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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 536

THE 6-FOOT-4-INCH WIND TUNNEL AT THE WASHINGTON NAVY YARD

By G. L. Desmond and J. A. McCrary

Aerodynamical Laboratory
C. & R. Department
Navy Yard, Washington, D. C.

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Preface.- Prior to July 1930, this laboratory was equipped with an 8- by 8-foot closed return-circuit wind tunnel (reference 1), and a 4- by 4-foot N.P.L.-type tunnel. The limitations of the latter together with demands for increased wind-tunnel testing facilities justified its replacement by a larger tunnel. Accordingly, the Bureau of Construction and Repair authorized the construction of an open-throat enclosed return-passage tunnel embodying the best available design information and scaled to suit housing facilities. This new tunnel with a circular jet of 6-foot-4-inch diameter provides a smooth air stream capable of a maximum speed of 120 miles per hour. The tunnel construction was begun in August 1930 and completed in April 1931. The aerodynamic balance was installed in September 1932.

The material of this report falls naturally into three parts. The first part is a description of the tunnel and its auxiliary equipment. The second part is a discussion of the calibration tests which have been carried on since the completion, but interrupted from time to time for the prosecution of more urgent work. The most important results of these tests are presented in graphical form. In conclusion, typical air force and moment curves are presented for the XPH-1 flying boat and compared with similar results from the 8- by 8-foot wind tunnel.

DESCRIPTION OF THE TUNNEL

General.- The 6-foot-4-inch wind tunnel is located on the second and third floors of the Model Storage Building, in which the 8- by 8-foot wind tunnel is also housed. A sectional elevation and the principal dimensions of the tunnel are given in figure 1.

The air flows from a pressure chamber 12 feet 8 inches square, accelerates through the converging entrance cone

to form a circular air jet of 6-foot-4-inch diameter, and passes the open test section, a distance of 6 feet 7 inches. Entering the belled exit cone, whose throat diameter is 6 feet 7-1/4 inches, the air decelerates through the enclosed return passage, completing its circuit on the floor above where the tunnel cross section once more becomes 12 feet 8 inches square.

The tunnel has an over-all length of 56 feet 4 inches, a height of 30 feet, and a maximum width of 12 feet 8 inches. It is constructed of sheet metal one-sixteenth inch thick, riveted into sections, and stiffened with steel angles. The sections are bolted together in assembly and supported by steel footings from the floors of the building. Air leakage is materially reduced by tarred roofing paper in the riveted seams, and felt between the bolted sections.

Test section.- The entrance and exit cones are made of laminated wood, each turned to size in a lathe, and bolted in place. This construction was of value during calibration tests when alterations were desired. A wooden platform below the open jet provides easy access to the test section and also serves as a protection for the balance. A carriage with a vertical member on each side of the air stream is suspended from the ceiling so that it may be moved upstream or downstream. This facilitates the suspension of test specimens in the air stream which do not require force measurements and which are not suitable for mounting on the aerodynamic balance.

Exit cone.- In the original construction the exit cone was belled from 8-foot diameter to a throat of 6-foot-8-inch diameter (see fig. 2), whence it expanded as a right circular cone in continuance of the return passage. Principally because of the expansion in passing the open test section, the entire air stream could not enter the return passage through the exit cone. As a result, a "stagnation ring" was formed in the bell and the outer boundary of air deflected making an undesirable spill into the vicinity of the operator. This exit cone was later replaced, the original 8-foot diameter decreased to 7 feet 3½ inches, equivalent to the "stagnation ring," and the spill allowed to pass on downstream.

Guide vanes.- As shown in figure 3, guide vanes are placed in the corners of the tunnel to assist in turning the air smoothly. The vanes immediately upstream from the

entrance cone have the dimensions as given in figure 3. The vanes in the remaining three corners of the tunnel are larger and are dimensioned according to figure 4. The cambered surfaces are circular arcs intersecting at the trailing edge and connected at the leading edge by an arc of small radius.

The vane contours were formed by nailing galvanized metal sheets to the wooden leading and trailing edges separated by properly shaped ribs.

Honeycomb.- A honeycomb placed ahead of the entrance cone served to stabilize the air flow and smooth out pressure surges. It is formed by 16 concentric rings whose radii increase in intervals of 4-3/4 inches to a maximum diameter of 12 feet 7 inches. Radial vanes are spot welded at uniform intervals between the rings, so that the cells have an approximate area of 17.4 square inches. The depth of the honeycomb is 24 inches.

Propeller and motor.- The air flow in the tunnel is generated by a three-blade, adjustable-pitch, aluminum-alloy propeller designated as Bureau of Aeronautics Design CS-3. The tips of the original 13-foot diameter propeller were cut off to a diameter of 10 feet 7½ inches for use in the tunnel.

The propeller is mounted on a 4-3/4-inch diameter steel drive shaft, 13 feet 9½ inches long and directly coupled to the driving motor outside of the tunnel. The d-c, shunt-wound, interpole-drive motor has a rating of 200 horsepower at 230 volts and 1,200 r.p.m. The Ward Leonard, or voltage control system, is used for speed regulation and permits the close adjustment of any desired air speed within the range of 10 to 120 miles per hour.

Four struts of 3/4- by 6-inch bar steel spaced 90° apart were originally installed to support the thrust bearing immediately behind the propeller. The propeller blades whipping past these struts set up pressure pulses that could be distinctly heard at the higher tunnel speeds, and could easily be distinguished from the other tunnel noises. To reduce the noise from this source, the above struts were replaced by a second set having a cross section of aerodynamic form but curved away from the propeller as far as strength considerations permitted. This arrangement, shown in figure 1, has been found beneficial in reducing some of the noise of operation.

Air-speed measurement.- A U.S.N. standard pitot tube, fastened to the face of the entrance cone and calibrated to the average dynamic pressure of the test section, is used in connection with a multiple-tube manometer to determine the air speed.

The manometer is shown at the left in figure 5. Eight glass tubes are partially imbedded in its sloping face, their ends terminating in side wells and the side wells properly connected to the pressure inlets and main liquid reservoir. The glass tubes are set at varying slopes in order to have nearly uniform graduations on the mile-per-hour scale. The ends of the tubes overlap to keep the meniscus of the indicating fluid (alcohol) always visible. An adjustable float in the main liquid well provides an adjustment for zero setting. The manometer has a range of 0 to 8.5 inches of water, equivalent to an air-speed range of 0 to 130 miles per hour.

Attack-angle measurement.- An intense line source of light, focused through a lens and reflected from a small mirror on the spindle of the aerodynamic balance to a ground-glass scale, serves to measure the angle of attack of airplane and airfoil models. This method increases the accuracy of setting over the vernier scale, with which the balance is equipped, and also permits the compensation of any bending or deflection that occurs in the balance system.

The mirror may be seen projecting through the windshield in figure 6 and the graduated scale is shown on the underside of the platform near the top center of figure 5. The mirror consists of five trapezoidal-shaped, plane facets of polished stainless steel fastened to a steel base in such manner as to form the concave segment of a prismatoidal surface. This assembly is clamped to the balance spindle and rotates with the test specimen about the moment axis when the angle of attack is changed. When the normal median plane of a facet is vertically above the center of rotation, the incident light beam is reflected downward in the vertical plane to the ground-glass scale. Rotating the mirror changes the incidence angle of the light beam with a resultant shift in the reflected image on the scale. With 5° rotation from the center position, the light beam is intercepted by the matched edges of an adjoining facet to form two images, one image leaving, and the other entering the scale. Each facet has a range of 10° rotation and the mirror has a total range of 50°.

