CHARACTERISTICS OF NINE RESEARCH WIND TUNNELS OF THE LANGLEY AERONAUTICAL LABORATORY

NACA

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CHARACTERISTICS OF NINE RESEARCH WIND TUNNELS

OF THE LANGLEY AERONAUTICAL LABORATORY

INTRODUCTION

This document was prepared in response to requests of the aircraft industry for information on NACA research wind tunnels. Characteristics are given of nine selected wind tunnels of the NACA Langley Aeronautical Laboratory located at Langley Field, Virginia. A table summarizing certain important characteristics of these wind tunnels is given immediately following the introduction. Characteristics of six Ames wind tunnels are given in a separate volume (ref. 1).

Wind tunnels, accessory equipment, and instrumentation are continually being improved as new and better techniques are developed. It is essential, therefore, that agencies planning models for tests in the wind tunnels described in this manual consult the staff of the Langley Aeronautical Laboratory to take advantage of the latest techniques and equipment. Details such as balance dimensions and model-mounting dimensions can be supplied at that time. In some cases models can be designed to accommodate tests in more than one NACA wind tunnel.

NACA research facilities in general are available for use by other Government agencies provided the projects are of sufficient importance to warrant interference with the NACA research program, and, provided further, that other suitable facilities are not available, either commercially or in the Government. A complete index of all transonic and supersonic wind tunnels in the United States is given in reference 2.

Proprietary tests on a fee basis are conducted in NACA research facilities only in exceptional circumstances. On the other hand, testing time is reserved in the NACA Unitary Plan Wind Tunnels for proprietary tests on a fee basis if the need arises (ref. 3). It is the policy of the NACA not to compete with commercially available facilities.

Requests for all projects should be addressed to the Director, National Advisory Committee for Aeronautics, 1512 H Street, N. W., Washington 25, D. C. The usual practice is to arrange for conferences between the NACA, the interested contractor, and - in the case of Government projects - the sponsoring branch of the Government. Advance consultation with the NACA should always take place prior to making definite plans for tests in NACA facilities.

Requests for NACA tests from the Air Force, Navy, and Army are coordinated by two NACA allocation and priority groups, one on aircraft and missiles projects and one on propulsion projects. Each group comprises one member each from the NACA, the Air Force, the Navy, and the Army. Requests for tests from military contractors should be processed via the appropriate military member of the pertinent allocation and priority group. Currently, the Air Force members are located at the Wright Air Development Center, and the Navy members at the Bureau of Aeronautics. The Army member for the aircraft and missile group is located at the Ballistic Research Laboratories, Aberdeen Proving Ground, and for the propulsion group in the Office of the Chief of Ordnance.

REFERENCES

1. Anon: Characteristics of Six Research Wind Tunnels of the Ames Aeronautical Laboratory. NACA, 1957.
2. Anon: Characteristics of Major United States Transonic and Supersonic Wind Tunnels and Air-Breathing Engine Test Facilities. CAF 201/2, Office Assist. Secy. Defense, Res. and Dev., Oct. 3, 1956. (Distributed by ASTIA.)
3. Anon: Manual for Users of the Unitary Plan Wind Tunnel Facilities of the National Advisory Committee for Aeronautics. NACA, 1956.

SUMMARY OF WIND-TUNNEL CHARACTERISTICS

Wind tunnel	Test section size, ft	Mach number	Stagnation pressure, atm.	Stagnation temperature, °F	Reynolds number per ft, × 10^{-6}	Dynamic pressure, lb/sq ft	Typical model size	Model support system	Flow visualization
16-foot transonic tunnel	(Octagonal) 15.5 between sides 22 long	0.2 to 1.10	1.00	40° to 180°	1.2 to 4.0	58 to 830	5 ft span 8 ft long	Sting type on vertical strut	Shadowgraph
8-foot transonic tunnel	(Dodecagonal) 7.3 between sides 5 long	0.2 to 1.20	1.00	40° to 180°	1.2 to 4.0	58 to 870	2 ft span 2.5 ft long	Sting type on vertical strut	Schlieren
8-foot transonic pressure tunnel	7.13 high 7.14 wide 5 long	0.6 to 1.20 and 1.43 with slot filler blocks	0.25 to 1.00	123°	1 to 4	100 to 910	2 ft span 2.5 ft long	Sting type on vertical strut	Schlieren
4- by 4-foot supersonic pressure tunnel	4.5 high 4.5 wide 7 long	1.4, 1.6, 1.8, and 2.0	0.25 to 2.0	110°	4.17 at M = 1.4 3.98 at M = 1.6 3.71 at M = 1.8 3.41 at M = 2.0 (at 1 atmosphere)	912 at M = 1.4 892 at M = 1.6 835 at M = 1.8 757 at M = 2.0 (at 1 atmosphere)	2 ft span 3 ft long	Sting type and semispan type	Schlieren
7- by 10-foot high-speed tunnel	6.6 high 9.6 wide 8.7 long	0.4 to 0.95	1.00	30° to 160°	2.5 to 4.0	200 to 750	2 to 3 ft span 3 to 4 ft long	Sting type and semispan type	---------
7- by 10-foot 300-MPH tunnel	7 high 10 wide 15 long	0 to 0.4	1.00	40° to 110°	0 to 2.5	0 to 200	4 to 7 ft span 5 to 8 ft long	Strut type on balance frame, or sting type	---------
20-foot free spinning tunnel	(Dodecagonal) 20 between sides 25 long (vertical)	0 to 0.09	1.00	40° to 100°	0 to 0.62	0 to 11	1 to 2 ft span 2 to 3 ft long	Free-spinning and gooseneck rotary arm	---------
Full-scale tunnel	(Open throat) 30 high 60 wide 56 long	0 to 0.14	1.00	40° to 100°	0 to 1.0	0 to 30	50 ft span 15,000 lb gross wt. 25 ft diam. for helicopter rotors	Strut type on balance frame	---------
Transonic blowdown tunnel	(Octagonal) 2.2 between sides 1 to 1.5 long	0.6 to 1.45	1 to 5	Continually decreases during run. Maximum decrease is 40°	2 to 27	600 to 4,400	0.83 ft span 1 to $2\frac{1}{2}$ - inch body diameter	Sting type on curved vertical strut	Schlieren

16-FT TRANSONIC

THE LANGLEY 16-FOOT TRANSONIC TUNNEL

Langley Aeronautical Laboratory
Langley Field, Virginia

NACA

LANGLEY 16-FOOT TRANSONIC TUNNEL

GENERAL DESCRIPTION

The Langley 16-foot high-speed tunnel has been in operation as a transonic tunnel since December 1950. The tunnel, as shown in figure 1, is a single return, atmospheric type, with an air exchange for cooling. The air-exchange tower has adjustable intake and exit vanes to provide a small amount of control over the tunnel air temperature. Normally the vanes are adjusted to give the maximum amount of air exchange, approximately 20 percent. The power section of the tunnel, located between two sets of turning vanes, consists of two counterrotating fans, 34 feet in diameter, each of which is driven through a long shaft by a 30,000-horsepower electric motor externally mounted from the ends of the power section. The pitch of the fan blades is fixed, but their rotational speed may be controlled continuously up to a maximum of 366 revolutions per minute by use of a variable-frequency power supply for the drive motors.

TEST SECTION

A sketch of the test section is shown in figure 2, and figure 3 is a photograph of the test section with the top portion in the raised position for installation of a model. The flats (or walls), the open slots, the diffuser entrances, and the model sting-support system are all enclosed in a cylindrical tank which is 52 feet long and 32 feet in diameter. The flats make up the sides of the octagonal-shaped test section, and eight slots comprising approximately 1/8 of the total periphery are located at the corners between the flat sides. The slots terminate at the diffuser entrances. The wall-divergence angle may be varied remotely from 0° to about 0.8° by changing the slope of a forward straight portion of the flats relative to the tunnel center line. For most investigations the walls are diverged 0.08° and the Mach number variations over the entire Mach number range are within ±0.006 throughout a test region length of about 22 feet.

TEST CONDITIONS

The Mach number in the test region may be varied from about 0.2 to 1.08. Since the speed of sound in air depends only on temperature, the velocity at a particular Mach number in the test region depends upon the stagnation temperature, which varies over a considerable range in the Langley 16-foot transonic tunnel. This range of stagnation temperatures is shown in figure 4. Note that the upper limit for stagnation temperature is 180° F, which has been imposed because of the effect of higher temperatures on the structural characteristics of the wind-tunnel fan blades and on the accuracy of the strain-gage balances used in test models. Also shown in figure 4 is the variation of Reynolds number (per foot) and dynamic pressure with Mach number. Since the Langley 16-foot transonic tunnel operates at a stagnation pressure which is equal to atmospheric, the test conditions at any given Mach number may easily be determined from a knowledge of the atmospheric conditions, the information presented in figure 4, and any compressible-flow tables for air which give pressure, temperature, and density ratios referred to stagnation conditions.

MODEL-SUPPORT SYSTEM

The sting-type support used in the 16-foot transonic tunnel is mounted from a 14-inch-diameter cylindrical body which is supported on a vertical cantilever strut of circular-arc section as shown in figure 5. The strut is mounted on shoes which slide on a circular-arc track so that the model angle of attack can be varied from -5° to +15° about a point (tunnel station 134) on the tunnel center line and 95.25 inches ahead of the cylindrical body. By using angle adapters, or couplings, the following angle range may be obtained:

Adapter angle, deg	Angle-of-attack range, deg
0	-5 to +15
2	-3 to +17
5	0 to +20
10	+5 to +25
15	+10 to +30

Angles of yaw equal to the adapter angles may be obtained by manually rotating the adapter 90°; or, depending on the load ranges of the strain-gage balance, a large range of sideslip angles at 0° angle of attack may be obtained by rotating the model 90° (with the 0° coupling installed) and using the angle-of-attack change mechanism to raise or lower the vertical support strut.

These adapters and the inner sting, which is fastened to the cylindrical body on the support strut, are standard equipment of the model-support system. The sting adapters vary for different models and for different strain-gage balances. For the majority of investigations of specific models it is necessary to build a special sting adapter. In order to facilitate the construction of these special sting adapters a plug gage is available to insure a proper fit at the joint.

At the present time the model support strut has the following load limits:

Normal force, lb	12,000
Axial force (in combination with above normal force), lb	600
Side force, lb	1,000

MODELS

The general type of model investigated in the 16-foot transonic tunnel is of steel construction with a wing span from 5 to 6 feet and a body length of about 8 feet. A typical model installation is shown in figure 6. A very careful stress analysis is required for all models and control surfaces, because a failure might result in extensive and costly damage to the tunnel drive fans.

Since the models are usually built to a relatively large scale they can be instrumented for the investigation of small component parts of the airplane, such as the loads and hinge moments of ailerons. Models may be instrumented for the measurement of 400 to 450 wing and body pressures, which are recorded on film by taking pictures of five 100-tube manometers. The pressures may be used to study the loads on the basic wing, body, flaps, spoilers, chord extensions, and horizontal and vertical tails. Forces and moments on the entire model are measured by means of six-component strain-gage balances mounted within the model. Strain-gage balances are also used on flaps, ailerons, elevons, slats, etc. to determine the normal force, hinge moments, or other desired loads. Strain gages are also used to measure wing-root bending moments, tail-root bending moments, or the stress at any desired point on the model. Miniature pressure pick-ups are used in wing surfaces, horizontal and vertical tail surfaces, or at any other desired locations on the model to obtain instantaneous amplitude and frequency of pressures on these surfaces. Generally, both force and pressure data are obtained simultaneously.

For models requiring the simulation of a hot jet exhaust, a technique has been developed which utilizes the decomposition of hydrogen peroxide for jet simulation. Details of this technique and space requirements in the models for the decomposition chamber may be obtained by contacting the Langley Aeronautical Laboratory.

INSTRUMENTATION

Balances

The Langley laboratory has available a wide variety of strain-gage balances which can normally be used in different models and tunnels without recalibration. The type most generally used in models at the Langley 16-foot transonic tunnel has six components, and they range in size from 8 to 36 square inches in cross-sectional area and from 1 to 2 feet in length. The load ranges of these balances used most frequently in the past for models in the 16-foot transonic tunnel are:

Normal force, lb	±3,000 to ±12,500
Axial force, lb	±250 to ±1,000
Side force, lb	±500 to ±1,000
Pitching moment, in-lb	±10,000 to ±36,000
Rolling moment, in-lb	±4,000 to ±25,000
Yawing moment, in-lb	±8,000 to ±16,500

Details of balances available at the Langley Laboratory can be ascertained by consultation with the wind-tunnel staff. Forces and moments on components such as control surfaces are usually measured by strain-gage devices designed as part of each model. Such strain gages should be designed in accordance with specifications which can be obtained from the laboratory to insure compatibility with the recording equipment.

Manometers

Five 100-tube mercury monometers as shown in figure 7 are available for the measurement of steady pressures. The working height is 32 inches, and the scales have 0.10-inch divisions. Recording is by photography.

Data Recording and Reduction

The wire strain-gage indicators of the readout system are self-contained electronic indicators designed for use with a full bridge wire strain gage. Normally about 7.5 volts of filtered direct current are supplied to 120-ohm gages. With this type of operation 1,000-micro-inch strain will give a 2,000-count span. If this value of supply voltage produces too much strain-gage heating, a reduced voltage may be used. The voltage may be reduced to 4.5 volts without affecting the span.

A semiautomatic force data readout system provides tabulated raw data and punch card storage of raw data concurrent with the operation of the wind tunnel. Provision is made for 12 automatic channels of strain-gage-data output, and eight channels of four-digit manually operated inputs are available for tabulating and punching constants, configuration codes, and other information necessary for data reduction and identification. The data are then processed on electronic computing machines to obtain the desired coefficients. These coefficients and their proper identification are then machine tabulated to provide a printed record of the results. The punched cards may also be fed into an automatic plotting device for the preparation of plots necessary for data analysis. Figure 8 is a photograph of the control room at the Langley 16-foot transonic tunnel showing the data readout equipment.

Eighty channels of dynamic data from electrical strain gages and electronic pressure gages can be transmitted from the model support strut to the control room. These data may be recorded on magnetic tape or on photographic paper by means of recording oscillographs. The tape recorder can record only 12 channels simultaneously, but if required, suitable switching can be provided so that additional channels can be recorded by taking more than one tape record at any test condition. Both 18-channel and 36-channel recording oscillographs are available.

Records are made on magnetic tape when mean-square or root-mean-square values of the dynamic data are required, or when power spectrums of the dynamic data are required. Suitable equipment to reduce the data to these forms from the tape records is located in the Langley Instrument Research Division and is operated by Instrument Research Division personnel. The number of power spectra obtained must be kept to a minimum because approximately 1/2-hour is required to obtain a power spectrum for one channel at one test condition. Time histories, instantaneous amplitudes and/or peak-to-peak values of the dynamic data may be determined from the recording-oscillograph records. Commercial readers are available at the Instrument Research Division and are usually operated by the computing staff of the facility in which the data were obtained.

Steady pressures are recorded by photographing the 100-tube mercury manometers shown in figure 7. The film records are coded for identification of test conditions, and the data are transferred to punched cards by the use of a film reading device coupled to the card-punch machine. The data are then processed on electronic computing machines to obtain individual pressure coefficients as well as wing section normal-force and pitching-moment coefficients (using a rectangular step integration). The data cards are also sent through a tabulator for listing the coefficients and their identification to provide a printed record of the results. The cards can also be fed into an automatic plotting device for the preparation of chordwise pressure distribution plots. The use of this electronic equipment greatly reduces the time required for processing large quantities of pressure data.

Flow Visualization

A shadowgraph system which utilizes divergent light from a high-pressure mercury lamp (B-H6 bulb).is used in the Langley 16-foot transonic tunnel. The light rays, after passing through the flow field around the model, fall upon the opposite wall of the tunnel which serves as a screen. The resulting "shadow picture" is then photographed with a camera having an f2.5 lens and a shutter speed of 1/150 second. This technique allows a survey of the entire flow field around large models (fuselage lengths of about 8 feet) but detects only the relatively strong disturbances such as steady shock waves. Figure 9 shows a typical shadowgraph picture taken of a model in the Langley 16-foot transonic tunnel test section.

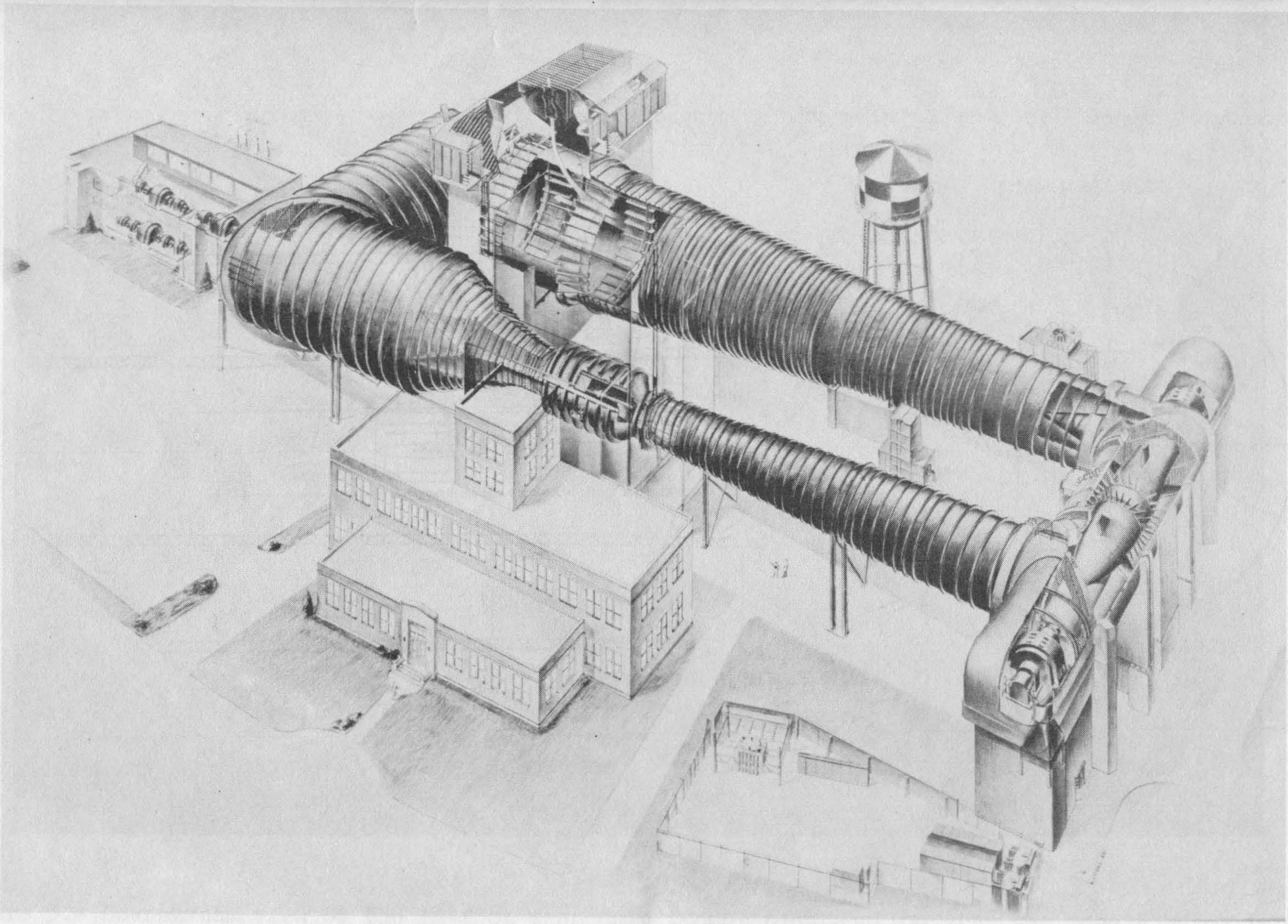


Figure 1.- The Langley 16-foot transonic tunnel. L-88143

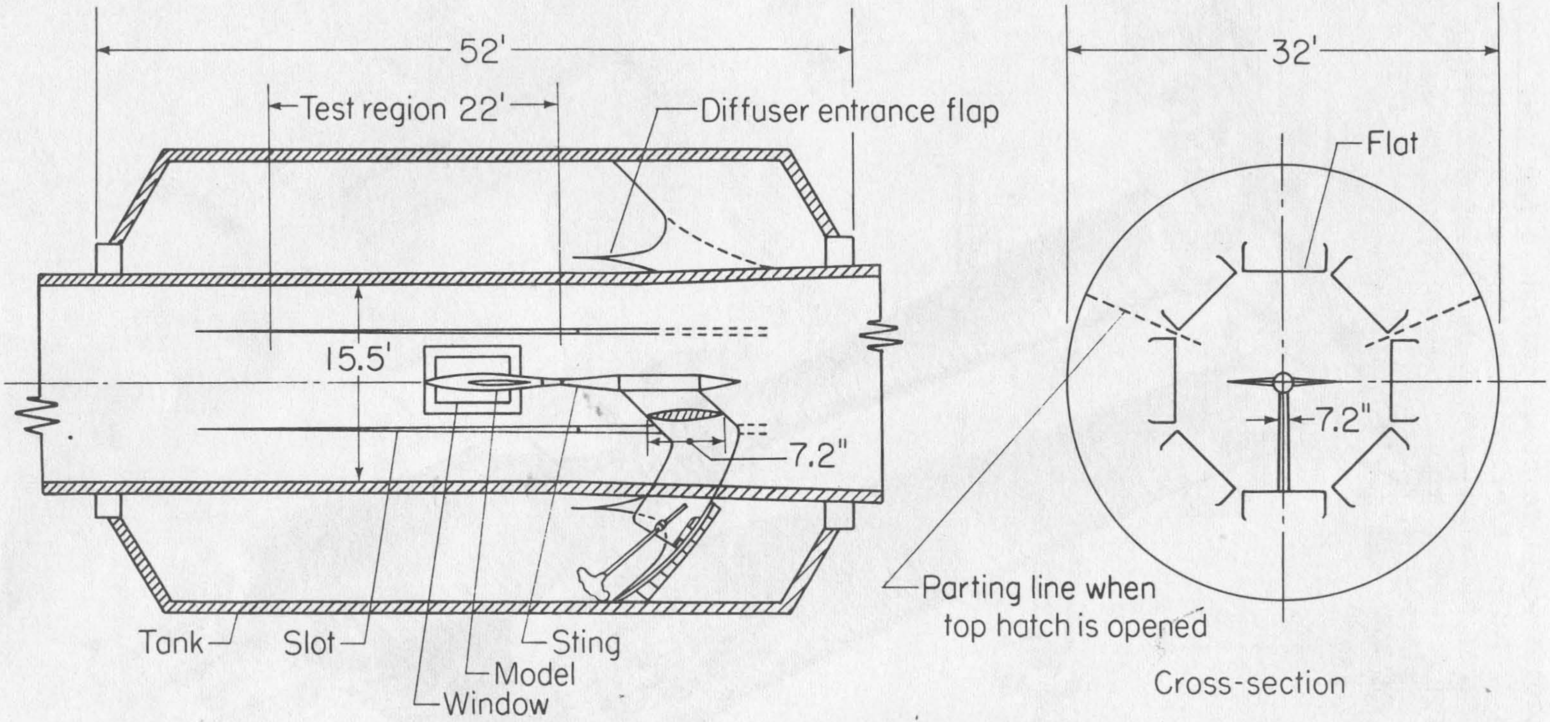
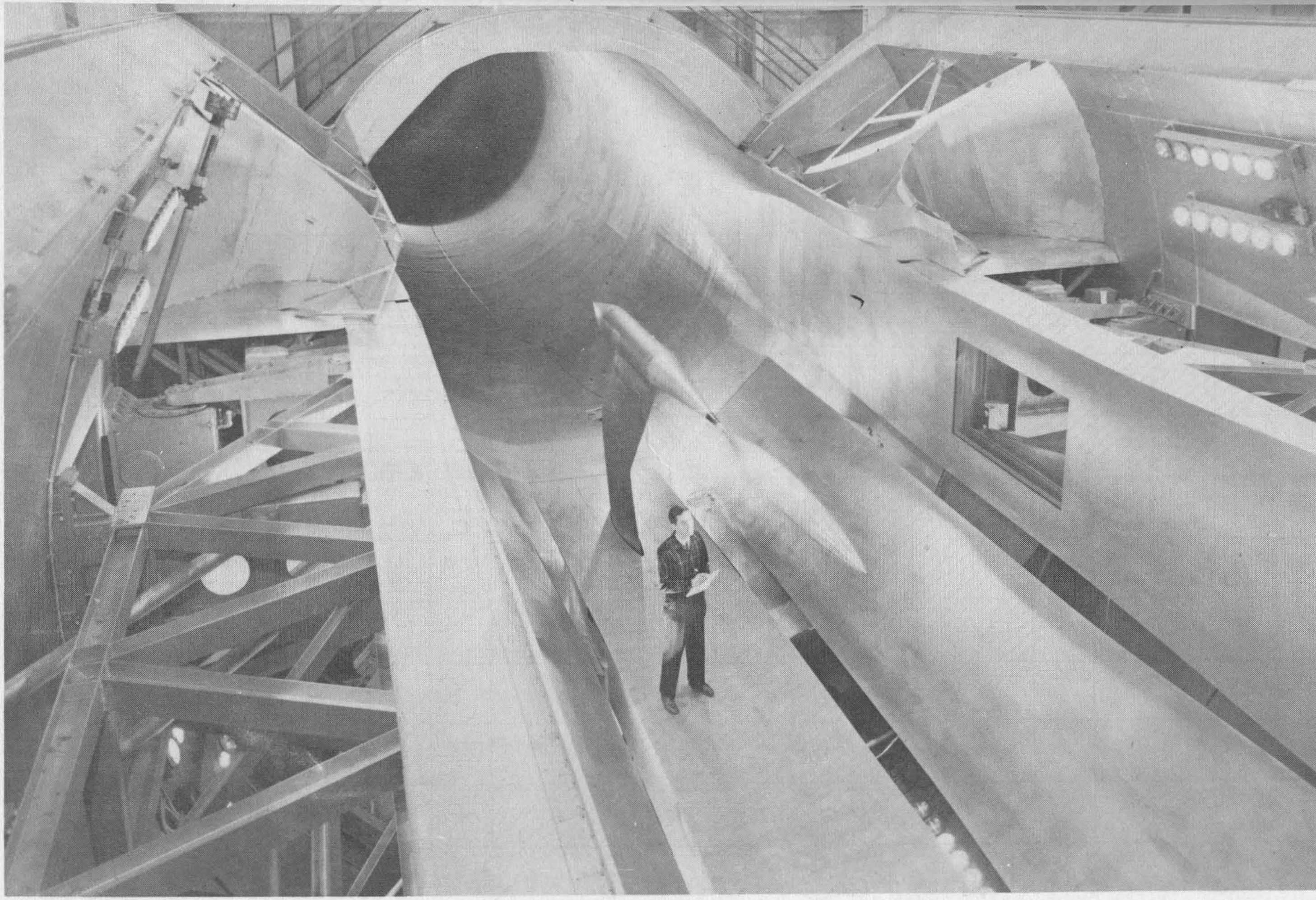


Figure 2.- Schematic sketch of the test section of the Langley 16-foot transonic tunnel.



