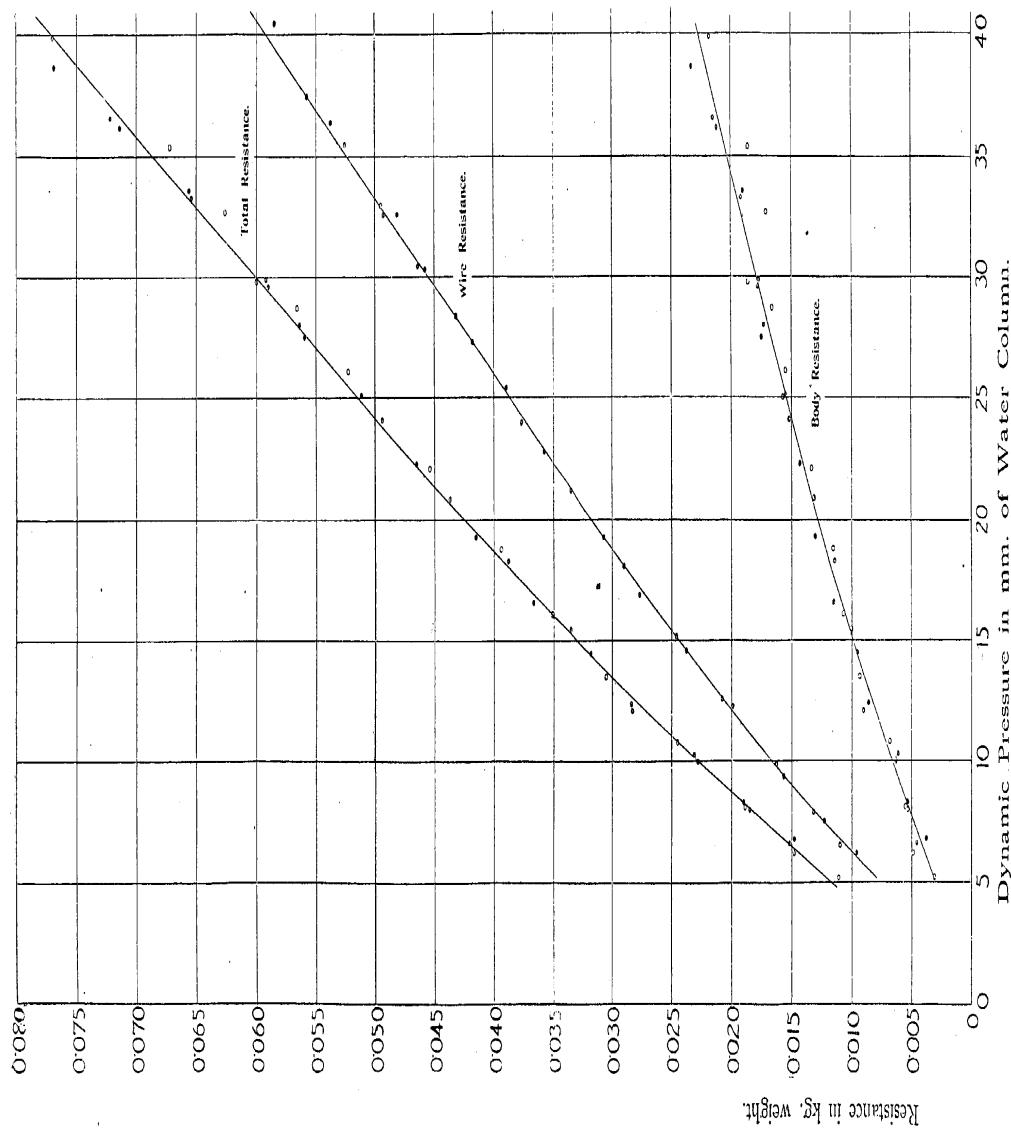


Fig. 12. Total, Wire and Body Resistances of the Short Model.
The Technical Department of Board of Military Air Service.

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Table X.—Resistance and Resistance Coefficient reduced to
the Standard Condition of Air. (Atmospheric temperature 15°C.
Atmospheric pressure 760 mm. Hg.)
Short Model.

The Technical Department of Board of Military Air Service.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Wire resistance, kg. weight.	Difference of total resistance and wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient.	Reynolds' number.
5.2	0.0111	0.0080	0.0031	0	0.0031	0.0243	0.99 × 10 ⁵
6.2	0.0148	0.0099	0.0049	„	0.0049	0.0321	1.08 „
8.1	0.0189	0.0134	0.0055	„	0.0055	0.0276	1.24 „
10.8	0.0245	0.0180	0.0065	0.0003	0.0068	0.0254	1.43 „
13.5	0.0305	0.0221	0.0084	0.0009	0.0093	0.0281	1.59 „
16.1	0.0351	0.0260	0.0091	0.0016	0.0107	0.0269	1.74 „
18.8	0.0394	0.0300	0.0094	0.0021	0.0115	0.0248	1.87 „
22.1	0.0454	0.0348	0.0106	0.0027	0.0133	0.0246	2.04 „
26.1	0.0523	0.0402	0.0121	0.0034	0.0155	0.0241	2.20 „
28.7	0.0566	0.0437	0.0129	0.0037	0.0166	0.0235	2.32 „
29.8	0.0600	0.0452	0.0148	0.0038	0.0186	0.0253	2.37 „
35.4	0.0672	0.0529	0.0143	0.0037	0.0180	0.0208	2.58 „
32.7	0.0626	0.0492	0.0134	„	0.0171	0.0213	2.48 „
6.6	0.0152	0.0106	0.0046	0	0.0046	0.0284	1.12 × 10 ⁵
8.0	0.0185	0.0132	0.0053	„	0.0053	0.0269	1.22 „
10.0	0.0228	0.0167	0.0061	0.0002	0.0063	0.0252	1.37 „
12.1	0.0283	0.0200	0.0083	0.0007	0.0090	0.0301	1.52 „
15.5	0.0336	0.0250	0.0086	0.0014	0.0100	0.0261	1.70 „
18.3	0.0388	0.0294	0.0094	0.0020	0.0114	0.0253	1.85 „
20.9	0.0437	0.0331	0.0106	0.0025	0.0131	0.0255	1.98 „
24.1	0.0494	0.0373	0.0121	0.0031	0.0152	0.0256	2.13 „
25.0	0.0512	0.0387	0.0125	0.0032	0.0157	0.0255	2.15 „
28.0	0.0564	0.0428	0.0136	0.0037	0.0173	0.0250	2.29 „
29.6	0.0590	0.0450	0.0140	0.0038	0.0178	0.0244	2.35 „
39.9	0.0770	0.0590	0.0180	„	0.0218	0.0222	2.73 „
36.6	0.0722	0.0545	0.0177	„	0.0215	0.0239	2.61 „
33.3	0.0654	0.0500	0.0154	„	0.0192	0.0235	2.50 „
6.8	0.0148	0.0110	0.0038	0	0.0038	0.0227	1.13 × 10 ⁵
8.3	0.0190	0.0137	0.0053	„	0.0053	0.0259	1.26 „

*The Resistance of the Airship Models.*Table X.—*Continued.*

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Wire resistance, kg. weight.	Difference of total resistance and wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient.	Reynolds' number.
10.3	0.0231	0.0172	0.0059	0.0002	0.0061	0.0237	1.38×10^5
12.4	0.0284	0.0204	0.0080	0.0006	0.0086	0.0283	1.52 "
14.5	0.0318	0.0235	0.0083	0.0012	0.0095	0.0265	1.65 "
16.6	0.0367	0.0268	0.0099	0.0016	0.0115	0.0282	1.76 "
19.3	0.0415	0.0307	0.0108	0.0022	0.0130	0.0273	1.90 "
22.3	0.0465	0.0350	0.0115	0.0028	0.0143	0.0260	2.04 "
25.1	0.0512	0.0389	0.0123	0.0032	0.0155	0.0251	2.18 "
27.5	0.0560	0.0421	0.0139	0.0036	0.0175	0.0258	2.26 "
29.9	0.0592	0.0454	0.0138	0.0039	0.0177	0.0240	2.35 "
38.7	0.0769	0.0574	0.0195	0.0038	0.0233	0.0245	2.70 "
36.2	0.0714	0.0540	0.0174	"	0.0212	0.0239	2.59 "
33.6	0.0656	0.0504	0.0152	"	0.0195	0.0222	2.50 "

Table XI.—Horizontal Buoyancy.

The Technical Department of Board of Military Air Service

Dynamic pressure, at No. 25. mm. water.	Horizontal buoyancy, kg. weight.	
	Long model.	Short model.
8.0	1000.0	0
10.0	0.0004	0.0002
12.0	0.0006	0.0007
14.0	0.0009	0.0012
16.0	0.0020	0.0016
18.0	0.0025	0.0020
20.0	0.0030	0.0024
22.0	0.0034	0.0023
24.0	0.0039	0.0031
26.0	0.0042	0.0034
28.8	0.0046	0.0037

II. Technical Department of Board of Military Air Service. 25

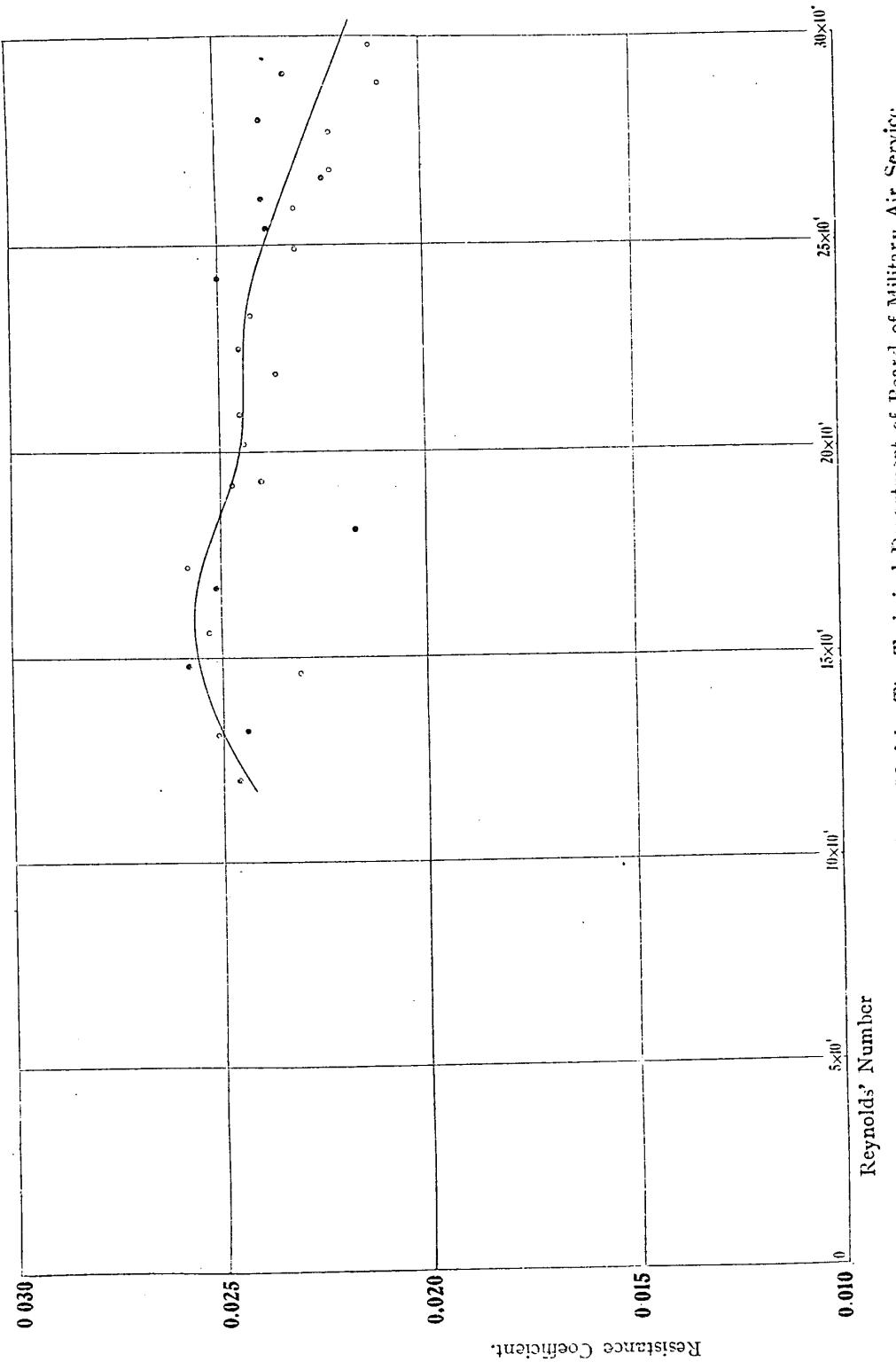


Fig. 2.—Resistance Coefficient of the Long Model. The Technical Department of Board of Military Air Service.

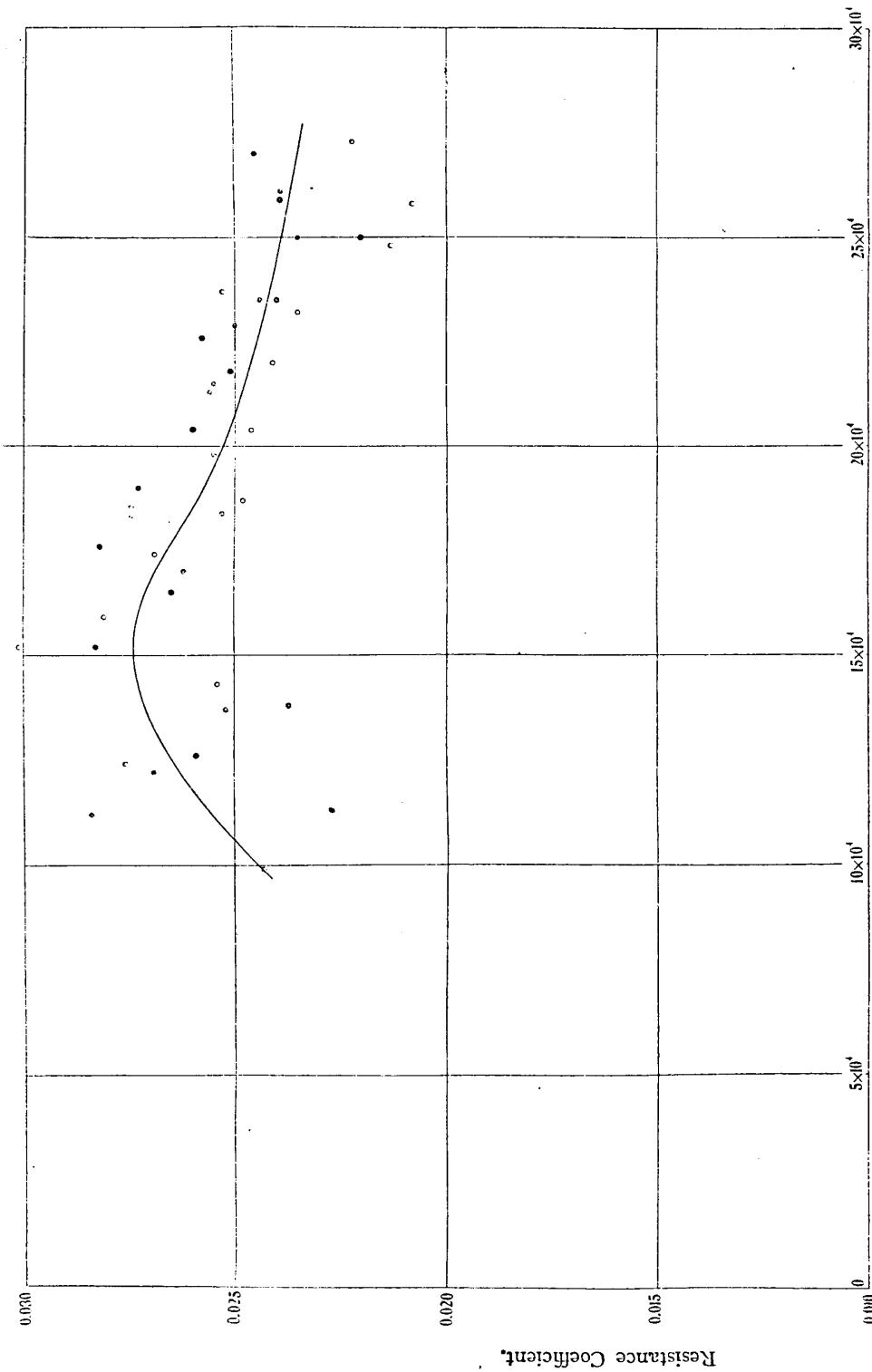


Fig. 14.—Resistance Coefficient of the Short Model. The Technical Department of Board of Military Air Service.
Reynolds' Number.

CHAPTER III.

MEASUREMENTS AT THE WIND TUNNEL OF THE AERONAUTICAL RESEARCH INSTITUTE OF TÔKYÔ IMPERIAL UNIVERSITY.

1. *Description of the Wind Tunnel and the Aerodynamic Balance.*

The wind tunnel of the institute, which was expeditiously built to meet the emergency after the great Earthquake, is of the Göttingen type. It consists of the nozzle, the diffuser and the return duct. At the right angle bents it is provided with wind deflectors to make the wind uniform. An equalizer of honeycomb type is placed at the entrance to the nozzle where the section of the tunnel is maximum. To minimize the disturbance due to the existence of the equalizer itself, it is made of wooden planks of stream line section, which are arranged in two sets, vertical and horizontal, one directly behind the other.

The tunnel is made entirely of wood excepting the wind deflectors which are of tin plate. Its general outline and dimensions are shown in Fig. 3 and Table XII respectively.

Table XII.—Dimensions of the Wind Tunnel.

The Aeronaut. Research Inst., Tôkyô Imperial University.

Diameter of nozzle	1.20 m.
Diameter of diffuser	1.30 m.
Diameter of fan	1.82 m.
Ratio of contraction of area at nozzle	6.93
Total length of tunnel	16.56 m.
Power of motor	20 H. P.

The fan is directly coupled to the motor shaft. It is made of wood and two bladed.

The general principle of the weighing system of resistance is illustrated in Fig. 15. As fulcra pointed cones are used instead of knife edges to facilitate its alignment.