THE AERODYNAMIC BALANCE

General.- The aerodynamic balance for the 6-foot-4-inch wind tunnel is a modification of the 6-component balance now in use in the 8- by 8-foot wind tunnel. The continued satisfactory working of the original balance since its installation in 1921, together with its ease of operation, adaptability to airplane-model testing, and accuracy of measurements, was sufficient evidence that a similar type balance would be desirable for the new wind tunnel. The new balance maintains the working principles of the original balance. The test specimen, however, is supported above the weighing mechanism instead of below it as in the case of the balance of the 8- by 8-foot tunnel. Only a brief description of the balance structure will be given here as a detailed discussion of the original balance may be found in reference 2.

The weighing mechanism of the balance is shown photographically in figure 5. The steel tube penetrating the platform at the top of the picture is the spindle, and carries the model as shown in figure 6. The windshield surrounding the spindle is made to the Navy No. II strut section, and reduces the tare forces of the balance to about 10 percent of the minimum drag of an average airplane model. A sectional elevation of the balance in figure 7 shows the important working parts.

Force system.- A steel frame mounted on four elastic steel posts is capable of very nearly frictionless motion in any direction in a horizontal plane. This motion is constrained, however, to provide horizontal translation in one direction, which motion, when connected through a bell-crank system to a weighing beam, provides for measurement of drag forces. There is no provision for the measurement of side drag forces since the necessity of such measurement is too infrequent, and they may be obtained on the balance of the 8- by 8-foot tunnel when needed. However, a side drag weighing mechanism could easily be installed on the new balance should it become necessary.

A lift tube is supported vertically at the center of the floating frame through elastic knife-edges to a properly counterbalanced weighing beam. The lift pipe is guided in frictionless vertical translation by horizontal, taut, elastic steel rods. These rods also serve to transmit any horizontal translation of the lift tube to the

floating frame. The lift and drag weighing beams are set above the surface of an all-metal table which surrounds the floating frame.

Moment system.- Inside of, and supported by, the upper end of the lift tube, is a close-fitting steel yaw tube. At the point of support, a worm gear, with a micrometer head, engaging a worm wheel on the yaw tube, serves to rotate the yaw tube, and eventually the test specimen, through any desired angle of yaw. Inside of the yaw tube, a third or center tube is supported as a frictionless torsional pendulum. A taut, steel wire, 0.135-inch diameter, anchored within, and coaxial with the center tube, is firmly grasped at its mid-point by a transverse bridge bar securely seated in the yaw tube. The anchors for this wire are of sufficient size to accommodate hardened, steel inserts. Four radial knife-edges, 90° apart, at each end of the yaw tube, press against these inserts at the axis of the center tube and hold it coaxial with the yaw tube. In this manner, the center tube pivots without friction relative to the yaw tube. This movement, however, is constrained and transmitted through a bell-crank linkage to the yawing moment weighing beam.

The center tube extends above the weighing beams into the air stream of the tunnel. A machined steel shank, fitted into the end of the center tube carries a pulley wheel in conjunction with a dovetail fitting for holding the test specimen. This pulley is mounted on an elastic knife-edge. Pitching moments about this knife-edge are transferred by a taut, steel belt to a weighing beam below, also mounted on elastic knife-edges. A worm sector and gear with a micrometer head in the belt-and-pulley system provides for pitching the test specimen in the air stream to any desired attitude. The moment weighing system, including the beam, is assembled on the upper end of the center tube as a separate unit and may be removed from the balance with ease, leaving the air stream clear for tests not requiring the use of the balance.

All forces and moments are weighed on beams vibrating between electric contact stops at the beam ends. The contacts energize the 1/200 horsepower motors used in driving the rider weights to balance positions. The movement between the stops never exceeds 0.003 inch, which movement when transferred to the floating members of the balance reduces to the order of 0.0006 inch as a maximum, and fixes

the displacements and resultant friction losses as negligible quantities. A micrometer disk at the end of each beam, together with graduations on the beam, make it possible to record forces to 0.001 pound and moments to 0.001 pound-inch. The balance is supported on a steel structure independent of the surrounding building. This leaves the balance free from vibrations of the building and improves its performance greatly.

CALIBRATION TESTS

General.- A transverse central area, 4 feet square, at the model test location, 2 feet 5 inches downstream from the entrance cone, was carefully surveyed for pressure distribution and for angularity of the air stream. Wire mesh properly located on the upstream side of the honeycomb served to bring the dynamic pressure distribution over the reference area within ±1 percent of the mean value at 40 miles per hour. The static pressure amounted to 1.5 percent of the dynamic pressure and decreased slightly at the outer boundaries of the transverse reference area. The wind direction was within ±0.2° of level. Measurements of the wind direction in yaw were not obtained. Surveys at stations upstream and downstream from the reference area, and at different air speeds, showed the above flow conditions to hold within desirable limits.

Operating characteristics.- Measurements of the power input and speed of the drive motor were made for the airspeed range of the tunnel. These quantities are plotted in figure 8, together with the calculated horsepower of the air stream at the test section and the resultant conventional energy ratio. The horsepower input to the drive motor was calculated from the voltmeter and ammeter readings for the several air speeds. Data and facilities were not available for calculating the motor efficiency, and this factor is not included in the derived energy ratio.

The energy ratio at the usual test air speed of 40 miles per hour, is 1.28. The maximum energy ratio of 1.56 occurs at the maximum air speed of 120 miles per hour. Before the installation of the honeycomb, this maximum ratio was 1.75. The comparatively low value of this ratio is due in part to the propeller, the blades of which were set at a pitch angle to load the drive motor to rated capacity. In consequence, the pitch angle is well below the value for best efficiency.

Pulsations and bleeder holes.- After reducing the bell on the exit cone (see p. 2), violent pulsation developed at critical air speeds of 30 and 55 miles per hour, and at all speeds above 85 miles per hour. The division of the outer air boundary at the lip of the exit cone was unstable, and the resultant alternate inflow and spill caused periodic pressure pulses that came into resonance with the tunnel structure at these air speeds.

As a first trial at damping the pulsations, 10 openings, each 4 by 8 inches, were cut in the return passage 11 feet downstream from the exit cone. These were distinctly beneficial, and increasing the number of openings to 20, eliminated the severe pulsations. Some minor vibrations and pulsations remained but their origin could be traced to the tunnel structure. These were eliminated by installing tie rods at vital points and by fastening wood lagging to the large flat surfaces of the pressure chamber.

Static pressure gradient downstream.- The downstream static pressure gradient, measured on the center line, was adjusted to within desirable limits after several changes of the entrance and exit cones. The results for ten different entrance- and exit-cone conditions are shown in figure 2, in as nearly self-explanatory manner as possible. Condition I shows the gradient of the original tunnel, in which there was no flare on the entrance cone, and the exit cone had the large bell previously noted. As a first trial to improve this gradient, a flare was formed of wooden ribs covered with cardboard and fastened to the face of the entrance cone (condition II). In the remaining tests the flare was formed by working out the interior surface at the mouth of the entrance cone to a template. A decrease in the exit-cone throat diameter was accomplished by fastening wooden bands in the throat. These bands were faired as well as possible to eliminate undue disturbance.