L-69734

Figure 3.- Downstream view of the 16-foot transonic tunnel test section with the access hatch in the raised position.

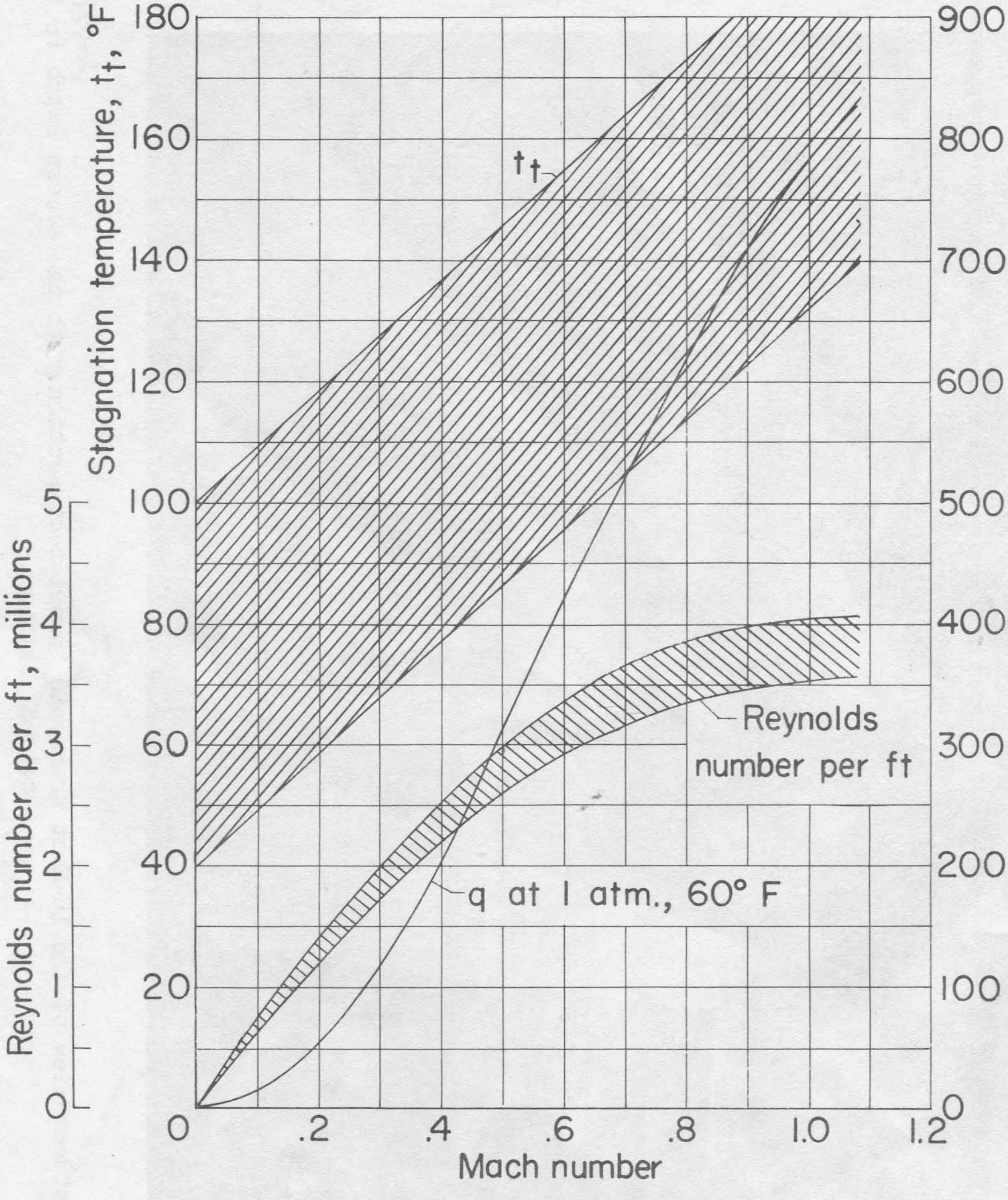


Figure 4.- Variation of stagnation temperature, Reynolds number per foot, and dynamic pressure with Mach number. Langley 16-foot transonic tunnel.

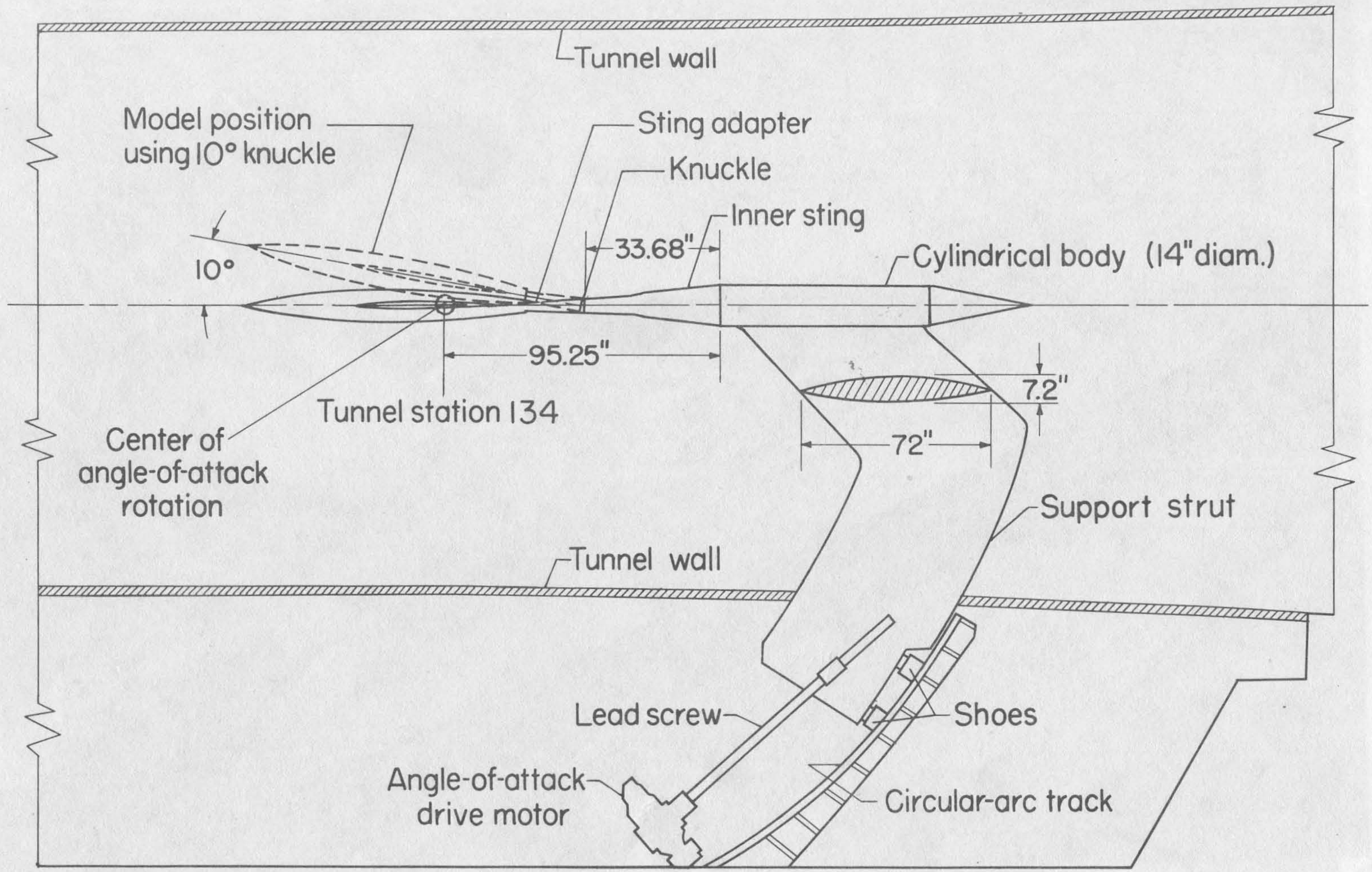


Figure 5.- Sketch showing details of model-support system in Langley 16-foot transonic tunnel.

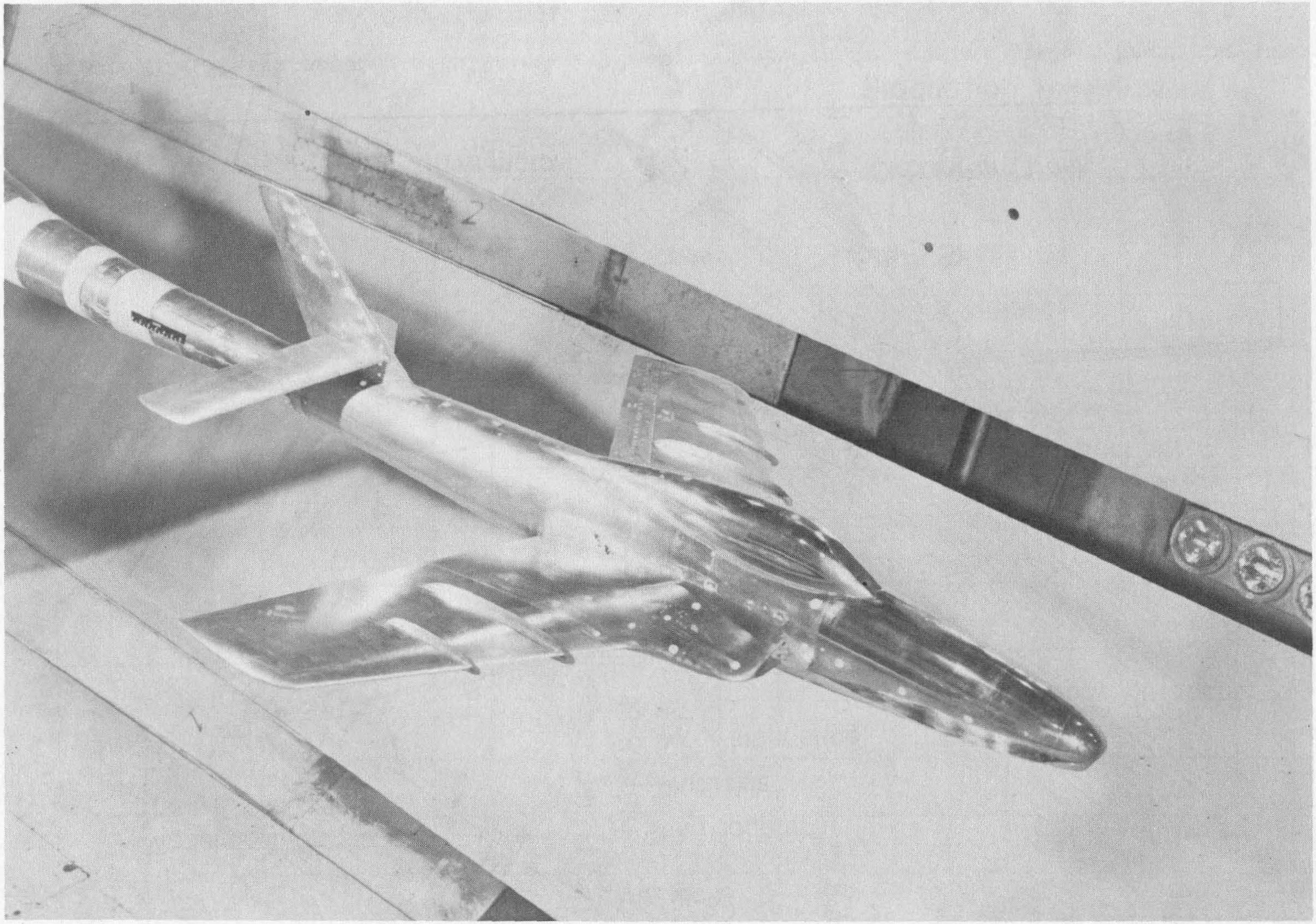
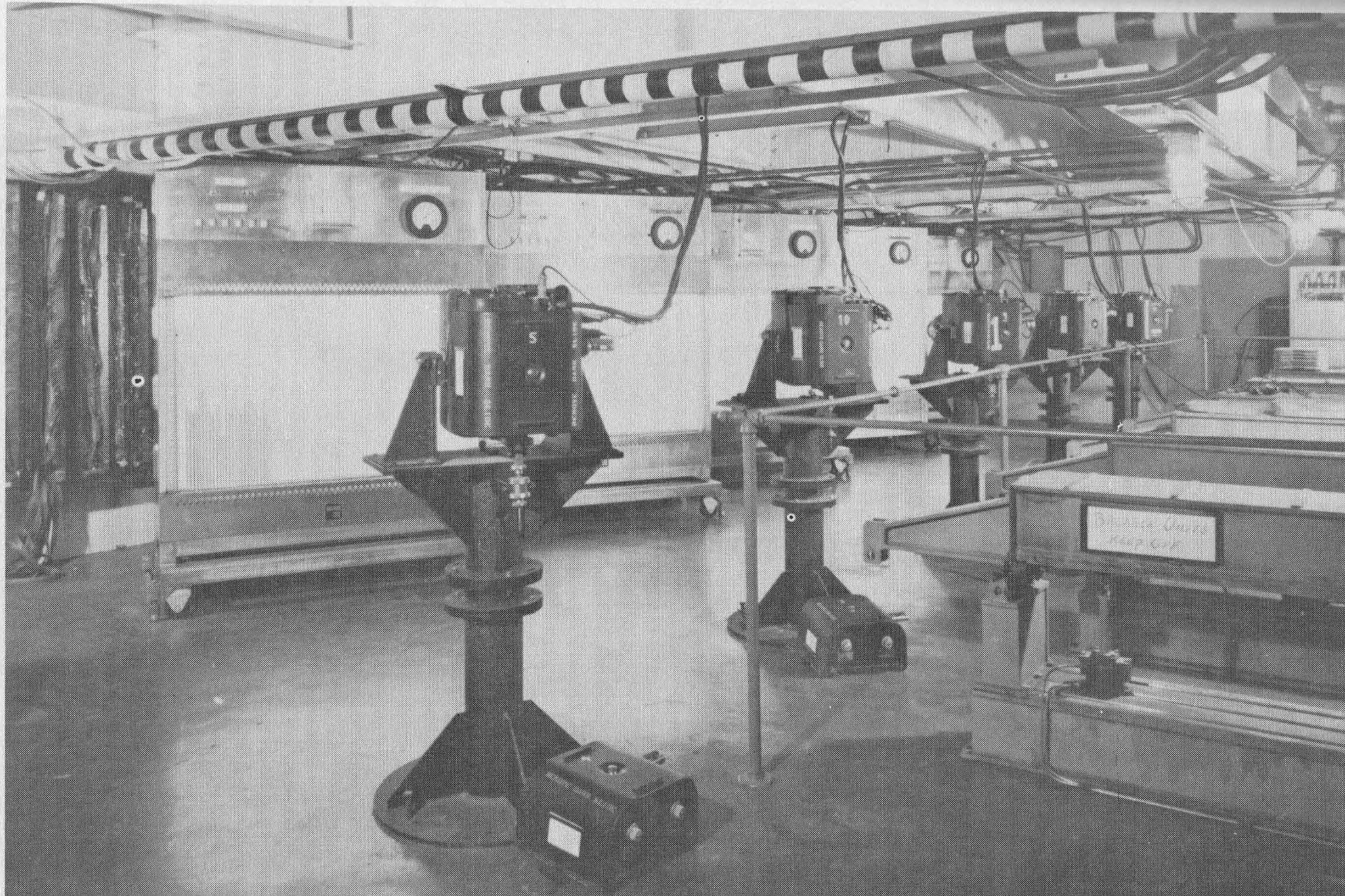
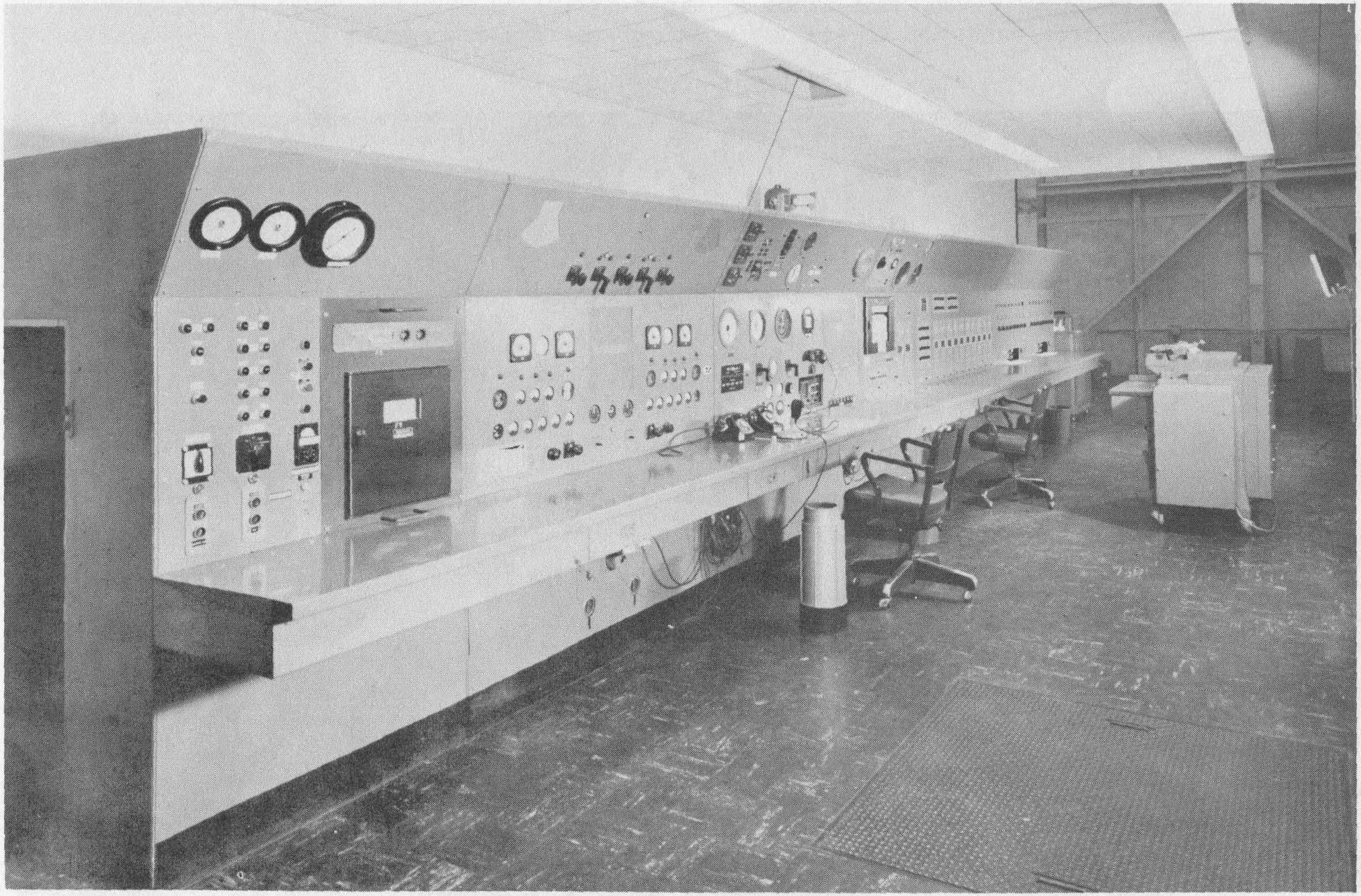


Figure 6.- A typical model installation in Langley 16-foot transonic tunnel. L-85401



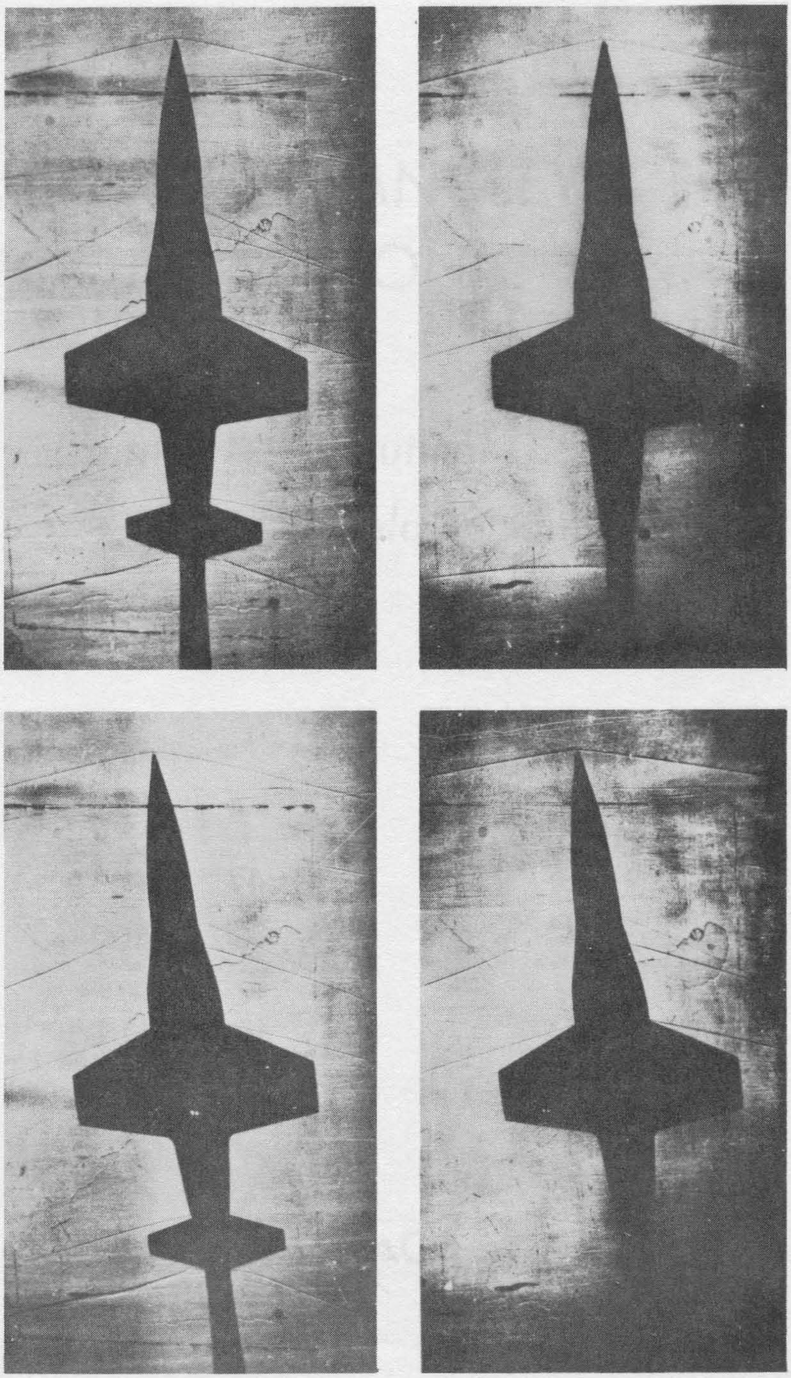
L-87837

Figure 7.- Mercury manometers and cameras used for steady pressure measurements at the Langley 16-foot transonic tunnel.



L-89943

Figure 8.- The control room at the Langley 16-foot transonic tunnel showing data readout equipment at far end of control panel.



L-89365

Figure 9.- Photographs illustrating shadowgraph technique used in the Langley 16-foot transonic tunnel.

THE LANGLEY 8-FOOT TRANSONIC TUNNEL

Langley Aeronautical Laboratory
Langley Field, Virginia

LANGLEY 8-FOOT TRANSONIC TUNNEL

GENERAL DESCRIPTION

An aerial view of the Langley 8-foot transonic tunnel is shown in the foreground of figure 1. (In the background is the 8-foot transonic pressure tunnel.) The tunnel is a single-return, atmospheric type with cooling accomplished through air exchange. The amount of air exchanged can be controlled with adjustable vanes.

The fan section of the tunnel is made up of two tandem rotors having 17 fixed-pitch blades in each. Prerotation vanes upstream direct the air into the rotors and counterrotation vanes downstream reduce the rotation of the air mass leaving the fans. The two rotors are mounted on the same shaft and are driven by a 22,000-horsepower motor. The motor-speed control is variable from 0 to 990 rpm.

TEST SECTION

The test section of the Langley 8-foot transonic tunnel is dodecagonal in cross section and has a cross-sectional area of about 43 square feet. Longitudinal slots are located between each of the 12 wall panels to allow continuous operation through the transonic speed range. The slots contain about 11 percent of the total periphery of the test section. Six of the twelve panels have windows in them to allow for schlieren observations. The entire test section is enclosed in a hemispherical shaped chamber. A drawing of the test section is shown in figure 2, and figure 3 is a photograph of the interior at the test region.

TEST CONDITIONS

The Mach number in the test section can be continuously varied from 0 to about 1.2, the higher value being somewhat dependent on model size. The Mach number distribution is reasonably uniform throughout the test region length of about 5 feet. The maximum deviations from the average stream Mach number are of the order of 0.010 at the highest test Mach number.

The stagnation temperature of the tunnel air can be controlled within limits by the vanes and blocks in the air-exchange tower. Generally, stagnation temperatures around 150° F are maintained. The maximum stagnation temperature permissible is 180° F, this limit being imposed because of some of the tunnel equipment.

Since the tunnel operates around atmospheric stagnation pressure the Reynolds number is about 3.5 to 4.0 million per foot at the higher test Mach numbers. Figure 4 shows the variation of stagnation temperature, Reynolds number per foot, and dynamic pressure with Mach number.

MODEL-SUPPORT SYSTEM

The sting-type model-support system is used in the Langley 8-foot transonic tunnel. The sting is attached to a tapered support strut which in turn is connected downstream to a motor-driven metal arc. (See figs. 2 and 3.) The system is designed so as to keep the center of gravity of the model on the center line of the tunnel throughout an angle-of attack range from -10 to +14 degrees. For angles of attack outside of this range a series of angular couplings are provided. A large range of yaw angles can be obtained by suitable model or coupling rotation. In addition to angular displacement the model-support system can be moved axially about 26 inches to position the models in different parts of the test section. The load limits on the model support are 2,000 pounds of normal force, 400 pounds of axial force, and 175 pounds of side force.

MODELS

Generally steel models with wing spans of the order of 2 feet are used for investigations in the Langley 8-foot transonic tunnel. The models can be instrumented for pressure-distribution measurements or strain-gage-balance measurements. Since the bodies used are small (3 to 4 inches in diameter), space is not sufficient to allow for extensive pressure measurements in conjunction with the strain-gage-balance measurements. A typical model installed in the 8-foot transonic tunnel is shown in figure 5. Pressure distributions give much detailed information about the configurations and can be integrated to give either overall forces and moments or forces and moments on component parts. The strain-gage balances generally give overall forces and moments; however, other strain gages can be mounted at various locations on the model to measure forces and moments on component parts and to get an indication of the buffet stresses.