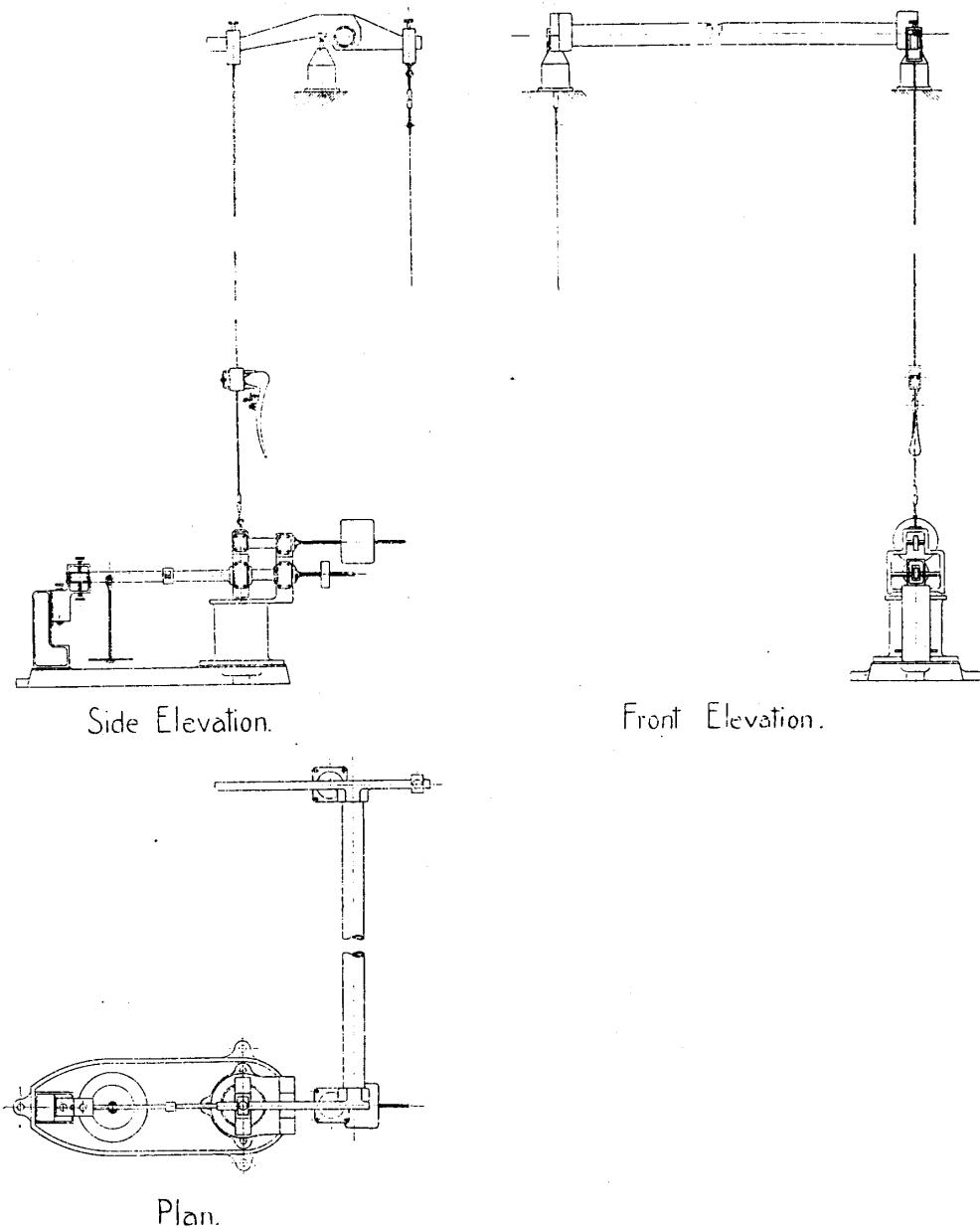


Fig. 15. Drag Balance for the Wind Tunnel of the Aeronaut. Research Inst.,
Tôkyô Imperial University.

The balance gives a direct reading of the amount of the resistance. A division of the weighing lever of the balance corresponds to one gramme, so that one-tenth of a gramme can easily be estimated.

2. Characteristics of the Wind Tunnel.

a) Distribution of Air Velocity.

The dynamic pressure was determined by a portable Pitot-static tube of Prof. Prandtl's type at each of the 27 positions, which are shown in Fig. 8, for the same indication of the fixed standard Pitot-static tube, which was of the same type. The results are given in Table XIII. There the differences between the dynamic pressure q at each measured point and that of the standard Pitot-static tube q_0 are given in percentage of the latter indication.

Table XIII.—Velocity Distribution.

The Aeronautical Research Institute, Tôkyô Imperial University.

Position number.	$\frac{q - q_0}{q_0} \times 100$		Position number.	$\frac{q - q_0}{q_0} \times 100$		Position number.	$\frac{q - q_0}{q_0} \times 100$	
	$q_0 = 7.8$ mm. water.	$q_0 = 13.5$ mm. water.		$q_0 = 7.8$ mm. water.	$q_0 = 13.5$ mm. water.		$q_0 = 7.8$ mm. water.	$q_0 = 13.5$ mm. water.
11	+1.5	+1.8	21	+1.1	+2.0	31	-0.2	+0.8
12	+0.9	+0.9	22	+0.6	+1.6	32	-0.1	+1.3
13	"	"	23	"	+1.1	33	-0.5	-0.5
14	+0.4	+1.9	24	+0.4	+1.2	34	-0.2	+0.8
15	+0.8	+1.0	25	-0.3	+1.6	35	"	+0.7
16	"	+1.5	26	+0.4	+1.0	36	"	+0.2
17	+0.2	+1.2	27	+1.1	"	37	+0.3	"
18	+1.1	"	28	"	+1.1	38	"	0
19	+0.2	"	29	+0.6	"	39	"	-0.1

b) Direction of Air Flow.

The general direction of the air flow was determined from the direction of a fine flexible silk fibre placed at the position No. 25 of the wind tunnel. Any possible error due to the slight weight of the fibre could be detected by varying the velocity of the air, presuming that the change of the air velocity does not much affect the direction of the general flow of air, at least, near the center line of the wind tunnel. This general direction of flow being taken for the axis of

reference, the relative deviation from it of the direction of air flow was determined at the 27 points, shown in Fig. 8, with Prof. Tamaru's yawmeter. The results are given in Table XIV, where the angle of deviation from the vertical and the horizontal plane parallel to the axis are given in degrees. The deviation downward from the horizontal plane and that towards the right from the vertical plane facing the wind are taken positive.

Table XIV.—Direction of Air Flow.

The Aeronautical Research Institute, Tôkyô Imperial University.

Position number.	Deviation angle in degrees		Position number.	Deviation angle in degrees		Position number.	Deviation angle in degrees	
	from horizontal plane.	from vertical plane.		from horizontal plane.	from vertical plane.		from horizontal plane.	from vertical plane.
11	-0.18	+0.41	21	-0.09	+0.41	31	+0.04	+0.16
12	-0.08	+0.15	22	-0.33	+0.44	32	-0.48	-0.16
13	-0.81	-0.08	23	-0.34	-0.17	33	-0.11	+0.25
14	-0.05	+0.07	24	-0.06	0	34	+0.09	-0.17
15	+0.20	+0.08	25	0	0	35	-0.15	-0.06
16	+0.46	-0.03	26	+0.35	-0.03	36	+0.45	-0.24
17	-0.58	+0.01	27	-0.48	0	37	-0.54	-0.38
18	-0.38	-0.16	28	-0.34	-0.11	38	-0.40	-0.35
19	+0.01	-0.24	29	-0.37	-0.33	39	-1.09	-0.59

The dynamic pressure of the standard Pitot-static tube = 18 mm. water column.

c) Gradient of Static Pressure and Horizontal Buoyancy.

The gradient of static pressure which existed along the axis of the wind tunnel was removed to some extent by adjusting the angle of the nozzle, but it is difficult to make it entirely vanish. So the difference of the static pressure indication p_s of the static opening of the portable Pitot-static tube of Prof. Prandtl's type and that of the standard Pitot-static tube p_{ss} was measured at ten points along the axis of the wind tunnel for seven different air velocities.

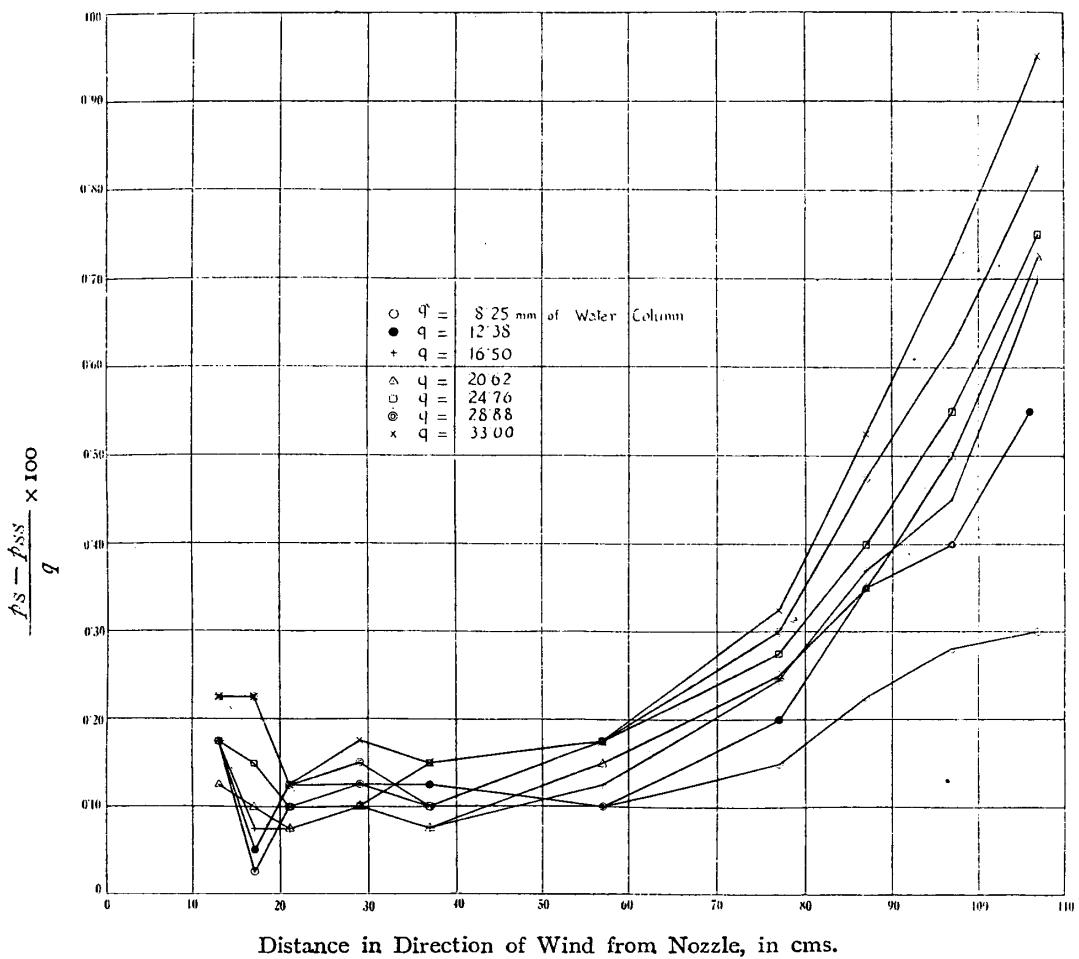


Fig. 16.—Distribution of Specific Static Pressure Difference.
The Aeronautical Research Institute, Tôkyô Imperial University.

The results are given in Table XV and Fig. 16, where the ratio of the said difference to the dynamic pressure of the standard Pitot-static tube is given. This ratio $\frac{p_s - p_{ss}}{q}$ shall be called in the following "specific static pressure difference."

To deduce the amount of the correction for horizontal buoyancy we assume that the effect due to the gradient of the static pressure is not affected by the existence of the model. Then if we denote by B the amount of the horizontal buoyancy, we have

$$B = 2\pi \int p_s r \cos \theta ds, \quad (1)$$

where r is the radius of any section of the model perpendicular to its axis, θ the angle between the inward normal to the surface and the axis of the model taken positive in the direction of the wind and ds an element of the generating curve of the model. The integration is to be taken along the generating curve from the vertex to the tip of the tail of the model.

Table XV.—Specific Static Pressure $\left(\frac{p_s - p_{ss}}{q} \right)$ along Air Current.

The Aeronautical Research Institute, Tôkyô Imperial University.

Distance from the nozzle, cm.	Dynamic pressure, mm. water.						
	0.83	1.24	1.65	2.06	2.48	2.89	3.30
13	1.75	1.17	0.88	0.50	0.58	0.64	0.56
17	0.25	0.33	0.38	0.40	0.50	"	"
21	1.00	0.83	"	0.30	0.33	0.36	0.31
29	1.25	"	0.50	0.40	"	0.43	0.44
37	1.00	"	0.38	0.30	0.50	0.29	0.38
57	1.90	0.68	0.63	0.60	0.58	0.50	0.44
77	1.55	1.33	1.23	1.00	0.92	0.86	0.81
87	2.25	2.34	1.85	1.40	1.33	1.36	1.31
97	2.80	2.60	2.25	2.00	1.83	1.79	1.81
107	3.00	3.66	3.55	2.90	2.50	2.36	2.38

We can write also by integration by parts

$$B = -\pi \int_0^l \frac{dp_s}{dx} r^2 dx, \quad (2)$$

where x denotes the length along the axis from the vertex and l the total length of the model. Thus we see that so far as the horizontal

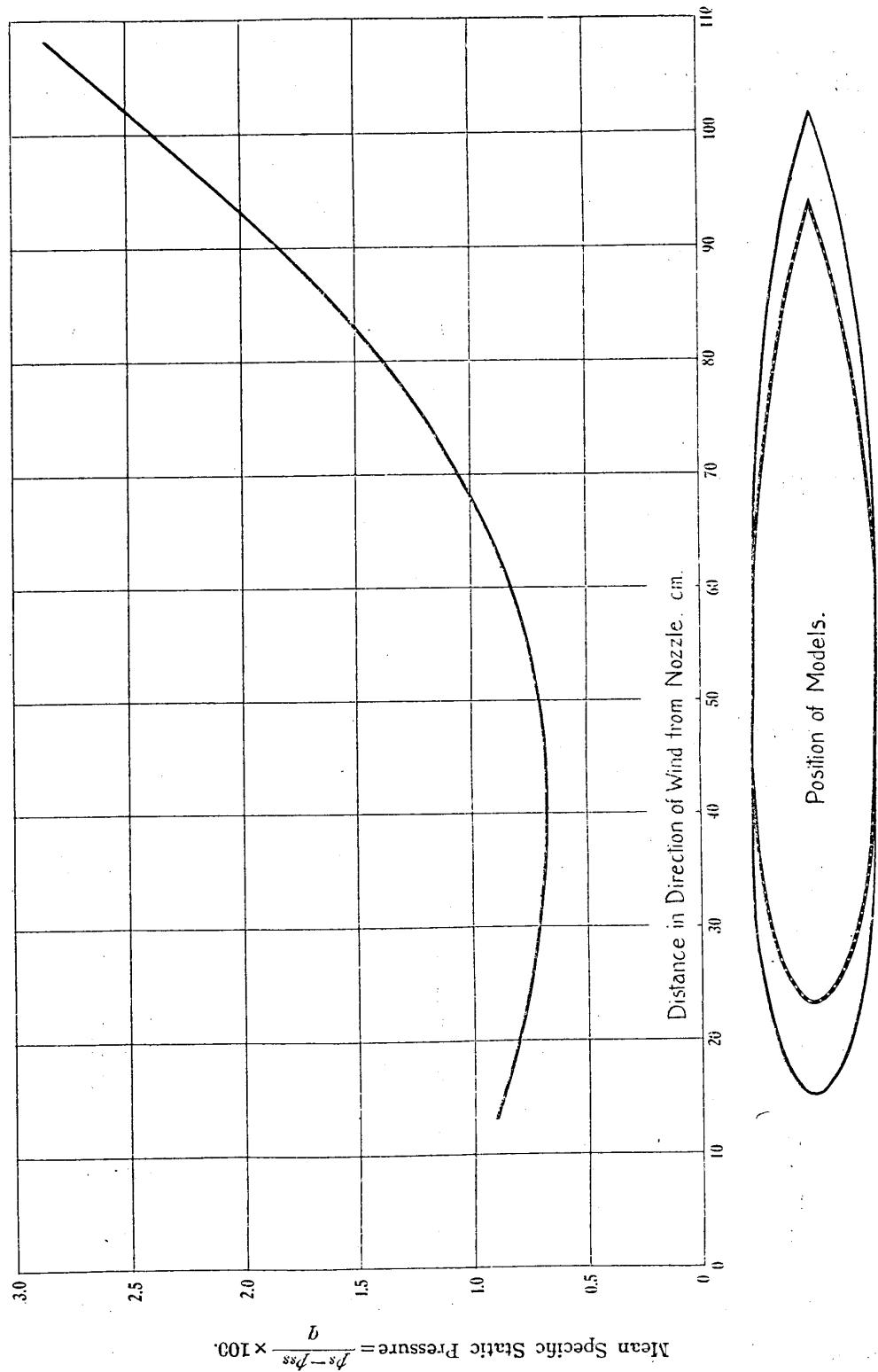


Fig. 17.—Distribution of Mean Specific Static Pressure. The Aeronautical Research Institute, Tôkôyo Imperial University.

buoyancy is concerned the gradient of the static pressure along the axis of the model only is of importance. As can be seen from the results of the measurements (Fig. 16), curves of the specific static pressure difference for different values of standard dynamic pressure can be made to coincide by a parallel shifting along the ordinate. This would mean that

$$\frac{d}{dx} \left(\frac{p_s - p_{ss}}{q} \right) = \frac{1}{q} \frac{dp_s}{dx} = G \quad (3)$$

is independent of q . The value of this quantity G was determined for each x , from the mean curve of specific static pressure distribution (Fig. 17) with the result given in Table XVI. With the known value of G , the magnitude of B can be obtained thus :—

$$B = -\pi q \int_0^l Gr^2 dx.$$

The integration was performed mechanically.

Table XVI.—Gradient of Mean Specific Static Pressure G .
The Aeronaut. Research Inst., Tôkyô Imperial University.

Distance from the nozzle, cm.	Gradient of mean specific static pressure per cm.	Distance from the nozzle, cm.	Gradient of mean specific static pressure per cm.
0	-0.000152	50	+0.000189
5	-0.000124	55	+0.000244
10	-0.000104	60	+0.000300
15	-0.000079	65	+0.000366
20	-0.000056	70	+0.000438
25	-0.000038	75	+0.000486
30	+0.000019	80	+0.000531
35	+0.000060	85	+0.000559
40	+0.000096	90	+0.000588
45	+0.000145	95	+0.000608

The actual amount of the horizontal buoyancy necessary for the correction is quite small as can be seen from Tables XXI and XXII.

3. *Measurement of Resistance.*

The model was suspended as described in Art. 5, Chapter I, with its axis in coincidence with the axis of reference of the wind tunnel. Special care was taken in fixing wire to the model so as to minimize the disturbance. It was effected by simply passing the wire through the hole of the lug and making a knot inside. The readings of resistance were taken for some twenty different values of the dynamic pressure, as indicated by the standard Pitot-static tube, ranging from 1.68 to 33.6 mm. water column. Fluctuation of the wind velocity during the experiment was kept as small as possible by adjusting a fine rheostat. The readings of the balance were taken when the velocity of the air had been constant for some time which was signalled with an electric bell. This was done at least twice for each measurement. Readings were taken with the air velocity in increasing as well as decreasing steps, to ascertain the difference if any. The effect of the tension weight was also examined by varying its amount. These effects were all quite within the experimental error.

The results are given in Tables XVII, XVIII and in Figs. 18, 19.