From the results, it may be seen that the flare on the entrance cone affects the pressure gradient considerably, the effect reaching with decreasing magnitude to the exit cone. Condition X is a graph of the pressure gradient existing in the present calibration. It was considered satisfactory because the variation over a normal model length is within ±0.5 percent of the dynamic pressure, and the air flow is smooth. Conditions II, III, and IV show a lower pressure at the entrance cone, but this was obtained at the expense of a noticeably rough boundary layer. The same pressure reduction could probably be accomplished with

smoother flow if the length of the flare along stream were increased. This was not possible without decreasing the length of the open jet or cutting into the entrance cone farther than desired.

Conditions VI, VII, and VIII show that a decrease in area of the exit cone lowers the static pressure at the exit cone slightly. Further, this effect carries only to about midway of the test section and does not change the pressure at the entrance cone.

The drop in static pressure near the exit cone in conditions IX and X, as compared to prior conditions, was a result of cutting the bleeder holes in the return passage. An earlier survey of the return passage had shown an abnormal pressure rise from the exit cone to the first set of guide vanes. Apparently the air was being dammed at this point. The bleeder holes permitted a pressure relief but did not eliminate the air damming at the vanes. In order to do this, a relocation of the vanes would be necessary.

XPH-1 FLYING-BOAT TESTS

General.- The agreement of results for several airfoil and airplane models tested in the 6-foot-4-inch wind tunnel and in the 8- by 8-foot wind tunnel was sufficiently close to permit routine testing to be undertaken. Accordingly, the XPH-1 flying boat was given a complete routine test in pitch and yaw. The lift, drag, and pitching-moment curves from this test for neutral elevator are plotted in figures 9 and 10, in comparison with a similar test in the 8- by 8-foot tunnel. These results have not been corrected for tunnel-wall interference as such corrections are never applied to ordinary airplane-model tests, and it is thought that the comparison of measured forces are the most desirable. An exemplary plot of these corrections to drag are shown in figure 10, and their application brings the lift vs. drag curves into good agreement.

The pitching-moment curve from the 6-foot-4-inch tunnel, shown in figure 9, indicates static instability in the attack-angle range of -8° to -3°. This condition was contradictory to full-scale performance, and it was further disproved in the 8- by 8-foot tunnel test. In addition, the latter test shows a better stability throughout

the entire test range. Such a condition is expected in comparing results from open-throat and closed-throat tunnels, but the difference in this case exceeds the expectation sufficiently to indicate an external deficiency in the operation of the 6-foot-4-inch tunnel. A careful study of the possible discrepancies disclosed two major considerations. This difference could be due to the turbulence of the air stream as it affected the flow around the hull of the flying boat, or to an interference from the windshield of the balance spindle. Both of these possibilities were investigated.

Turbulence.- The drag of a 5-inch diameter brass sphere was used as an index of turbulence of the air flow in the two tunnels. For drag measurement, the sphere was supported on a streamlined clip fastened to the spindle of the aerodynamic balance. The tare drag of the clip was measured with the sphere suspended in close proximity to, but not touching, the clip. It has been shown by tests (reference 3) that supporting the sphere in the above manner introduces an interference in the boundary layer in such manner as to increase the drag of the sphere. An attempt was made to approximate this interference drag by placing a dummy clip above but not touching the sphere, thereby doubling the interference. The drag coefficients of the sphere calculated from test data thus obtained are plotted against Reynolds Number in figure 11. Using the drag coefficient of 0.3 as a criterion, the critical Reynolds Number of the 6-foot-4-inch wind tunnel is R_c = 295,000, and the corresponding value in the 8- by 8-foot tunnel is R_c = 210,000. These values are subject to a small error because of the method of support, but the comparison between the two tunnels is thought to be reliable. The high value of R_c in the 6-foot-4-inch tunnel, indicating comparatively smooth air flow, was confirmed by the abrupt break in lift at the burble of an airplane or airfoil model.

Two methods were used to increase the turbulence in the 6-foot-4-inch tunnel. In the first case, a grating of strings of 0.06-inch diameter and spaced one half inch apart was stretched horizontally across the air stream at the entrance cone. In the second case, a wire screen of 0.105-inch-diameter wire and 1-1/4-inch mesh was placed about 6 inches inside the entrance cone. The turbulence of the air stream as indicated by the sphere drag (fig. 11) was thus increased to equal the turbulence of the 8- by 8-foot tunnel.

Force tests were made on the XPH-1 flying boat for each of the above conditions, and the results are plotted in comparison with the original values in figure 9. The drag of the model was decreased in the attack-angle range of -8° to -3°, but it remained unaffected for the remainder of the test range. The slope of the lift curve and the maximum lift of the model were both increased. The sharp break in lift at the burble was also diminished. These changes in forces, however, failed to change the pitching moments except in the negative range in question. Here the previous instability was improved to a neutral stability, indicating that the divergence of the original results was due in part to a difference in flow conditions.

Although the sphere drag tests indicated that the turbulence of the 6-foot-4-inch tunnel was increased to closely approximate that of the 8- by 8-foot tunnel, the lift curve of the XPH-1 flying boat indicates a greater turbulence effect by use of the string grating than by use of the wire screen. From this it would seem that the sphere measures a "resultant" turbulence that is not completely defined. In addition to a component of magnitude, turbulence may have a component of a dimension which is the "coarseness" or "fineness" of the turbulence grain, and this component is effective in the air flow about a body. No means are available as yet for the complete measurement of turbulence..

Spindle interference.- Because the pitching-moment curves from the two tunnels did not have the same slope, yet the lift and drag forces agreed within the limits of tunnel-wall corrections, it was assumed that the horizontal tail surfaces were being deprived of their full lifting effort by an adverse air flow induced by the windshield of the balance spindle. This was proved by mounting an airfoil on the balance in such manner that the angle of attack could be kept constant and the airfoil rotated through each of the regions traversed by the wings and the tail surfaces of the flying boat. In both cases the lift of the airfoil decreased as its position shifted to correspond to an increase in attack angle of the flying boat. The percentage decrease in lift at the normal wing position was relatively small and not serious, but in the case of the tail-surface position, this decrease was appreciable.

Wind-direction surveys with a yaw head in the vicinity of the windshield showed that the wash over the un-

shielded spindle was only slightly better than with the windshield in place. End plates proved of no value in destroying the wash unless the plate was quite large. Under these circumstances the model was subjected to an interference by its proximity to the large plate. Finally, the shield was made as neat and as small as the movement of the model permitted. A small vane, 4 by 12 inches, was fastened to the top rear of the windshield and tilted to the air stream to form a counteracting up-wash. The inclination of this vane was determined by the condition of constant lift on the previously mentioned airfoil for all positions.

In addition, three vanes of sheet metal, 2 by 8 feet, were hinged on the honeycomb and adjusted until the average wind direction forward of the windshield was within $\pm 0.2^{\circ}$ to level.

The results of a test on the XPH-1 flying boat under these corrected conditions are shown in figure 10, and the force and moment plots from the two tunnels now show good agreement.

CONCLUSIONS

The 6-foot-4-inch wind tunnel and its auxiliary equipment has proven itself capable of a continuous and reliable output of data. The real value of the tunnel will increase as experience is gained in checking the observed tunnel performance against full-scale performance. Such has been the case of the 8- by 8-foot tunnel, and for that reason the comparisons in the calibration tests have been presented.

Aerodynamical Laboratory,
C. & R. Department, Navy Yard,
Washington, D. C.