INSTRUMENTATION

Balances

A variety of strain-gage balances are available for use in the models. Generally, six components of force and moment can be measured with these balances and different balances can be used for different load ranges. A typical balance would be about 6 to 10 inches long with 1 to 2.5 square inches of cross-sectional area, and would sustain maximum loads of about 1,200 pounds normal force, 2,000 inch-pounds pitching moment, 85 pounds axial force, 1,000 inch-pounds rolling moment, 1,000 inch-pounds yawing moment, and 250 pounds side force. For investigation of drag at low lift, balances are available which have lower load ranges for axial force and permit more accurate drag measurements. Details of balances available at the laboratory can be ascertained by consultation with the wind-tunnel staff.

Manometers

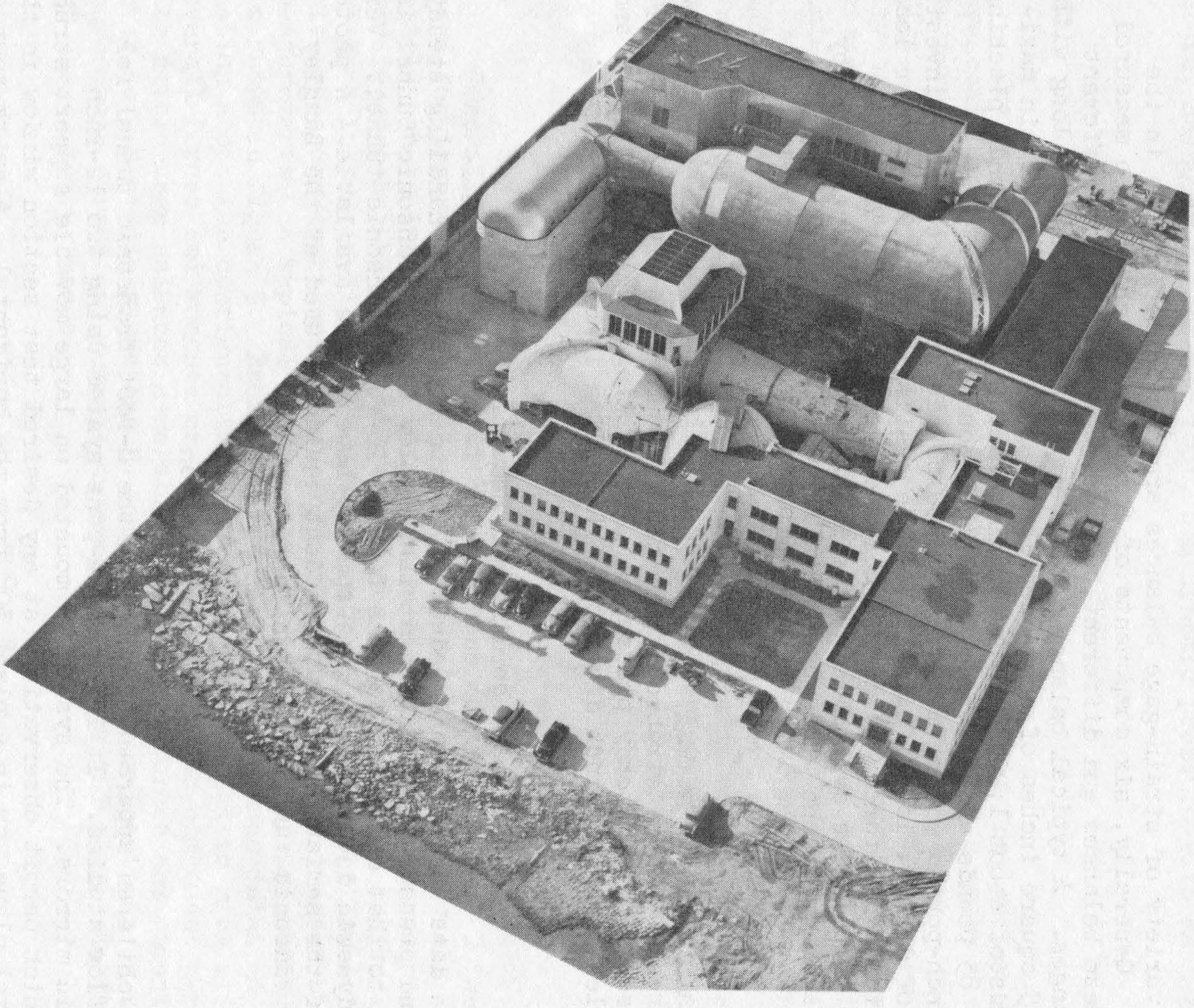
Three 100-tube tetrabromethane-filled manometers are available for the measurement of steady pressures. The working height is 10 feet, and the scales have 0.10-inch divisions. Recording is by photography.

Data Recording and Reduction

The data recording and reduction equipment used for handling steady force and pressure information at the Langley 8-foot transonic tunnel is similar to that described for the Langley 16-foot transonic tunnel. Very little dynamic data recording equipment, however, is available. A photograph of the semiautomatic data readout equipment used at the Langley 8-foot transonic tunnel is shown in figure 6.

Flow Visualization

A schlieren apparatus is used in the 8-foot transonic tunnel for visual flow studies. It is a single-pass system using two 12-inch parabolic mirrors. The system is mounted on large movable support structures which permit observations at any desired test section window in the horizontal plane, or in a plane 30° from the horizontal. A spark source is used for photographic recording with a still camera. The entire system is located within the test chamber and is operated by remote control. A sample of some schlieren results is shown in figure 7.



L-78271

Figure 1.- Aerial photograph of 8-foot tunnels. The 8-foot transonic tunnel is in the foreground; the 8-foot transonic pressure tunnel in the background.

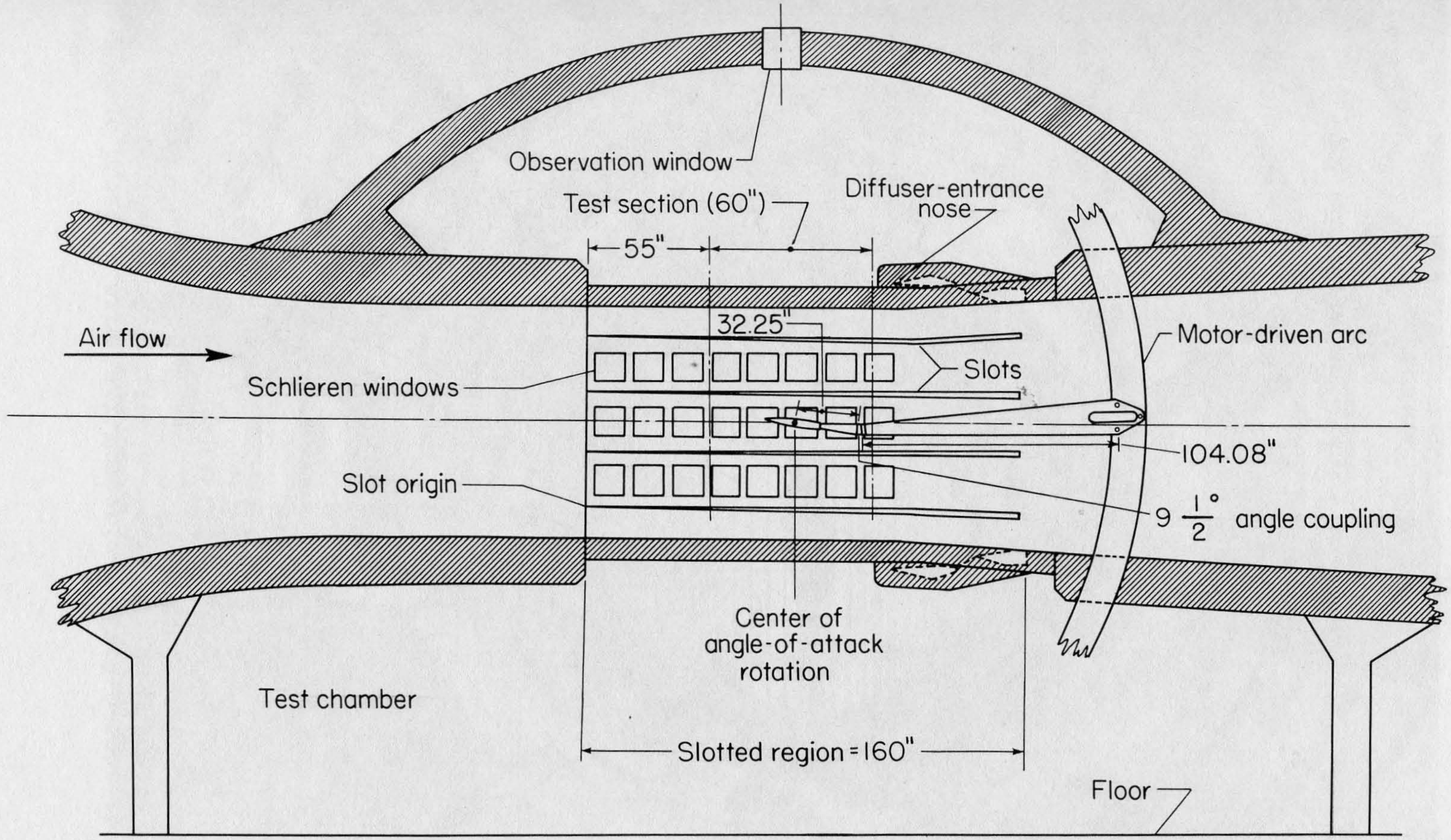


Figure 2.- Details of test section in the Langley 8-foot transonic tunnel.

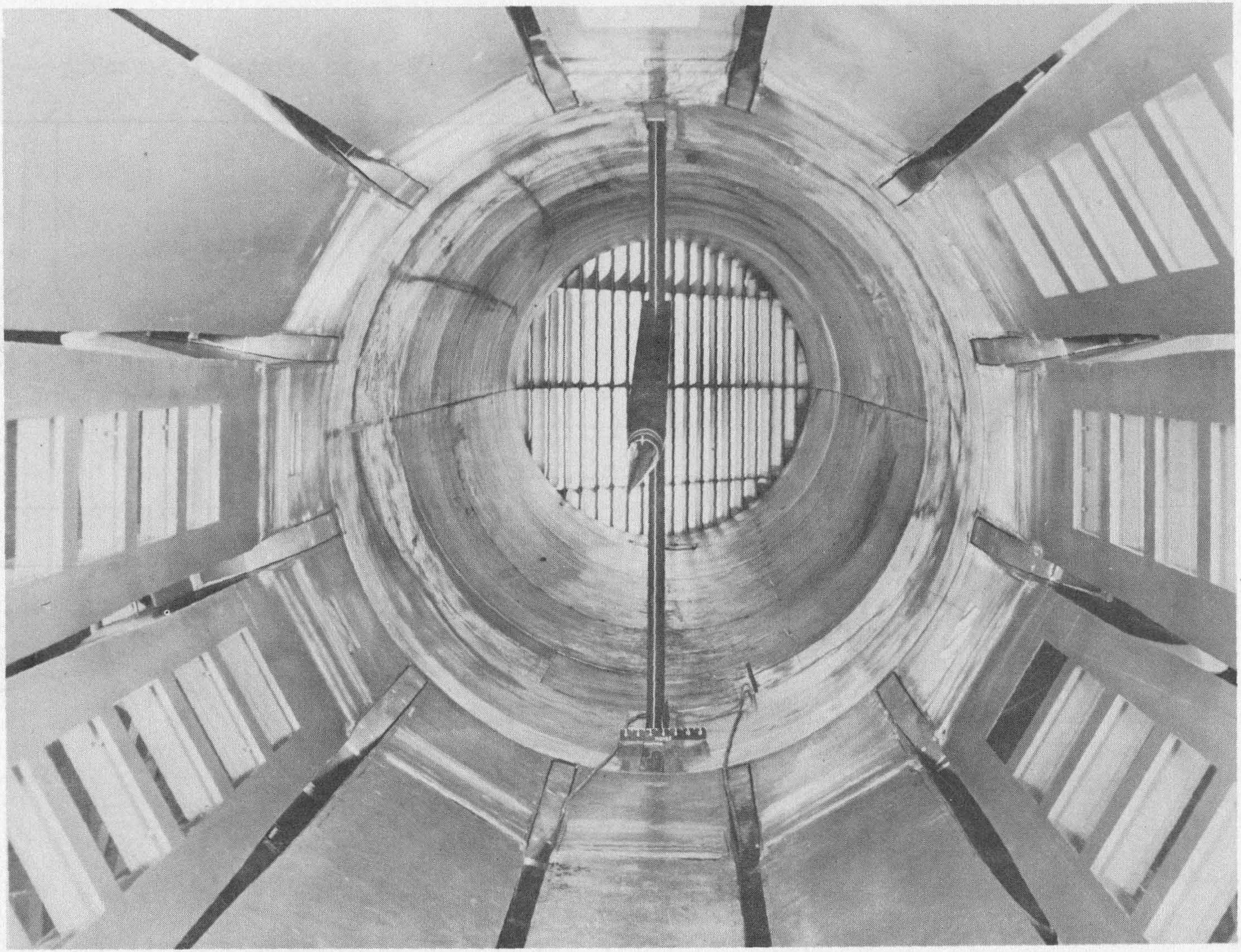


Figure 3.- Interior view of the test region in the Langley 8-foot transonic tunnel. L-57-959

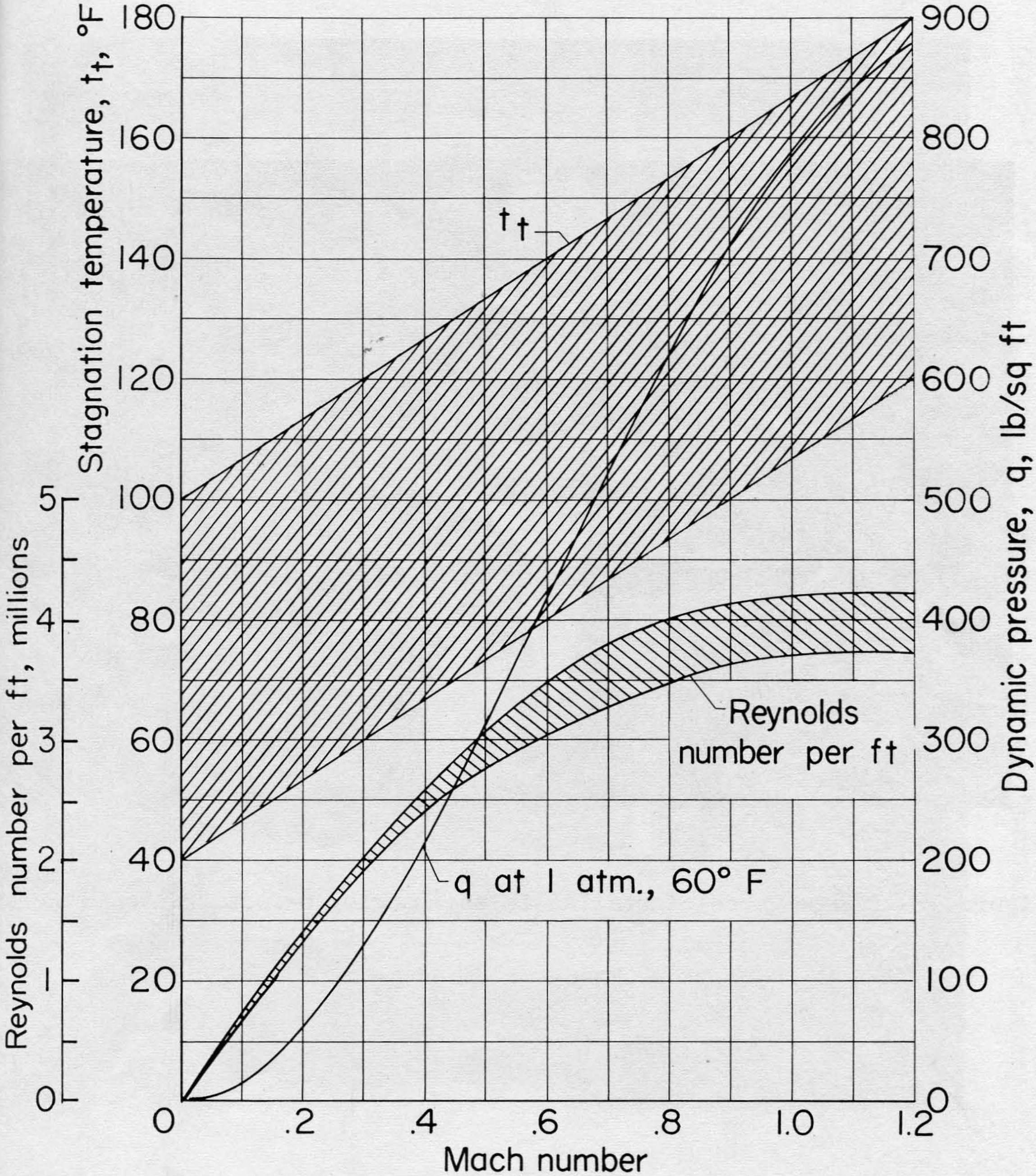
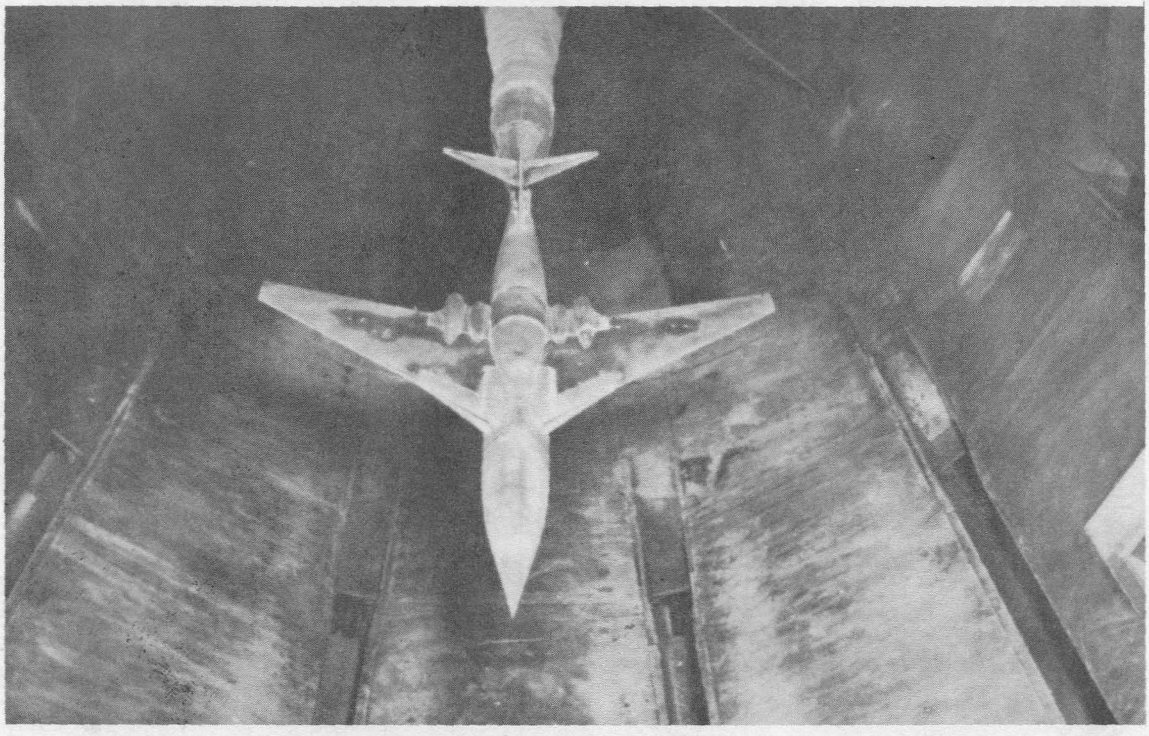


Figure 4.- Variation of stagnation temperature, Reynolds number per foot, and dynamic pressure with Mach number. Langley 8-foot transonic tunnel.



L-73936

Figure 5.- Typical model installed in the Langley 8-foot transonic tunnel.

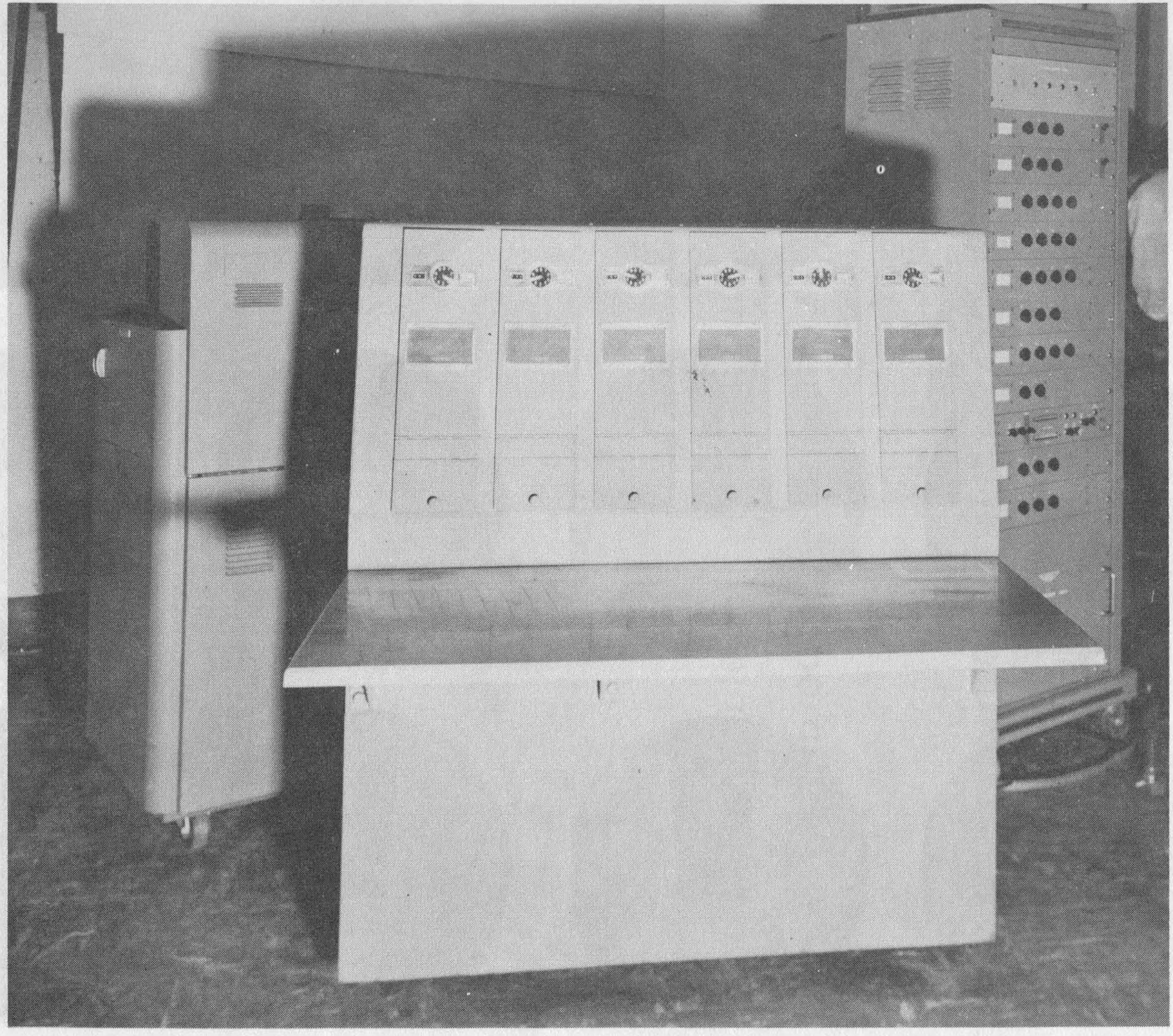
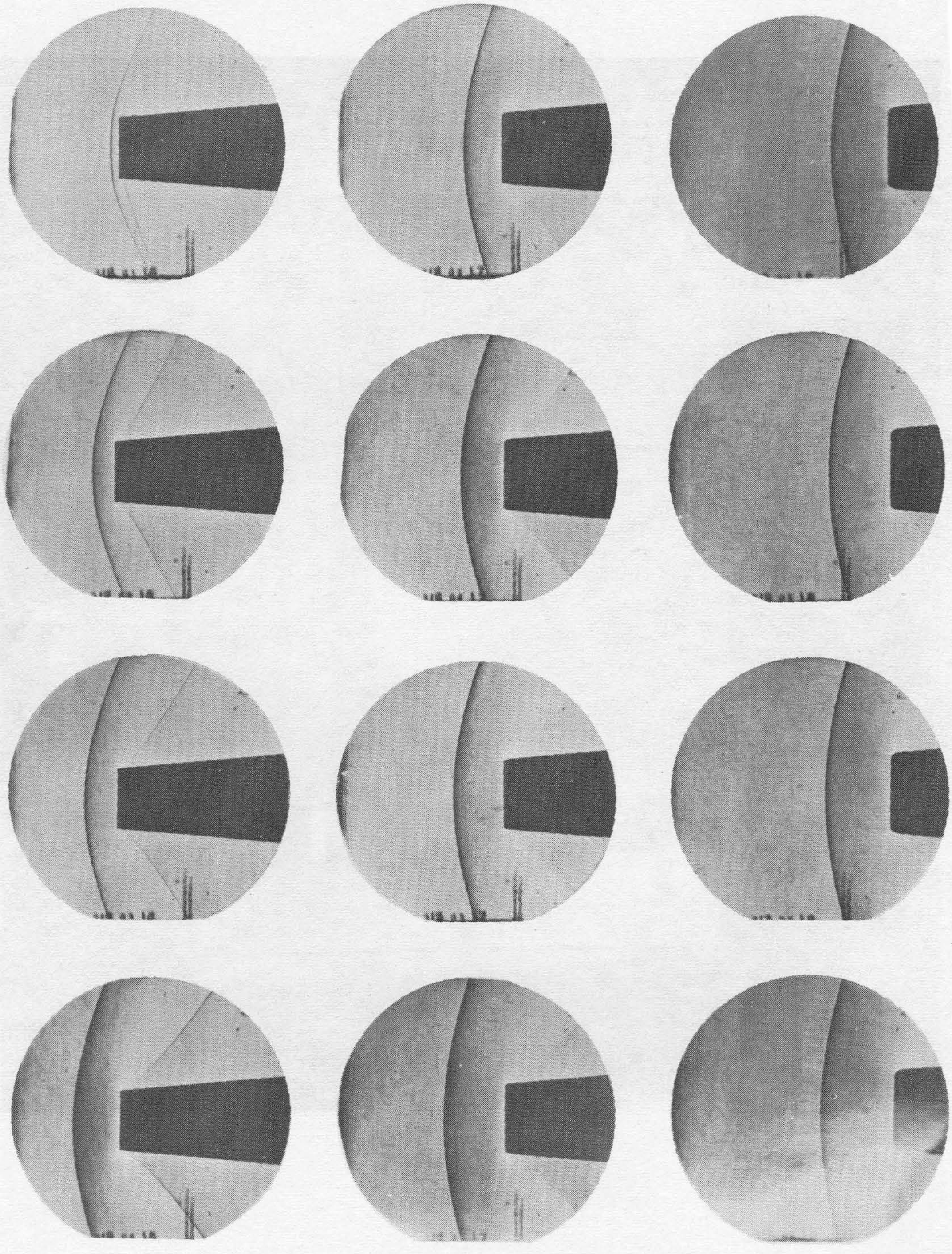


Figure 6.- Photograph of the semiautomatic readout equipment. L-82293



L-92449.1
Figure 7.- Samples of schlieren photographs from the Langley 8-foot transonic tunnel.