Table XVII.—Total Resistance. *Long Model.*
The Aeronautical Research Inst., Tôkyô Imperial University.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmos- pheric tem- pera- ture, °C.	Atmos- pheric pres- sure, mm. Hg.	Density of air, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coeffi- cient <i>K</i>	Reduction to standad condition of air, (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Total resistance, kg. weight.
1.68	0.0033						1.76	0.0035
2.52	0.0046						2.64	0.0048
3.37	0.0058	Mean 10°	Mean 760.7	1.248	0.00001760	1.048	3.53	0.0061
4.21	0.0068						4.41	0.0071
5.05	0.0084						5.29	0.0088
6.73	0.0111						7.05	0.0116

Table XVII.—Continued.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Density of air, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coefficient K	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Total resistance, kg. weight
8.41	0.0137				0.971/0000.0	1.048	8.81	0.0144
10.09	0.0164						10.57	0.0172
11.77	0.0189						12.34	0.0198
13.45	0.0210						14.09	0.0220
15.14	0.0239						15.86	0.0250
16.81	0.0265						17.61	0.0278
18.50	0.0293						19.38	0.0307
21.02	0.0331	Mean 10.0°	Mean 760.7	1.248	0.971/0000.0	1.048	22.02	0.0347
23.55	0.0371						24.68	0.0389
26.08	0.0415						27.32	0.0435
28.60	0.0453						29.98	0.0475
31.12	0.0488						32.61	0.0511
33.65	0.0527						35.26	0.0552
1.63	0.0030						1.75	0.0031
2.52	0.0044						2.63	0.0046
3.37	0.0059						3.50	0.0061
4.21	0.0072						4.38	0.0075
5.05	0.0087						5.26	0.0091
6.73	0.0112						7.01	0.0117
8.41	0.0140						8.76	0.0146
10.09	0.0163	Mean 10.6°	Mean 760.1	1.244	0.971/0000.0	1.048	10.50	0.0170
11.77	0.0190						12.25	0.0198
13.45	0.0215						14.00	0.0224
15.14	0.0237						15.75	0.0247
16.81	0.0265						17.50	0.0276
18.50	0.0289						19.25	0.0301
21.02	0.0328						21.90	0.0341
23.55	0.0371						24.50	0.0386
26.08	0.0406						27.15	0.0423
28.60	0.0456						29.77	0.0475
31.12	0.0489						32.40	0.0509
33.65	0.0526						35.02	0.0548

Table XVII.—Continued.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Density of air, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coefficient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Total resistance, kg. weight.
1.68	0.0027						1.74	0.0028
2.52	0.0039						2.60	0.0040
3.36	0.0058						3.47	0.0060
4.20	0.0069						4.34	0.0071
5.04	0.0084						5.20	0.0087
6.72	0.0114						6.94	0.0118
8.40	0.0140						8.68	0.0145
10.08	0.0166						10.41	0.0172
11.76	0.0193						12.15	0.0199
13.44	0.0219						13.88	0.0226
15.12	0.0239						15.61	0.0247
16.80	0.0265						17.35	0.0274
18.48	0.0289						19.08	0.0299
21.00	0.0326						21.69	0.0337
23.52	0.0370						24.30	0.0382
26.03	0.0405						26.89	0.0418
28.57	0.0451						29.50	0.0465
31.09	0.0486						32.10	0.0502
33.60	0.0523						34.70	0.0540

Table XVIII.—Total Resistance. Short Model.

The Aeronautical Research Inst., Tôkyô Imperial University.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Density of air, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coefficient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Total resistance, kg. weight.
1.68	0.0030	Mean 12.5°	Mean 765.6	1.245	0.0001772	1.031	1.73	0.0031
2.52	0.0043						2.60	0.0044
3.36	0.0055						3.46	0.0057
4.20	0.0067						4.33	0.0069

Table XVIII.—*Continued.*

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Density of air, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coefficient K	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Total resistance, kg. weight.
Mean 12.5°	5.04	0.0077	Mean 765.6	1.245	0.00001772	1.301	5.20	0.0079
	6.72	0.0103					6.93	0.0106
	8.40	0.0125					8.66	0.0129
	10.08	0.0144					10.39	0.0149
	11.76	0.0163					12.12	0.0173
	13.44	0.0193					13.85	0.0199
	15.12	0.0218					15.59	0.0225
	16.80	0.0243					17.32	0.0250
	26.03	0.0375					26.75	0.0387
	28.57	0.0410					29.44	0.0423
	31.09	0.0450					32.05	0.0464
	33.60	0.0475					34.64	0.0499
Mean 13.3°	1.68	0.0029	Mean 765.5	1.241	0.00001776	1.304	1.72	0.0030
	2.52	0.0041					2.58	0.0042
	3.36	0.0054					3.44	0.0055
	4.19	0.0065					4.29	0.0068
	6.71	0.0102					6.88	0.0105
	8.39	0.0127					8.60	0.0130
	10.06	0.0148					10.30	0.0152
	11.74	0.0172					12.02	0.0176
	13.41	0.0193					13.74	0.0198
	15.10	0.0216					15.46	0.0221
	16.77	0.0242					17.18	0.0248
	18.45	0.0264					18.90	0.0270
	20.97	0.0304					21.48	0.0311
	23.48	0.0339					24.05	0.0347
	26.00	0.0374					26.63	0.0383
	28.51	0.0414					29.21	0.0424
	31.02	0.0449					31.83	0.0460
	33.56	0.0479					34.38	0.0490

Table XVIII.—*Continued.*

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Density of air, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coefficient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Total resistance, kg. weight.
5.03	0.0077						5.11	0.0078
10.06	0.0149						10.22	0.0151
11.74	0.0168						11.92	0.0171
16.76	0.0243						17.04	0.0247
18.44	0.0263						18.74	0.0267
20.95	0.0304	Mean 14.1°	Mean 765.4	1.237	0.00001780	0.101	21.29	0.0309
23.47	0.0338						23.83	0.0343
25.99	0.0373						26.40	0.0379
28.50	0.0411						28.96	0.0418
31.10	0.0449						31.60	0.0456
33.52	0.0477						34.07	0.0485

The wire resistance was measured in exactly the same way as described in Art. 6, Chapter I. A few measurements were made for two different sizes of the holes on the wooden model for wire resistance measurement, to ascertain the effect of the size of the holes if any. But no perceptible difference was found.

The same number of measurements were taken as in the case of the total resistance. The velocities of the air were adjusted as near as possible to the values at which the total resistance were measured.

The results are given in Tables XIX, XX and in Figs. 18, 19.

4. *Resistance and Resistance Coefficient.*

The body resistance was deduced with the method described in Art. 7, Chapter I and corrected for the horizontal buoyancy as described in Art. 2. (c) of this chapter. They are given in Tables XXI, XXII and in Figs. 18, 19. Then the resistance coefficient, defined in Art. 7, Chapter I, was calculated in Tables XXI, XXII. The resistance coefficient as a function of Reynolds' number is shown in Fig. 20.

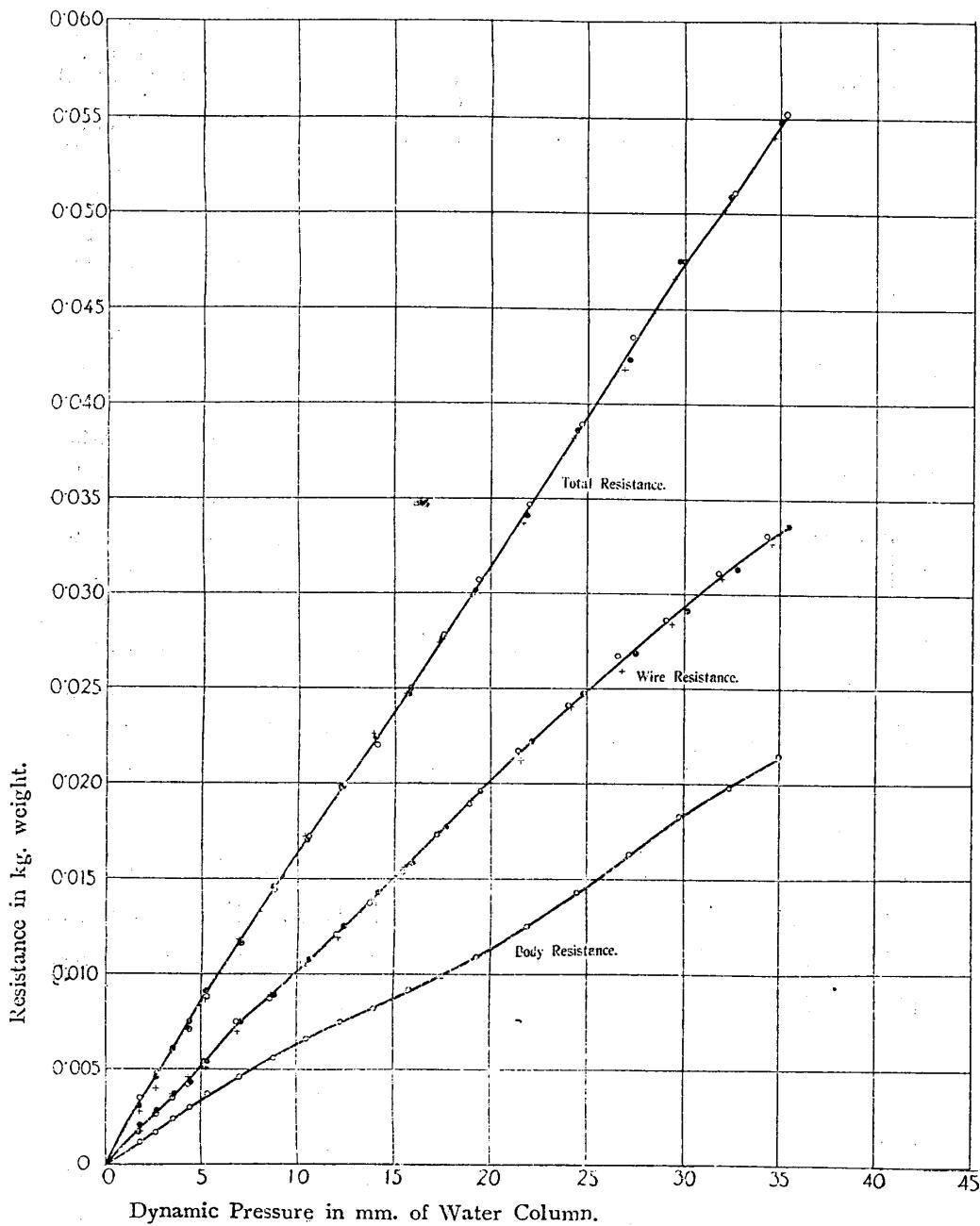


Fig 18.—Total, Wire and Body Resistances of the Long Model.

The Aeronautical Research Inst., Tôkyô Imperial University.

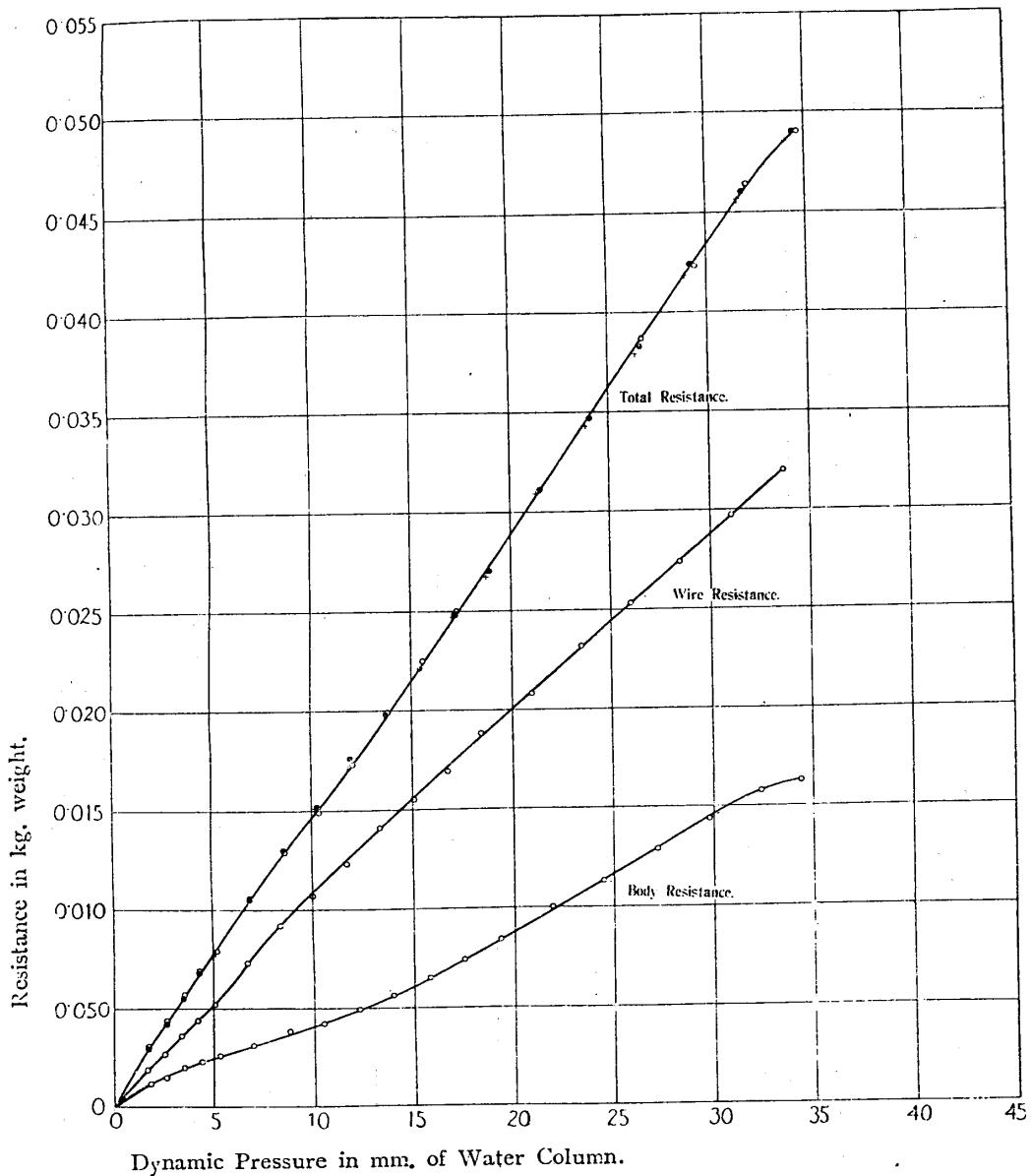


Fig. 19.—Total, Wire and Body Resistances of the Short Model.
The Aeronautical Research Inst., Tôkyô Imperial University.

*The Resistance of the Airship Models.*Table XIX.—Wire Resistance. *Long Model.*

The Aeronautical Research Inst., Tôkyô Imperial University.

Dynamic pressure, mm. water.	Wire resistance, kg. weight.	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Density of air, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coefficient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Wire resistance, kg. weight.
1.68	0.0017	Mean 12.5°	Mean 75.4°	1.227	0.00001767	1.022	1.72	0.0017
2.52	0.0026						2.58	0.0027
3.36	0.0034						3.43	0.0035
4.20	0.0041						4.29	0.0042
5.04	0.0053						5.15	0.0054
6.72	0.0073						6.87	0.0075
8.40	0.0085						8.58	0.0087
10.08	0.0104						10.30	0.0106
11.76	0.0118						12.02	0.0121
13.44	0.0134						13.73	0.0137
15.12	0.0150						15.45	0.0153
16.80	0.0169						17.17	0.0173
18.48	0.0185						18.88	0.0189
21.00	0.0212						21.46	0.0217
23.52	0.0236						24.05	0.0241
26.03	0.0261						26.60	0.0267
28.57	0.0280						29.20	0.0286
31.09	0.0304						31.78	0.0311
33.60	0.0324						34.33	0.0331
1.68	0.0020	Mean 97°	Mean 762.8	1.252	0.00001758	1.054	1.77	0.0021
2.52	0.0027						2.66	0.0029
3.37	0.0036						3.55	0.0038
4.21	0.0041						4.44	0.0043
5.05	0.0051						5.32	0.0054
6.73	0.0071						7.10	0.0075
8.41	0.0084						8.86	0.0089
10.09	0.0102						10.63	0.0108
11.77	0.0119						12.40	0.0125
13.45	0.0136						14.18	0.0143
15.14	0.0150						15.95	0.0158
16.81	0.0168						17.72	0.0177

Table XIX.—*Continued.*

Dynamic pressure, mm. water.	Wire resistance, kg. weight.	Atmos- pheric tempera- ture, °C.	Atmos- pheric pressure, mm. Hg.	Density of air, kg/m ³ .	Coefficient of viscosity of air, kg/m.s. (absolute)	Coeffi- cient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
							Dynamic pressure, mm. water.	Wire resistance, kg. weight.
18.50	0.0186	Mean 97°	Mean 762.8	1.252	0.00001758	1.054	19.49	0.0196
21.02	0.0211						22.15	0.0222
23.55	0.0234						24.82	0.0247
26.08	0.0254						27.49	0.0268
28.60	0.0276						30.13	0.0291
31.12	0.0297						32.80	0.0313
33.65	0.0319						35.47	0.0336
1.68	0.0017	Mean 123°	Mean 762.3	1.241	0.00001770	1.029	1.73	0.0018
2.52	0.0026						2.59	0.0027
3.36	0.0036						3.46	0.0037
4.20	0.0045						4.32	0.0046
5.04	0.0050						5.19	0.0051
6.72	0.0068						6.92	0.0070
8.40	0.0086						8.65	0.0089
10.08	0.0101						10.37	0.0104
11.76	0.0116						12.10	0.0119
13.44	0.0135						13.83	0.0139
15.12	0.0152						15.56	0.0156
16.80	0.0169						17.29	0.0174
18.48	0.0186						19.01	0.0191
21.00	0.0206						21.61	0.0212
23.52	0.0233						24.21	0.0240
26.03	0.0252						26.80	0.0259
28.57	0.0276						29.40	0.0284
31.09	0.0299						32.00	0.0308
33.60	0.0318						34.59	0.0327

Table XX.—Wire Resistance. *Short Model.*

The Aeronautical Research Inst., Tôkyô Imperial University.

Dynamic pressure, mm. water.	Wire resistance, temp. kg. weight. °C.	Atmospheric pressure, mm. Hg.	Density of air, kg/m³.	Coefficient of viscosity of air, kg/m.s. (absolute)	Coefficient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
						Dynamic pressure, mm. water.	Wire resistance, kg. weight.
1.67	0.0019					1.67	0.0019
2.51	0.0027					2.52	0.0027
3.35	0.0036					3.36	0.0036
4.18	0.0044					4.19	0.0044
5.02	0.0052					5.04	0.0052
6.69	0.0073					6.71	0.0073
8.37	0.0092					8.40	0.0092
10.04	0.0107					10.06	0.0107
11.71	0.0123					11.75	0.0123
13.38	0.0141					13.42	0.0141
15.06	0.0155					15.10	0.0155
16.73	0.0169					16.77	0.0169
18.41	0.0187					18.46	0.0188
20.91	0.0207					20.98	0.0208
23.42	0.0231					23.49	0.0232
25.92	0.0252					26.00	0.0253
28.45	0.0273					28.52	0.0274
30.96	0.0296					31.04	0.0297
33.48	0.0319					33.58	0.0320
Mean 16.2°		Mean 768.0		0.0000001789		1.002	

Table XXI.—Resistance and Resistance Coefficient reduced to
the Standard Condition of Air. (Atmospheric temperature 15°C.
Atmospheric pressure 760 mm. Hg.)