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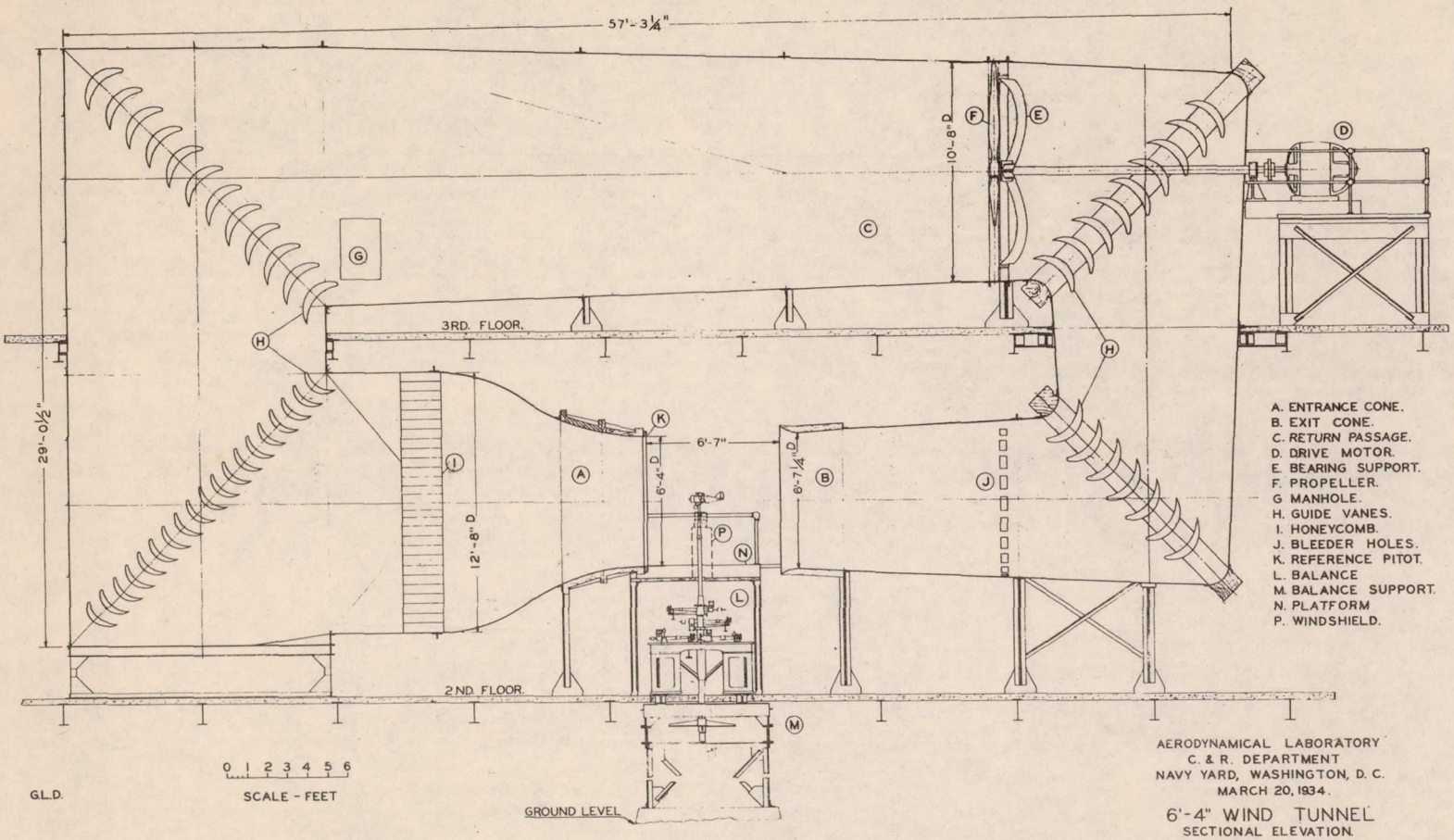

57'-3¼"
29'-0½"
10'-8" D
12'-8" D
6'-4" D
6'-7"
6'-7¼" D
3RD. FLOOR.
2ND. FLOOR.
GROUND LEVEL
A. ENTRANCE CONE.
B. EXIT CONE.
C. RETURN PASSAGE.
D. DRIVE MOTOR.
E. BEARING SUPPORT.
F. PROPELLER.
G MANHOLE.
H. GUIDE VANES.
I. HONEYCOMB.
J. BLEEDER HOLES.
K. REFERENCE PITOT.
L. BALANCE
M. BALANCE SUPPORT.
N. PLATFORM
P. WINDSHIELD.
0 1 2 3 4 5 6
SCALE - FEET
G.L.D.
AERODYNAMICAL LABORATORY
C. & R. DEPARTMENT
NAVY YARD, WASHINGTON, D. C.
MARCH 20, 1934.
6'-4" WIND TUNNEL
SECTIONAL ELEVATION.

Figure 1.

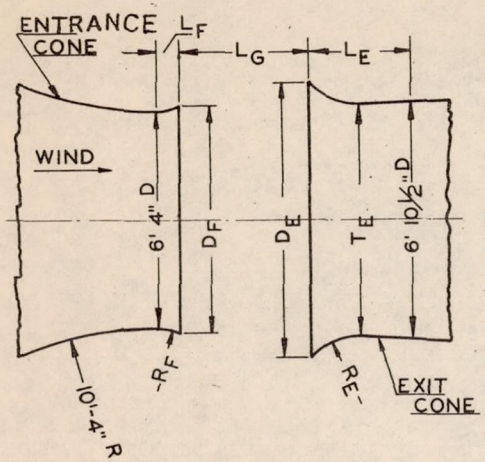


TABLE OF DIMENSIONS.

COND. NO.	ENT. CONE D_F	ENT. CONE R_F	ENT. CONE L_F	EXIT CONE D_E	EXIT CONE T_E	EXIT CONE R_E	EXIT CONE L_E	GAP L_G	REMARKS
I	6'-4"	0	0	8'-0"	6'-8"	2'-0"	3'-0"	6'-10½"	ORIGINAL DESIGN
II	6'-5 7/16"	1'-6"	5"	7'-3"	6'-8"	2'-0"	2'-6¾"	6'-8¾"	ENT. CONE FLARED
III	6'-4¾"	FAIRED	4"	7'-3"	6'-6½"	2'-0"	2'-6¾"	7'-3¾"	ENT. CONE FLARED
IV	6'-4¾"	FAIRED	6"	7'-3"	6'-6½"	2'-0"	2'-6¾"	7'-1¾"	ENT. CONE FLARED
V	6'-4¼"	∞	4"	7'-3"	6'-6½"	2'-0"	2'-6¾"	7'-3¾"	ENT. CONE FLARED
VI	6'-4⅜"	3'-0"	4"	7'-3"	6'-8"	2'-0"	2'-6¾"	7'-3¾"	EXIT CONE THROAT DIAMETER DECREASED.
VII	6'-4⅜"	3'-0"	4"	7'-3"	6'-6½"	2'-0"	2'-6¾"	7'-3¾"	EXIT CONE THROAT DIAMETER DECREASED.
VIII	6'-4⅜"	3'-0"	4"	7'-3"	6'-5"	2'-0"	2'-6¾"	7'-3¾"	EXIT CONE THROAT DIAMETER DECREASED.
IX	6'-4⅜"	∞	6"	7'-3½"	6'-7¼"	1'-6"	3'-1"	6'-7"	BLEEDER HOLES IN RETURN PASS. NEW EXIT CONE.
X	6'-4 9/16"	∞	9"	7'-3½"	6'-7¼"	1'-6"	3'-1"	6'-7"	EXISTING CONDITION.