THE LANGLEY
8 FOOT TRANSONIC PRESSURE TUNNEL

Langley Aeronautical Laboratory
Langley Field, Virginia

NACA

LANGLEY 8-FOOT TRANSONIC PRESSURE TUNNEL

GENERAL DESCRIPTION

The Langley 8-foot transonic pressure tunnel is a single-return, closed-circuit pressure type, capable of operating at atmospheric stagnation pressure and below.

The tunnel-fan section is composed of a single rotor followed immediately downstream by two sets of straightening vanes. The rotor is about 17 feet in diameter and has 32 wooden blades. The straightening vanes are made of aluminum, and there are 23 in each set. Power to the fan is furnished by a 25,000-horsepower wound-rotor induction motor with speed control to 840 rpm. Test section Mach number is obtained and kept constant by controlling the rotational speed of the drive motor. A perspective drawing of the tunnel is shown in figure 1.

The tunnel-air temperature is controlled by finned cooling coils across one corner of the tunnel. Water is circulated through the cooling coils and is then pumped from the tunnel to a three-cell redwood cooling tower where it is cooled by the atmosphere. The tunnel air can also be dried to a dewpoint of -40° F by circulating it through a dryer using silica gel as a desiccant.

TEST SECTION

The test section of the Langley 8-foot transonic pressure tunnel is rectangular in cross section and has a cross-sectional area of approximately 50 square feet. The upper and lower walls of the test section are slotted to permit continuous operation through the transonic-speed range. The slots comprise approximately 5 percent of the total periphery of the test section. Each vertical side wall contains 15 rectangular optical plate glass windows for use with the schlieren observation system. The entire test section is enclosed in a large tank about 36 feet in diameter. Some details of the test section are shown in figure 2.

TEST CONDITIONS

The Mach number in the test section can be continuously varied from 0 to 1.20, the higher value being somewhat dependent on model size.

The Mach number distribution is reasonably uniform throughout the test-region length of about 5 feet. The maximum deviation from the average stream Mach number is of the order of 0.010 at the higher test Mach numbers.

The longitudinal slots in the upper and lower walls of the test section can be enclosed with specially designed filler blocks which convert the slotted test section to a supersonic nozzle. At the present time these filler blocks are available for a Mach number of 1.43.

The stagnation pressure of the tunnel can be varied continuously from 1/4 to 1 atmosphere. This pressure range affords a test Reynolds number range from about 1 million to 4 million per foot. Figure 3 shows the variation of stagnation temperature, Reynolds number per foot, and dynamic pressure with Mach number.

The stagnation temperature t_t of the tunnel air can be automatically controlled and kept constant and uniform across the test section. In addition, the dewpoint can be easily maintained below 0° F during operation. Control of both the stagnation temperature and dewpoint gives good control over the humidity to avoid condensation effects.

Preliminary data indicate that the turbulence level in the test section is reasonably low.

MODEL-SUPPORT SYSTEM

The sting-type model-support system, as shown in figure 2, is used in the 8-foot transonic pressure tunnel. The sting is attached to a tapered support strut which in turn is connected downstream to a motor-driven metal arc. The system is so designed as to keep the center of gravity of the model on the center line of the tunnel through a range of angle of attack from -10° to 15°. For angles of attack outside this range, a series of angular couplings are provided. A large range of yaw angles may be obtained by suitable model or coupling rotation. In addition to angular displacement, the model support system can be moved axially about 84 inches to position the model in different parts of the test section. The load limits on the model support are 4,000 pounds of normal force, 400 pounds of axial force, and 400 pounds of side force.

MODELS

The description of models previously given for the Langley 8-foot transonic tunnel also applies to models for the Langley 8-foot transonic pressure tunnel. Models for the two tunnels may be made interchangeable. A typical model installed in the 8-foot transonic pressure tunnel is shown in figure 4.

INSTRUMENTATION

Balances

The strain-gage balances available for use at the Langley 8-foot transonic pressure tunnel are the same as those previously described for the Langley 8-foot transonic tunnel. Details of these balances may be ascertained by consultation with the wind-tunnel staff.

Manometers

Three 100-tube tetrabromoethane-filled manometers are available for the measurement of steady pressures. The working height is 10 feet, and the scales have 0.10-inch divisions. Recording is by photography.

Data Recording and Reduction

The data recording and reduction equipment used for handling steady-force and pressure information at the Langley 8-foot transonic pressure tunnel is similar to that described for the Langley 16-foot transonic tunnel. Very little dynamic data recording equipment, however, is available. A photograph of the semiautomatic data readout equipment used at the Langley 8-foot transonic pressure tunnel is shown in figure 5.

Flow Visualization

A schlieren apparatus is used in the 8-foot transonic pressure tunnel for visual flow studies. It is a single-pass system using two 16-inch parabolic mirrors. Operation of the knife edge, the camera, and other equipment, as well as the position of the schlieren system relative to the test section, is remotely controlled by an observer in the control room. The schlieren apparatus is mounted on a crane above the test section, which allows its position to be varied vertically, horizontally, and in yaw in the horizontal plane. Roll positions can be obtained by manual adjustments. Generally, a still camera is used for recording the flow phenomena; however, a movie camera can be used in its place. A reflector is provided to show the schlieren image on a ground glass screen near the control desk at any time that a visual observation of the image is desired. Some sample results from the schlieren system are shown in figure 6.

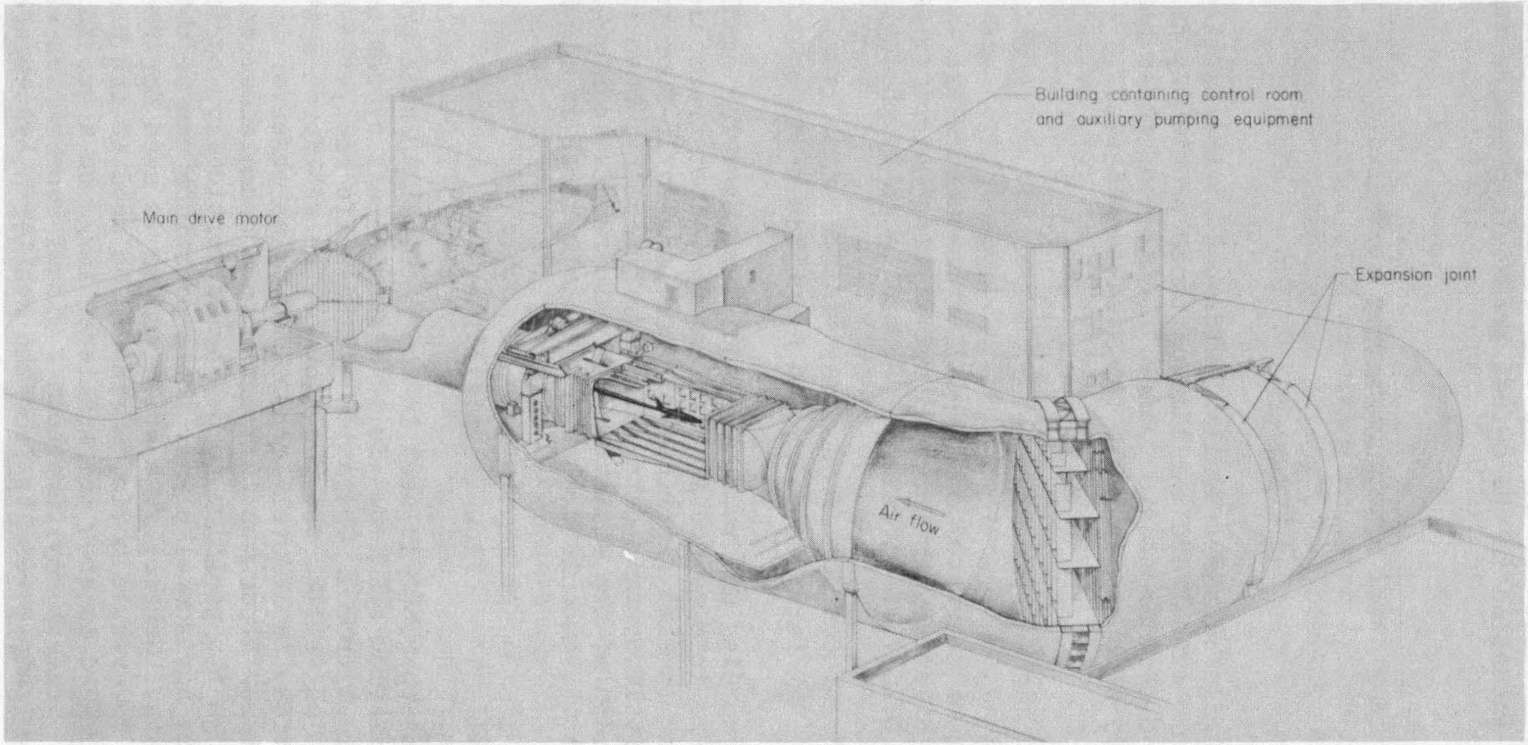


Figure 1.- Perspective drawing of Langley 8-foot transonic pressure tunnel. L-57-2529

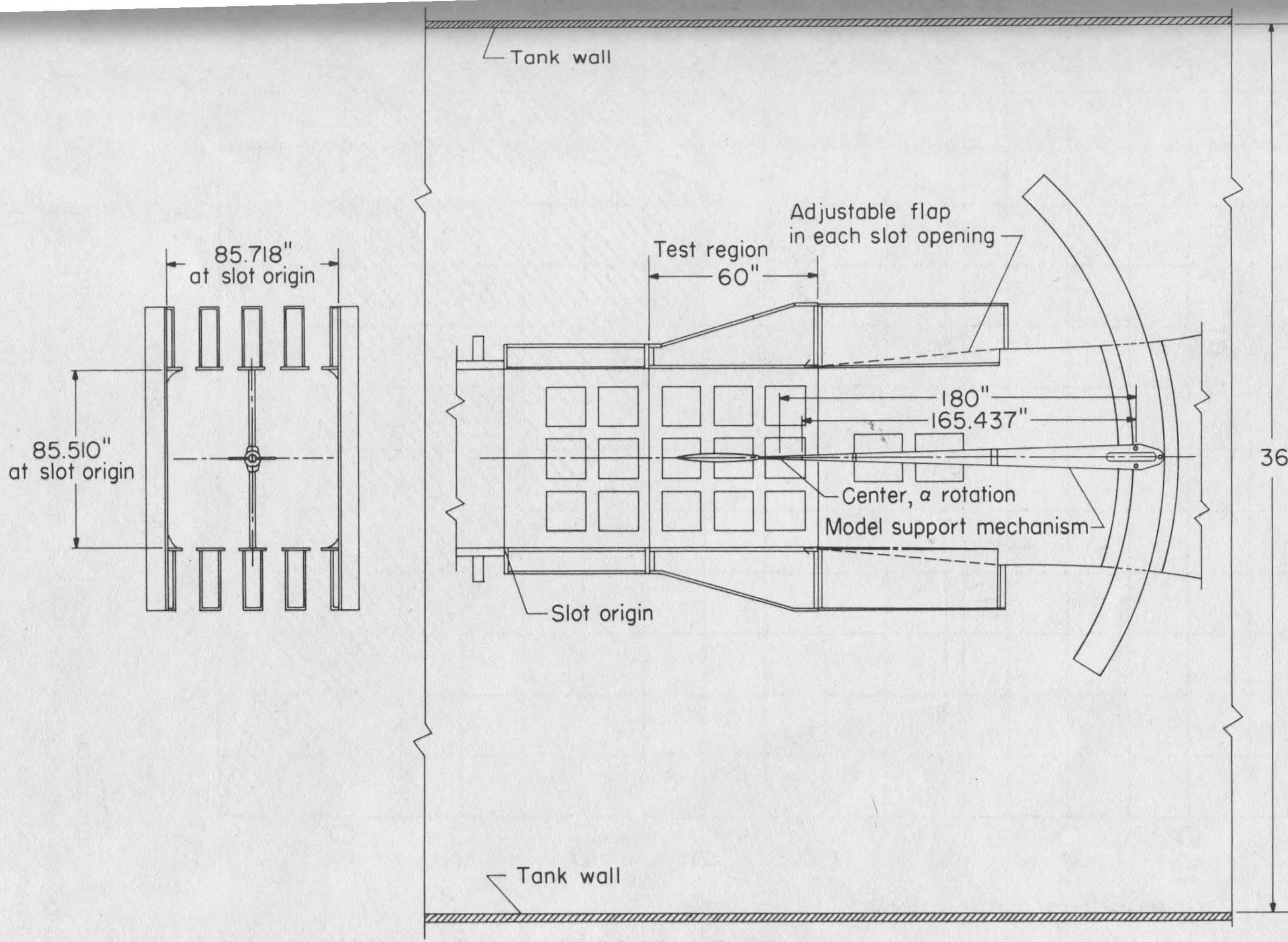


Figure 2.- Details of test section and location of model in the Langley 8-foot transonic pressure tunnel.

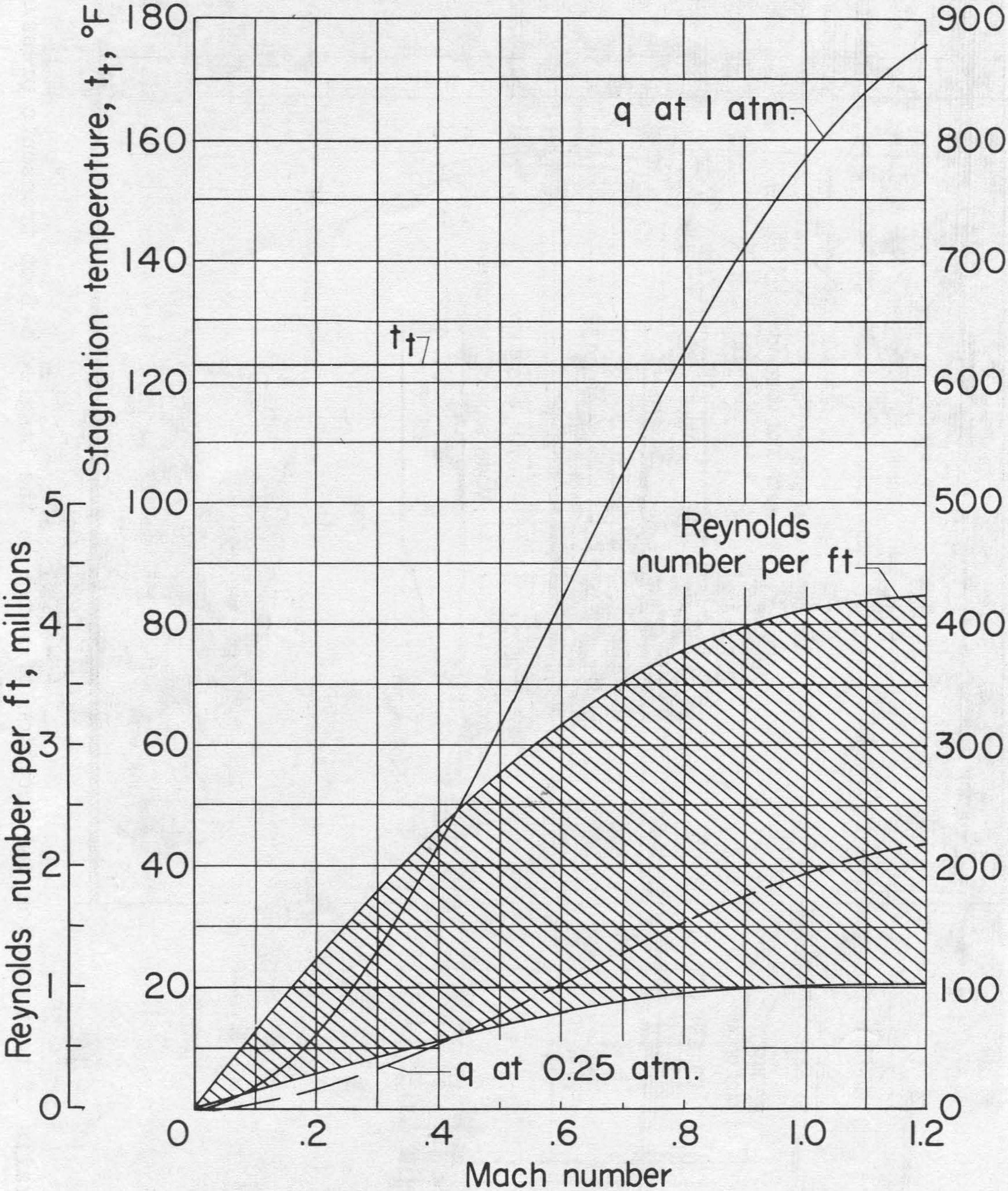
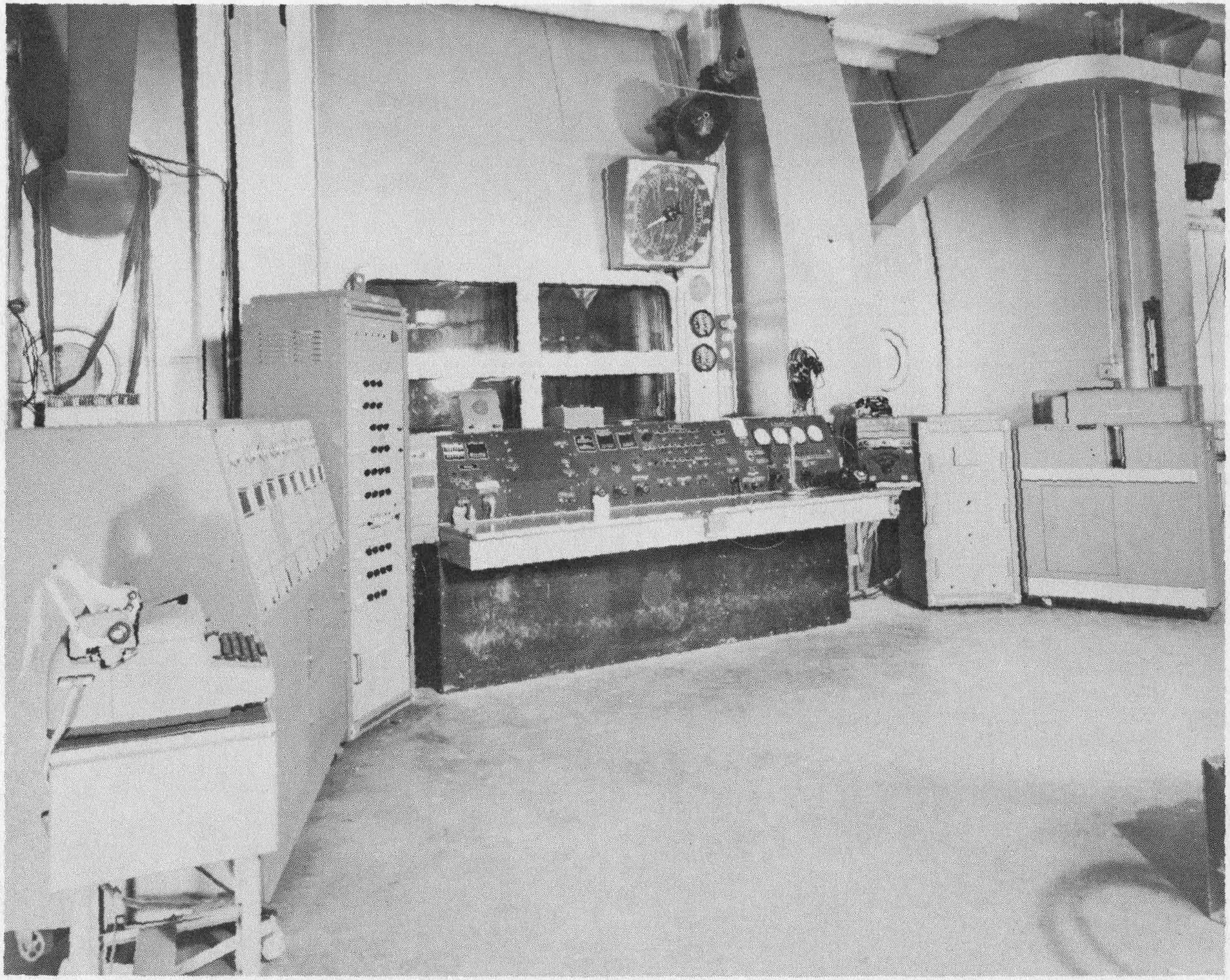


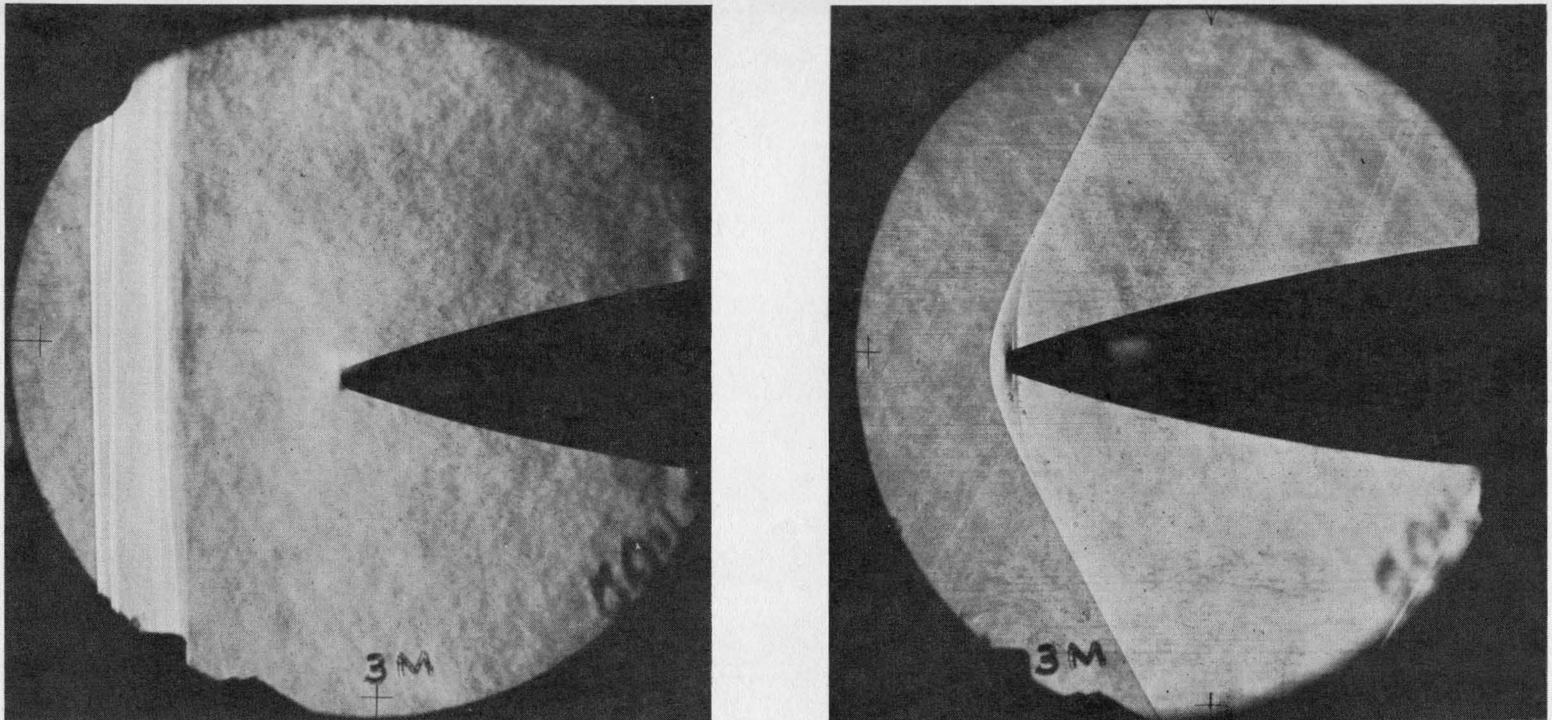
Figure 3.- Variation of stagnation temperature, Reynolds number per foot, and dynamic pressure with Mach number. Langley 8-foot transonic pressure tunnel.

Figure 4.- Typical model installation in Langley 8-foot transonic pressure tunnel. L-89765



L-85293

Figure 5.- Tunnel control panel and semiautomatic readout equipment in the Langley 8-foot transonic pressure tunnel.



L-57-1649

(a) Mach number = 1.03.

(b) Mach number = 1.20.

Figure 6.- Sample of schlieren results from the Langley 8-foot transonic pressure tunnel.

THE LANGLEY
4-BY 4-FOOT SUPERSONIC PRESSURE TUNNEL

Langley Aeronautical Laboratory

Langley Field, Virginia

NACA

LANGLEY 4- BY 4-FOOT SUPERSONIC PRESSURE TUNNEL

GENERAL DESCRIPTION

The Langley 4- by 4-foot supersonic pressure tunnel is a closed-throat, single-return, continuous-operation tunnel, driven by an axial-flow compressor. A perspective drawing of the tunnel exterior is shown in figure 1. The axial-flow compressor is driven by two variable-speed electric motors developing a total of 45,000 horsepower under normal operating conditions, with a half-hour overload rating of 60,000 horsepower. The motors turn at approximately 800 rpm and, by means of a speed-increasing gear box, turn the axial-flow compressor at 1300 rpm. The axial-flow compressor has seven stages and was designed for a compression ratio of 2. The flow capacity is 870,000 cubic feet per minute at 1300 rpm. There are two screens ahead of the axial-flow compressor to protect it from debris that may result from model or tunnel failure.

Cooling coils are located at the first corner downstream of the compressor. The coils are supplied with 7,000 gallons of water per minute, by which the tunnel air temperature is reduced from about 300° F to 110° F. This is a constant-volume system with cooling water supplied by cooling towers. The tunnel temperature is controlled to ±1° F by proportional bypass of the cooling towers.

The air flow then passes through the settling chamber, at which point air may be discharged or dry air added. Dry makeup air is stored at 125 lb/sq in., abs. and -70° F dewpoint in storage tanks having a total volume of 10,000 cubic feet. This dry makeup air is inbled to the tunnel as needed to change tunnel pressure and to maintain a low residual tunnel dewpoint to prevent adverse aerodynamic condensation effects. At a Mach number of 1.6 and a stagnation pressure of 1/4 atmosphere, a dewpoint of -30° F is necessary to avoid condensation effects.

TEST SECTION

The test section is 54 inches wide with fixed side walls, and the upper and lower walls are adjustable so that the height will vary from approximately 51 to 64 inches. The Mach number may be changed by jacking the walls of the flexible nozzle against interchangeable templates.