Long Model.

The Aeronautical Research Inst., Tôkyô Imperial University.

Dynamic pressure, mm. water	Total resistance, kg. weight	Wire resistance, kg. weight	Difference of total resistance and wire resistance, kg. weight	Horizontal buoyancy, kg. weight	Body resistance, kg. weight	Resistance coefficient.	Reynolds' number.
1.8	0.0031	0.0019	0.0012	0.0000	0.0012	0.0218	6.44 × 10 ⁴
2.6	0.0044	0.0027	0.0017	"	0.0017	0.0214	7.74 "
3.5	0.0060	0.0036	0.0024	"	0.0024	0.0224	8.99 "
4.4	0.0074	0.0044	0.0030	"	0.0030	0.0223	10.07 "
5.3	0.0090	0.0053	0.0037	"	0.0037	0.0228	11.05 "
7.0	0.0117	0.0071	0.0046	"	0.0046	0.0215	12.70 "
8.8	0.0146	0.0090	0.0056	0.0001	0.0057	0.0212	14.25 "
10.5	0.0172	0.0106	0.0066	"	0.0067	0.0209	15.56 "
12.3	0.0199	0.0124	0.0075	"	0.0076	0.0202	16.84 "
14.0	0.0223	0.0141	0.0082	"	0.0083	0.0194	17.96 "
15.8	0.0249	0.0157	0.0092	"	0.0093	0.0193	19.08 "
17.5	0.0275	0.0176	0.0109	"	0.0109	0.0187	20.08 "
19.3	0.0303	0.0194	0.0109	"	0.0110	0.0186	21.10 "
21.9	0.0344	0.0219	0.0125	"	0.0126	0.0188	22.47 "
24.5	0.0386	0.0243	0.0143	0.0002	0.0145	0.0193	23.76 "
27.2	0.0430	0.0267	0.0163	"	0.0165	0.0198	25.03 "
29.8	0.0472	0.0289	0.0183	"	0.0185	0.0203	26.21 "
32.4	0.0510	0.0312	0.0198	"	0.0200	0.0202	27.32 "
35.0	0.0548	0.0333	0.0215	"	0.0217	0.0203	28.39 "

Table XXII.—Resistance and Resistance Coefficient reduced to
the Standard Condition of Air. (^{Atmospheric temperature 15° C.}
^{Atmospheric pressure 760 mm. Hg.})

Short Model.

The Aeronautical Research Inst., Tôkyô Imperial University.

Dynamic pressure mm. water	Total resistance, kg. weight.	Wire resistance, kg. weight.	Difference of total resistance and wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient.	Reynolds' number
1.8	0.0032	0.0020	0.0012	0.0000	0.0012	0.0269	5.81 × 10 ⁴
2.6	0.0043	0.0028	0.0015	„	0.0015	0.0233	6.98 „
3.5	0.0057	0.0037	0.0020	„	0.0020	0.0231	8.11 „
4.4	0.0069	0.0046	0.0023	„	0.0023	0.0211	9.08 „
5.3	0.0082	0.0056	0.0026	„	0.0026	0.0198	9.95 „
7.0	0.0107	0.0076	0.0031	„	0.0031	0.0179	11.45 „
8.8	0.0132	0.0094	0.0038	0.0001	0.0039	0.0179	12.85 „
10.5	0.0154	0.0112	0.0042	„	0.0043	0.0165	14.03 „
12.3	0.0178	0.0129	0.0049	„	0.0050	0.0164	15.18 „
14.0	0.0201	0.0145	0.0056	„	0.0057	0.0164	16.19 „
15.8	0.0227	0.0162	0.0065	„	0.0066	0.0168	17.20 „
17.5	0.0251	0.0177	0.0074	„	0.0075	0.0173	18.10 „
19.3	0.0277	0.0193	0.0084	„	0.0085	0.0178	19.02 „
21.9	0.0316	0.0216	0.0100	„	0.0100	0.0186	20.25 „
24.5	0.0352	0.0239	0.0113	0.0002	0.0115	0.0189	21.41 „
27.2	0.0392	0.0263	0.0129	„	0.0131	0.0194	22.57 „
29.8	0.0430	0.0286	0.0144	„	0.0146	0.0198	23.62 „
32.4	0.0467	0.0309	0.0158	„	0.0160	0.0199	24.63 „

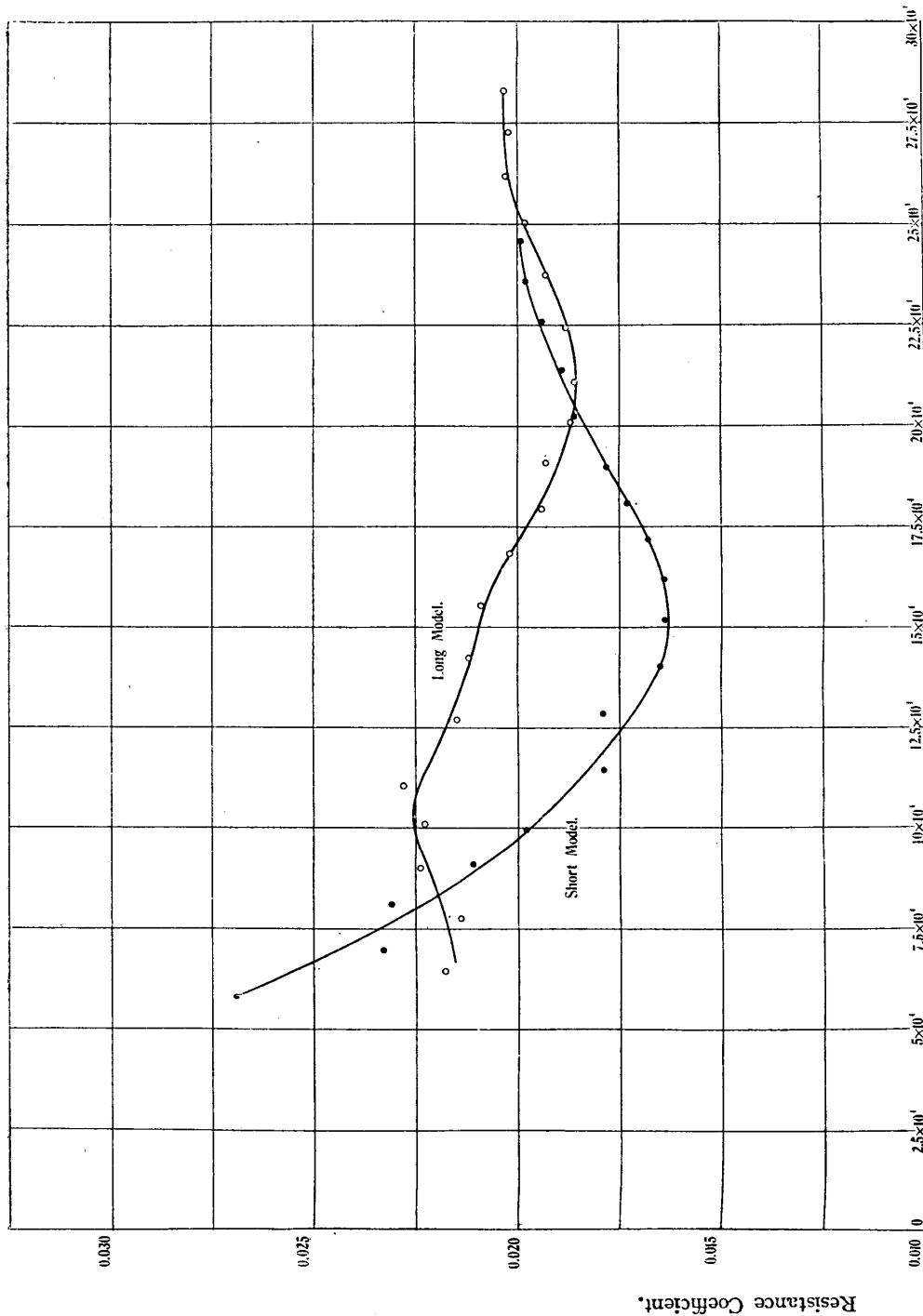


Fig. 20.—Resistance Coefficient. The Aeronautical Research Inst., Tōkyō Imperial University.

CHAPTER IV.

MEASUREMENTS AT THE WIND TUNNEL OF THE AERONAUTICAL RESEARCH LABORATORIES, IMPERIAL JAPANESE NAVY.

1. *Description of the Wind Tunnel and the Aerodynamic Balance.*

The wind tunnel, in which the measurements were made, is of the Eiffel type. The diameter is 1.25 m. An electric motor of 100 H.P. is directly coupled to a four-bladed air-screw. An outline of the tunnel is shown in Fig. 4.

There is only one set of stream strainer of honeycomb type near the external end of the inlet-tube.

The wind velocity can be regulated from the inside of the observation chamber by varying the field current of the electric motor. Any required air velocity could be obtained within the range from about 3 m/s to 50 m/s.

The balance used is one of the Gottingen type (Fig. 7). A variation of one gramme in resistance may be compensated by sliding the weight on the arm of the balance about 1 mm.

2. *Characteristics of the Wind Tunnel.*

a) Determination of Air Velocity.

The air velocity was determined by measuring the static pressure difference between two different sections of the stream, both of which have parallel air streams but different sectional areas. The one section *A* is chosen just behind the honeycomb strainer and the other *B* in the observation chamber. The pressure difference is measured by a vertical alcohol manometer, the reading of which is facilitated by aid of a micrometer and a magnifying glass.

If v_1 be the air velocity and p_1 the static pressure at the section *A*, and v and p_2 the corresponding values in the observation chamber, and p_0 and ρ_0 the atmospheric pressure and density respectively at the instant of the observation, we have, taking $\rho=\rho_0$,

$$p_0 - p_1 = \frac{1}{2} \rho_0 v_1^2,$$

and

$$p_0 - p_2 = \frac{1}{2} \rho_0 v^2;$$

so that

$$\Delta p = p_1 - p_2 = \frac{1}{2} \rho_0 (v^2 - v_1^2)$$

If the sectional area of the stream at *A* be *n* times that at *B*, we get the required dynamic pressure *q* from the following expression

$$q = \frac{1}{2} \rho_0 v^2 = \frac{n^2}{n^2 - 1} \Delta p.$$

The values of *q* given by this formula were compared to those given by Pitot-static tubes set in the same stream, the result of which

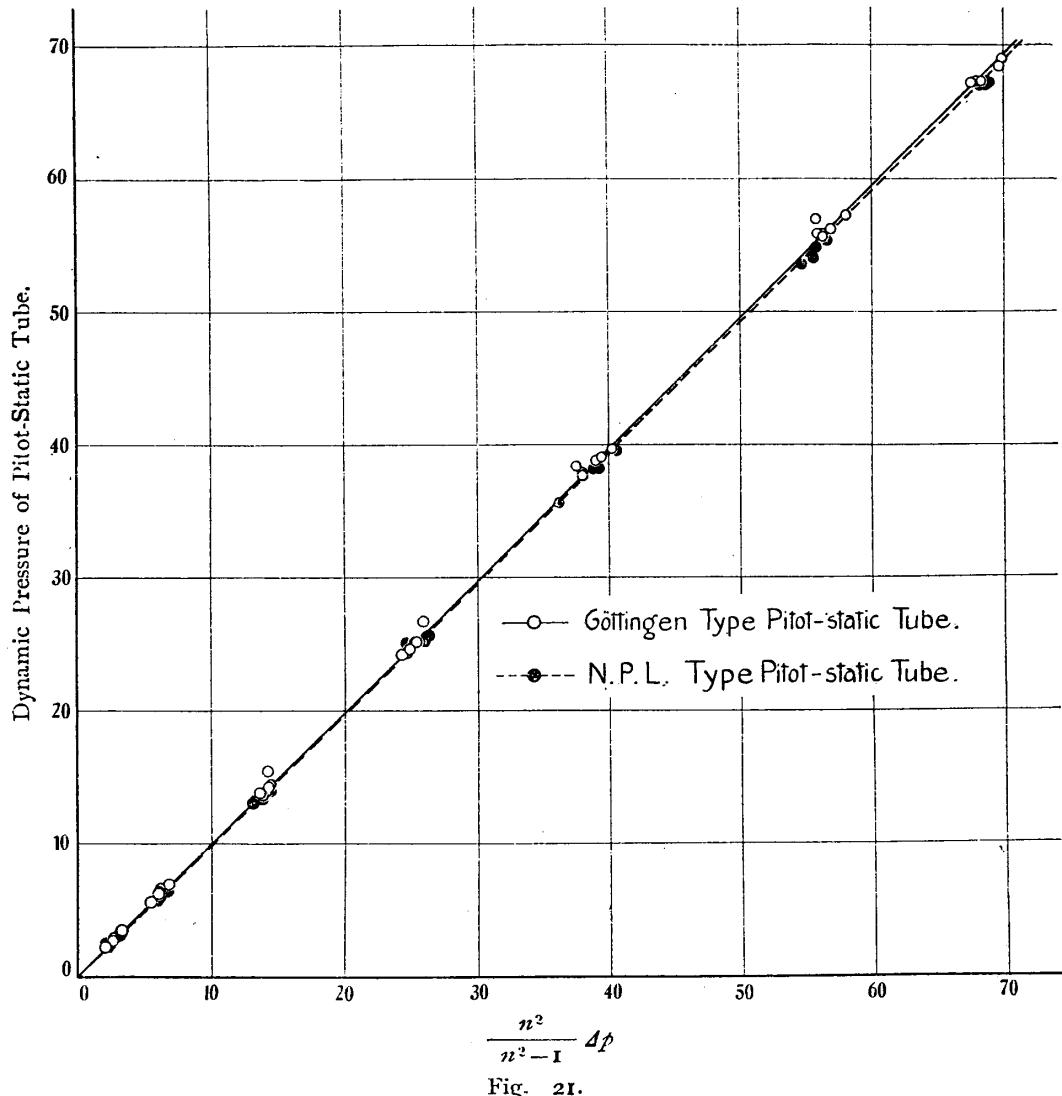


Fig. 21.

is shown in Fig. 21 and can be expressed by the following relation :

$$q_N/q = 0.983,$$

and

$$q_G/q = 0.990;$$

where q_N and q_G express the values of q given by Pitot-static tubes of N. P. L. type and of Göttingen type respectively. The former tube has a certificate of the N. P. L. and the latter tube was calibrated in the Aerodynamische Versuchsanstalt zu Göttingen.

b) Distribution of Air Velocity.

We measured the distribution of air velocity in the stream under a velocity of about 30 m/s.

It is quite uniformly distributed throughout the stream in the observation chamber, the discrepancy being nowhere over one percent.

Table XXIII shows the result; numbers in that Table are the ratios of the readings of the Pitot-static tube set in the stream to the readings of the standard manometer put in the chamber and out of the stream.

Table XXIII.—Velocity Distribution.

The Aeronautical Research Labors., I. J. N.

Position number.	$\frac{q}{q_0}$ (at 30 m/s.)	Position number.	$\frac{q}{q_0}$ (at 30 m/s.)	Position number.	$\frac{q}{q_0}$ (at 30 m/s.)
11	1.05	21	1.05	31	1.05
12	"	22	1.04	32	"
13	1.03	23	1.03	33	1.03
14	1.04	24	1.04	34	1.05
15	1.05	25	1.05	35	"
16	1.04	26	"	36	1.04
17	"	27	1.04	37	1.05
18	1.05	28	1.05	38	"
19	"	29	"	39	"

c) Direction of Air Flow.

The directions of the air flow at the 27 points in the stream were examined with the result shown in Table XXIV. They are fairly parallel to the axis of the wind tunnel, and small discrepancies shown in the Table can have no effect upon the measurement of the resistance.

Table XXIV.—Direction of Air Flow.

The Aeronautical Research Labors., I. J. N.

Position number.	Deviation angle in degrees		Position number.	Deviation angle in degrees		Position number.	Deviation angle in degrees	
	from hori- zontal plane.	from vertical plane.		from hori- zontal plane.	from vertical plane.		from hori- zontal plane.	from vertical plane.
11	+0.2	-0.1	21	+0.1	0.0	31	+0.5	+0.1
12	0.0	+0.1	22	0.0	+0.5	32	0.0	+0.3
13	+0.1	-0.8	23	+0.1	0.0	33	+0.7	+0.2
14	+0.2	+0.5	24	-0.2	+0.1	34	+0.5	+0.4
15	0.0	+0.1	25	0.0	+0.2	35	0.0	+0.1
16	0.0	-0.4	26	+0.2	-0.2	36	+0.5	-0.5
17	-0.3	+0.8	27	-0.2	+0.2	37	-0.5	0.0
18	0.0	-0.1	28	0.0	-0.3	38	0.0	-0.6
19	+0.1	-0.6	29	+0.1	-0.7	39	+0.2	-0.9

d) Gradient of Static Pressure and Horizontal Buoyancy.

At any point x , on the axis of the wind tunnel which is taken for the x -axis pointing downwind, was put a Prof. Prandtl's type Pitot-static tube (dia. 6 mm.), whose static hole was connected to one end of a manometer, the other end of which was exposed at a fixed point out of the stream in the observation chamber.

By varying the position of the Pitot-static tube on the axis of the tunnel, we measured the difference of the static pressure at several points on the axis from that at the fixed point.

If p_{ss} be the static pressure at a fixed point out of the stream and p_s that at a point x on the axis, the measured pressure difference Δp is

$$\Delta p = p_s - p_{ss}.$$

Observed values of Δp are throughout positive and those of $\frac{\Delta p}{q}$ are found to increase with the wind velocity v . The rate of increase of $\frac{\Delta p}{q}$ with v at every point on the axis is approximately a constant common to all x , so that it can be expressed by the following formula

$$\frac{\Delta p}{q} = \varphi + kv, \quad (1)$$

where v is the wind velocity and k is a constant. If v be expressed in m/s then k is equal to 0.004. The value of φ , found as the mean of the values of $\frac{\Delta p}{q}$ for $v=0$, as a function of x , is shown in Fig. 22.

If we suppose that the effect of the static pressure gradient Δp along the axis of the stream do not vary by the presence of the model, the force B acting on the model due to the static pressure gradient in the stream is

$$B = - \int \frac{d\varphi_s}{dx} dV,$$

where V is the volume of the model.

We have by equation (1)

$$B = -q \int \frac{d\varphi}{dx} dV = q\Phi, \quad (2)$$

where $\Phi = -0.0000478$ for the long model,
 $= -0.0000249$ for the short model.

The values of B are shown in Tables XXIX, XXX and Figs. 23, 24.

3. *Measurement of Total Resistance.*

The models were suspended by the method explained in Art. 5, Chapter I.