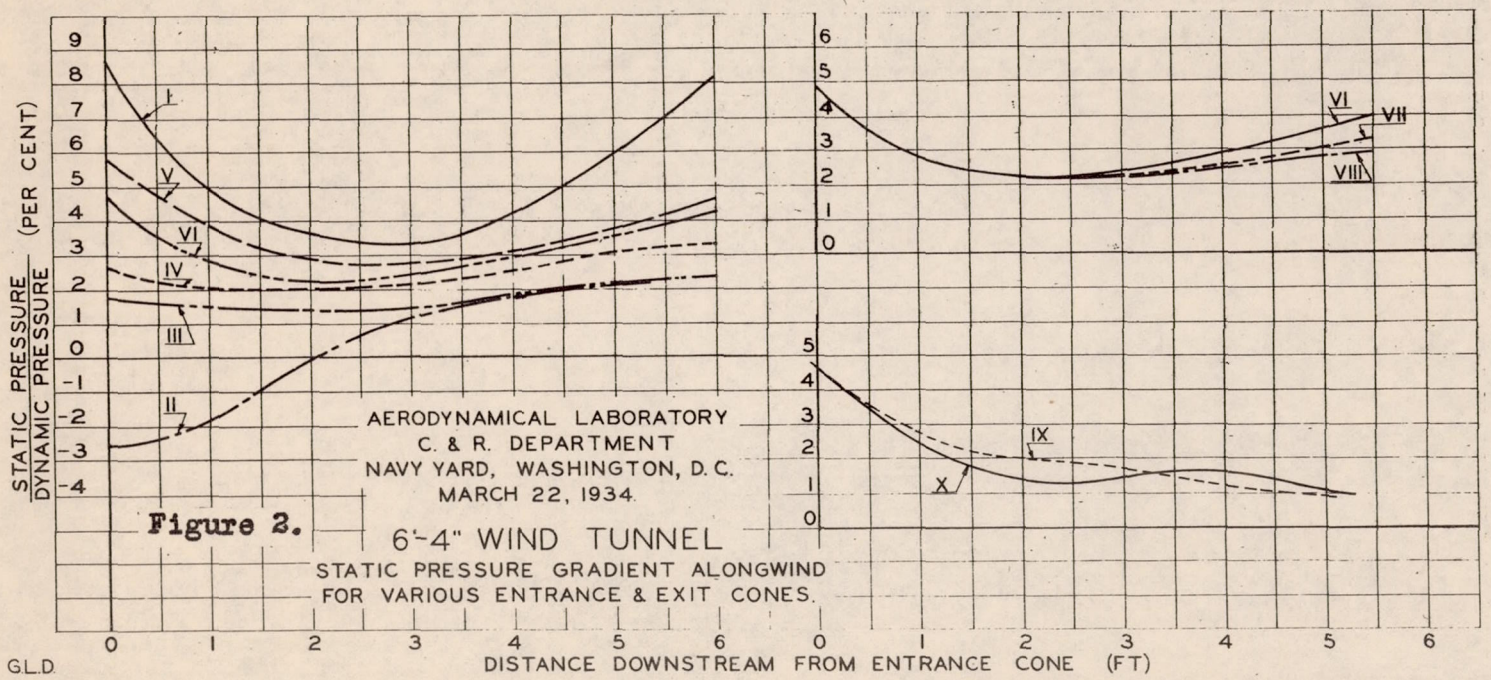


Figure 2.

G.L.D.

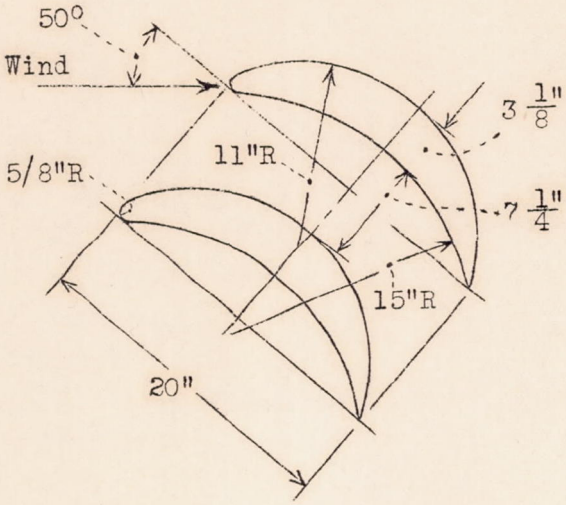


Figure 3.

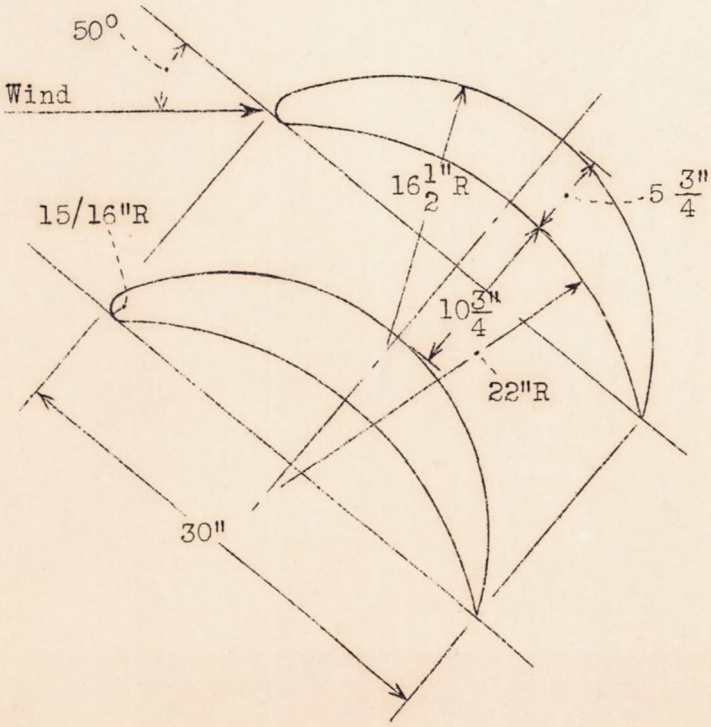


Figure 4.