TEST CONDITIONS

The design Mach number range is from 1.25 to 2.0, but the nozzles currently calibrated are for Mach numbers of 1.4, 1.6, 1.8, and 2.0. The extreme operating stagnation-pressure range is from 1/8 atmosphere to $2\frac{1}{2}$ atmospheres, absolute, but accuracy and overload considerations limit normal running to the pressure range from 1/4 atmosphere to 2 atmospheres. The normal stagnation temperature is about 110° F. The following table shows the conditions in the test section at various Mach numbers for a stagnation temperature of 110° F and a stagnation pressure of 1 atmosphere:

Test section Mach number	(1.25)	1.4	1.6	1.8	2.0	(2.2)
Dynamic pressure, lb/sq ft	894	912	892	835	757	671
Static pressure, lb/sq ft	817	665	498	368	270	198
Velocity, ft/sec	1276	1388	1522	1641	1744	1834
Reynolds number per foot, millions	4.21	4.17	3.98	3.71	3.41	3.11

MODEL-SUPPORT SYSTEMS

The model-support system has a large support strut located on the tunnel horizontal center line. Two lead screws located in this strut drive the model support sting, giving angle of attack α or angle of sideslip β, depending on the position in which the model is mounted on the model support. The support sting can also be traversed across the tunnel. Figure 2 is a sketch showing the position of a model relative to the sting support and to the schlieren window, and figure 3 shows typical models mounted on the sting support in the test section. The angle-of-attack range is limited to ±15°. A 15° offset rotary sting may be mounted on the model support and is remotely operated from the control room. The purpose of this offset sting is to increase the angle of attack of the present system to 30° and to permit combined angle of attack and roll for stability investigations. Since the 15° offset rotary sting moves the model closer to the tunnel wall, the reflected shock wave from the nose of the model at a Mach number of 1.4 usually interferes with the tail of the model. Mach numbers above 1.4 are not affected by reflected shock wave unless the models are exceptionally long. A straight rotary sting is available for lower angle-of-attack ranges at lower Mach numbers.

The model support has provision for 240 internal (0.055 O.D. tube) and 72 external (0.070 O.D. tube) pressure leads. The model support also has provisions for 47 electrical leads for strain-gage balances and other remote-control model mechanisms. The rotary sting has provision for 33 electrical leads but no pressure leads are available because of limited space due to its rotational drive mechanism.

A boundary-layer bypass plate is also available for semispan models, and has provisions for a strain-gage balance and pressure leads. The angle of attack may be remotely operated from the control room. Figure 4 is a sketch of the boundary-layer bypass plate and figure 5 is a photograph of a semispan delta wing mounted on the bypass plate.

MODELS

Although considerations of test-section size and the strain-gage balance to be used determine the size of the model to be tested, complete models usually have a wing span of about 2 feet and a body length of $2\frac{1}{2}$ to 3 feet. Shock waves reflected from the tunnel walls at different Mach numbers must be considered in determining the length of model to be investigated. Typical model installations are shown in figures 3 and 5.

The materials used in the 4-foot supersonic pressure tunnel models vary from plastic covered wood to heat-treated steel, depending on the load conditions. This is possible because of the low operational temperature of the tunnel. It must be remembered that tunnels in general have some sandblasting; therefore, those parts of the models which would be subjected to sandblasting should be made of steel and aluminum alloy to resist this abrasion.

Since the 4-foot supersonic pressure tunnel is a fixed Mach number tunnel, the model will experience dynamic starting and stopping loads as the tunnel shock passes over the model. These dynamic loads can be minimized by reducing the tunnel pressure to allow the shock to pass through the test section, but the resulting dynamic loads are not calculable. The above condition is considered a minimum-stress condition, since the maximum stress may occur as a result of a sudden loss of power while the tunnel is at the normal stagnation pressure. Therefore, on the basis of experience, a minimum static safety factor of four (4) on the yield stress or of five (5) on the ultimate stress are required.

INSTRUMENTATION

Balances

The strain-gage balances available for use at the Langley 4- by 4-foot supersonic pressure tunnel are similar to those previously described for the Langley 8-foot transonic tunnel. In addition, there are available three semispan balances for use with the bypass plate described under "Model-Support Systems." Details of these balances may be ascertained by consultation with the wind-tunnel staff.

Manometers

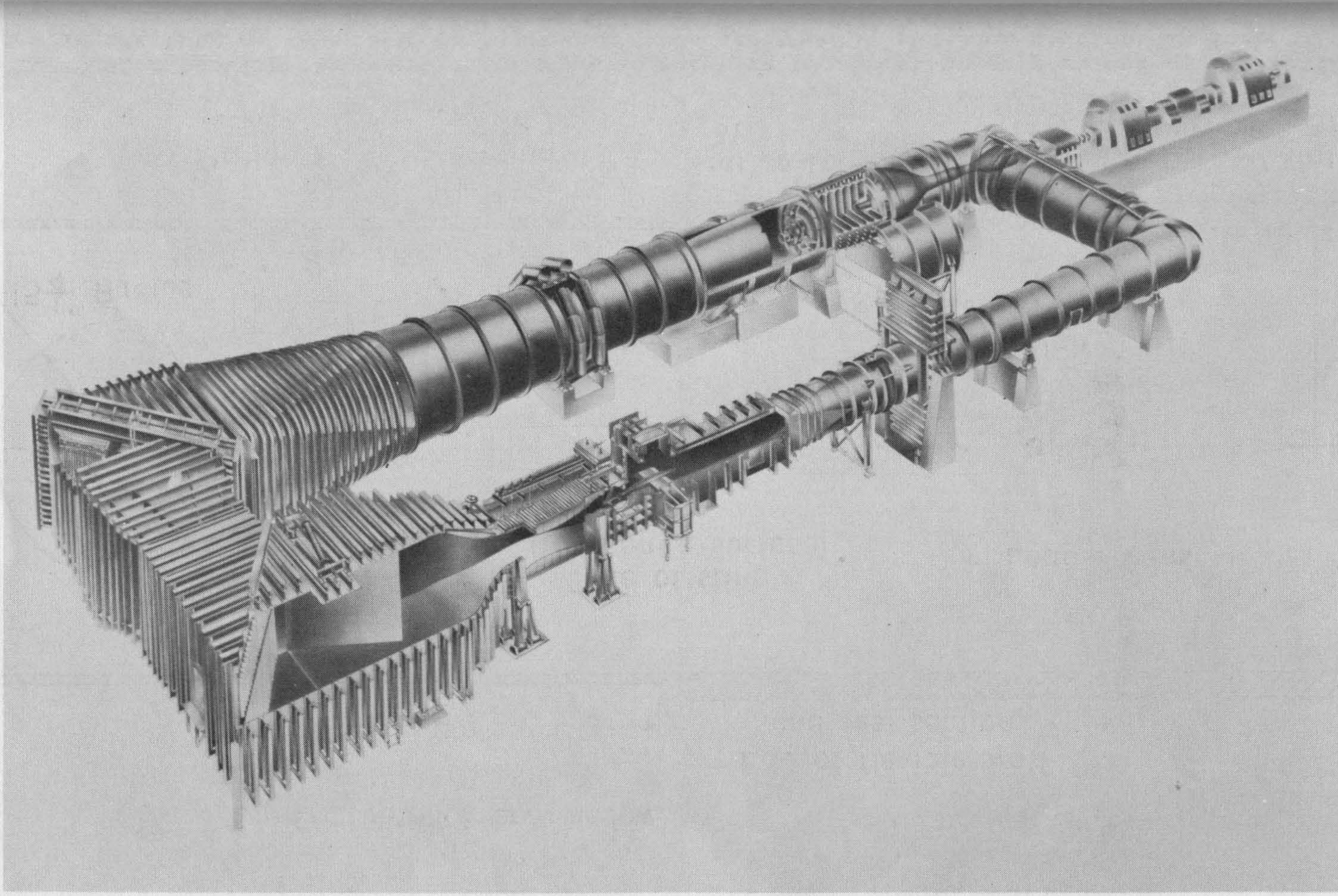
Six 40-tube mercury manometers with a working height of 6 feet are available for the measurement of steady pressures. Also available is a mercury-filled 150-tube variable inclination manometer board with tubes 7 feet long. Recording is by photography.

Data Recording and Reduction

The data recording and reduction equipment used for handling steady force and pressure information at the Langley 4- by 4-foot supersonic pressure tunnel is similar to that described for the Langley 16-foot transonic tunnel. Figure 6 is a photograph taken in the control room showing the data readout equipment.

Flow Visualization

A schlieren system is available with interchangeable mirrors (12- and 30-inch), and a remotely controlled interchangeable light source (Bol lamp and spark gap). A sample of a schlieren photograph made at the Langley 4- by 4-foot supersonic pressure tunnel is shown in figure 7.



L-60681

Figure 1.- Pictorial drawing of the Langley 4- by 4-foot supersonic pressure tunnel.

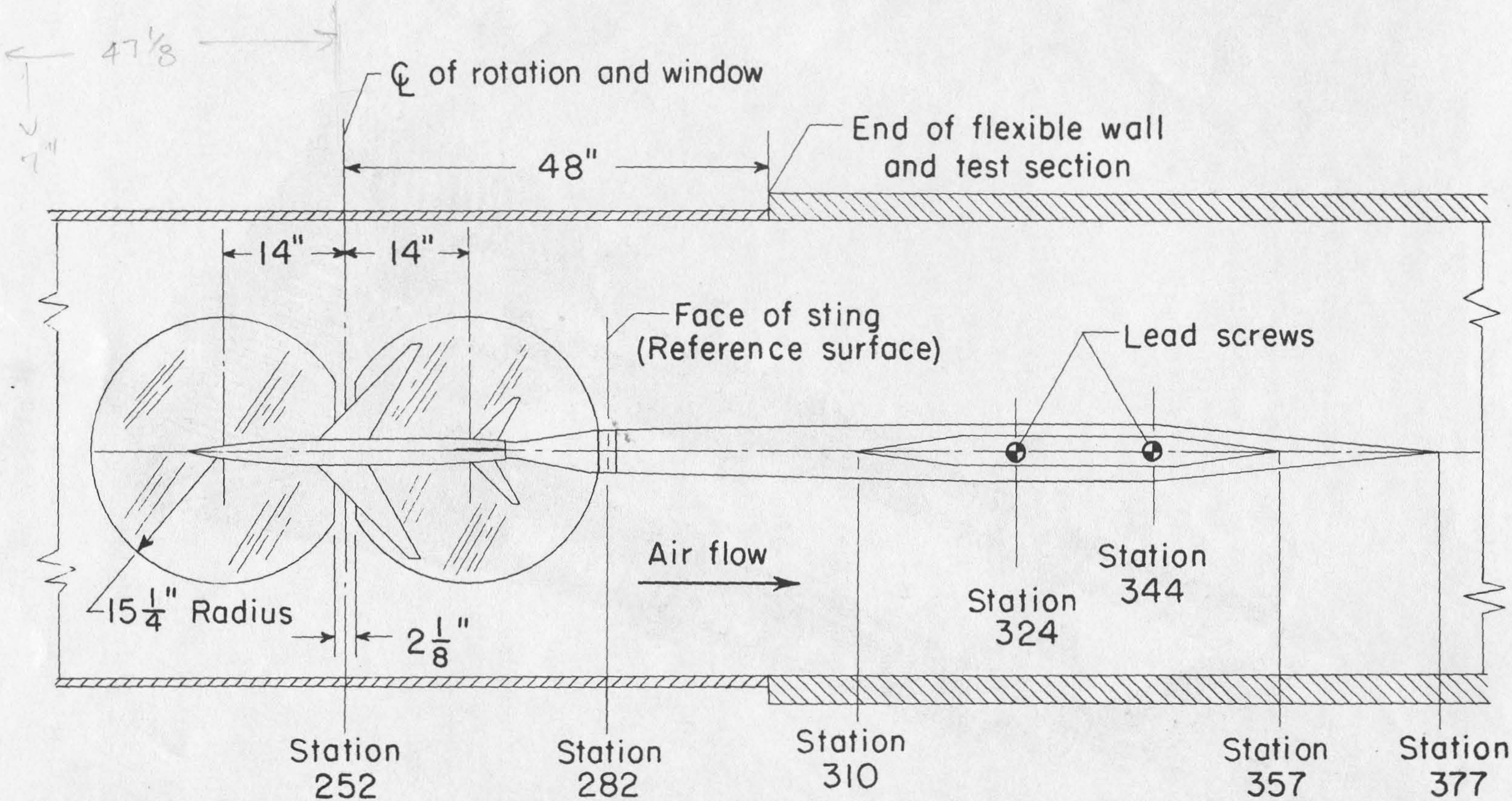
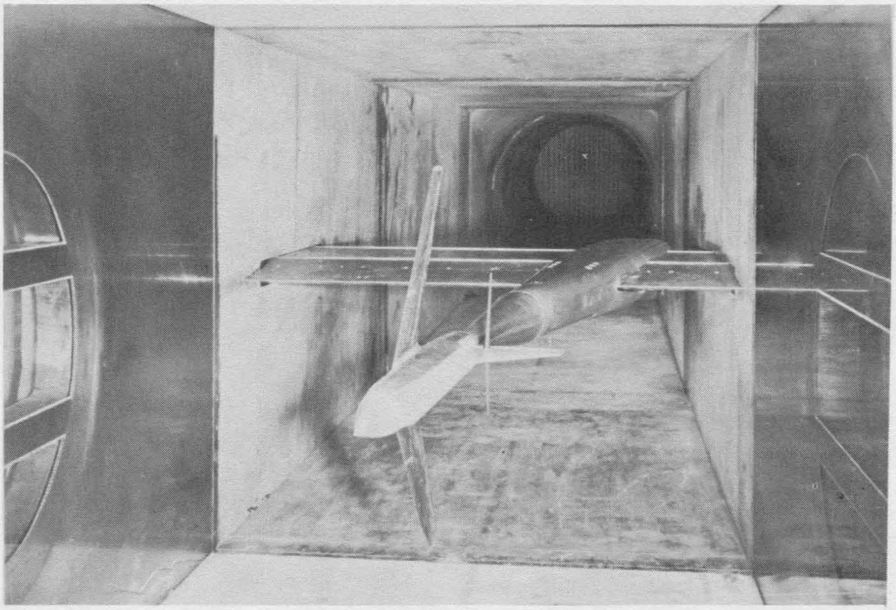
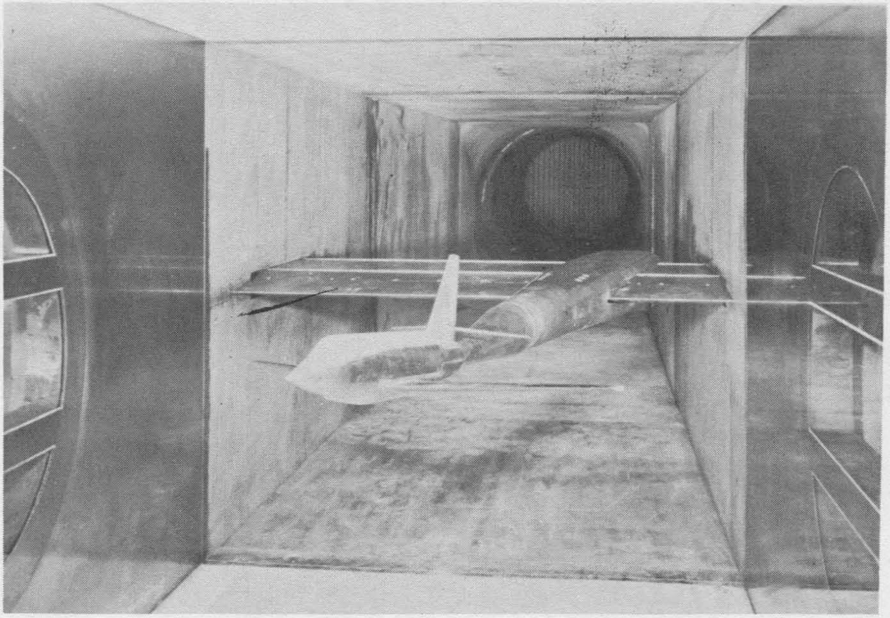


Figure 2.- Sketch showing the position of a model relative to the sting support and to the schlieren window in the Langley 4- by 4-foot supersonic pressure tunnel. (Tunnel stations in inches; reference station 0 taken at the start of the flexible nozzle.)

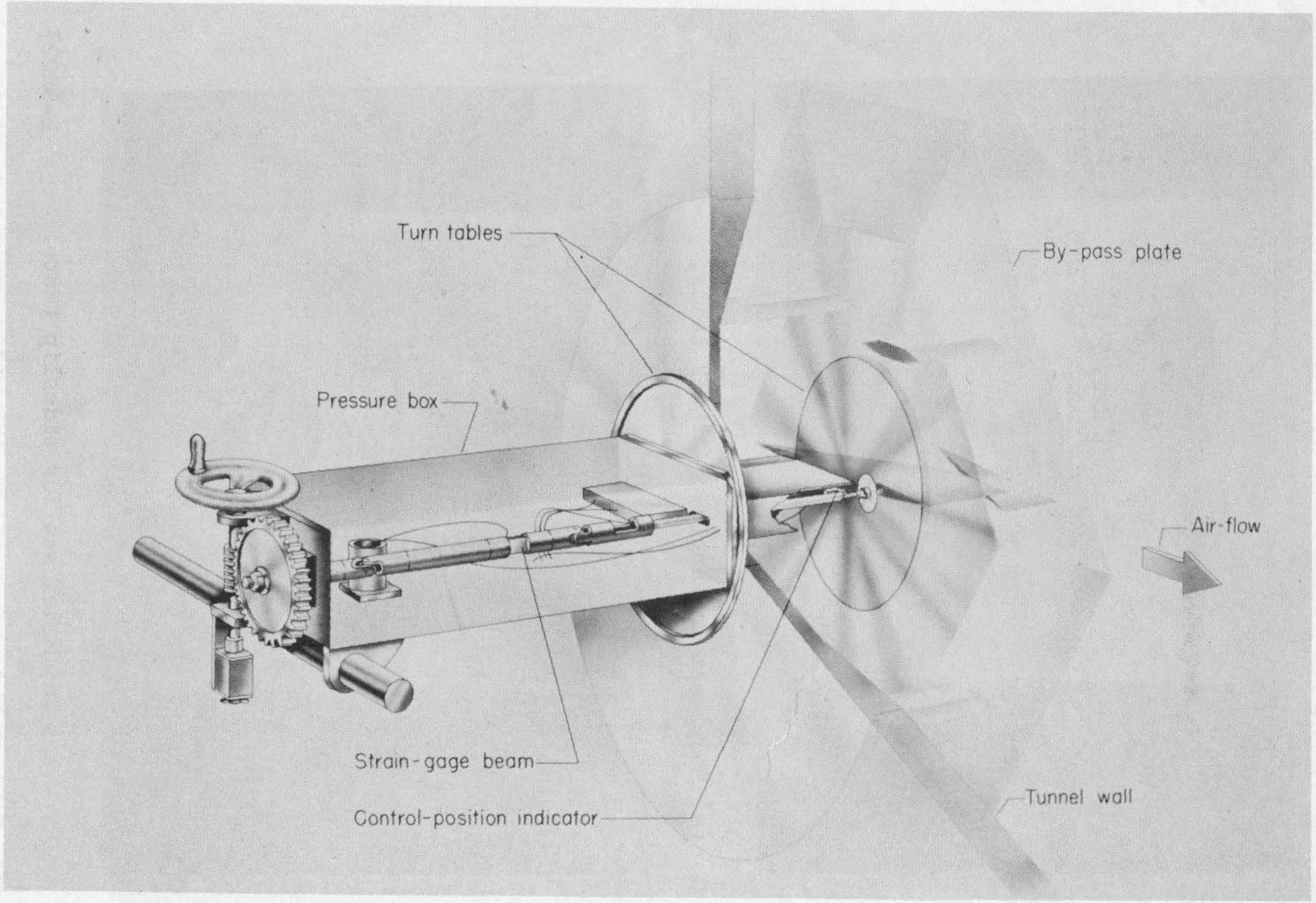


(a) Model set for angle-of-attack tests. L-62225



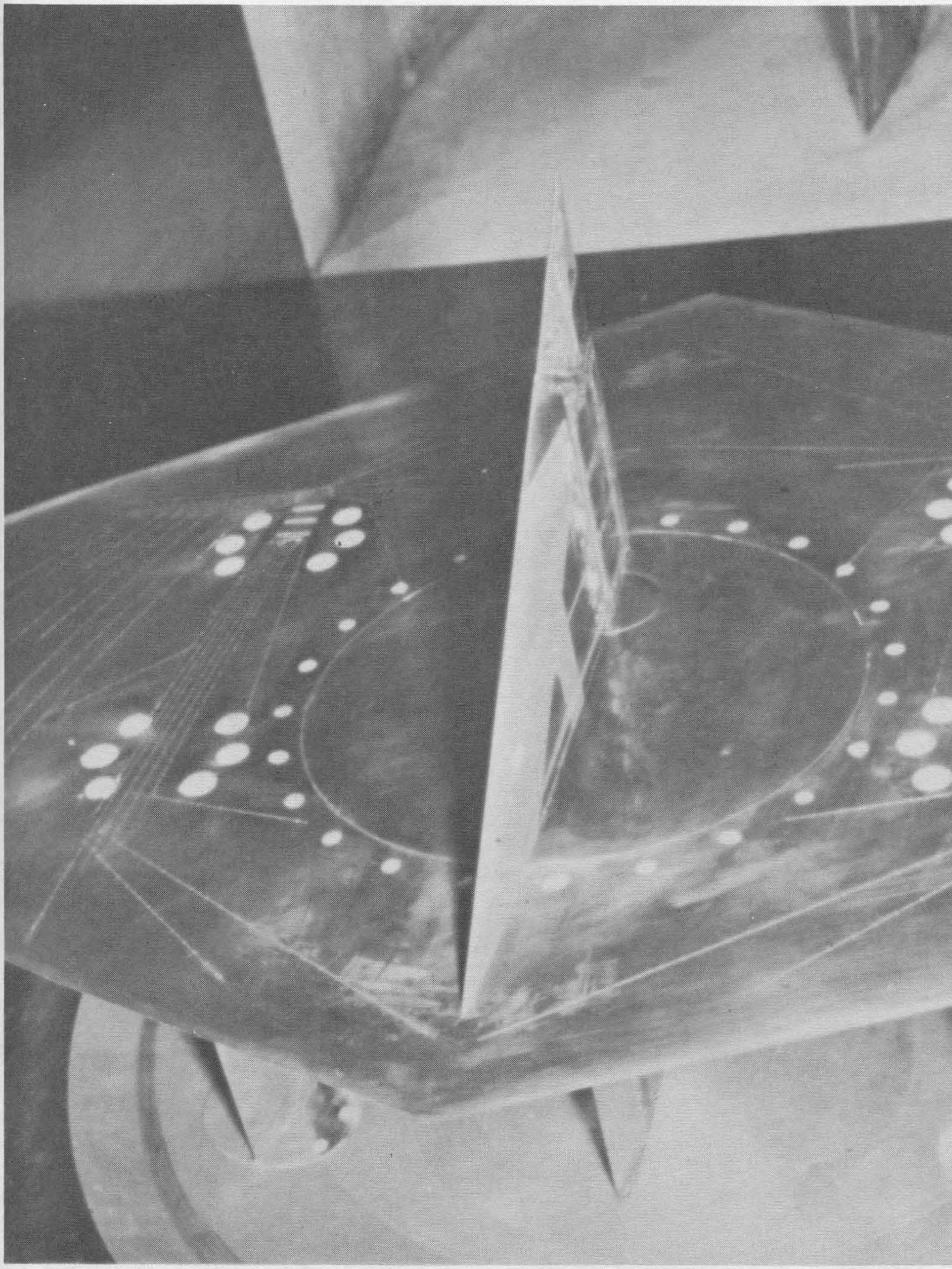
(b) Model set for sideslip tests. L-62227

Figure 3.- Typical models mounted on the sting support in the Langley 4- by 4-foot supersonic pressure tunnel.



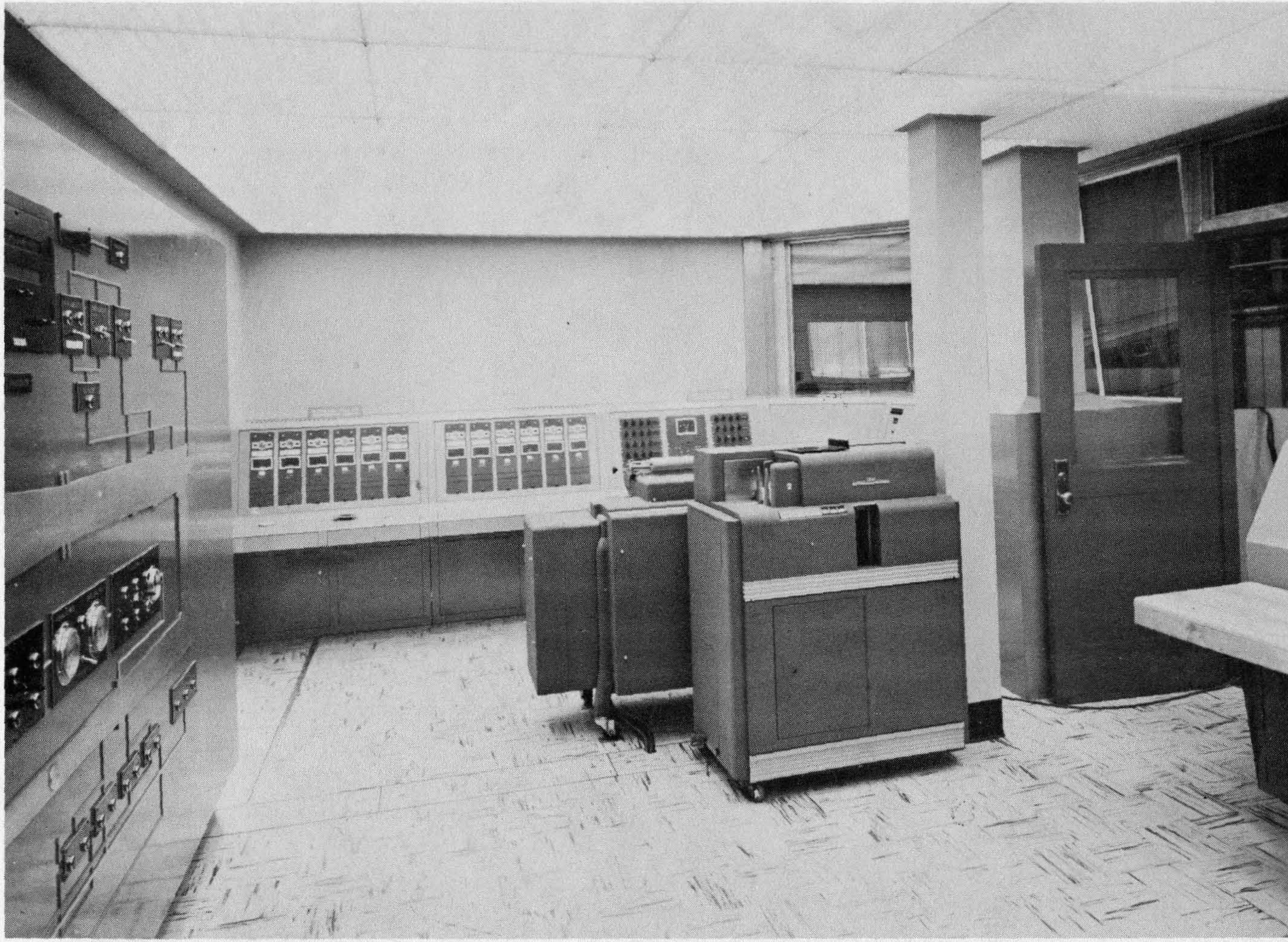
L-77038

Figure 4.- Sketch of the boundary-layer bypass plate of Langley 4- by 4-foot supersonic pressure tunnel.