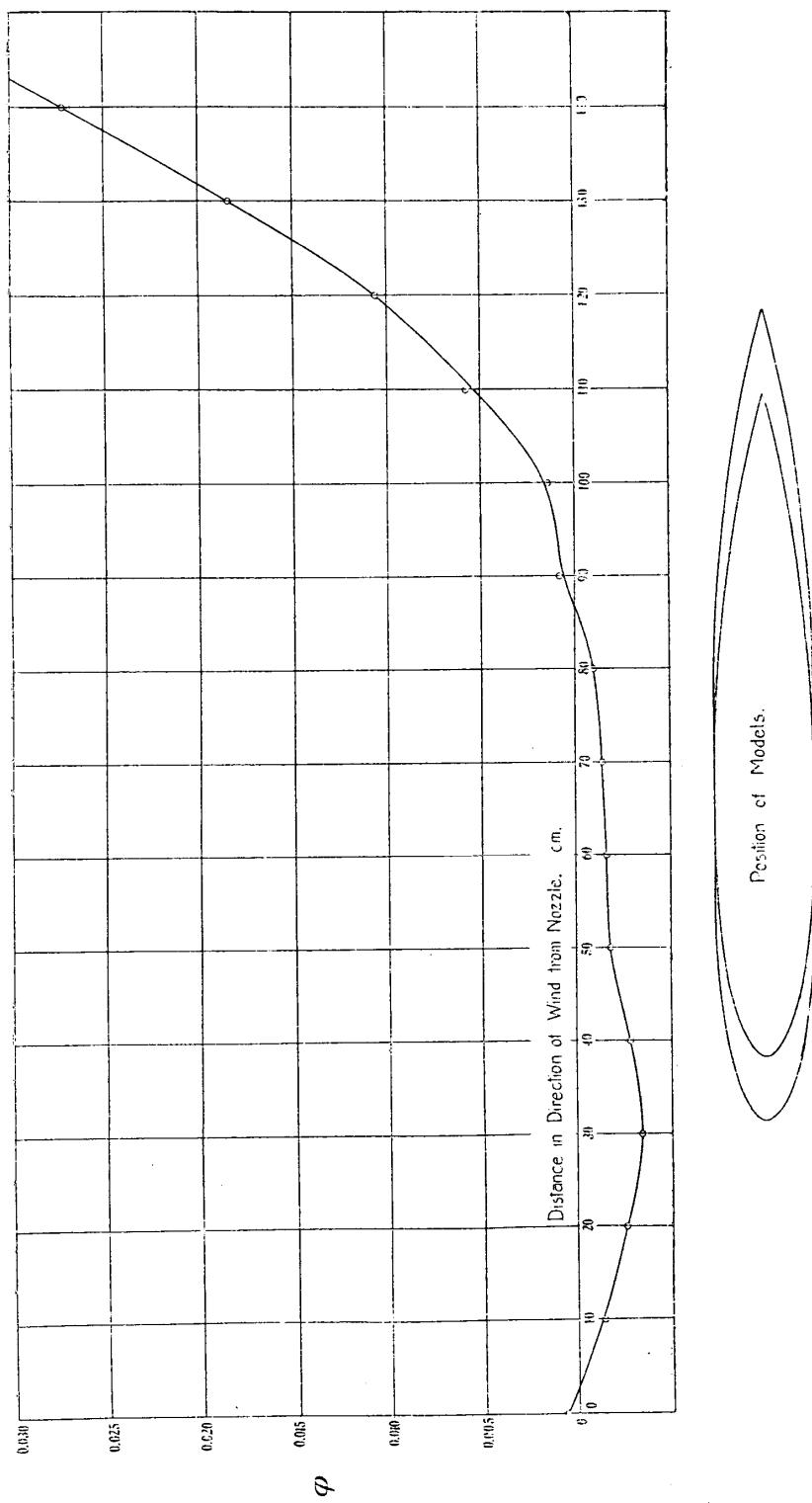


Fig. 22.—Variation of φ along the Axis of the Wind Tunnel.
The Aeronautical Research Laboratories, I. J. N.

Six measurements were made for the long model and five for the short. In the last two observations for the long model and the last three for the short the surface of the models had been wiped with a polishing liquid, so that the surfaces were made free from dirt and stains. By this we intended to see how the result is affected by the surface condition of the model.

The result of observations is shown in Tables XXV, XXVI and Figs. 23, 24.

Table XXV.—Total Resistance. *Long Model.*
The Aeronautical Research Labors., I. J. N.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K</i>	Reduction to standard condition of air (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Total resistance, kg. weight.
1.85	0.00296				1.81	0.00290
3.32	0.00484				3.26	0.00475
5.34	0.00820				5.24	0.00804
6.73	0.01018				6.60	0.00999
11.35	0.01719				11.13	0.01686
12.11	0.01857				11.88	0.01822
15.64	0.02460				15.34	0.02413
20.98	0.03320				20.53	0.03257
26.62	0.04199				26.11	0.04119
29.69	0.04703				29.13	0.04614
38.47	0.06027	Mean 18.3°	Mean 768.7	0.981	37.74	0.05912
43.27	0.06817				42.45	0.06687
49.95	0.07795				49.00	0.07647
56.34	0.08813				55.27	0.08646
64.17	0.09663				62.95	0.09479
71.28	0.10996				70.46	0.10787
78.13	0.11915				76.65	0.11689
90.32	0.13664				88.60	0.13404
100.24	0.15077				98.34	0.14791
111.76	0.16816				109.64	0.16506
132.03	0.19711				129.52	0.19336
149.10	0.22092				146.27	0.21672
158.35	0.23445				155.34	0.22995

Table XXV.—Continued.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K</i>	Reduction to standard condition of air. (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Total resistance, kg. weight.
1.86	0.00327	Mean 11.2°	Mean 771.3	1.050	1.95	0.00343
3.13	0.00505				3.29	0.00530
5.17	0.00831				5.43	0.00873
6.35	0.00999				6.67	0.01049
9.87	0.01504				10.36	0.01579
12.70	0.01999				13.34	0.02099
16.05	0.02573				16.85	0.02639
21.00	0.03285				22.05	0.03449
25.16	0.03958				26.42	0.04156
30.66	0.04789				32.19	0.05028
35.36	0.05551				37.13	0.05829
40.65	0.06382				42.68	0.06701
51.37	0.08005				53.94	0.08405
55.18	0.08549				57.94	0.08976
61.92	0.09667				62.79	0.09872
71.83	0.11073				72.84	0.11228
79.05	0.12441				80.16	0.12311
90.22	0.13645				91.48	0.13836
102.03	0.15466				103.51	0.15683
110.89	0.16445				112.44	0.16675
122.15	0.18286				123.86	0.18542
126.67	0.18959				128.44	0.19224
144.13	0.21373	Mean 21.5°	Mean 752.5	0.935	146.15	0.21672
157.50	0.23451				159.71	0.23779
98.32	0.14922				99.70	0.15131
1.80	0.00310				1.68	0.00290
7.34	0.01146				6.87	0.01073
16.31	0.02572				15.27	0.02407
25.75	0.04028				24.10	0.03770
41.14	0.06301				38.51	0.05898
57.20	0.08692				53.54	0.08136
77.08	0.11645				72.15	0.10900

Table XXV.—*Continued.*

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Total resistance, kg. weight.
99.60	0.14955	Mean 21.0°	Mean 752.5	Mean 0.936	93.23	0.14000
100.14	0.14925				93.73	0.13970
76.70	0.11695				71.79	0.10947
50.49	0.08694				52.87	0.08138
39.29	0.06100				36.78	0.05710
25.25	0.03920				23.63	0.03669
14.68	0.02245				13.74	0.02101
6.96	0.01068				6.51	0.01000
2.26	0.00342				2.12	0.00320
0.29	0.00082				0.27	0.00075
0.84	0.00162	Mean 22.9°	Mean 752.4	0.919	0.77	0.00149
2.39	0.00390				2.20	0.00358
3.77	0.00600				3.46	0.00551
5.78	0.00890				5.31	0.00818
7.45	0.01136				6.85	0.01044
8.87	0.01322				8.15	0.01215
11.18	0.01672				10.27	0.01537
13.18	0.01998				12.11	0.01836
1.26	0.00220	Mean 21.8°	Mean 758.6	0.917	1.18	0.00206
15.07	0.02248				14.12	0.02106
25.11	0.03741				23.53	0.03505
40.51	0.06025				37.96	0.05645
56.45	0.08391				52.89	0.07862
75.57	0.11239				70.81	0.10531
99.68	0.14734				93.40	0.13806
100.22	0.14795				93.91	0.13863
74.99	0.11208				70.26	0.10502
56.95	0.08537				53.36	0.07999
38.33	0.05712				35.92	0.05352
14.77	0.02175				13.84	0.02038
7.32	0.01099				6.86	0.01030

Table XXV.—Continued.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Coefficient K	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water,	Total resistance, kg. weight.
0.11	0.00046				0.10	0.00043
0.84	0.00173				0.77	0.00160
1.09	0.00214				1.01	0.00198
2.39	0.00405				2.21	0.00375
4.02	0.00641				3.71	0.00593
5.57	0.00874				5.15	0.00809
7.53	0.01144				6.97	0.01058
8.91	0.01368				8.24	0.01265
11.34	0.01721				10.49	0.01592
13.27	0.01999				12.27	0.01849

Table XXVI.—Total Resistance. Short Model
The Aeronautical Research Labors., I. J. N.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric temperature, °C.	Atmospheric pressure, mm. Hg.	Coefficient K	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Total resistance, kg. weight.
1.64	0.00275				1.63	0.00273
3.92	0.00569				3.90	0.00566
4.81	0.00637				4.78	0.00683
7.25	0.00981				7.21	0.00975
11.63	0.01550				11.56	0.01541
13.49	0.01834				13.41	0.01823
18.93	0.02570				18.82	0.02555
23.27	0.03129				23.13	0.03110
28.33	0.03846				28.16	0.03823
33.05	0.04464				32.85	0.04437
38.23	0.05131				38.00	0.05100
46.79	0.06151				46.51	0.06114
52.14	0.06838				51.83	0.06797
59.35	0.07848				58.99	0.07801

Table XXVI.—*Continued.*

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Total resistance, kg. weight.
69.04	0.08986	Mean 15.9°	Mean 761.6	0.991	68.63	0.08932
75.53	0.09810				75.08	0.09751
85.57	0.10977				85.06	0.10911
95.60	0.12155				95.03	0.12082
104.95	0.13224				104.32	0.13145
115.70	0.14764				115.01	0.14675
128.22	0.16206				127.45	0.16109
139.56	0.17501				138.72	0.17369
150.35	0.18943				149.45	0.18829
154.23	0.19620				153.39	0.19502
4.14	0.00619	Mean 14.8°	Mean 761.8	1.005	4.16	0.00622
4.85	0.00697				4.87	0.00700
7.34	0.01031				7.38	0.01036
9.87	0.01345				9.92	0.01352
13.12	0.01797				13.19	0.01806
18.53	0.02543				18.62	0.02556
22.53	0.03093				22.64	0.03108
27.81	0.03781				27.95	0.03820
33.46	0.04488				33.63	0.04510
39.29	0.05214				39.49	0.05240
44.65	0.05912				44.87	0.05942
52.24	0.06894				52.50	0.06928
59.67	0.07925				59.97	0.07965
67.94	0.08956				68.28	0.09001
77.52	0.10085				77.91	0.10135
85.24	0.11097				85.67	0.11142
97.35	0.12521				97.84	0.12584
104.86	0.13611				105.38	0.13679
116.17	0.14897				116.75	0.14971
125.54	0.16154				126.17	0.16235
138.62	0.17647				139.31	0.17735
151.28	0.19129				152.04	0.19225
156.77	0.19827				157.55	0.19926

Table XXVI.—Continued.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Total resistance, kg. weight.
2.14	0.00359				20.7	0.00348
3.99	0.00590				38.6	0.00571
7.02	0.00974				68.0	0.00943
9.00	0.01240				8.71	0.01200
11.65	0.01910				11.23	0.01566
13.62	0.01932				13.18	0.01870
17.75	0.02499				17.18	0.02419
21.53	0.03060				20.84	0.02962
26.83	0.03706				25.97	0.03587
29.98	0.04182				29.02	0.04048
37.55	0.05136				36.35	0.04972
44.45	0.05997				43.03	0.05805
51.39	0.06834				49.75	0.06615
58.90	0.07985				57.02	0.07729
67.29	0.09025				65.14	0.08736
76.15	0.10078				73.71	0.09756
86.75	0.111454				83.97	0.11087
93.31	0.12328				90.32	0.11934
104.12	0.13604				100.79	0.13169
116.52	0.15111				112.19	0.14627
127.08	0.16543				123.10	0.16014
142.13	0.18509				137.58	0.17917
147.89	0.19311				143.16	0.18693
154.87	0.20270				149.91	0.19621
0.59	0.00121				0.90	0.11100
1.69	0.00288				1.71	0.00291
2.36	0.00384				2.38	0.00387
3.50	0.00534				3.53	0.00539
4.85	0.00712				4.89	0.00718
7.56	0.01068				7.63	0.01058
11.06	0.01539				11.16	0.01553
14.60	0.02034				14.73	0.02052
18.95	0.02611				19.12	0.02634
Mean 18.3°						
Mean 758.5						
Mean 14.5°						
Mean 763.3						
Mean 1.009						

Table XXVI.—Continued.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Total resistance, kg. weight.
22.84	0.03100				23.05	0.03128
28.03	0.03754				28.28	0.03788
34.02	0.04557				34.33	0.04598
39.09	0.05194				39.44	0.05241
44.45	0.05838				44.85	0.05891
52.89	0.06814				53.37	0.06375
59.90	0.07641				60.44	0.07710
63.13	0.08703	Mean 14.5°	Mean 763.3	1.009	68.74	0.08781
75.26	0.09536				75.94	0.09622
85.90	0.10711				86.67	0.10807
96.03	0.12026				96.89	0.12134
106.03	0.13164				106.98	0.13282
115.23	0.14291				116.27	0.14420
128.06	0.15804				129.21	0.15946
139.46	0.17209				140.72	0.17364
150.14	0.18593				151.49	0.18760
156.93	0.19464				158.34	0.19639
0.17	0.00045	Mean 14.6°	Mean 763.6	1.008	0.17	0.00045
0.80	0.00146				0.81	0.00147
1.10	0.00190				1.11	0.00192
2.49	0.00380				2.51	0.00383
4.09	0.00588				4.12	0.00593
5.78	0.00824				5.83	0.00831
7.64	0.01063				7.70	0.01072
9.16	0.01268				9.23	0.01278
11.18	0.01559				11.27	0.01571
13.38	0.01850				13.49	0.01865
1.89	0.00297				1.91	0.00299
3.50	0.00513				3.53	0.00517

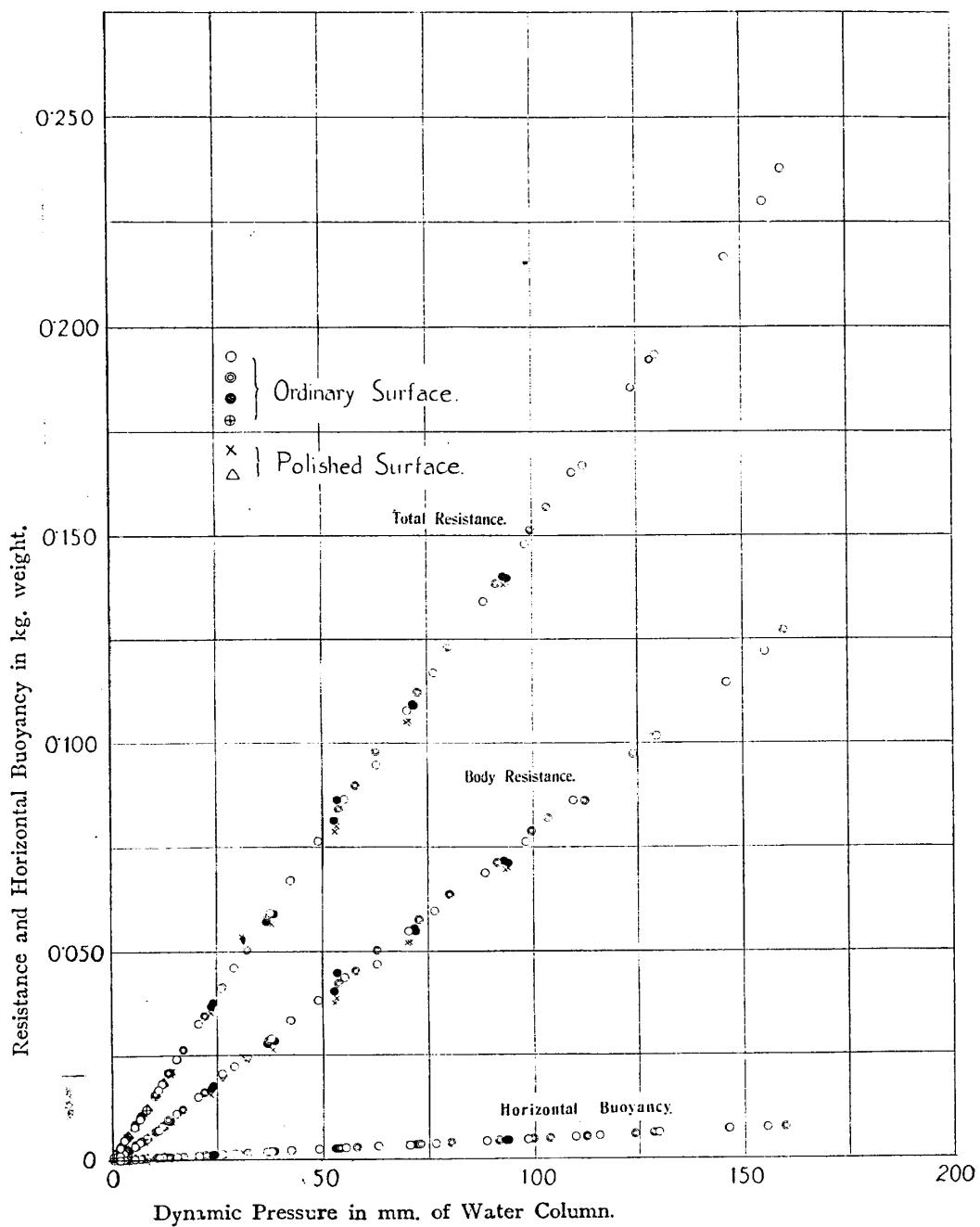


Fig. 23.—Total and Body Resistances and Horizontal Buoyancy of the Long Model.
The Aeronautical Research Laboratories, I. J. N.