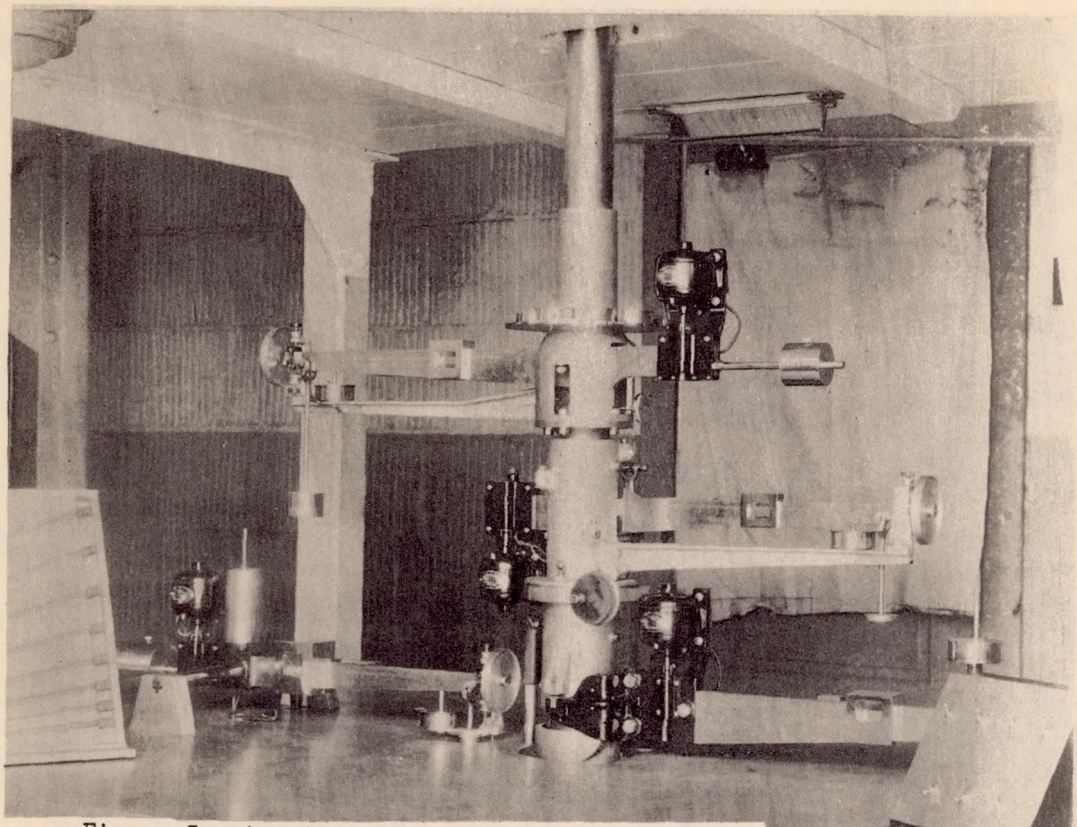


Figure 5.- Aerodynamical balance of the 6'-4" wind tunnel.

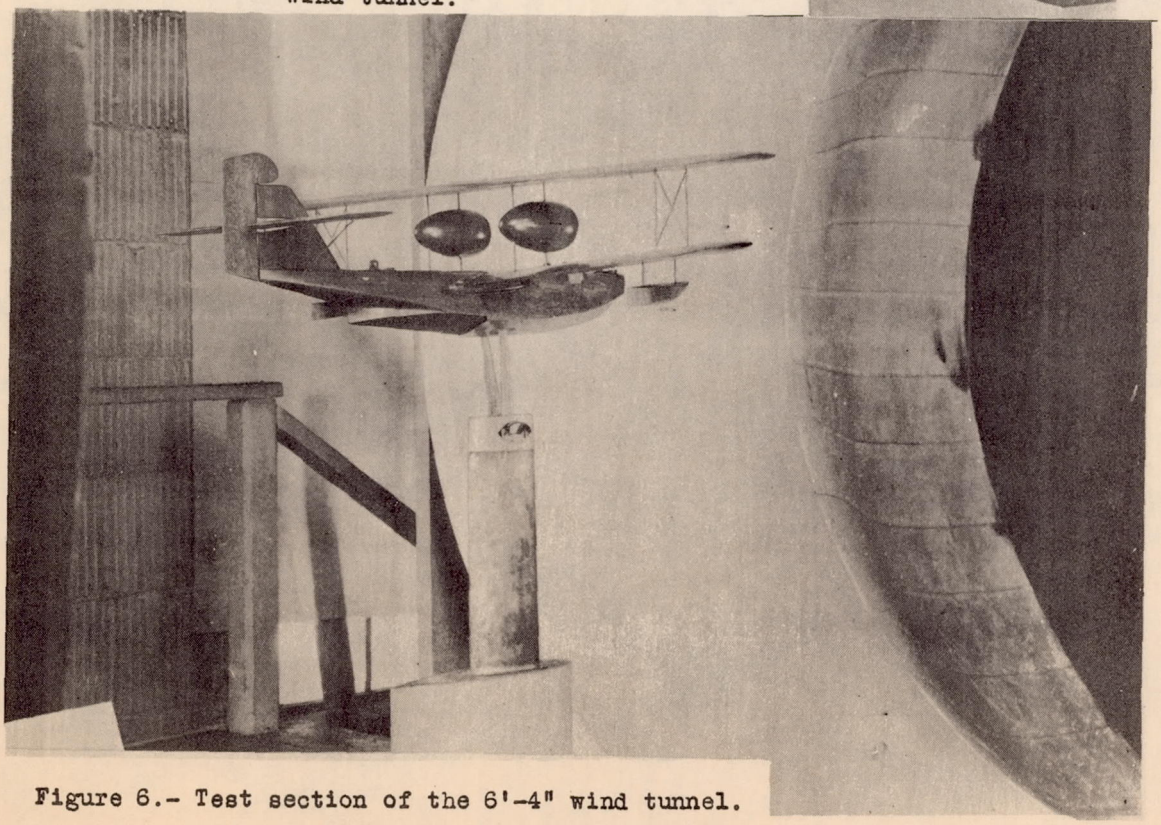


Figure 6.- Test section of the 6'-4" wind tunnel.