L-75279

Figure 5.- A semispan delta-wing model mounted on the boundary-layer bypass plate of the Langley 4- by 4-foot supersonic pressure tunnel.



L-93230

Figure 6.- Control room of the Langley 4- by 4-foot supersonic pressure tunnel with the data readout equipment in the background.

L-57-1650

Figure 7.- A schlieren photograph made in the Langley 4- by 4-foot supersonic pressure tunnel.

THE LANGLEY HIGH-SPEED 7- BY 10-FOOT TUNNEL

Langley Aeronautical Laboratory
Langley Field, Virginia

NACA

HIGH-SPEED
7- BY 10-FT

LANGLEY HIGH-SPEED 7- BY 10-FOOT TUNNEL

GENERAL DESCRIPTION

The Langley high-speed 7- by 10-foot tunnel is a closed, single-return wind tunnel, which operates with atmospheric stagnation pressure. Shop and office space and other auxiliary facilities are shared by the high-speed 7- by 10-foot tunnel (on the right in fig. 1) and the 300-MPH 7- by 10-foot tunnel, which is described elsewhere in this manual. The high-speed tunnel is powered by a 14,000-horsepower variable-speed electrical-drive system, which turns the single 18-blade fixed-pitch wooden fan of $28\frac{1}{2}$-foot diameter at speeds up to 490 rpm. A set of countervanes downstream from the fan removes the airstream rotation imparted by the fan. The tunnel is cooled by an air-exchange system which introduces filtered atmospheric air into the diffuser a short distance downstream from the test section. A like amount of heated tunnel air is exhausted at a station downstream from the drive section. A two-part noise-suppression system is installed, which consists of a sound-absorbing blanket surrounding the tunnel shell in the vicinity of the drive fan and sound-absorbing baffles installed in the airstream at either end of the drive section.

A series of four turbulence-damping screens of 16-mesh wire cloth is installed in the large settling chamber ahead of the entrance cone. This installation reduces the turbulence and airstream roughness to the low values required for reliable studies of dynamic stability and buffeting phenomena.

TEST SECTION

The Langley high-speed 7- by 10-foot tunnel has a conventional closed rectangular fixed geometry test section having dimensions as shown in figure 2. Fluorescent lights are installed in the small corner fillets for illumination of the test setups.

The test chamber surrounding the test section is vented to the tunnel at a point downstream from the test section so that during tunnel operation the test-chamber pressure will drop to a value as low as 21.5 inches of mercury, absolute. Test personnel may remain in the test chamber during tunnel operation to observe the model or to operate items of test equipment if necessary. During the more routine types of tests, however, all tunnel operation and data-recording functions are performed at locations outside of the test chamber. Figure 3 is a view across the test chamber showing the large door in the tunnel through which models are taken for installation. The test section, test chamber, and model-shop floors are on the same level for ease of model handling. The test-section observation windows appear at the right in figure 3.

TEST CONDITIONS

The Mach number in the test region may be varied from 0 to 0.95, but accuracy of speed determination at Mach numbers below about 0.4 suffers because of instrument limitations. At the high Mach numbers, a gradient amounting to a Mach number change of less than 0.01 over the length of a typical sting-mounted model exists because the wall divergence is greater than that required to compensate for boundary-layer growth. This velocity gradient gives rise to a longitudinal bouyancy force which is small compared to typical minimum drag values and is accounted for in the data-reduction process.

The variation with Mach number of stagnation temperature, dynamic pressure, and Reynolds number per foot of reference length is presented in figure 4. The stagnation temperature t_t is not allowed to exceed 160° F. The stagnation pressure is essentially equal to atmospheric pressure.

MODEL-SUPPORT SYSTEMS

The support system used most frequently in the high-speed 7- by 10-foot tunnel is the variable angle-of-attack sting system. The general arrangement of this system is shown in figure 2, and figure 5 is a photograph of a model mounted on the sting support. The rear portion of the sting is mounted on two vertically sliding elements of the vertical support strut. These sliding elements are actuated by lead screws driven through a gear train in such a manner that the sting may be either translated vertically or rotated through a total range of about 26° about a point located approximately at the model center. The forward part of the sting, to which the model is attached through a strain-gage balance, is mounted to the rearward part by means of a coupling which determines the relative angle between the two parts of the sting. The available coupling angles range from 0° to 24° in 3° increments. In addition, two combined angle couplings are available which give a 4° sideslip angle in combination with either 12° or 24° pitch-angle increments. The couplings may be rotated either 90° or 180° and the combined angle couplings may be turned end for end so that any angle of attack between +36° and -36° may be obtained with sideslip angles of +4°, 0°, or -4°. Any 26° range of angles of attack between these limits may be covered by remote control during tunnel operation. The sting translation feature allows the model to be vertically positioned in the center of the tunnel at any angle of attack. By rolling the model through 90°, a remotely controlled range of sideslip angles of ±13° may be obtained with angles of attack between ±24° set by the coupling. With this arrangement, the model is displaced laterally from the tunnel center by a distance proportional to the angle of attack.

The sting-support system may be used within the following load limits:

Normal force, lb	2,000
Side force, lb	1,200

Other components of load may usually be ignored.

One rather specialized sting-support system is the variable-sideslip sting illustrated in figure 6. This apparatus, which was designed for small models (about 1 foot span), utilizes the variable angle-of-attack and coupling features of the standard sting support system but in addition incorporates a hydraulically actuated variation of sideslip angle. The hydraulic system follows a programmed sequence which causes the model to be moved to 5° sideslip, then to -5° sideslip, and returned to zero, remaining at each of these angles for an interval of 5 seconds. The model motions are made at a slow, constant rate. This apparatus allows the determination of lateral static stability derivatives along with the longitudinal characteristics, with the opportunity for a detailed study of any nonlinearities in lateral characteristics which may occur in this sideslip-angle range.

A turntable is provided in the tunnel ceiling from which large semispan models (2 to 3 feet semispan) may be mounted. Forces and moments are measured by a five-component strain-gage balance having interchangeable beams so that a choice of load limits and sensitivities is available. A full 360° range of angle of attack may be used if desired. Figure 7 is a photograph of a typical ceiling-mounted semispan model.

Although a number of test installations have been made in the high-speed 7- by 10-foot tunnel with which various dynamic stability derivatives were measured, the development of techniques for measuring dynamic characteristics is proceeding at such a rate that descriptions of those used in the past would be generally of little value. If dynamic stability tests in the high-speed 7- by 10-foot tunnel are desired by any agency, consultations with the tunnel staff are necessary to provide a choice of the currently available test setup and technique which would best fulfill the purpose of the tests.

The forced rolling apparatus is the one dynamic test model support which will be described because it is considered to be a relatively permanent item of test equipment. This apparatus, which is illustrated in figure 8, will roll a model at a steady angular velocity about an axis parallel to the air stream. Angles of attack other than zero are obtained by the use of a bent sting which is so designed that the model reference point lies on the axis of rotation. Stings giving angles of attack of 0° to 20° in 2° increments are available. The housing downstream from the sting contains a hydraulic motor which can roll the sting and model at any speed up to 900 revolutions per minute in either direction. The model is typically mounted on a conventional internal strain-gage balance so that the six components of force and moment are measured during rolling. A bank of 24 silver slip rings with dual brushes contained in the sting housing is used to transfer the electrical signals from the rotating balance to the stationary support system.

MODELS

The models tested on the sting-support system generally have a wing span from 2 to 3 feet and a body length of 3 to 4 feet. Materials of construction are usually steel or aluminum alloy with wood or reinforced plastic used for parts which are not highly stressed. If the model is to be used for dynamic tests, it is desirable to keep the weight and moments of inertia as low as practical. The pitching moment of inertia is particularly significant in tests involving pitching oscillation or steady rolling at angles of attack other than zero.

In the usual static test, the six components of force and moment are measured by an internal strain-gage balance. Special additional strain-gage installations are often used for measurement of loads on individual model components, bending moments at the root of wings or tail surfaces, or hinge moments of flaps or control surfaces.

For pressure-distribution measurements, up to 120 pressure tubes may be handled through the standard sting support system; however, only a small number of pressure measurements may be taken simultaneously with force measurements.

INSTRUMENTATION

Balances

The Langley Laboratory has available a wide variety of strain-gage balances which normally can be used in different models and tunnels without recalibration. Those generally used in the high-speed 7- by 10-foot tunnel fall into two categories, the six-component internal balances used with sting-supported models, and a five-component semispan balance used with models mounted from the ceiling.

The physical size of the internal balances normally used at the high-speed 7- by 10-foot tunnel varies from about 0.45-inch diameter by 5 inches long to about 2 by $2\frac{3}{4}$ by 10 inches long. A photograph of one of the larger balances installed in a typical model is shown in figure 9. Figure 10 illustrates an application of a small balance installed in a missile model to measure the forces on the missile in the presence of the airplane. The size, mounting dimensions, and load ranges of various balances may be ascertained by consultation with the wind-tunnel staff.

Manometers

Steady pressures are recorded by photographing either of two multiple-tube manometers. One is a 150-tube mercury manometer with a working height of 32 inches. The other is a tetrabromoethane-filled 100-tube manometer with a working height of 10 feet.

Data Recording and Reduction

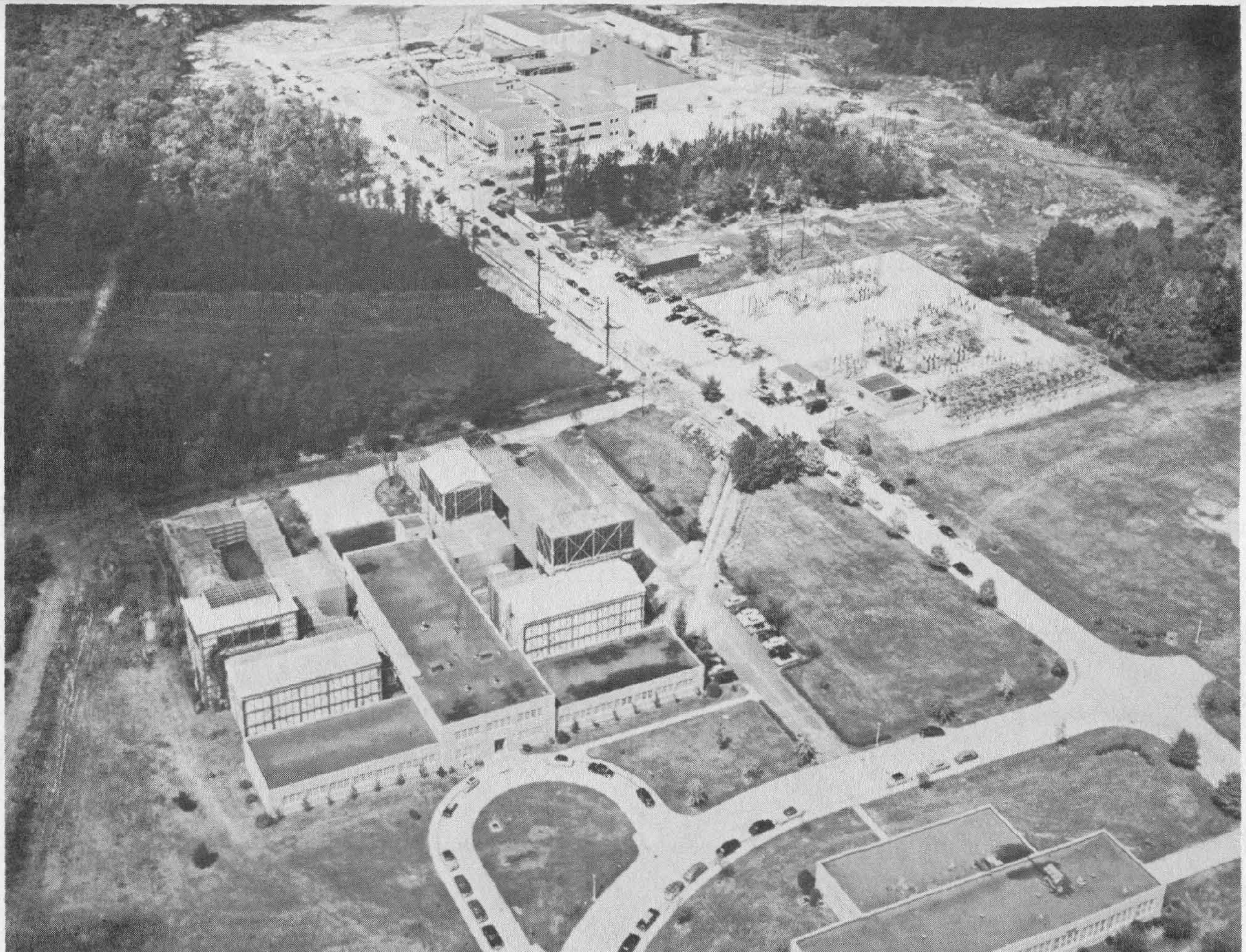
The wire strain-gage indication of the readout system are self-contained strip-chart recording potentiometers designed for use with a full-bridge wire strain gage. Seven such indicators are provided. Each strain-gage output is recorded as a deflection on the strip chart, and visual estimation of the average of such a record is relatively simple, even for unsteady model flow conditions. The data are usually transcribed manually to data sheets as the tests are run. Subsequent data reduction is performed on computing equipment available at the Langley Laboratory. Cables are installed to handle up to 50 channels of data from the test section to the control room. Portable readout instrumentation is used when more than seven channels of data are to be recorded simultaneously.

Steady-pressure data are transcribed from the film records to punched cards and are then processed in automatic computing, integrating, tabulating, and plotting equipment in the same manner as that described for the 16-foot transonic tunnel.

Only a limited amount of dynamic data instrumentation is available.

Flow Visualization

No permanent flow visualization equipment is provided for the Langley high-speed 7- by 10-foot tunnel, but tufts may be installed on the model surfaces and a photographic record made.



L-81707

Figure 1.- Aerial view of Langley 7- by 10-foot tunnels. The high-speed tunnel is on the right and the 300-MPH tunnel in on the left.

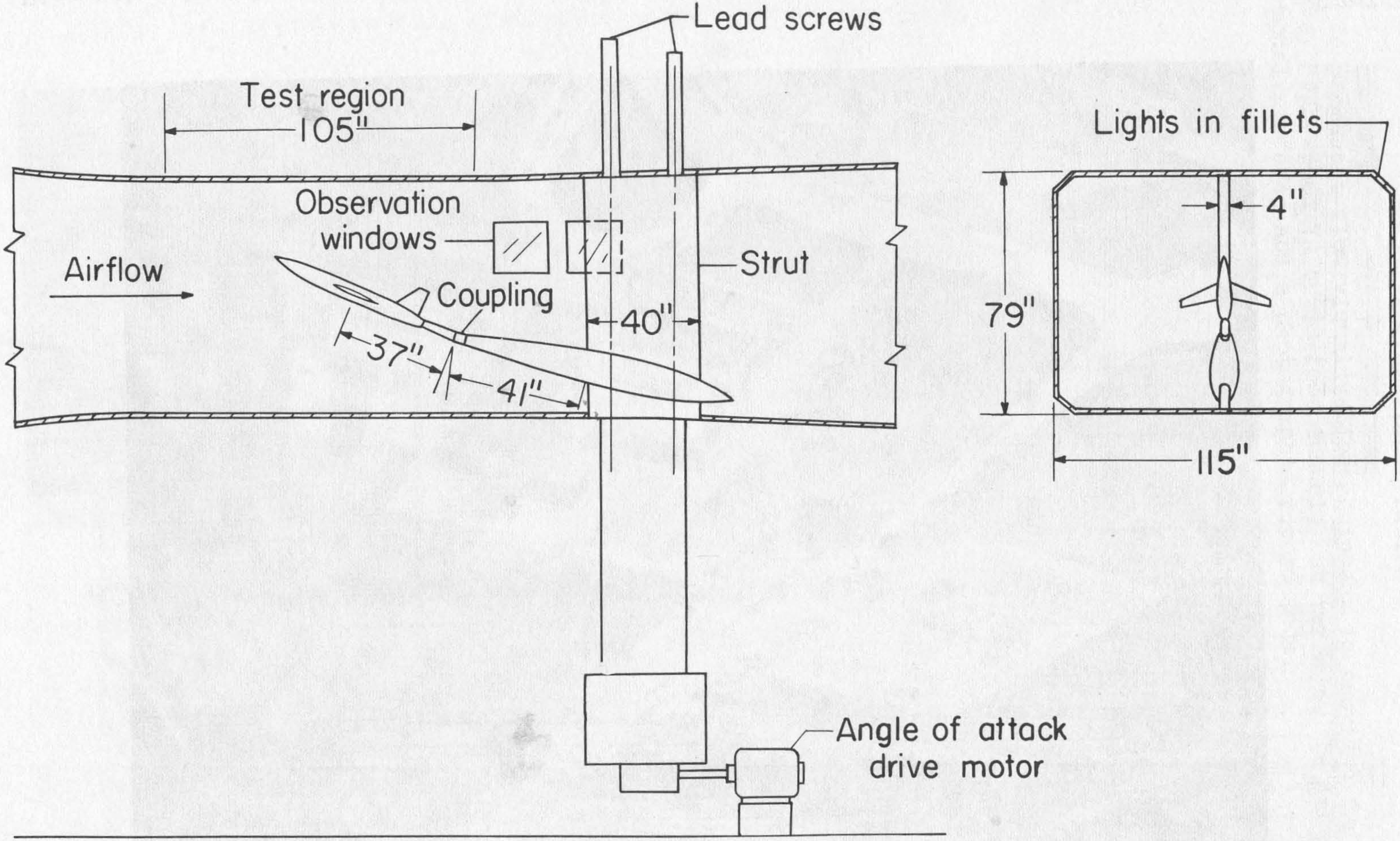


Figure 2.- Sketch of test section and sting support system of the Langley high-speed 7- by 10-foot tunnel. All dimensions in inches.

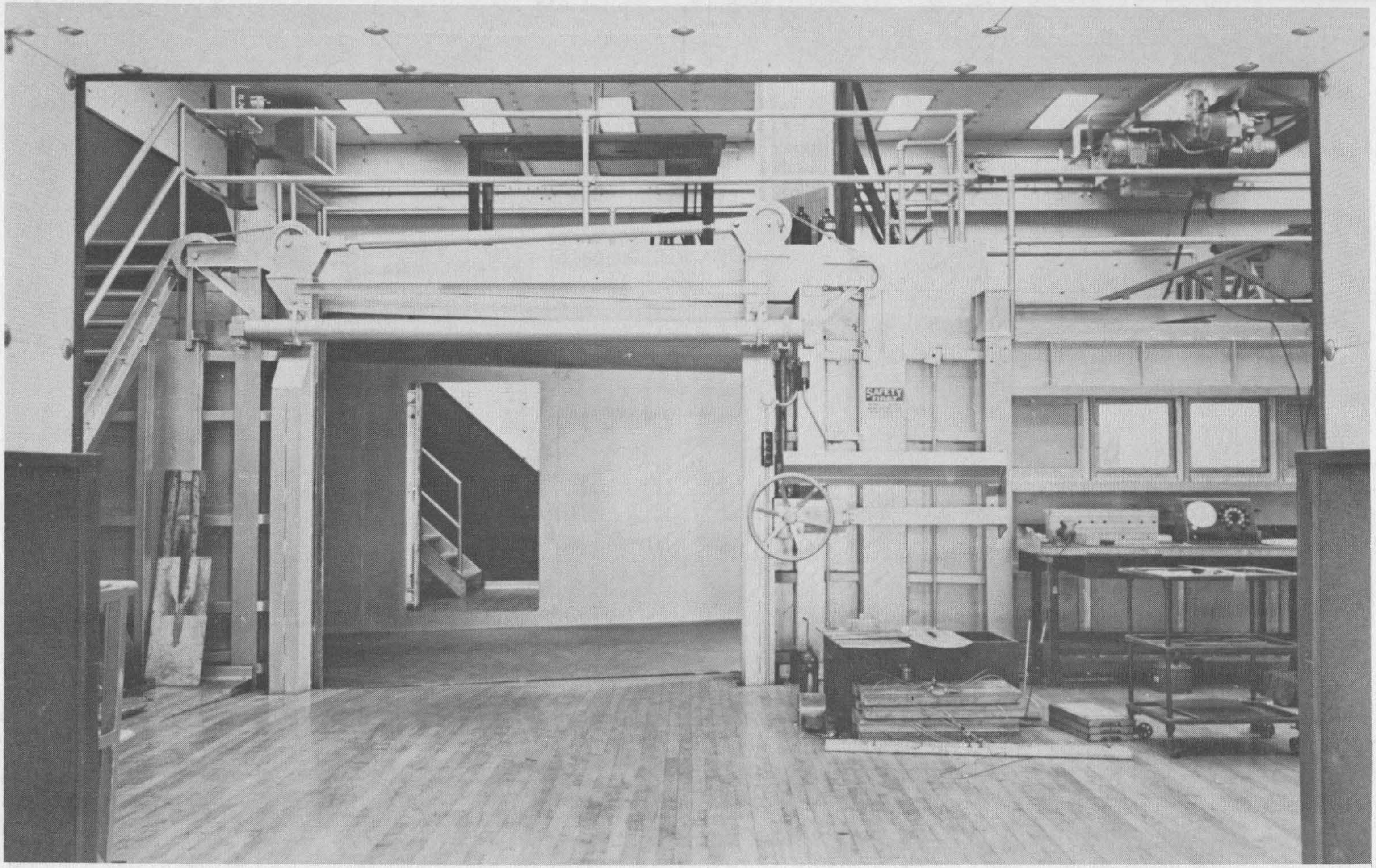


Figure 3.- View across test chamber of Langley high-speed 7- by 10-foot tunnel. L-54318