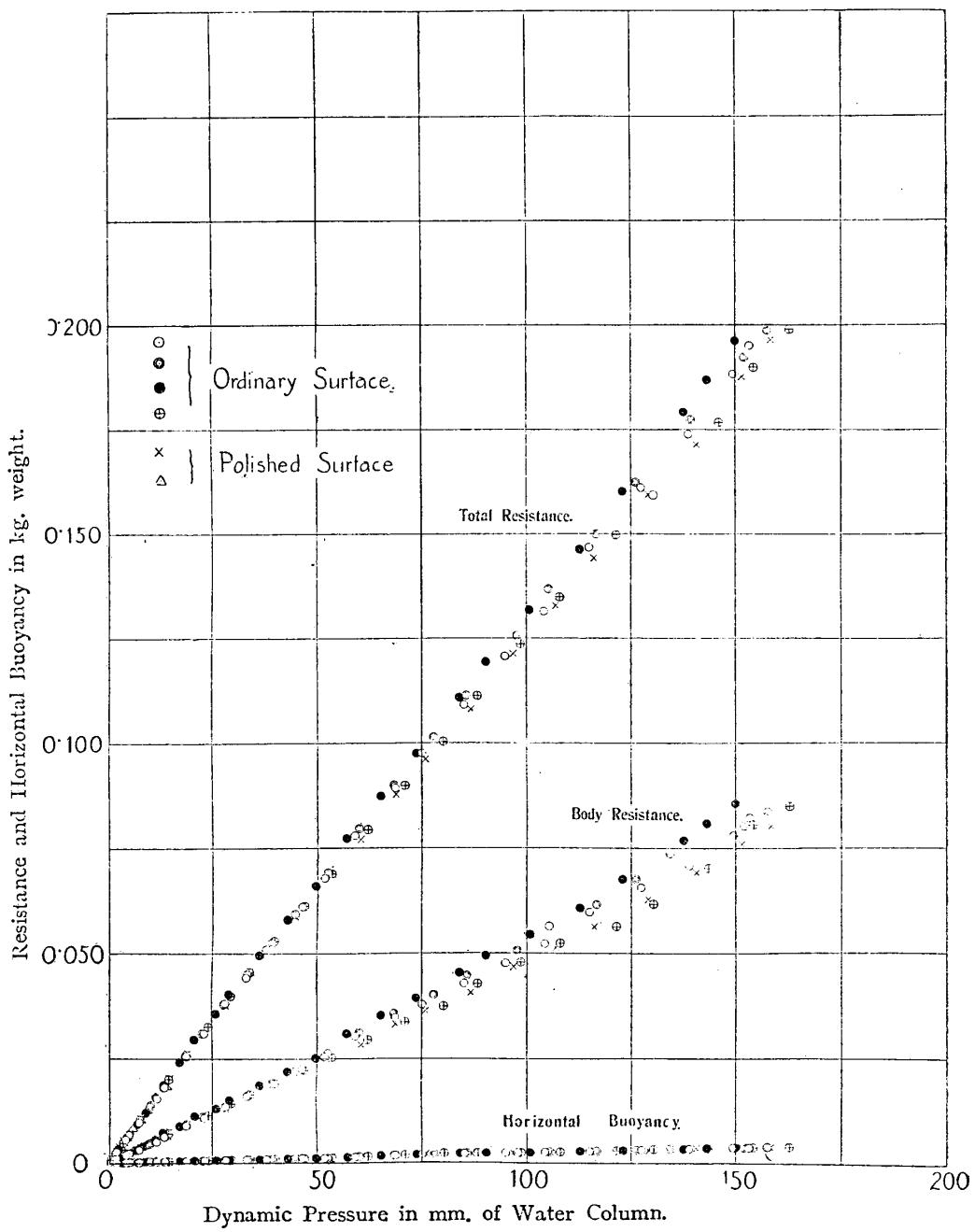


Fig. 24.—Total and Body Resistances and Horizontal Buoyancy of the Short Model.
The Aeronautical Research Laboratories, I. J. N.

4. Measurement of Resistance of Suspension Wires.

The method of measurement of the resistance of the suspension wires was the same as that explained in Art. 6, Chapter I. We made two observations for the long model and three for the short. The observed results are given in Tables XXVII, XXVIII and Figs. 25, 26.

In the present measurement the range of q (mm. of water column) was from 0·6 to 160, and the diameter of the suspension wire 0·023 cm., so that Reynolds' number ranged from about 50 to 800.

The curves representing $K_w F_w^{(W)} = F_s^{(W)}$ against $K_w q_w = q_s$ are shown in Figs. 25 and 26, where $F_w^{(W)}$ is the measured resistance in kg. These curves can be expressed by the following formula

$$F_s^{(W)} = \alpha q_s^{0.905}, \quad (3)$$

where α is a constant and is equal to

$\alpha = 1.12$ under $q_s = 9.5$ mm. for both models,

and $\alpha = 1.20$ above $q_s = 3.0$ mm. for the long model,

$\alpha = 1.23$ above $q_s = 3.0$ mm. for the short model.

This inequality of α for the two models for large values of q_s results from the difference of the lengths of the suspension wires in the two cases, but is not at all appreciable as long as q_s is small.

5. Resistance and Resistance Coefficient.

Subtracting $K_w F_w^{(W)} = F_s^{(W)}$ and B corresponding to the same value of q_s from $K_t F_t^{(T)} = F_s^{(T)}$, we get the body resistance of the model. This is shown in Tables XXV, XXVI and Figs. 23, 24.

The resistance coefficients C_x of the models as functions of Reynolds' number R are given in Tables XXIX, XXX and Figs. 27, 28.

It may be remarked that the correction of the resistance coefficient for the horizontal buoyancy is a constant and is equal to

$$\frac{B}{q V^{\frac{2}{3}}} = \frac{\Phi}{V^{\frac{2}{3}}} = 0.00156 \text{ for the long model,}$$

$$= 0.00100 \text{ for the short model.}$$

Table XXVII.—Wire Resistance. *Long Model*

The Aeronautical Research Labors., I. J. N.

Dynamic pressure, mm. water.	Wire resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Wire resistance, kg. weight.
2.05	0.00226	Mean 22.15°	Mean 757.1	0.932	1.91	0.00211
4.15	0.00403				3.87	0.00376
5.45	0.00520				5.08	0.00485
6.95	0.00638				6.48	0.00613
11.39	0.01041				10.60	0.00970
13.15	0.01178				12.30	0.01098
16.96	0.01512				15.80	0.01469
22.62	0.02003				21.10	0.01867
28.02	0.02445				26.10	0.02279
31.83	0.02759				29.70	0.02571
40.38	0.03457				37.60	0.03222
47.37	0.03987				44.20	0.03716
53.11	0.04409				49.50	0.04109
60.15	0.04959				56.10	0.04622
67.14	0.05460				62.60	0.05089
77.28	0.06187				72.00	0.05766
86.54	0.06776				80.70	0.06315
96.42	0.07483				89.90	0.06974
102.79	0.07935				95.80	0.07395
115.73	0.08877				107.90	0.08273
125.41	0.09555				116.90	0.08905
140.82	0.10733				131.20	0.10003
152.09	0.11411				141.80	0.10635
159.04	0.11843				148.20	0.11038
1.56	0.00167	Mean 18.3°	Mean 761.8	0.972	1.52	0.00162
	0.00412				3.88	0.00400
	0.00500				4.99	0.00486
	0.00716				7.40	0.00696
	0.00903				9.69	0.00877
	0.01236				13.40	0.01201
17.85	0.01599				17.30	0.01554

Table XXVII.—Continued.

Dynamic pressure, mm. water.	Wire resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K.</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Wire resistance, kg. weight.
22.51	0.01972				21.90	0.01917
27.79	0.02423				27.00	0.02355
33.35	0.02835				32.40	0.02756
38.26	0.03237				37.20	0.03146
43.73	0.03679				42.50	0.03576
52.60	0.04356				51.10	0.04234
65.80	0.04905				59.10	0.04768
67.83	0.05445				65.90	0.05293
75.94	0.06033	Mean 18.3°	Mean 761.8	0.972	73.80	0.05864
84.73	0.06690				82.40	0.06503
96.67	0.07465				94.00	0.07256
105.21	0.08074				102.30	0.07848
116.27	0.08898				113.00	0.08649
127.37	0.09633				123.80	0.09363
136.32	0.10330				132.50	0.10041
150.96	0.111291				146.70	0.10975
158.44	0.11694				154.00	0.11367

Table XXVIII.—Wire Resistance. Short Model.

The Aeronautical Research Labors., I. J. N.

Dynamic pressure, mm. water.	Wire resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K.</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Wire resistance, kg. weight.
0.84	0.00099				0.84	0.00098
3.08	0.00295				3.06	0.00294
5.14	0.00486				5.12	0.00484
7.75	0.00710				7.71	0.00706
10.03	0.00922				9.98	0.00917
13.44	0.01238	Mean 16.2°	Mean 763.8	0.995	13.40	0.01232
19.05	0.01721				19.00	0.01710

Table XXVIII.—Continued.

Dynamic pressure, mm. water.	Wire resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K.</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Wire resistance. kg. weight.
22.88	0.02052	Mean 16.2°	Mean 763.8	0.995	22.80	0.02042
27.93	0.02492				27.80	0.02480
32.53	0.02886				32.40	0.02872
39.27	0.03387				39.10	0.03370
44.63	0.03849				44.40	0.03830
50.36	0.04312				50.10	0.04290
58.83	0.04935				55.80	0.04910
67.34	0.05538				67.00	0.05510
74.46	0.06092				74.10	0.06062
84.87	0.06846				84.40	0.06812
94.86	0.07542				94.40	0.07504
105.35	0.08248				104.80	0.08207
114.28	0.08931				113.70	0.08886
127.14	0.09890				126.50	0.09841
137.59	0.0910.0				136.90	0.10547
150.27	0.11453				149.50	0.11396
155.45	0.11866				154.70	0.11807
0.63	0.00084	Mean 19.3°	Mean 763.6	0.966	0.60	0.00081
2.81	0.00292				2.70	0.00282
5.76	0.00554				5.60	0.00535
7.23	0.00630				7.00	0.00657
10.88	0.01008				10.50	0.00974
15.29	0.01394				14.80	0.01347
19.41	0.01769				18.80	0.01709
23.31	0.02085				22.50	0.02014
27.94	0.02506				27.00	0.02421
31.72	0.02811				30.60	0.02715
38.56	0.03376				37.20	0.03261
44.82	0.03847				43.30	0.03716
50.96	0.04322				49.20	0.04175
59.86	0.04943				57.80	0.04775
67.30	0.05595				65.00	0.05405
76.54	0.06208				73.90	0.05997

Table XXVIII.—Continued.

Dynamic pressure, mm. water.	Wire resistance, kg. weight.	Atmospheric tempera- ture, °C.	Atmospheric pressure, mm. Hg.	Coefficient <i>K.</i>	Reduction to standard condition of air, (15°C., 760 mm. Hg.)	
					Dynamic pressure, mm. water.	Wire resistance, kg. weight.
84.56	0.06801	Mean 19.3°	Mean 763.6	0.966	81.70	0.06570
93.81	0.07473				90.60	0.07219
103.17	0.08121				99.70	0.07845
116.20	0.09050				112.20	0.08742
126.15	0.09717				121.90	0.09387
139.39	0.10600				134.70	0.10240
151.02	0.11467				145.90	0.11077
159.63	0.12020				154.20	0.11611
65.79	0.05028				58.70	0.04857
0.17	0.00020				0.16	0.00000
0.80	0.00078	Mean 21.0°	Mean 763.0	0.949	0.76	0.00074
0.92	0.00106				0.87	0.00000
1.13	0.00122				1.07	0.00000
1.43	0.00149				1.36	0.00000
1.80	0.00179				1.71	0.00170
2.10	0.00204				1.99	0.00194
2.39	0.00227				2.27	0.00215
2.77	0.00258				2.63	0.00245
3.19	0.00294				3.06	0.00279
3.73	0.00352				3.54	0.00334
4.61	0.00412				4.37	0.00391
5.24	0.00501				4.97	0.00475
5.58	0.00519				5.30	0.00493
5.87	0.00540				5.57	0.00512
6.37	0.00585				6.04	0.00555
7.09	0.00654				6.72	0.00621
7.88	0.00717				7.48	0.00680
8.81	0.00794				8.36	0.00754
9.85	0.00884				9.33	0.00839
11.28	0.01038				10.70	0.00985
11.91	0.01084				11.30	0.01029
12.37	0.01138				11.70	0.01050
13.46	0.01225				12.80	0.01163
14.38	0.01302				13.60	0.01236

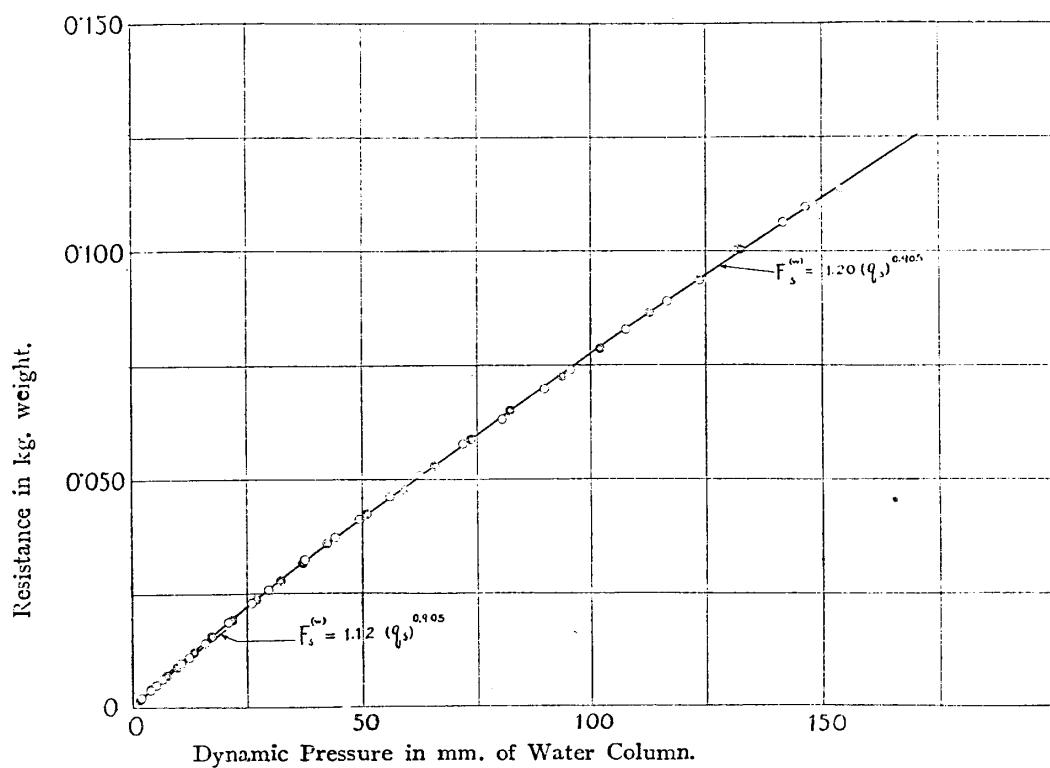
The Resistance of the Airship Models.

Fig. 25.—Wire Resistance of the Long Model.
The Aeronautical Research Laboratories, I. J. N.

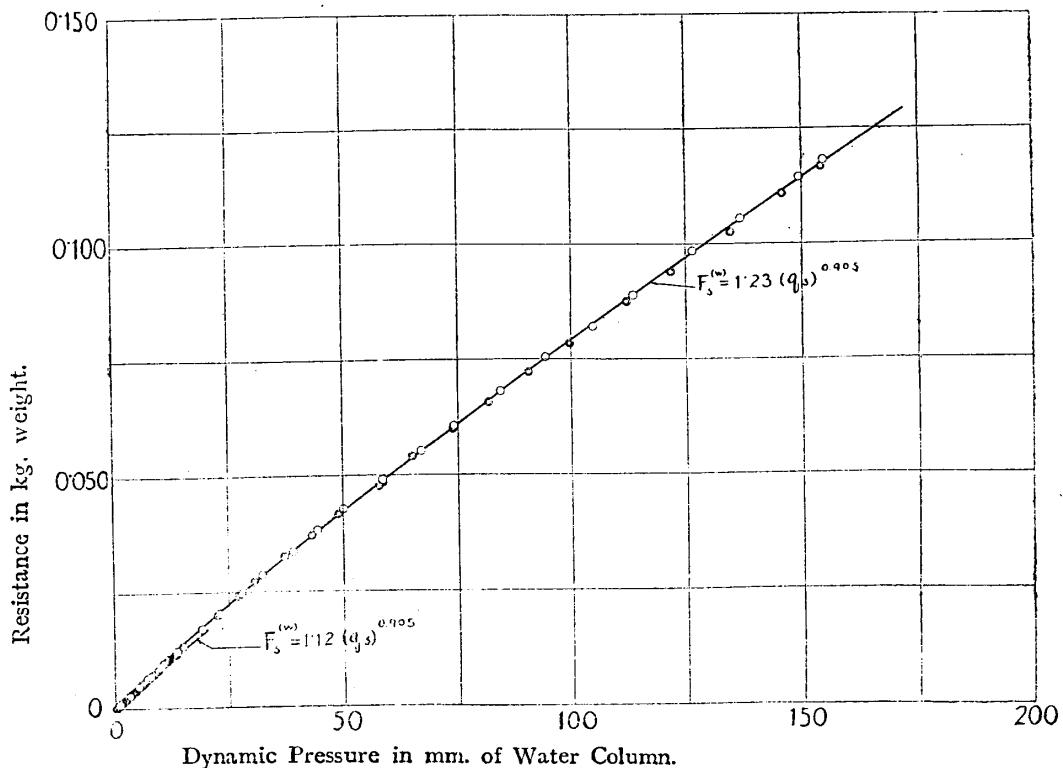


Fig. 26.—Wire Resistance of the Short Model.
The Aeronautical Research Laboratories, I. J. N.