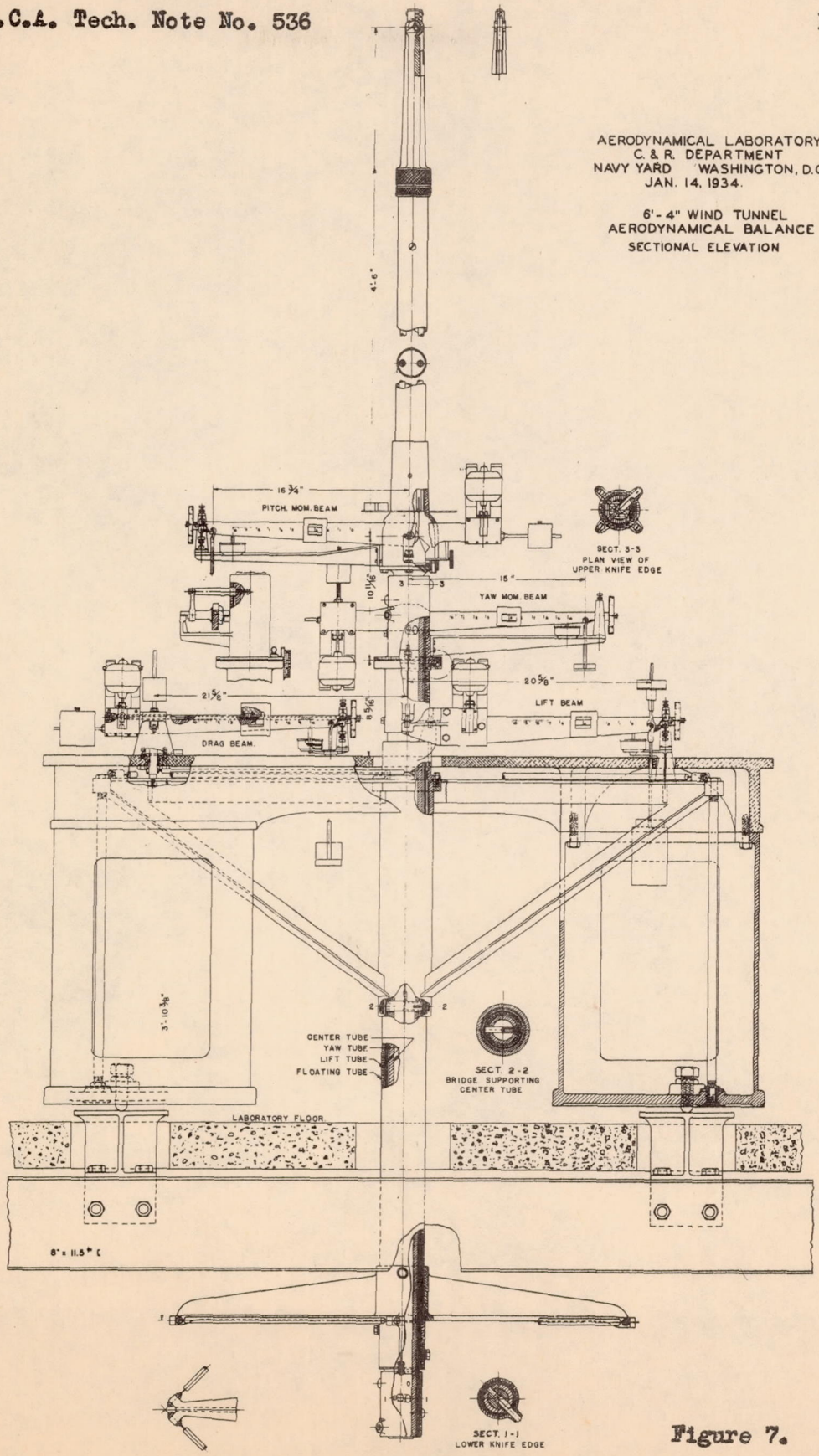
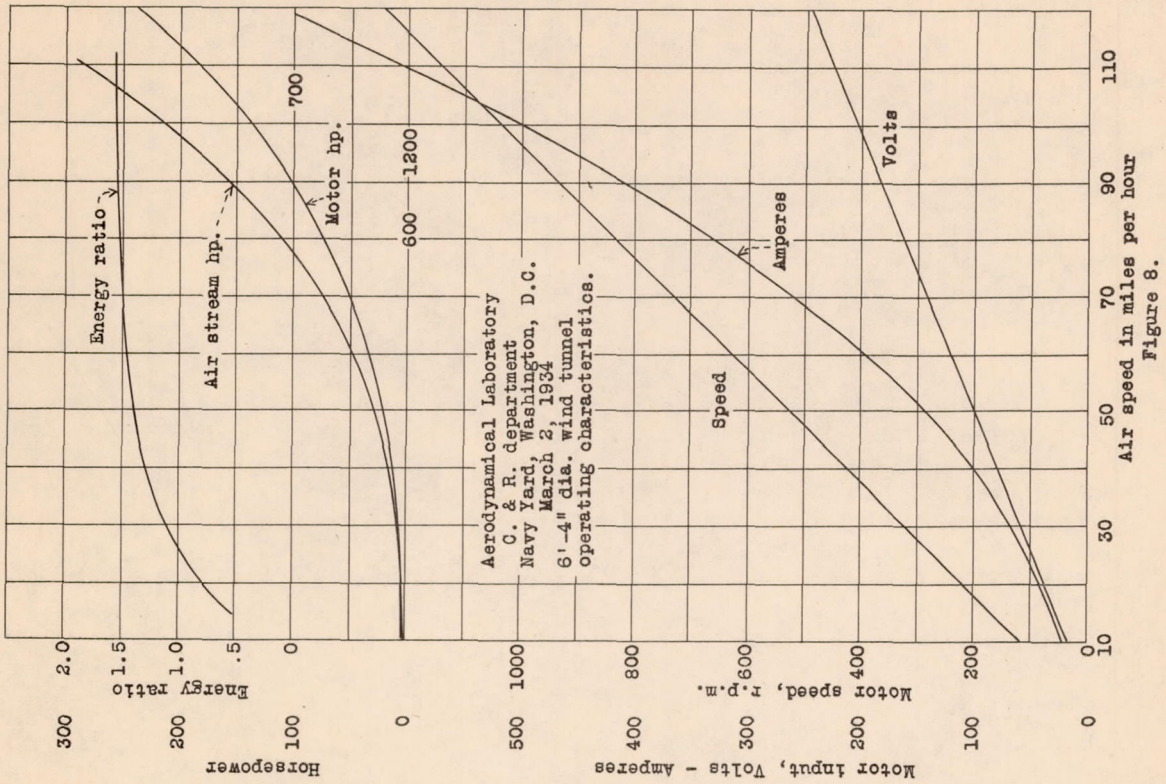

AERODYNAMICAL LABORATORY
C. & R. DEPARTMENT
NAVY YARD WASHINGTON, D.C.
JAN. 14, 1934.
6'-4" WIND TUNNEL
AERODYNAMICAL BALANCE
SECTIONAL ELEVATION
4'-6"
16 3/4"
PITCH. MOM. BEAM
SECT. 3-3
PLAN VIEW OF
UPPER KNIFE EDGE
15"
YAW MOM. BEAM
10 1/16"
20 5/8"
21 5/8"
8 5/16"
LIFT BEAM
DRAG BEAM.
3'-10 3/8"
CENTER TUBE
YAW TUBE
LIFT TUBE
FLOATING TUBE
SECT. 2-2
BRIDGE SUPPORTING
CENTER TUBE
LABORATORY FLOOR
8" x 11.5# C
SECT. 1-1
LOWER KNIFE EDGE

Figure 7.


Energy ratio
Air stream hp.
Motor hp.
700
600
1200
Aerodynamical Laboratory
C. & R. department
Navy Yard, Washington, D.C.
March 2, 1934
6'-4" dia. wind tunnel
operating characteristics.
Speed
Amperes
Volts
Air speed in miles per hour
Figure 8.
Energy ratio
Horsepower
Motor speed, r.p.m.
Motor input, Volts - Amperes