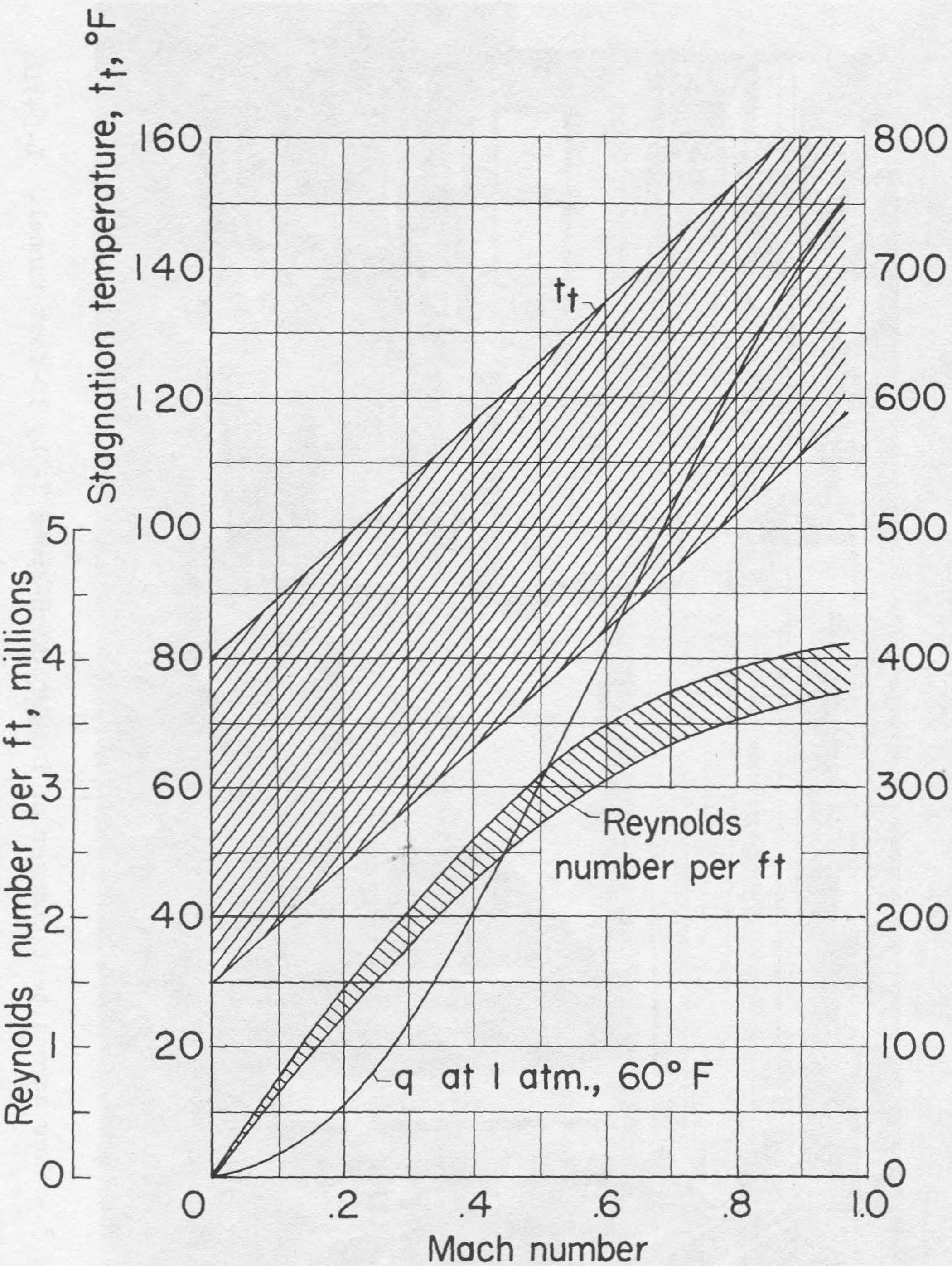
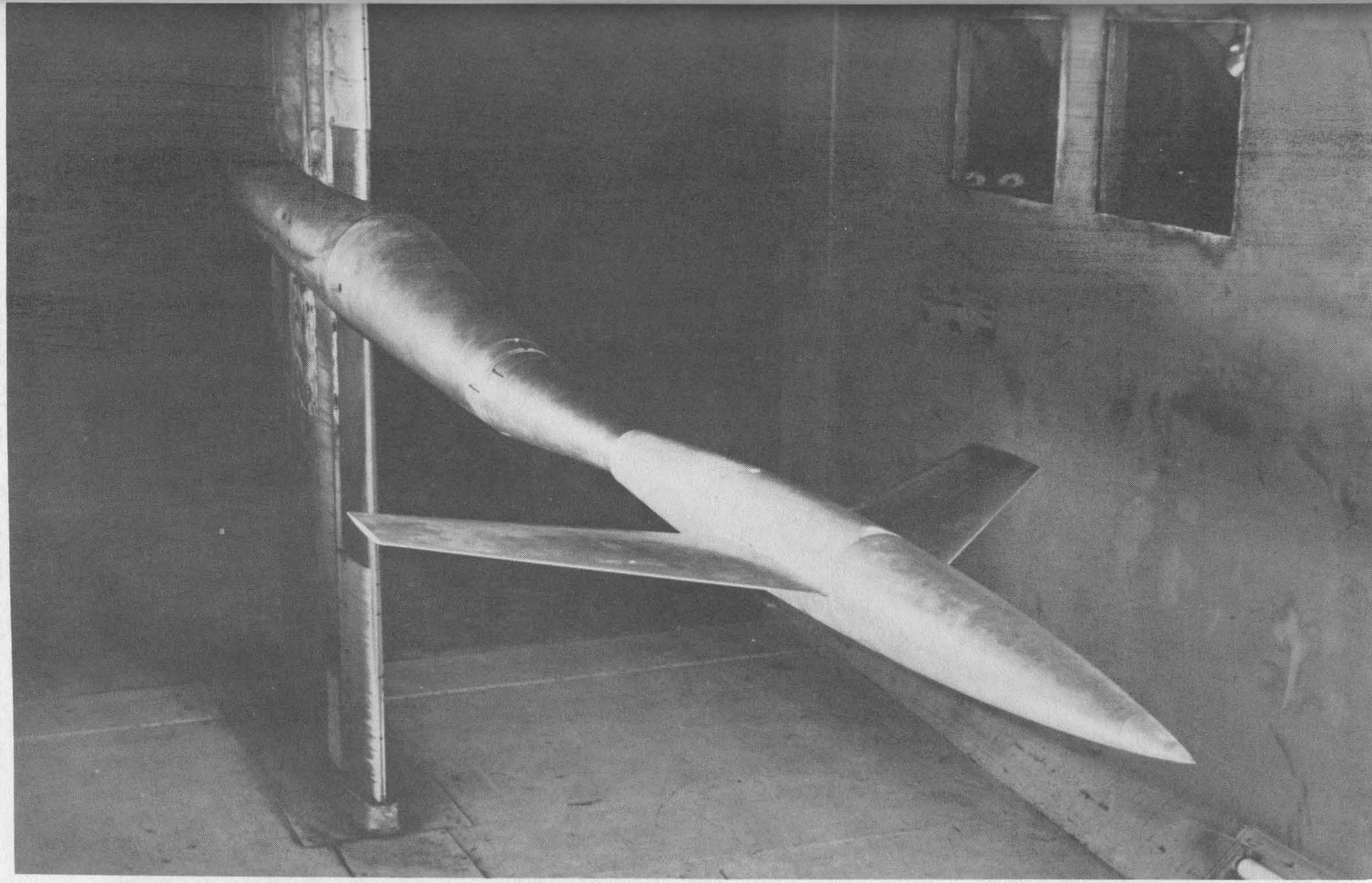
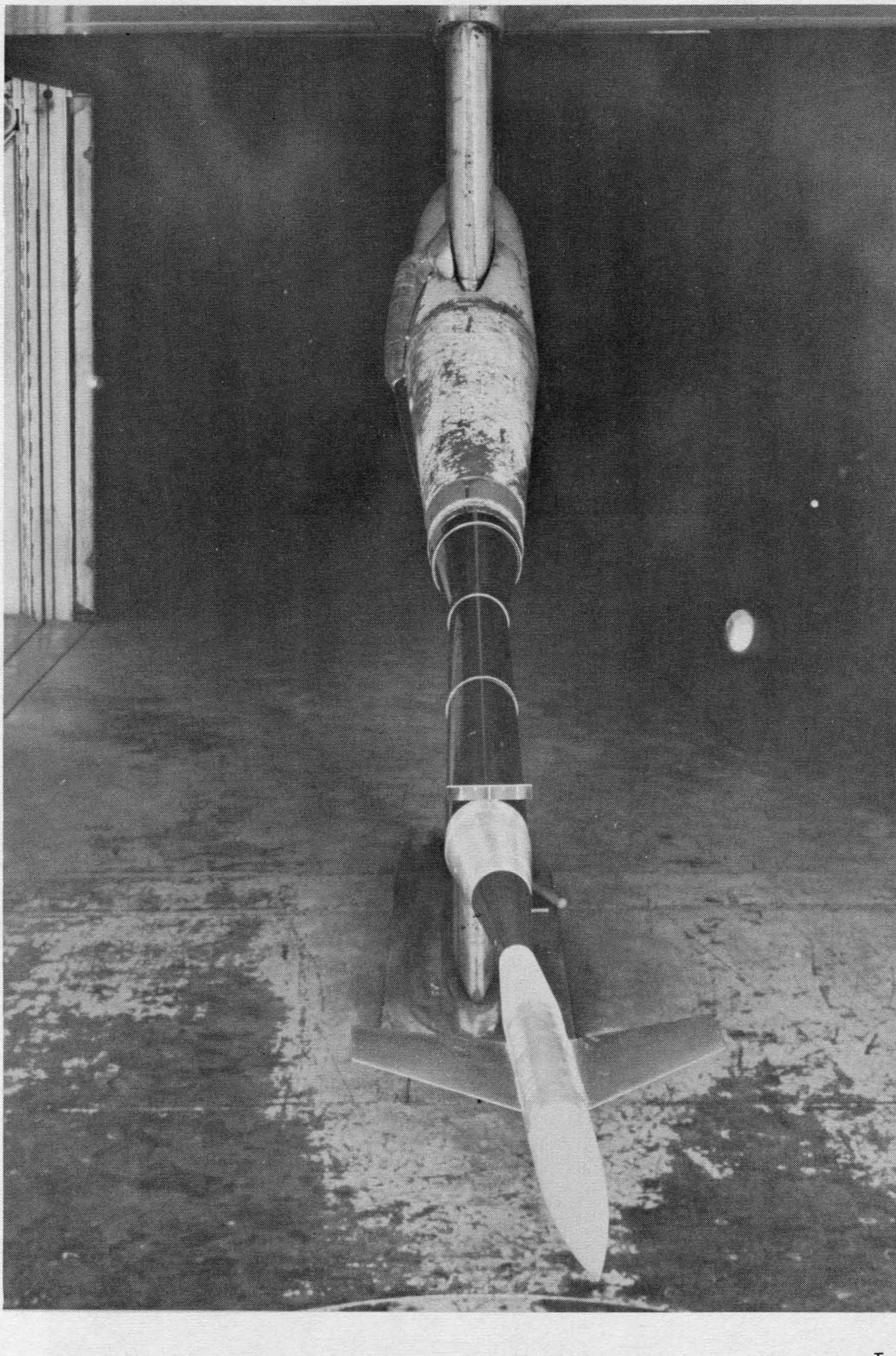


Figure 4.- Variation of stagnation temperature, Reynolds number per foot, and dynamic pressure with Mach number. Langley high-speed 7- by 10-foot tunnel.

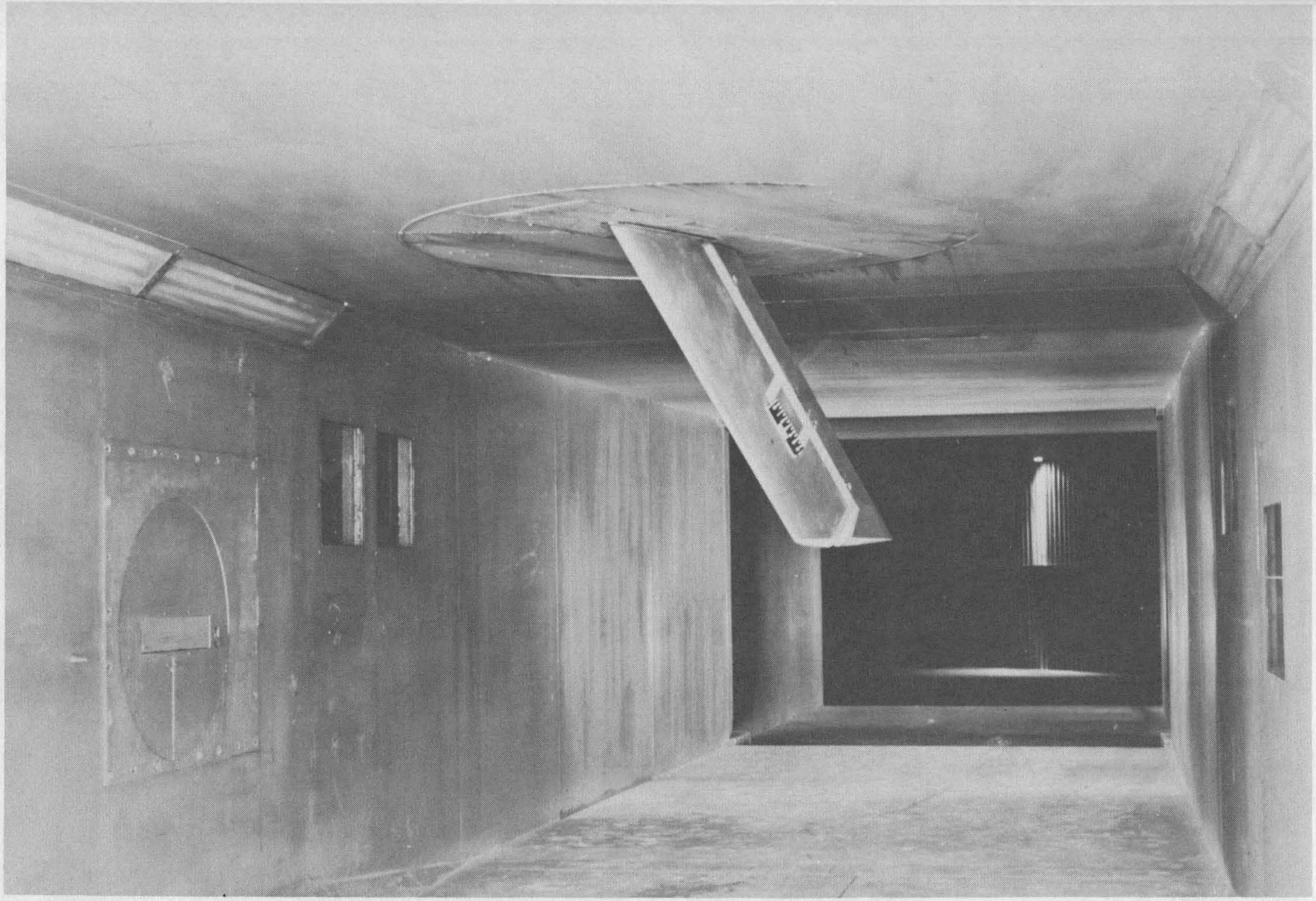


L-72400
Figure 5.- A typical sting-supported-model installation in the Langley high-speed 7- by 10-foot tunnel.



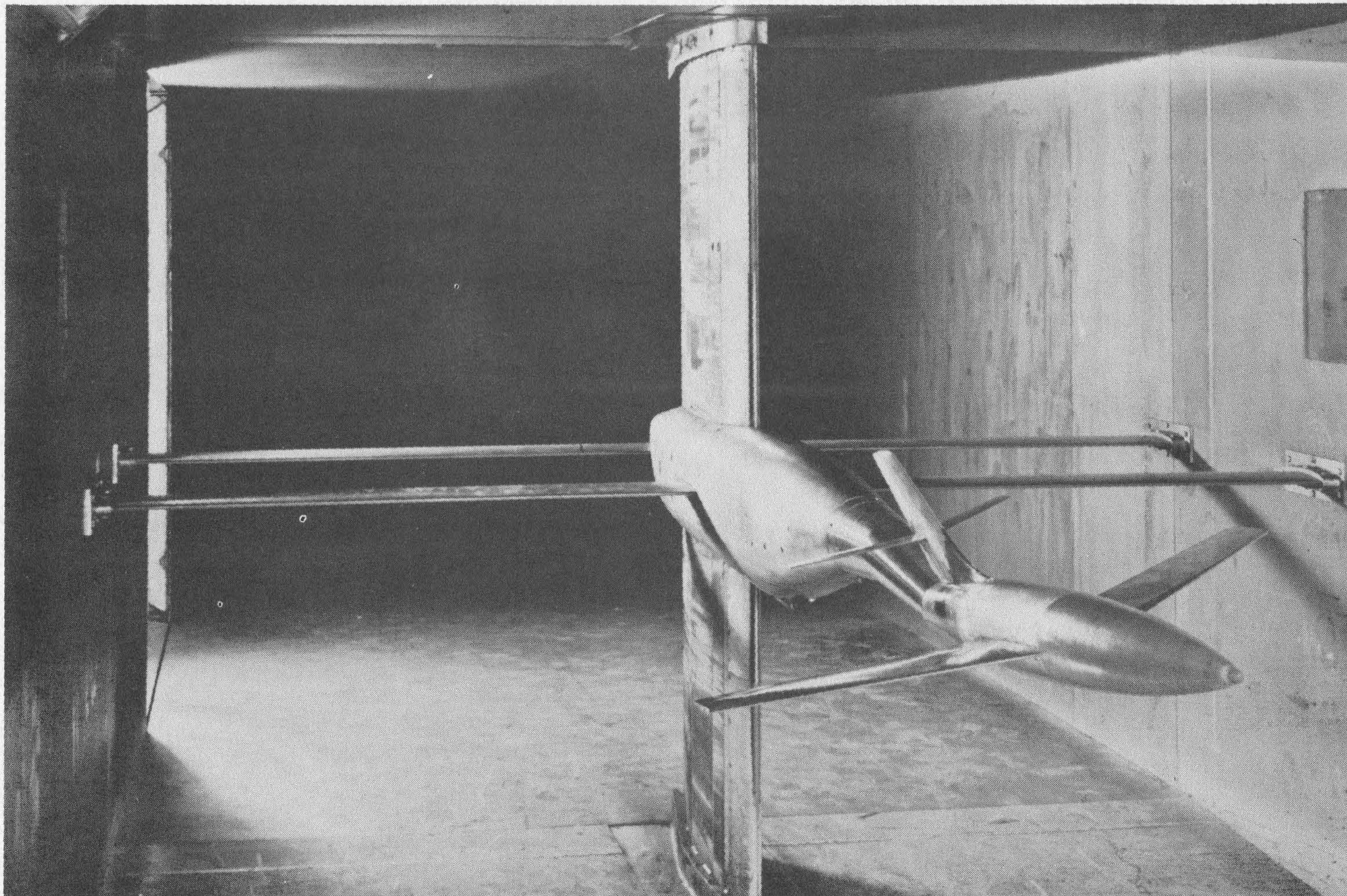
L-89040

Figure 6.- A model installation on the variable-sideslip sting in the Langley high-speed 7- by 10-foot tunnel.



L-53836

Figure 7.- A ceiling-mounted semispan model installation in the Langley high-speed 7- by 10-foot tunnel.



L-70082

Figure 8.- General view of the forced-rolling apparatus in the Langley high-speed 7- by 10-foot tunnel.

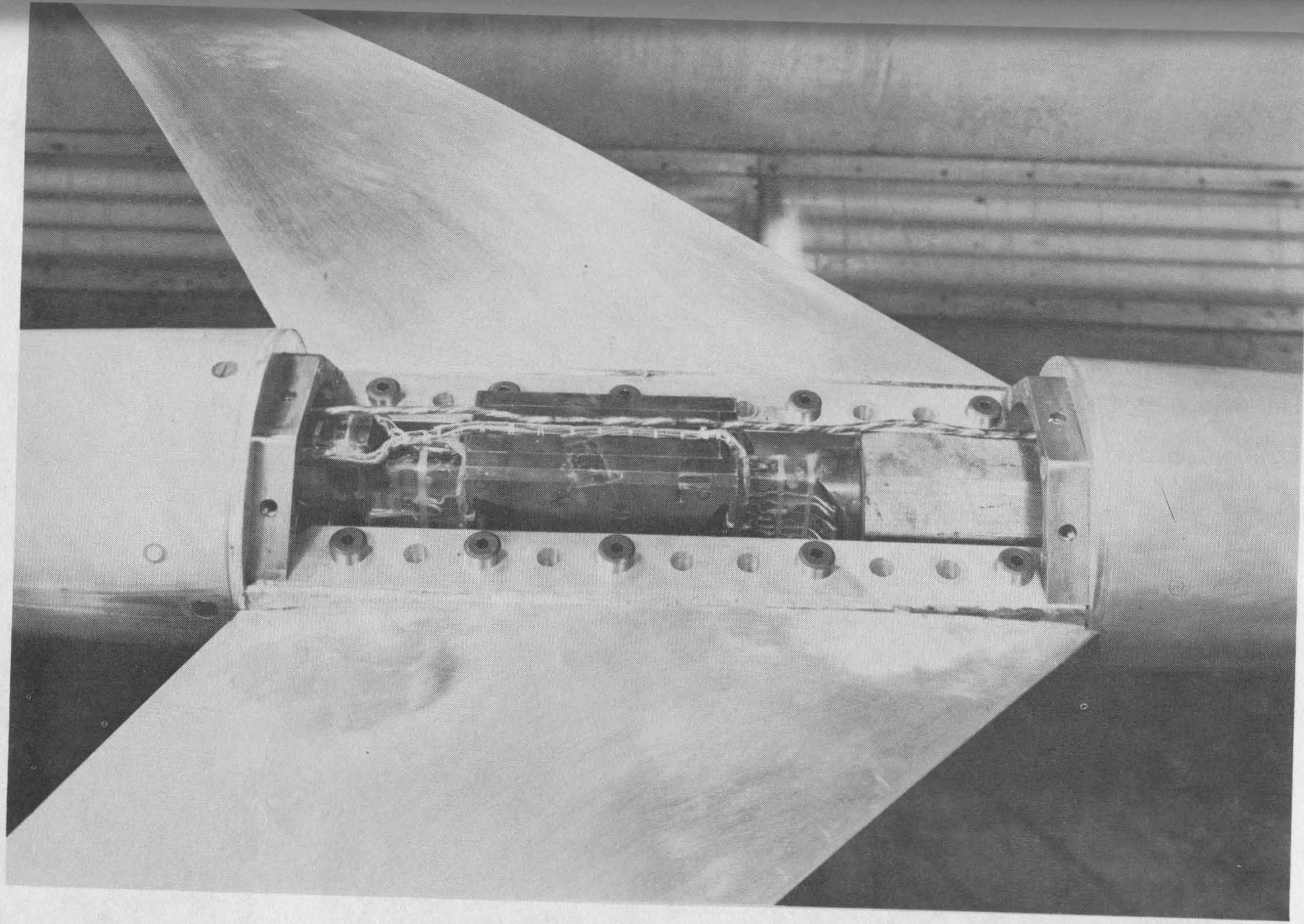
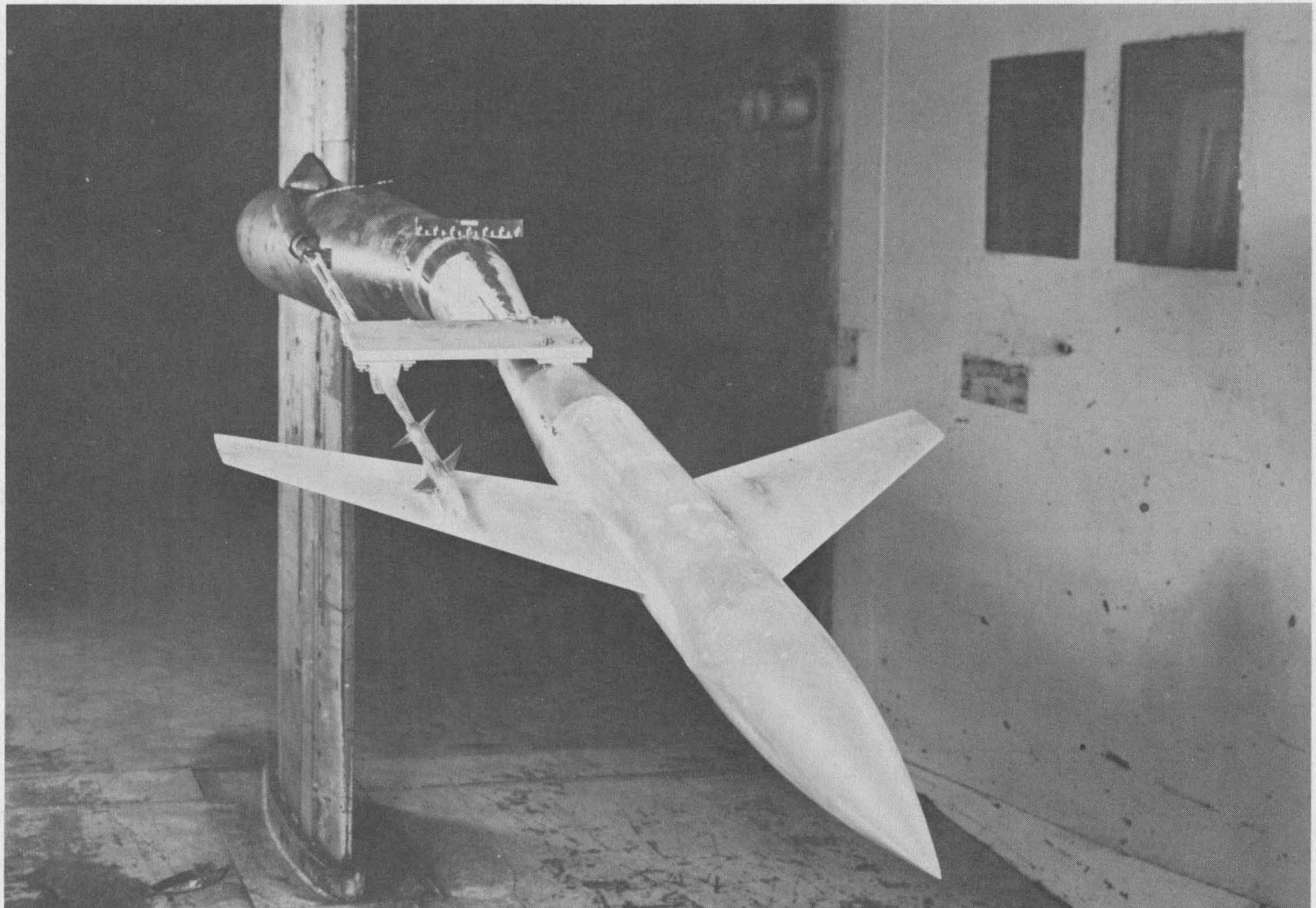


Figure 9.- An internal strain-gage balance installation. Top cover of model fuselage is removed. Langley high-speed 7- by 10-foot tunnel.

L-62265



L-90313
Figure 10.- An instrumented missile installation in the presence of an airplane model. Langley high-speed 7- by 10-foot tunnel.

THE LANGLEY
300-MPH 7-BY 10-FOOT TUNNEL

Langley Aeronautical Laboratory
Langley Field, Virginia

NACA

LANGLEY 300-MPH 7- BY 10-FOOT TUNNEL

GENERAL DESCRIPTION

The Langley 300-MPH 7- by 10-foot tunnel, which has been in operation since 1945, is a single return, rectangular closed-throat, atmospheric tunnel with about 10-percent air exchange accomplished by means of a ventilating tower. A sketch of the tunnel is shown in figure 1. The power section of the tunnel consists of an eight-blade, 29-foot-diameter fan driven by a 1,600-horsepower synchronous motor located in a nacelle in the return passage. The pitch of the fan blades is fixed, but the rotational speed can be controlled continuously up to a maximum of 360 rpm by means of a variable-frequency power supply for the drive motor.

In January, 1957, a second test section was installed on the contraction cone of the 300-MPH 7- by 10-foot tunnel as shown in figure 1. This additional test section is briefly described in the appendix at the end of the description of the 300-MPH 7- by 10-foot tunnel.

TEST SECTION

The 7-foot-high by 10-foot-wide test section is located in a test chamber adjacent to the shop, which is between the two 7- by 10-foot tunnels. (See fig. 1 in the description of the high speed 7- by 10-foot tunnel.) The test section extends 5 feet ahead of and 10 feet behind the center of the tunnel balance systems, as indicated in the plan view shown in figure 1. Additional test-section length can be obtained for unusually long models by installation of suitable fairings at the junctures of the tunnel walls. The test section is provided with large windows on both sidewalls through which visual observations and photographs of the test model can be made.

TEST CONDITIONS

Mach number, continuously variable (0 to 300 mph). . . . . . . 0 to 0.4
Stagnation pressure . . . . Atmospheric
Reynolds number per foot . . . . 0 to 2.5 million
Stagnation temperature, (dependent upon seasonal atmospheric
conditions), °F . . . . From about 40 to 110

MODEL-SUPPORT SYSTEMS

Several model test arrangements are used in the Langley 300-MPH 7- by 10-foot tunnel. Figure 2 illustrates three commonly used arrangements: the two-dimensional installation, the semispan installation, and the complete-model installation. These three installations are generally mounted on the tunnel six-component balance frame and mechanical-scale system (fig. 3). The load limits for this mechanical balance system are:

Lift, lb	-3,000 to 6,000
Drag, lb	-1,200 to 2,400
Side force, lb	-5,000 to 5,000
Pitching moment, ft-lb	-16,000 to 16,000
Rolling moment, ft-lb	-16,000 to 16,000
Yawing moment, ft-lb	-16,000 to 16,000

Since the two-dimensional installations (and usually the semispan installations) are mounted in a vertical plane, the lift-load limit for such installations is the side-force limitation of ±5,000 pounds. The angle-of-attack range for the two-dimensional installations is ±130°, and for the semispan installations the angle-of-attack range is unlimited.

Semispan models can also be mounted on a strain-gage-balance system through a reflection plane located on the ceiling turntable, floor turntable, or side wall of the tunnel as shown in figure 4. Load limits for such model installations are dependent upon the strain-gage balance used.

For complete model installations, either a single-strut system (fig. 5) or a twin-strut system (fig. 6) can be used. Each of the twin struts can be located at positions varying from 16 to 35 inches from the tunnel center line. The angle-of-attack and sideslip ranges, and the load limits for the strut-support systems are shown in the following table:

Strut arrangement	Ranges		Load limits					
	α, deg	β, deg	Lift, lb	Drag, lb	Side force, lb	Pitching moment, ft-lb	Rolling moment, ft-lb	Yawing moment, ft-lb
Single	-20 40	±45	±1,200	±500	±400	±500	±500	±500
Twin	-20 40	±45	±2,300	±1,170	±1,840	±1,440	±1,844	±1,480

A sting-support system is also used in the Langley 300-MPH 7- by 10-foot tunnel (figs. 7 and 8). Models for this type of installation are mounted, usually in the vertical plane (fig. 8(a)), to a sting which is attached to a circular-arc strut. When models are mounted in the vertical plane (fig. 8(a)), the angle of attack of the model can be varied to ±30° at fixed angles of sideslip from -5° to 25°. When mounted in the horizontal plane (fig. 8(b)), the angle of sideslip of the model can be varied to ±30° at fixed angles of attack from -5° to 25°. When larger angles of attack and sideslip are desired, special couplings between the model and sting may be used as illustrated in figure 8. The sting-supported models are mounted on internal strain-gage balances which are attached to the sting by means of adapters which generally vary for each model. For investigations of specific models, it is usually necessary to build a special sting adapter. To facilitate the construction of these special sting adapters, a plug gage is available to insure a proper fit. Load limits for sting-supported models usually depend upon the strain-gage balance used, so that the strength of the sting support is not critical.