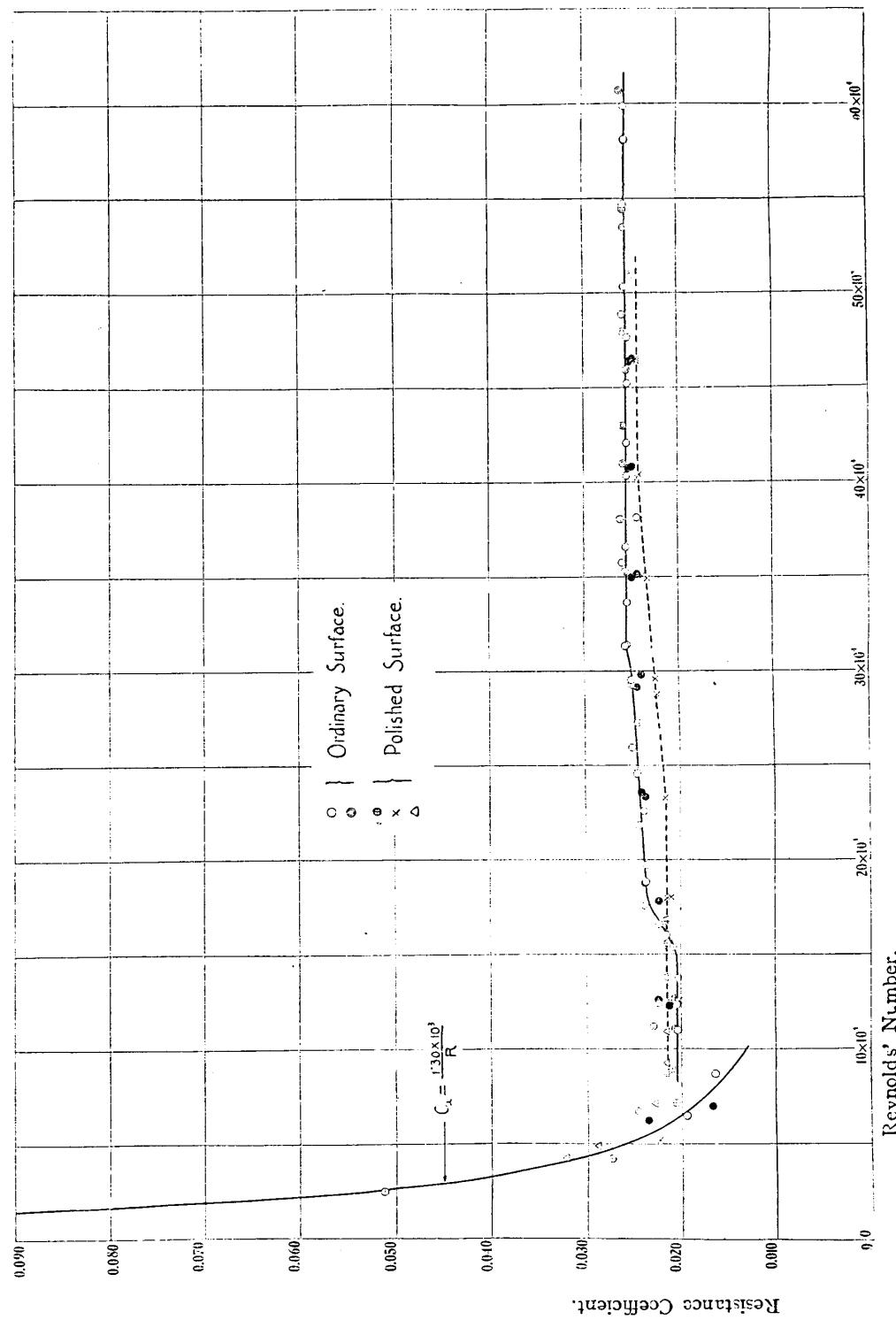
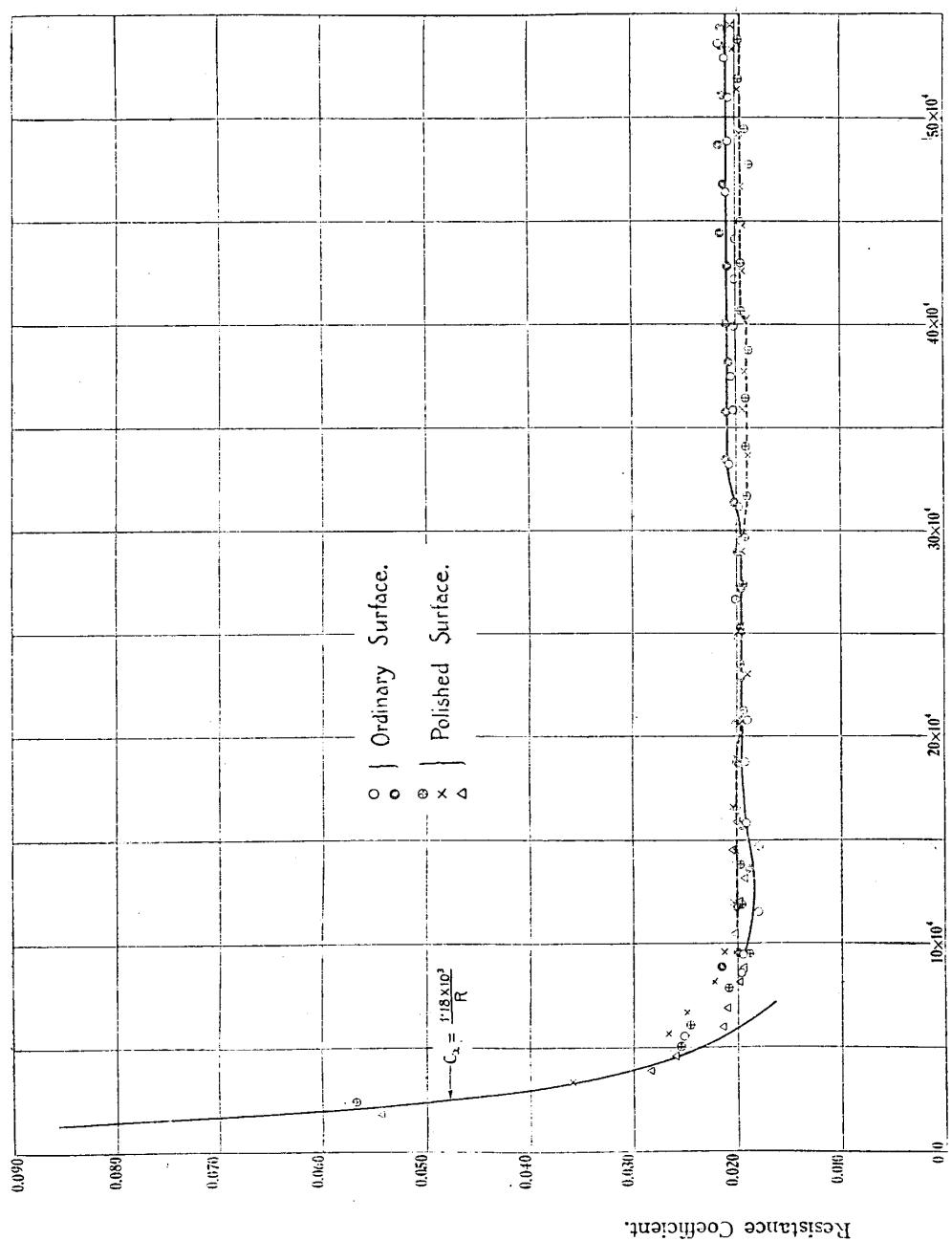


Fig. 27.—Resistance Coefficient of the Long Model.
The Aeronautical Research Laboratories, I. J. N.



Reynolds' Number.

Fig. 28.—Resistance Coefficient of the Short Model.
The Aeronautical Research Laboratories, I. J. N.

Table XXIX.—Resistance and Resistance Coefficient reduced to
the Standard Condition of Air. (Atmospheric temperature 15°C .
Atmospheric pressure 760 mm. Hg.)
Long Model.

The Aeronautical Research Labors., I. J. N.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient,	Reynolds' number.
1.81	0.00290	0.00191	0.00009	0.00008	0.0195	6.47×10^4
3.26	0.00475	0.00327	0.00016	0.00164	0.0164	8.67 "
5.24	0.00804	0.00502	0.00026	0.00328	0.0204	11.00 "
6.60	0.00999	0.00618	0.00032	0.00413	0.0205	12.35 "
11.13	0.01686	0.01077	0.00053	0.00732	0.0215	16.04 "
11.88	0.01822	0.01053	0.00057	0.00811	0.0223	16.57 "
15.34	0.02413	0.01374	0.00074	0.01113	0.0237	18.83 "
20.58	0.03257	0.01820	0.00099	0.01506	0.0244	21.80 "
26.11	0.04119	0.02232	0.00125	0.02062	0.0246	24.56 "
29.13	0.04614	0.02520	0.00140	0.02234	0.0251	25.94 "
37.74	0.05912	0.03203	0.00181	0.02890	"	29.52 "
42.45	0.06687	0.03562	0.00204	0.03329	0.0257	31.31 "
49.00	0.07647	0.04060	0.00235	0.03822	0.0255	33.64 "
55.27	0.08646	0.04523	0.00266	0.04389	0.0263	35.73 "
62.95	0.09479	0.05088	0.00302	0.04693	0.0244	38.13 "
70.46	0.10787	0.05641	0.00338	0.05484	0.0255	40.34 "
76.65	0.11639	0.06090	0.00368	0.05967	"	42.07 "
88.60	0.13404	0.06945	0.00425	0.06884	0.0254	45.24 "
98.34	0.14791	0.07627	0.00472	0.07636	"	47.66 "
109.64	0.16506	0.08420	0.00526	0.08612	0.0257	50.32 "
129.52	0.19336	0.09792	0.00621	0.10165	"	54.69 "
146.27	0.21672	0.10925	0.00703	0.11450	0.0256	58.12 "
155.34	0.22995	0.11537	0.00745	0.12208	0.0257	59.90 "
1.95	0.00343	0.00205	0.00009	0.00147	0.0247	6.72 "
3.29	0.00530	0.00330	0.00016	0.00216	0.0215	8.71 "
5.43	0.00873	0.00518	0.00022	0.00377	0.0230	11.20 "
6.67	0.01049	0.00624	0.00032	0.00457	0.0224	12.41 "
10.36	0.01579	0.00939	0.00050	0.00690	0.0218	15.47 "
13.34	0.02099	0.01194	0.00064	0.00969	0.0238	17.55 "
16.85	0.02639	0.01556	0.00081	0.01214	0.0236	19.72 "
22.05	0.03449	0.01943	0.00106	0.01612	0.0239	22.56 "
26.42	0.04156	0.02302	0.00127	0.01981	0.0245	24.69 "

Table XXIX.—*Continued.*

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient.	Reynolds' number.
32.19	0.05028	0.02767	0.00155	0.02416	0.0245	27.26×10^4
37.13	0.05829	0.03159	0.00178	0.02848	0.0251	29.27 "
42.68	0.06701	0.03579	0.00205	0.03327	0.0255	31.39 "
53.94	0.08405	0.04423	0.00258	0.04240	0.0257	35.28 "
57.94	0.08976	0.04720	0.00278	0.04534	0.0256	36.57 "
62.79	0.09872	0.05078	0.00302	0.05026	0.0262	28.06 "
72.84	0.11228	0.05808	0.00350	0.05770	0.0259	40.99 "
80.16	0.12311	0.06340	0.00385	0.06356	"	43.01 "
91.48	0.13836	0.07150	0.00439	0.07125	0.0255	45.94 "
103.51	0.15683	0.07992	0.00497	0.08188	0.0259	48.87 "
112.44	0.16675	0.08614	0.00540	0.08601	0.0250	50.93 "
123.86	0.18542	0.09398	0.00594	0.09738	0.0257	53.46 "
128.44	0.19224	0.09718	0.00617	0.10123	0.0258	54.44 "
146.15	0.21672	0.10918	0.00702	0.11456	0.0256	58.07 "
159.71	0.23779	0.11825	0.00764	0.12718	0.0261	60.70 "
99.70	0.15131	0.07723	0.00478	0.07886	0.0259	47.96 "
1.63	0.00290	0.00177	0.00003	0.00121	0.0236	6.23 "
6.87	0.01073	0.00640	0.00033	0.00466	0.0222	12.60 "
15.27	0.02407	0.01363	0.00074	0.01113	0.0238	18.73 "
24.10	0.03770	0.02112	0.00116	0.01774	0.0241	23.57 "
38.51	0.05898	0.03263	0.00185	0.02820	0.0240	29.80 "
53.54	0.08136	0.04398	0.00257	0.03995	0.0244	35.15 "
72.15	0.10900	0.05761	0.00346	0.05485	0.0249	40.82 "
93.23	0.14000	0.07271	0.00447	0.07176	0.0252	46.40 "
93.73	0.13970	0.07304	0.00450	0.07116	0.0248	46.54 "
71.79	0.10947	0.05736	0.00344	0.05555	0.0253	40.73 "
52.87	0.08138	0.04348	0.00254	0.04044	0.0250	34.96 "
36.73	0.05710	0.03128	0.00177	0.02759	0.0245	29.15 "
23.63	0.03669	0.02072	0.00113	0.01710	0.0237	23.34 "
13.74	0.02101	0.01230	0.00066	0.00937	0.0223	17.81 "
6.51	0.01000	0.00608	0.00031	0.00423	0.0213	12.27 "
2.12	0.00320	0.00222	0.00010	0.00108	0.0167	6.97 "
0.27	0.00075	0.00034	0.00010	0.00042	0.0512	2.49 "
0.77	0.00149	0.00083	0.00004	0.00065	0.0275	4.24 "
2.20	0.00358	0.00230	0.00011	0.00139	0.0206	7.14 "
3.46	0.00551	0.00346	0.00017	0.00222	0.0210	8.94 "

Table XXIX.—*Continued.*

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient.	Reynolds' number.
5.31	0.00838	0.00508	0.00026	0.00336	0.0207	11.05×10^4
6.85	0.01044	0.00633	0.00033	0.00439	0.0210	12.57 "
8.15	0.01215	0.00748	0.00039	0.00506	0.0203	13.73 "
10.27	0.01537	0.00932	0.00049	0.00654	0.0208	15.38 "
12.11	0.01836	0.01089	0.00058	0.00805	0.0218	16.72 "
1.18	0.00206	0.00131	0.00006	0.00081	0.0224	5.21 "
14.12	0.02166	0.01263	0.00068	0.00906	0.0210	18.04 "
23.53	0.03505	0.0261	0.00116	0.01560	0.0216	23.30 "
37.96	0.05645	0.03218	0.00182	0.02609	0.0225	29.60 "
52.89	0.07862	0.04350	0.00254	0.03766	0.0233	34.92 "
70.81	0.10531	0.05664	0.00340	0.05207	0.0241	40.41 "
93.40	0.13826	0.07232	0.00448	0.06372	0.0244	46.41 "
93.91	0.13863	0.07318	0.00450	0.06995	0.0244	46.51 "
70.26	0.10502	0.05623	0.00337	0.05216	0.0243	40.25 "
53.36	0.07999	0.04381	0.00256	0.03874	0.0238	35.05 "
35.92	0.05352	0.03060	0.00172	0.02464	0.0224	28.76 "
13.84	0.02038	0.01200	0.00066	0.00904	0.0214	17.87 "
6.86	0.01030	0.00639	0.00033	0.00424	0.0202	12.58 "
0.10	0.00043	0.00014	0.00000	0.00029	0.0950	1.52 "
0.77	0.00160	0.00088	0.0004	0.00076	0.0321	4.23 "
1.01	0.00198	0.00114	0.0005	0.00089	0.0288	4.81 "
2.21	0.00375	0.00231	0.00011	0.00155	0.0228	7.13 "
3.71	0.00593	0.00367	0.0018	0.00244	0.0215	9.25 "
5.15	0.00809	0.00495	0.00025	0.00339	0.0215	10.80 "
6.97	0.01058	0.00648	0.00233	0.00443	0.0208	12.67 "
8.24	0.01265	0.00760	0.00040	0.00545	0.0216	13.79 "
10.49	0.01592	0.00950	0.00050	0.00692	0.0216	15.57 "
12.27	0.01849	0.01102	0.00059	0.00806	0.0215	16.82 "

Table XXX.—Resistance and Resistance Coefficient reduced
to the Standard Condition of Air. (Atmospheric temperature $15^{\circ}\text{C}.$
(Atmospheric pressure 760 mm. Hg.)
Short Model.

The Aeronautical Research Labors., I. J. N.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient.	Reynold's number.
1.63	0.00273	0.00175	0.00004	0.00102	0.0252	5.52×10^4
3.90	0.00566	0.00385	0.000010	0.00191	0.0197	8.54 "
4.78	0.00683	0.00463	0.000012	0.00232	0.0195	9.45 "
7.21	0.00975	0.00671	0.000018	0.00322	0.0180	11.61 "
11.56	0.01541	0.01057	0.000028	0.00512	0.0179	14.71 "
13.41	0.01823	0.01220	0.000034	0.00637	0.0191	15.83 "
18.82	0.02555	0.01702	0.000047	0.00900	0.0192	18.77 "
23.13	0.03110	0.02074	0.000058	0.01094	0.0190	20.79 "
28.16	0.03823	0.02518	0.000071	0.01376	0.0197	22.95 "
32.35	0.04437	0.02895	0.000081	0.01623	0.0199	24.81 "
38.00	0.05050	0.03300	0.000095	0.01895	0.0201	26.66 "
46.51	0.06114	0.03966	0.000116	0.02264	0.0196	29.51 "
51.83	0.06797	0.04380	0.000130	0.02547	0.0198	31.15 "
58.99	0.07801	0.04917	0.000147	0.03031	0.0207	33.22 "
68.63	0.08932	0.05638	0.000172	0.03465	0.0203	35.85 "
75.08	0.09751	0.06115	0.000138	0.03824	0.0205	37.49 "
85.06	0.10911	0.06844	0.000213	0.04280	0.0202	39.91 "
95.03	0.12082	0.07565	0.000288	0.04755	0.0201	42.19 "
104.32	0.13145	0.08227	0.000260	0.05178	0.0200	44.13 "
115.01	0.14675	0.08932	0.000288	0.05971	0.0209	46.38 "
127.45	0.16109	0.09866	0.000319	0.06562	0.0207	48.83 "
138.72	0.17369	0.10652	0.000347	0.07091	0.0206	50.95 "
149.45	0.18829	0.11398	0.000374	0.07805	0.0210	52.85 "
153.30	0.19502	0.11660	0.000383	0.08225	0.0216	53.54 "
4.16	0.00622	0.00409	0.000010	0.00223	0.0216	8.85 "
4.87	0.00700	0.00470	0.000012	0.00242	0.0200	9.54 "
7.38	0.01036	0.00685	0.000018	0.00369	0.0201	11.75 "
9.92	0.01352	0.00914	0.000025	0.00463	0.0188	13.62 "
13.19	0.01806	0.01200	0.000033	0.00639	0.0195	15.70 "
18.62	0.02556	0.01688	0.000046	0.00914	0.0198	18.65 "
22.64	0.03108	0.02032	0.000057	0.01133	0.0201	20.60 "

Table XXX.—Continued.