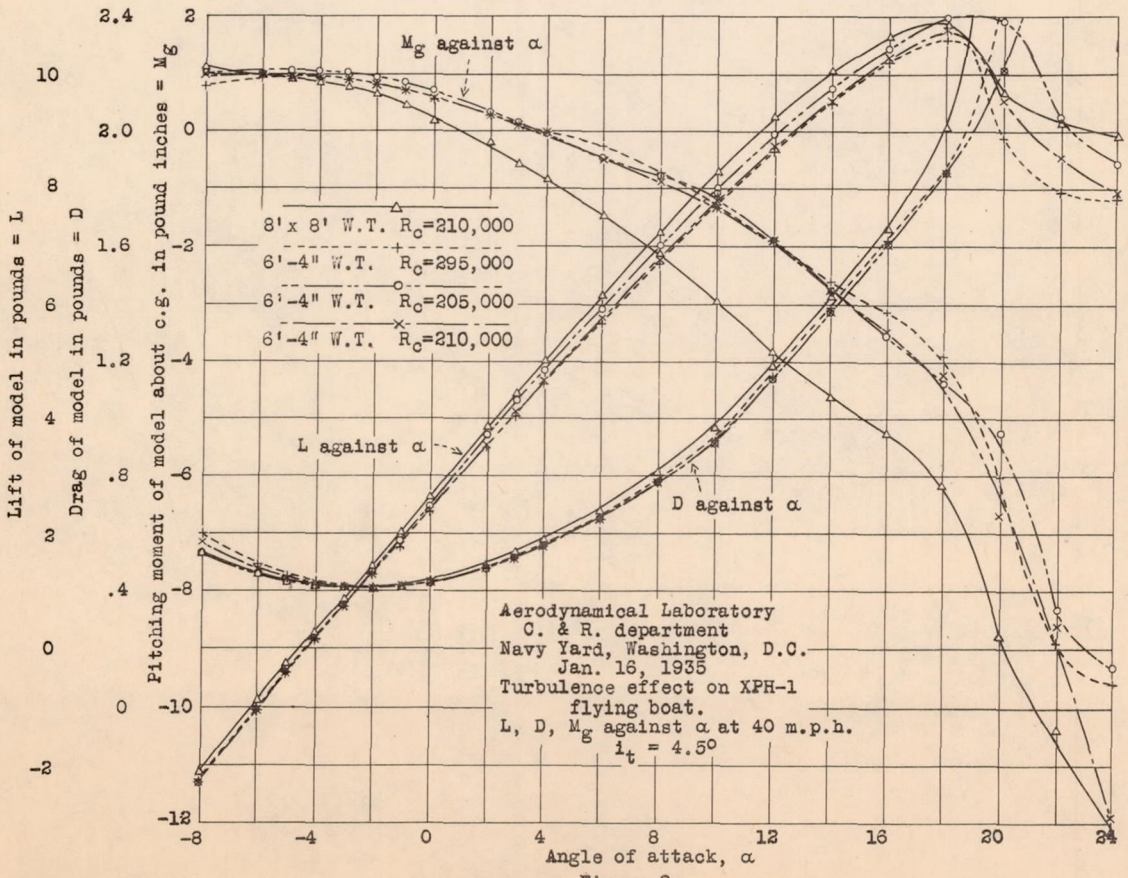
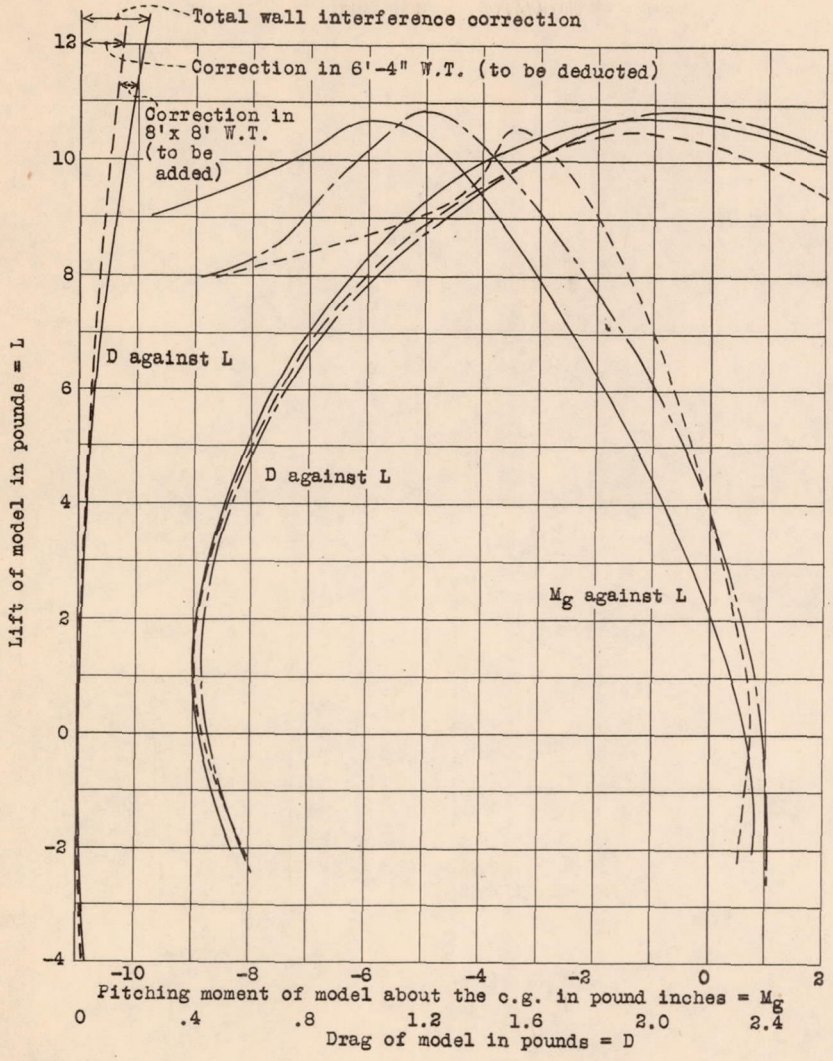

Lift of model in pounds = L
Drag of model in pounds = D
Pitching moment of model about c.g. in pound inches = M_g
M_g against α
8'x 8' W.T. R_c=210,000
6'-4" W.T. R_c=295,000
6'-4" W.T. R_c=205,000
6'-4" W.T. R_c=210,000
L against α
D against α
Aerodynamical Laboratory
C. & R. department
Navy Yard, Washington, D.C.
Jan. 16, 1935
Turbulence effect on XPH-1
flying boat.
L, D, M_g against α at 40 m.p.h.
i_t = 4.5°
Angle of attack, α

Figure 9.



8'x 8' W.T. $i_t = 5.5^\circ$

6'-4" W.T. $i_t = 5.5^\circ$ original test.

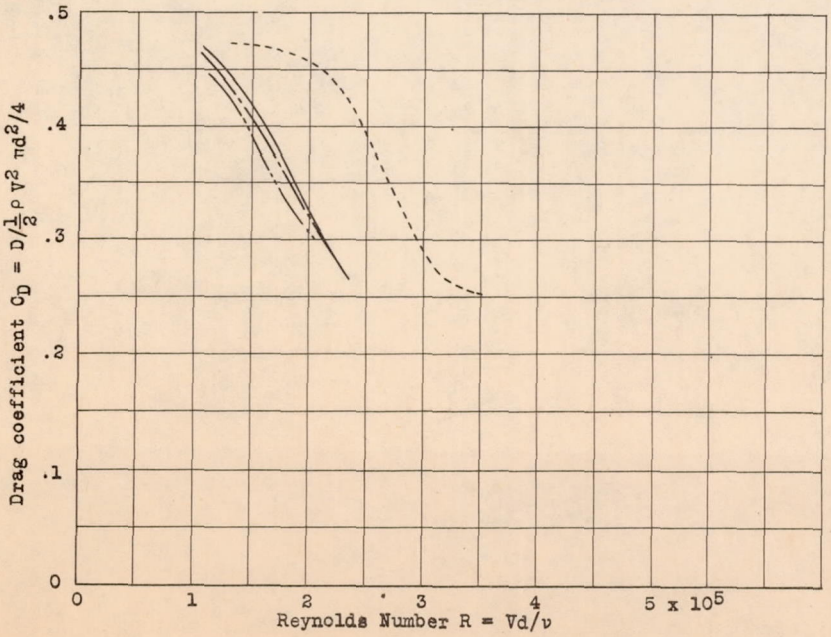
6'-4" W.T. $i_t = 4.5^\circ$ spindle interference corrected.

Aerodynamical Laboratory
C. & R. department
Navy Yard, Washington, D.C.
March 4, 1935
XPH-1 flying boat spindle interference correction.

D & M_g against L at 40 m.p.h.

$\alpha = -8^\circ$ to $+24^\circ$

Figure 10.



8' x 8' Wind tunnel

6'-4" W.T. R_c =295,000

6'-4" W.T. .06" string spaced .5".

6'-4" W.T. .105" wire, 1.25" mesh.

Aerodynamical Laboratory
C. & R. department
Navy Yard, Washington, D.C.
Jan. 16, 1935
Turbulence measured by sphere drag.

Sphere drag against Reynolds Number.
Sphere dia. = 5".

Figure 11.