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient.	Reynolds' number.
27.95	0.03800	0.02499	0.00070	0.01371	0.0197	22.86 × 10 ⁴
33.63	0.04515	0.02956	0.00084	0.01638	0.0196	25.07 "
39.49	0.05240	0.03415	0.00099	0.01924	0.0196	27.19 "
44.87	0.05942	0.03837	0.00112	0.02217	0.0199	23.97 "
52.50	0.06928	0.04428	0.00131	0.02631	0.0202	31.36 "
59.97	0.07965	0.04990	0.00150	0.03125	0.0210	33.48 "
68.28	0.09001	0.05628	0.00171	0.03564	0.0210	35.74 "
77.91	0.10135	0.06320	0.00195	0.04010	0.0207	38.17 "
85.67	0.11142	0.06890	0.00214	0.04466	0.0210	40.03 "
97.84	0.12584	0.07767	0.00245	0.05062	0.0208	42.81 "
105.38	0.13679	0.08305	0.00263	0.05637	0.0215	44.41 "
116.75	0.14971	0.09107	0.00292	0.06156	0.0212	46.75 "
126.17	0.16235	0.09780	0.00316	0.06771	0.0216	48.66 "
139.31	0.17735	0.10694	0.00349	0.07390	0.0213	51.05 "
152.04	0.19225	0.11578	0.00380	0.08027	0.0213	53.43 "
157.55	0.19926	0.11957	0.00394	0.08363	0.0214	54.30 "
2.07	0.00348	0.00217	0.00005	0.00136	0.0265	6.23 "
3.86	0.00571	0.00381	0.00010	0.00200	0.0208	8.50 "
6.80	0.00943	0.00636	0.00017	0.00324	0.0192	11.28 "
8.71	0.01200	0.00807	0.00022	0.00415	0.0192	12.77 "
11.23	0.01566	0.01033	0.00028	0.00561	0.0200	14.53 "
13.18	0.01870	0.01199	0.00033	0.00704	0.0215	15.72 "
17.18	0.02419	0.01564	0.00043	0.00893	0.0210	17.94 "
20.84	0.02962	0.01876	0.00052	0.01138	0.0220	19.76 "
25.97	0.03587	0.02327	0.00065	0.01325	0.0205	22.06 "
29.02	0.04048	0.02587	0.00073	0.01534	0.0213	23.31 "
36.35	0.04972	0.03174	0.00091	0.01889	0.0209	26.09 "
43.03	0.05805	0.03692	0.00108	0.02221	0.0218	28.39 "
49.75	0.06615	0.04218	0.00124	0.02521	0.0204	30.53 "
57.02	0.07729	0.04773	0.00143	0.03099	0.0219	32.68 "
65.14	0.08736	0.05379	0.00163	0.03520	0.0218	34.93 "
73.71	0.09756	0.06012	0.00184	0.03928	0.0214	37.16 "
83.97	0.11087	0.06762	0.00210	0.04535	0.0217	39.66 "
90.32	0.11934	0.07221	0.00226	0.04939	0.0220	41.13 "
100.79	0.13169	0.07981	0.00252	0.05440	0.0217	43.44 "
112.19	0.14627	0.08833	0.00282	0.06076	0.0217	45.94 "
123.01	0.16014	0.09555	0.00308	0.06767	0.0221	48.00 "

Table XXX.—*Continued.*

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient.	Reynolds' number.
137.58	0.17917	0.10574	0.00344	0.07637	0.0225	50.77×10^4
143.16	0.18693	0.10960	0.00358	0.08091	0.0227	51.78 "
149.91	0.19621	0.11428	0.00375	0.08568	0.0230	52.98 "
0.60	0.00112	0.00070	0.00002	0.00054	0.0359	3.34 "
1.71	0.00291	0.00182	0.00004	0.00113	0.0267	5.65 "
2.38	0.00387	0.00246	0.00006	0.00147	0.0249	6.63 "
3.53	0.00539	0.00352	0.00009	0.00166	0.0223	8.13 "
4.89	0.00718	0.00471	0.00012	0.00250	0.0213	9.57 "
7.63	0.01078	0.00710	0.00019	0.00387	0.0204	11.95 "
11.16	0.01553	0.01023	0.00028	0.00558	0.0201	14.48 "
14.73	0.02052	0.01343	0.00037	0.00746	0.0204	16.61 "
19.12	0.02634	0.01732	0.00048	0.00950	0.0200	18.92 "
23.05	0.03128	0.02067	0.00058	0.01119	0.0195	20.77 "
28.28	0.03788	0.02527	0.00071	0.01332	0.0190	23.01 "
34.33	0.04598	0.03012	0.00086	0.01672	0.0195	25.36 "
39.44	0.05241	0.03412	0.00093	0.01928	0.0197	27.18 "
44.85	0.05891	0.03834	0.00113	0.02170	0.0195	28.93 "
53.37	0.06375	0.04492	0.00133	0.02516	0.0190	31.62 "
60.44	0.07710	0.05026	0.00151	0.02335	0.0189	33.65 "
68.74	0.08781	0.05642	0.00172	0.03315	0.0194	35.88 "
75.94	0.09622	0.06180	0.00190	0.03632	0.0192	37.71 "
86.67	0.10807	0.06962	0.00214	0.04059	0.0190	40.29 "
96.89	0.12134	0.07699	0.00242	0.04677	0.0194	42.65 "
106.98	0.13282	0.08720	0.00267	0.05129	0.0193	44.77 "
116.27	0.14420	0.09077	0.00291	0.05634	0.0195	46.64 "
129.21	0.15946	0.09922	0.00323	0.06277	0.0196	49.21 "
140.72	0.17364	0.10791	0.00351	0.06925	0.0198	51.34 "
151.49	0.18760	0.10538	0.00379	0.07615	0.0202	53.25 "
158.34	0.19639	0.12010	0.00396	0.08025	0.0204	54.47 "
0.17	0.00045	0.00023	0.00010	0.00024	0.0543	1.79 "
0.41	0.00147	0.00092	0.00002	0.00057	0.0283	3.89 "
1.11	0.00192	0.00123	0.00003	0.00072	0.0260	4.56 "
2.51	0.00383	0.00258	0.00006	0.00130	0.0210	6.86 "
4.12	0.00593	0.00405	0.00009	0.00198	0.0194	8.79 "
5.83	0.00831	0.00553	0.00015	0.00293	0.0202	10.45 "
7.70	0.01072	0.00712	0.00019	0.00379	0.0198	12.01 "

Table XXX.—*Continued.*

Dynamic pressure, mm. water.	Total resistance, kg. weight.	Wire resistance, kg. weight.	Horizontal buoyancy, kg. weight.	Body resistance, kg. weight.	Resistance coefficient.	Reynolds' number.
9.23	0.01278	0.00858	0.00023	0.00443	0.0193	13.15×10^4
11.27	0.01571	0.01032	0.00028	0.00567	0.0203	14.53 "
13.49	0.01865	0.01228	0.00034	0.00671	0.0200	15.90 "
1.91	0.00299	0.00202	0.00005	0.00102	0.0214	5.98 "
3.53	0.00517	0.00352	0.00009	0.00174	0.0198	8.13 "

6. *Remarks.*

From all the observations we find that the resistance coefficient for the long model is larger than that for the short, and for values of R not exceeding 5×10^4 , C_x decreases with increase of air velocity, being approximately inversely proportional to the latter, while it becomes approximately constant when R exceeds a value about 30×10^4 , and for some value of R between these limits C_x attains its minimum value.

Finally the present experiment shows that the value of C_x varies with the condition of the surface of the model (as shown by the dotted lines in Figs. 27, 28), and we may infer that if coinciding results are demanded in such a test as this it is imperative to specify the condition of the surface of the model at the very instant of observation, particularly when the model has a large surface and the principal part of the total resistance is due to the surface friction.

APPENDIX.

DIMENSION OF THE AIRSHIP MODELS, MEASURED AT THE AERONAUTICAL RESEARCH INSTITUTE, TÔKYÔ IMPERIAL UNIVERSITY.

The measurement was made with a cathetometer and a universal measuring machine, both of the Société Génévoise d'Instruments de Physique.

The measurement has an accuracy of 0.01 mm.

The diameter in four longitudinal planes, passing through the axis of the model and making nearly 45 degrees to each other, was measured. In the following tables these planes are denoted with (1), (2), (3) and (4) respectively.

Total Length. *Long Model.*

Temp. 13.3°—13.4°C.

1	871.317 mm.	11	871.337 mm.
2	871.348	12	871.345
3	871.339	13	871.347
4	871.337	14	871.343
5	871.320	15	871.325
6	871.341	16	871.323
7	871.347	17	871.332
8	871.349	18	871.347
9	871.332	19	871.353
10	871.324	20	871.333
Mean		871.337 mm.	

Diameter. *Long Model.*

Distance from tail.	Distance from head.	Diameter (1)	Diameter (2)	Diameter (3)	Diameter (4)	Mean Diameter.
mm.	mm.	mm.	mm.	mm.	mm.	mm.
7	864.337	4.68	4.61	4.66	4.67	4.65
17	854. "	10.58	10.55	10.55	10.58	10.57
27	844. "	15.97	15.94	15.94	15.97	15.96
Joint		x	x	x	x	x
37	834. "	20.85	20.84	20.85	20.88	20.86

Appendix.

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Distance from tail.	Distance from head.	Diameter (1)	Diameter (2)	Diameter (3)	Diameter (4)	Mean Diameter.
mm.	mm.	mm.	mm.	mm.	mm.	mm.
47	824·337	25·65	25·69	25·64	25·63	25·65
57	814· "	30·40	32·47	30·39	30·40	30·42
67	804· "	34·63	34·68	34·67	34·69	34·68
77	794· "	38·86	38·89	38·87	38·87	38·87
87	784· "	42·99	42·98	42·96	42·96	42·98
97	774· "	46·85	46·89	46·83	46·85	46·86
107	764· "	50·43	50·48	50·44	50·44	50·45
117	754· "	53·92	53·95	53·92	53·89	53·92
127	744· "	57·31	57·36	57·32	57·34	57·33
137	734· "	60·53	60·55	60·54	60·55	60·54
147	724· "	63·63	63·61	63·61	63·61	63·62
157	714· "	66·72	66·69	66·69	66·70	66·70
167	704· "	69·76	69·77	69·74	69·75	69·76
177	694· "	72·36	72·38	72·32	72·35	72·35
Joint		x	x	x	x	x
187	684· "	74·95	74·92	74·82	74·89	74·90
Mean temp.→		13·1°	13·5°	12·3°	14·6°	13·4°

197	674·337	77·41	77·39	77·32	77·36	77·37
207	664· "	79·63	79·64	79·62	79·66	79·64
217	654· "	81·93	82·00	81·93	81·95	81·95
227	644· "	84·27	84·33	84·28	84·33	84·30
237	634· "	86·60	86·66	86·56	86·58	86·60
247	624· "	88·71	88·72	88·69	88·70	88·71
257	614· ..	90·66	90·70	90·66	90·68	90·68
267	604· ..	92·51	92·53	92·53	92·53	92·53
277	594· ..	94·32	94·36	94·33	94·32	94·33
287	584· ..	96·12	96·14	96·11	96·16	96·14
297	574· ..	97·75	97·82	97·76	97·76	97·77
307	564· ..	99·20	99·15	99·19	99·17	99·18
317	554· ..	100·49	100·43	100·48	100·41	100·45
Lug	o	o	o	o	o	o
337	534· ..	102·80	102·78	102·72	102·70	102·75
357	514· ..	104·41	104·45	104·40	104·42	104·43
377	494· ..	105·52	105·53	105·49	105·48	105·50
397	474· ..	106·16	106·19	106·12	106·16	106·16
417	454· ..	106·49	106·53	106·46	106·47	106·49

Appendix.

Distance from tail.	Distance from head.	Diameter (1)	Diameter (2)	Diameter (3)	Diameter (4)	Mean Diameter.
mm.	mm.	mm.	mm.	mm.	mm.	mm.
437	434·337	106·67	106·65	106·60	106·61	106·63
457	414· "	106·67	106·69	106·63	106·61	106·65
Lug	0	0	0	0	0	0
Mean temp.→		13·3°	13·7°	12·5°	14·6°	13·5°

486 837	384·5	106·62	106·69	106·58	106·55	106·61
506· "	364·5	106·63	106·67	106·61	106·61	106·63
526· "	344·5	106·63	106·68	106·60	106·62	106·63
546· "	324·5	106·65	106·70	106·62	106·61	106·65
566· "	304·5	106·65	106·66	106·64	106·63	106·65
586· "	284·5	106·64	106·60	106·62	106·61	106·62
606· "	264·5	106·64	106·62	106·62	106·60	106·62
626· "	244·5	106·59	106·62	106·56	106·55	106·58
Lug	0	0	0	0	0	0
646· "	224·5	106·16	106·19	106·14	106·13	106·16
656· "	214·5	105·81	105·87	105·82	105·82	105·83
666· "	204·5	105·26	105·36	105·27	105·29	105·30
676· "	194·5	104·63	104·74	104·64	104·68	104·67
686· "	184·5	103·77	103·85	103·78	103·73	103·79
696· "	174·5	102·68	102·79	102·66	102·66	102·70
706· "	164·5	101·28	101·37	101·29	101·27	101·30
716· "	154·5	99·67	99·74	99·64	99·67	99·63
726· "	144·5	97·81	97·90	97·81	97·83	97·84
736· "	134·5	95·73	95·81	95·71	95·74	95·75
746· "	124·5	93·38	93·49	93·42	93·35	93·41
756· "	114·5	90·76	90·84	90·77	90·75	90·78
Mean temp.→		13·3°	14·0°	14·1°	14·7°	14·0°

766 837	124·5	87·87	87·95	87·88	87·85	87·89
776· "	94·5	84·70	84·79	84·72	84·72	84·73
786· "	84·5	81·07	81·16	81·05	81·05	81·08
796· "	74·5	77·20	77·13	77·04	77·03	77·05
806· "	69·5	74·82	74·91	74·82	74·86	74·85
806· "	64·5	72·56	72·65	72·53	72·58	72·58
811· "	59·5	69·89	69·97	69·97	69·98	69·95
816· "	54·5	67·11	67·14	67·01	67·10	67·09

Distance from tail.	Distance from head.	Diameter (1)	Diameter (2)	Diameter (3)	Diameter (4)	Mean Diameter.
mm.	mm.	mm.	mm.	mm.	mm.	mm.
821·837	49·5	64·25	64·33	64·19	64·29	64·27
826· „	44·5	61·31	61·31	61·26	61·37	61·31
831· „	39·5	58·08	58·17	58·05	58·24	58·14
836· „	34·5	54·45	54·50	54·14	54·50	54·46
841· „	29·5	50·41	50·48	50·37	50·41	50·42
846· „	24·5	46·02	46·10	45·99	46·06	46·04
851· „	19·5	41·23	41·18	41·12	41·02	41·17
856· „	14·5	35·38	35·44	35·36	35·39	35·39
859· „	11·5	31·37	31·46	31·35	31·34	31·38
862· „	8·5	26·69	26·79	26·69	26·74	26·75
864· „	6·5	23·11	23·22	23·15	23·13	23·15
Joint		×	×	×	×	×
866· „	4·5	19·04	19·11	19·01	19·05	19·05
Mean temp.—→		13°	14°	14°	14°	14°

867·837	3·5	16·43	16·55	16·49	16·49	16·49
868· „	2·5	13·36	13·57	13·54	13·43	13·38
Joint		×	×	×	×	×
869· „	1·5	10·08	10·11	9·96	10·09	10·04
870· „	0·5	5·48	5·40	5·36	5·36	5·40
Mean temp.—→		12·9°	14°	14·2°	14·6°	14·1°

*Appendix.*Total Length. *Short Model.* Temp. 12.2°C.

		mm.		mm.	
1		711.274	6	711.270	
2		711.258	7	711.282	
3		711.269	8	711.276	
4		711.268	9	711.286	
5		711.273	10	711.271	
Mean		mm. 711.272			

Diameter. *Short Model.*

Distance from tail.	Distance from head.	Diameter (1)	Diameter (2)	Diameter (3)	Diameter (4)	Mean Diameter.
mm.	mm.	mm.	mm.	mm.	mm.	mm.
10	701.272	6.31	6.29	6.27	6.29	6.29
20	691. "	12.05	12.04	12.03	12.04	12.04
30	681. "	17.38	17.38	17.38	17.37	17.38
Joint		x	x	x	x	x
40	671. "	22.20	22.20	22.20	22.19	22.20
50	661. "	26.86	26.85	26.87	26.84	26.86
60	651. "	31.50	31.45	31.45	31.45	31.46
70	641. "	35.83	35.77	35.76	35.76	35.78
80	631. "	39.91	39.88	39.86	39.86	39.88
90	621. "	43.79	43.76	43.74	43.74	43.76
100	611. "	47.49	47.45	47.42	47.46	47.46
110	601. "	51.12	51.06	51.04	51.04	51.07
120	591. "	54.60	54.55	54.56	54.57	54.57
130	581. "	58.04	57.98	57.98	57.99	58.00
140	571. "	61.30	61.27	61.24	61.25	61.26
150	561. "	64.41	64.36	64.35	64.37	64.37
160	551. "	67.47	67.41	67.39	67.44	67.43
170	541. "	70.35	70.30	70.27	70.32	70.31
180	531. "	72.98	72.95	72.95	72.94	72.96
Joint		x	x	x	x	x
190	521. "	75.64	75.59	75.59	75.59	75.60
200	511. "	78.14	78.05	78.06	78.09	78.08
Mean temp. →		12.9°	13.4°	13.0°	14.1°	13.4°

Distance from tail.	Distance from head.	Diameter (1)	Diameter (2)	Diameter (3)	Diameter (4)	Mean Diameter
mm.	mm.	mm.	mm.	mm.	mm.	mm.
210	501.272	80.40	80.35	80.34	80.40	80.37
230	481. "	84.87	84.92	84.80	85.03	85.91
Lug	0	0	0	0	0	0
250	461. "	89.13	89.13	89.07	89.09	89.11
270	441. "	92.94	92.90	92.88	92.90	92.91
290	421. "	96.55	96.46	96.49	96.49	96.50
310	401. "	99.61	99.57	99.57	99.56	99.58
330	381. "	102.09	102.05	102.04	102.04	102.06
345	366. "	103.44	103.46	103.46	103.50	103.47
370	341. "	105.02	104.98	105.00	105.01	105.00
385	336. "	105.74	105.68	105.66	105.71	105.70
Lug	0	0	0	0	0	0
410	301. "	106.46	106.45	106.43	106.45	106.45
430	281. "	106.61	106.62	106.59	106.60	106.61
443.272	263	106.63	106.62	106.63	106.64	106.63
463. "	243	106.54	106.51	106.53	106.53	106.53
488. "	223	106.16	106.18	106.16	106.17	106.17
503. "	203	105.30	105.21	105.27	105.27	105.26
528. "	183	103.55	103.51	103.52	103.51	103.52
548. "	163	101.12	101.11	101.09	101.13	101.11
Lug	0	0	0	0	0	0
Mean temp.→		13.3°	13.5°	13.6°	14.2°	14.7°

Distance from tail.	Distance from head.	Diameter (1)	Diameter (2)	Diameter (3)	Diameter (4)	Mean Diameter.
568.272	143	97.57	97.57	97.55	97.59	97.57
578. "	133	95.48	95.44	95.46	95.47	95.46
588. "	123	93.16	93.10	93.08	93.13	93.12
598. "	113	90.48	90.47	90.47	90.48	90.48
608. "	103	87.58	87.54	87.57	87.59	87.57
618. "	93	84.32	84.31	84.31	84.32	84.32
628. "	83	80.60	80.61	80.61	80.63	80.62
638. "	73	76.59	76.56	76.58	76.59	76.58
Joint	x	x	x	x	x	x
648. "	63	72.02	72.04	72.02	72.01	72.02
653. "	58	69.40	69.46	69.44	69.44	69.43
658. "	53	66.65	66.69	66.67	66.64	66.66
663. "	48	63.77	63.81	63.77	63.75	63.78

Appendix.

Distance from tail.	Distance from head.	Diameter (1)	Diameter (2)	Diameter (3)	Diameter (4)	Mean Diameter.
668. "	43	60.65	60.64	60.64	60.67	60.65
673. "	38	57.27	57.28	57.26	57.27	57.27
678. "	33	53.50	53.49	53.50	53.48	53.49
683. "	28	49.29	49.28	49.27	49.28	49.28
688. "	23	44.63	44.63	44.63	44.61	44.63
693. "	18	39.43	39.41	39.36	39.40	39.40
696. "	15	35.91	35.89	35.88	35.85	35.88
699. "	12	31.97	31.97	31.92	31.92	31.95
Mean temp.→		13.5°	13.5°	13.6°	13.6°	13.6°

mm.	mm	mm.	mm.	mm.	mm.	mm.
702.272	9	27.58	27.56	27.56	27.54	27.56
704. "	7	24.39	24.44	24.37	24.39	24.40
Joint		×	×	×	×	×
706. "	5	20.96	21.03	21.02	20.99	21.00
707. "	4	18.87	18.87	18.83	18.83	18.85
708. "	3	16.31	16.40	16.35	16.32	16.35
709. "	2	13.29	13.35	13.33	13.30	13.32
Joint		×	×	×	×	×
710. "	1	9.27	9.50	9.38	9.39	9.40
Mean temp.→		13.2°	13.5°	13.3°	13.8°	13.5°