Attachment of the models directly to the floor of the test section by means of bolts (fig. 9) is occasionally used, if the desired measurement does not require the use of a balance system.

MODELS

The two-dimensional and semispan models are usually constructed of wood on a steel spar. Extremely thin wings are constructed entirely of steel or of steel covered with plastic. Wing areas of the two-dimensional models range from 14 to 21 square feet, and wing areas of the semispan models range from 10 to 15 square feet.

Complete models which are strut supported on the mechanical-balance system (figs. 5 and 6) usually have wing spans from about 4 to 7 feet, and are constructed of wood with internal steel spars and box beams for reinforcement. Complete models for the sting-support system are instrumented with internal strain-gage balances and usually have wing spans from about 2 to 4 feet (fig. 8).

Models are sometimes installed in the Langley 300-MPH 7- by 10-foot tunnel for the calibration of equipment such as the wind velocity and direction indicator shown in figure 9, or for studying vibration problems encountered on helicopters (fig. 10). A model installation for determining the effect of the ground on the characteristics of an airplane in landing and take-off is illustrated in figure 11. For such an investigation, a groundboard which completely spans the test section and extends several feet fore and aft of the model is used. The board moves vertically on steel supports and can be held stationary at any desired distance below the model. Either the single or the twin struts may be used to support the model for this type of investigation.

For models of propeller-driven aircraft (fig. 5), electric motors varying from 7 to 56 horsepower are available for installation in the models. These motors vary from 2 to 7 inches in diameter and from 8 to 14 inches in length. Two motor-generator sets are available to supply the power for these motors.

For investigations requiring a high-pressure air supply, such as the simulation of a cold jet exhaust or the study of high-lift blowing flaps, there is available at the Langley 300-MPH 7- by 10-foot tunnel 2 pounds of air per second at a pressure of 300 pounds per square inch. This air supply is provided on the tunnel balance frame in such a way that reactions on the scale system are eliminated except for the jet thrust at the nozzle exit on the model and the induced aerodynamic effects. For models requiring the simulation of a hot-jet exhaust, a technique has been developed which utilizes the decomposition of hydrogen peroxide for jet simulation. Details of this technique and space requirements in the models for the decomposition chamber may be obtained by contacting the tunnel staff.

INSTRUMENTATION

Balances

When the tunnel six-component balance frame is not used and the model is mounted on the sting support, an internal strain-gage balance is used. The strain-gage balance used normally has a cross-sectional area of about 6 square inches and is about 18 inches long. However, the laboratory has available a wide variety of strain-gage balances of different sizes and load ranges. Details of these balances may be ascertained by consultation with the wind-tunnel staff.

Manometers

A 200-tube manometer with a working height of 92 inches is available for the measurement of steady pressures. Either alcohol or water is normally used as a fluid. Recording is by photography.

Data Recording and Reduction

The mechanical-scale system of the Langley 300-MPH 7- by 10-foot tunnel is equipped with printers which record the data on tapes. However, during testing of models on which unsteady conditions are present, it has been found desirable also to make visual observations of the scales. These data are processed into coefficient form either manually or by means of automatic computing equipment. On sting-supported models, which use a six-component strain-gage balance, strip-chart recording potentiometers similar to those described for the Langley high-speed 7- by 10-foot tunnel are used for recording the data, which are then processed into coefficient form and plotted by means of a punch-card system.

Dynamic data are recorded on photographic paper by means of recording oscillographs. These oscillographs and related equipment for dynamic testing are shown in the tunnel test chamber in figure 10. Photographic techniques are sometimes used to study the motions of a model or its component parts, such as the path taken by an escape capsule upon ejection from an airplane (fig. 12).

Steady-pressure data are recorded by photographing the 200-tube manometer, and the data are then transcribed from the film records to punch cards and processed in the same manner as that described for the Langley 16-foot transonic tunnel.

Flow Visualization

No permanent flow visualization equipment is provided for the Langley 300-MPH 7- by 10-foot tunnel, but tufts are often installed on the model surfaces and are recorded photographically.

APPENDIX

THE 17-FOOT TEST SECTION OF THE LANGLEY

300-MPH 7- BY 10-FOOT TUNNEL

The additional test section (fig. 13) which has been installed on the contraction cone of the 300-MPH 7- by 10-foot tunnel is about 17 feet wide and 15.5 feet high. This test section was designed and built primarily to allow testing of relatively large powered models of the VTOL and STOL airplanes to high angles of attack without the adverse effects of tunnel-wall constraint. A photograph of this test section with a semispan powered model and ground board installed is shown in figure 13. The 7- by 10-foot test section, previously described, may be seen in the background of figure 13.

The maximum velocity in this larger test section is about 76 miles per hour, and the stagnation pressure is, of course, atmospheric. The maximum test Reynolds number is about 700,000 per foot.

Electrical strain-gage balances are used to measure forces and moments on both semispan and complete models. The following table shows the approximate model sizes which are suitable for tests, the angular limits for model attitudes, and the approximate force limits which are compatible with the equipment:

Semispan models:	
Semispan, ft	4
Wing area, sq ft	6
Angle-of-attack range, deg	0 to 360
Lift, lb	200
Complete models:	
Span, ft	8
Wing area, sq ft	10
Angle-of-attack range, deg	±30
Angle-of-sideslip range, deg	±180
Lift, lb	1,000

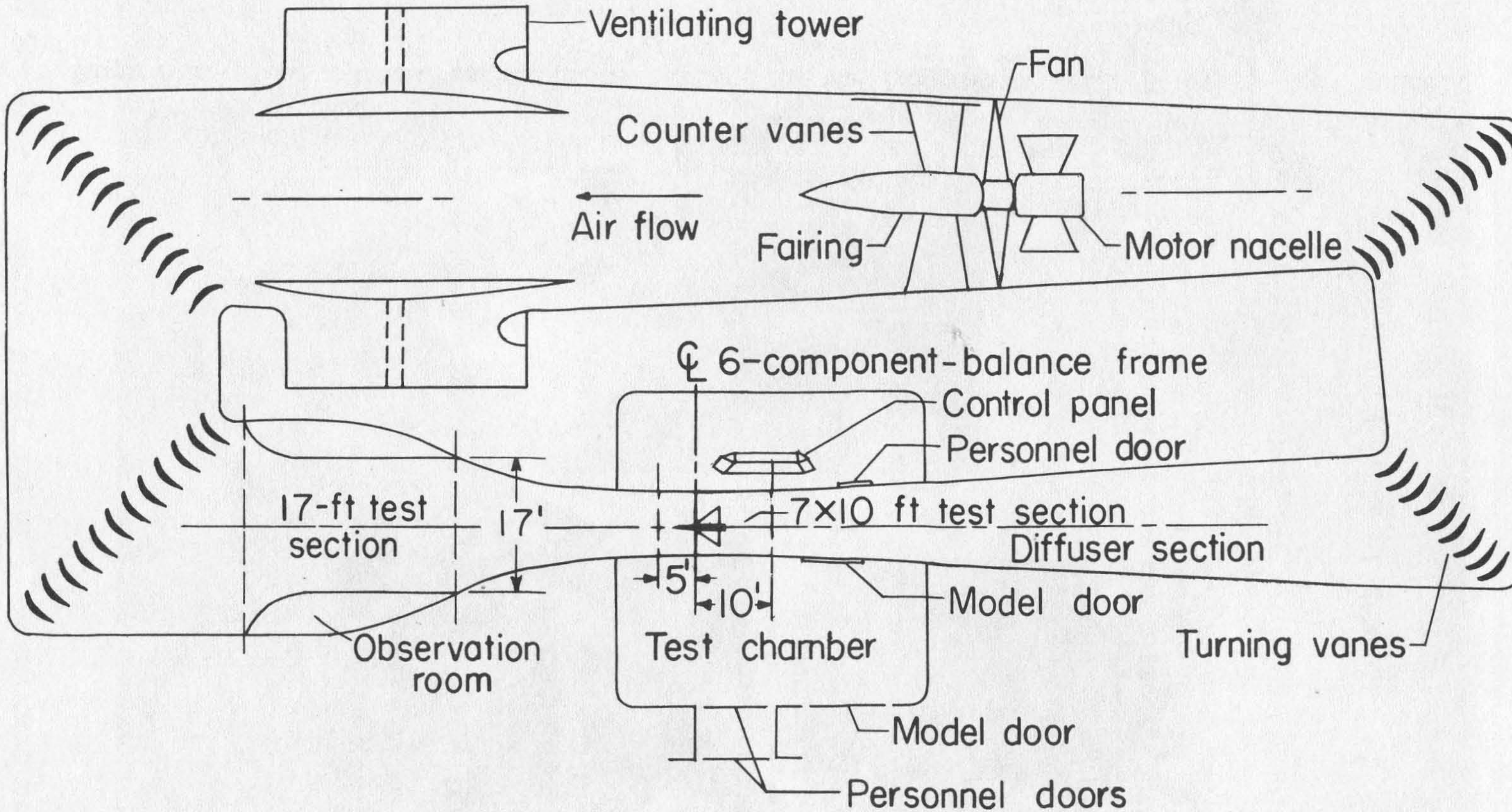
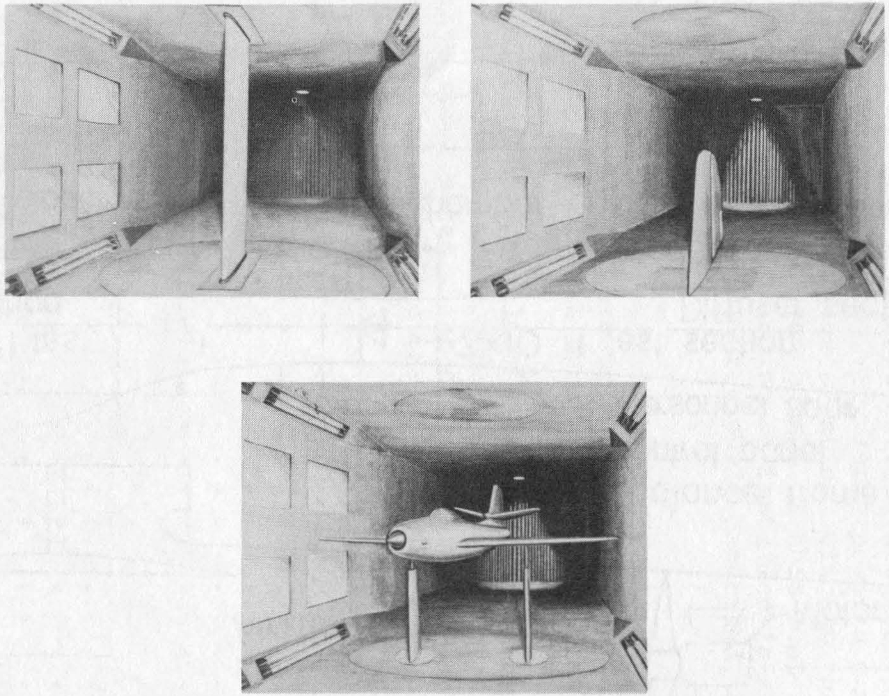
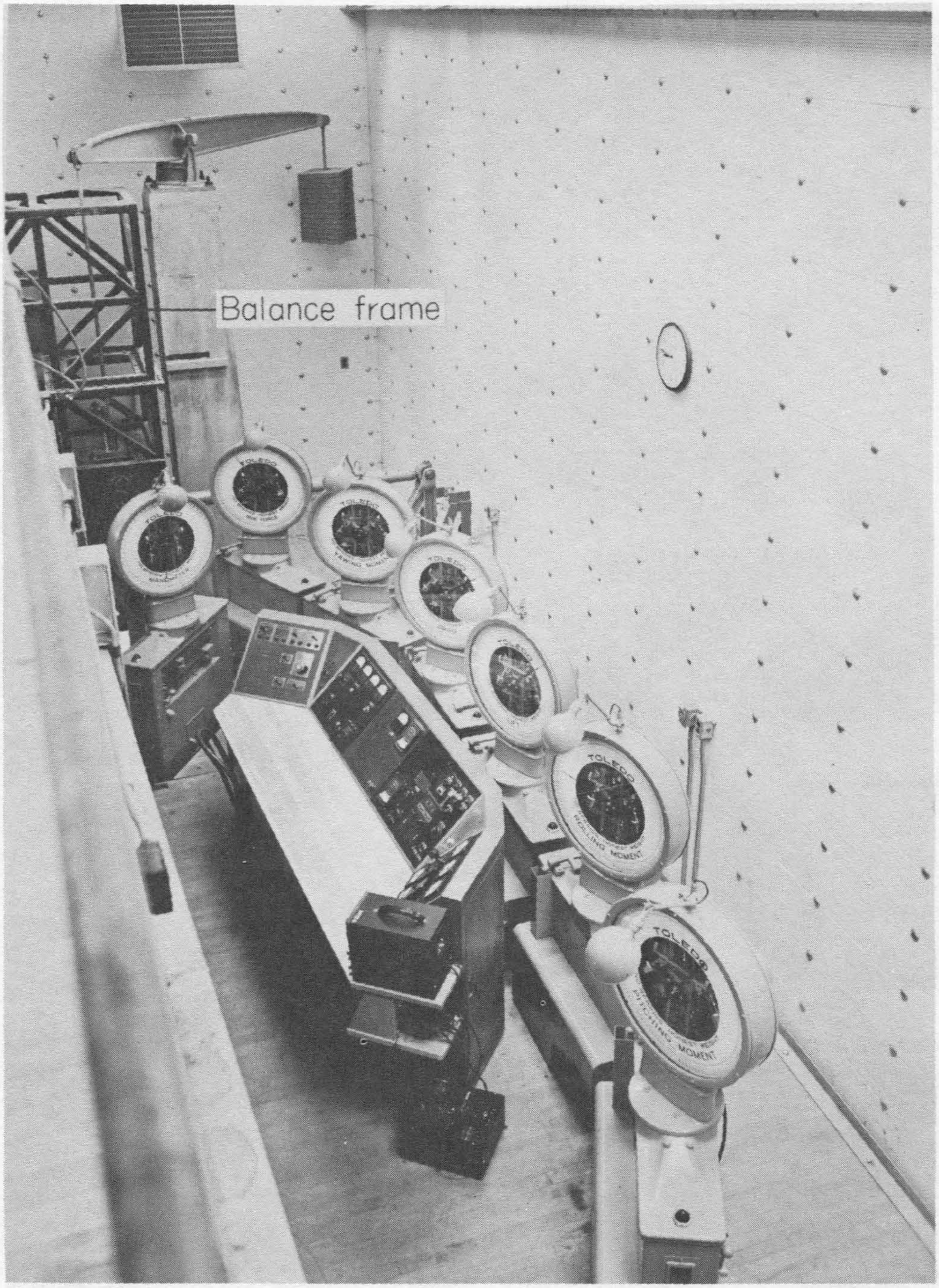


Figure 1.- Plan view of the Langley 300-MPH 7- by 10-foot tunnel.



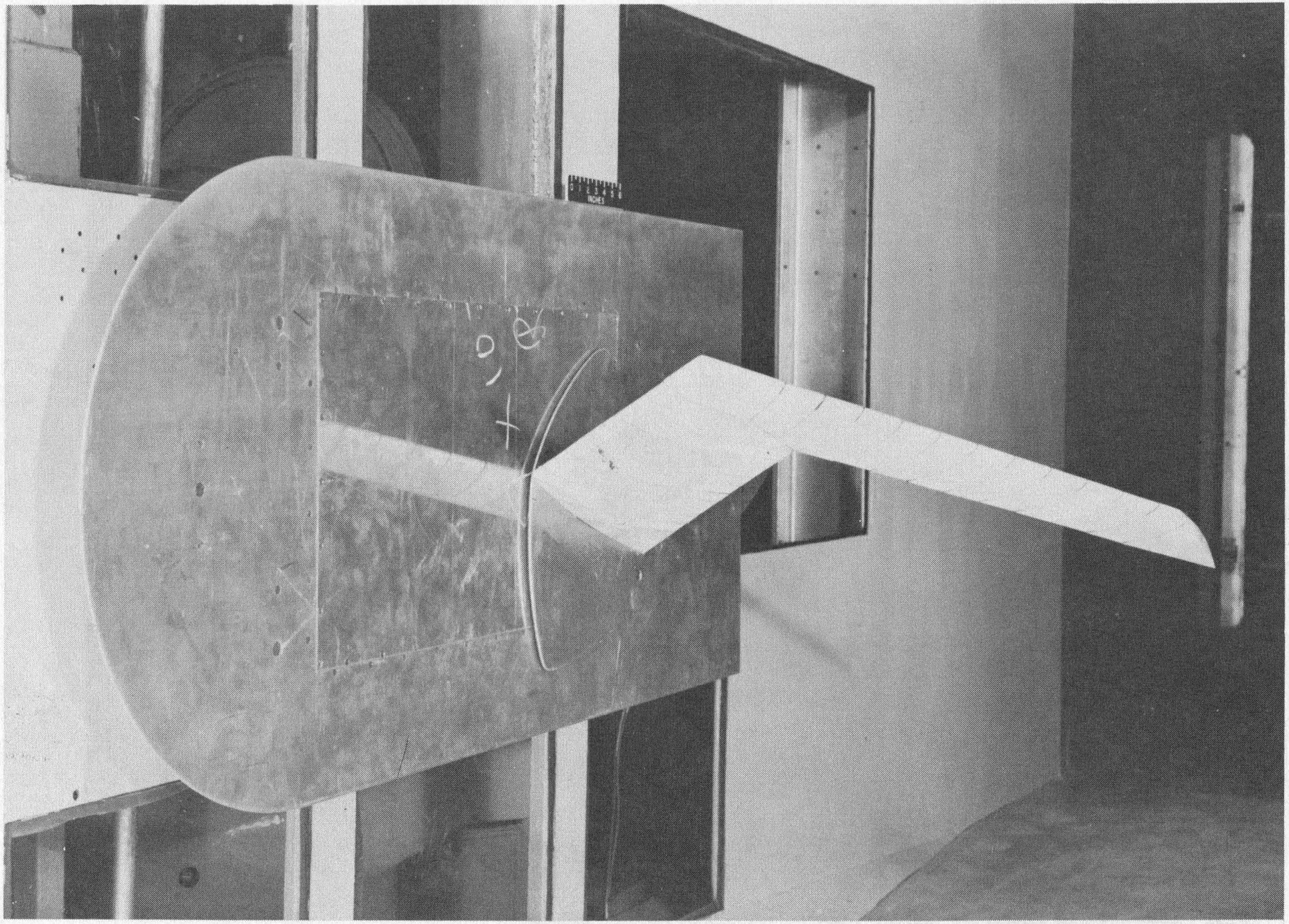
L-47042

Figure 2.- Some typical model installations in the Langley 300-MPH 7- by 10-foot tunnel.

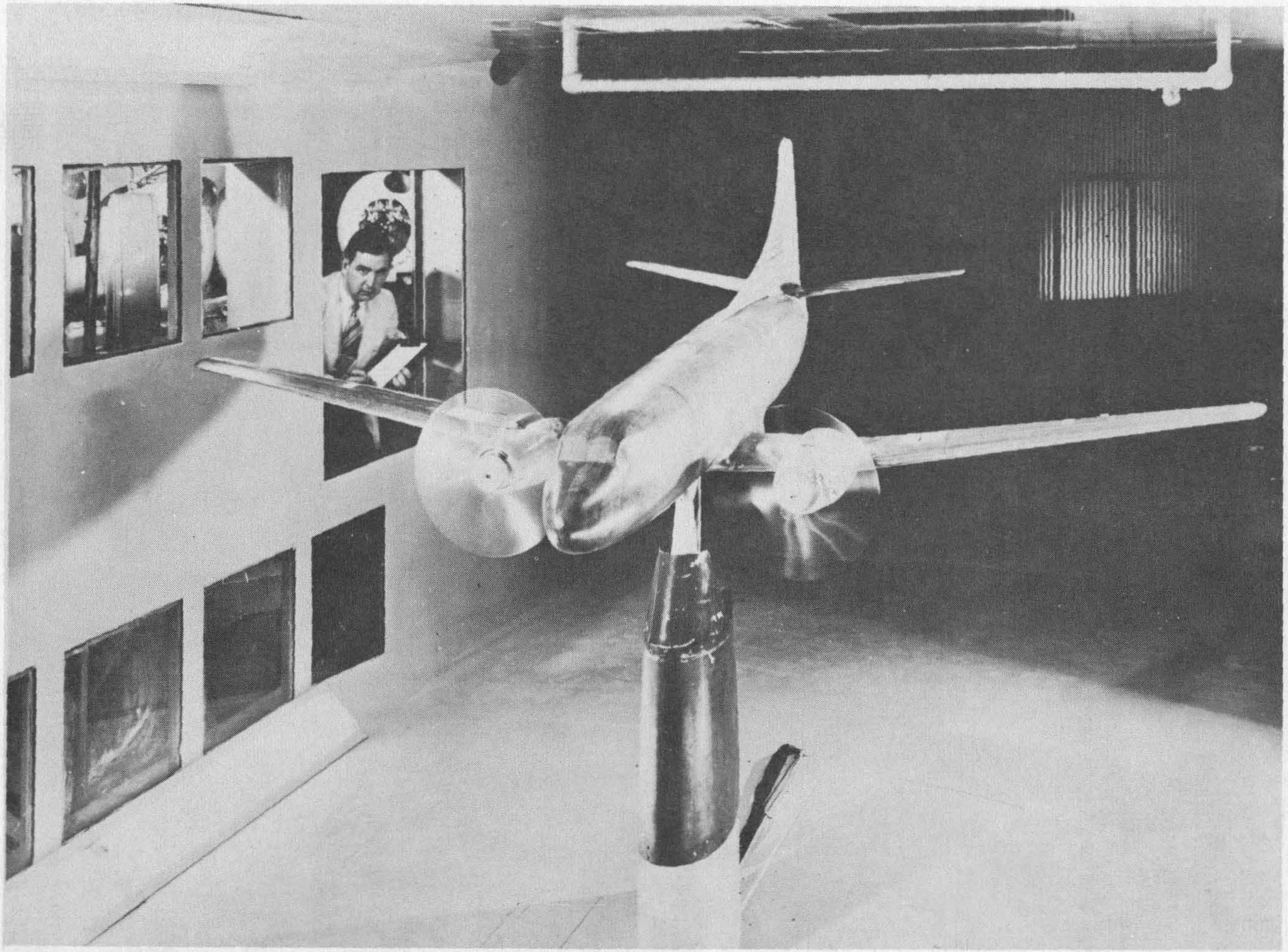


L-43763.1

Figure 3.- View of control panel and of six-component balance frame and scale system of the Langley 300-MPH 7- by 10-foot tunnel.

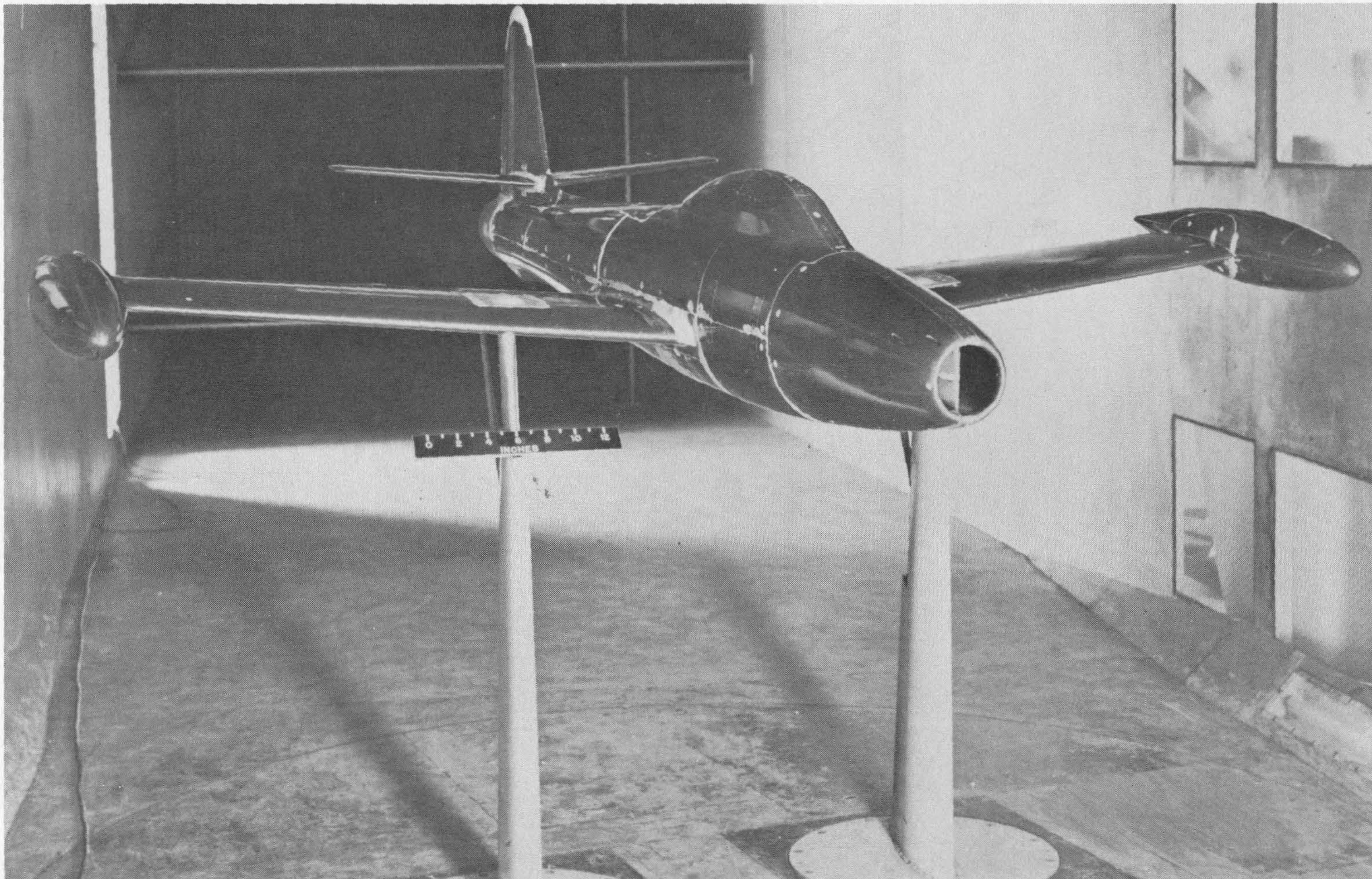


L-68735
Figure 4.- Reflection-plane semispan-model installation in the Langley 300-MPH 7- by 10-foot tunnel.



L-75503.1

Figure 5.- A single-strut installation of a powered model in the Langley 300-MPH 7- by 10-foot tunnel.



L-45262

Figure 6.- Twin-strut installation of a typical model in the Langley 300-MPH 7- by 10-foot tunnel.

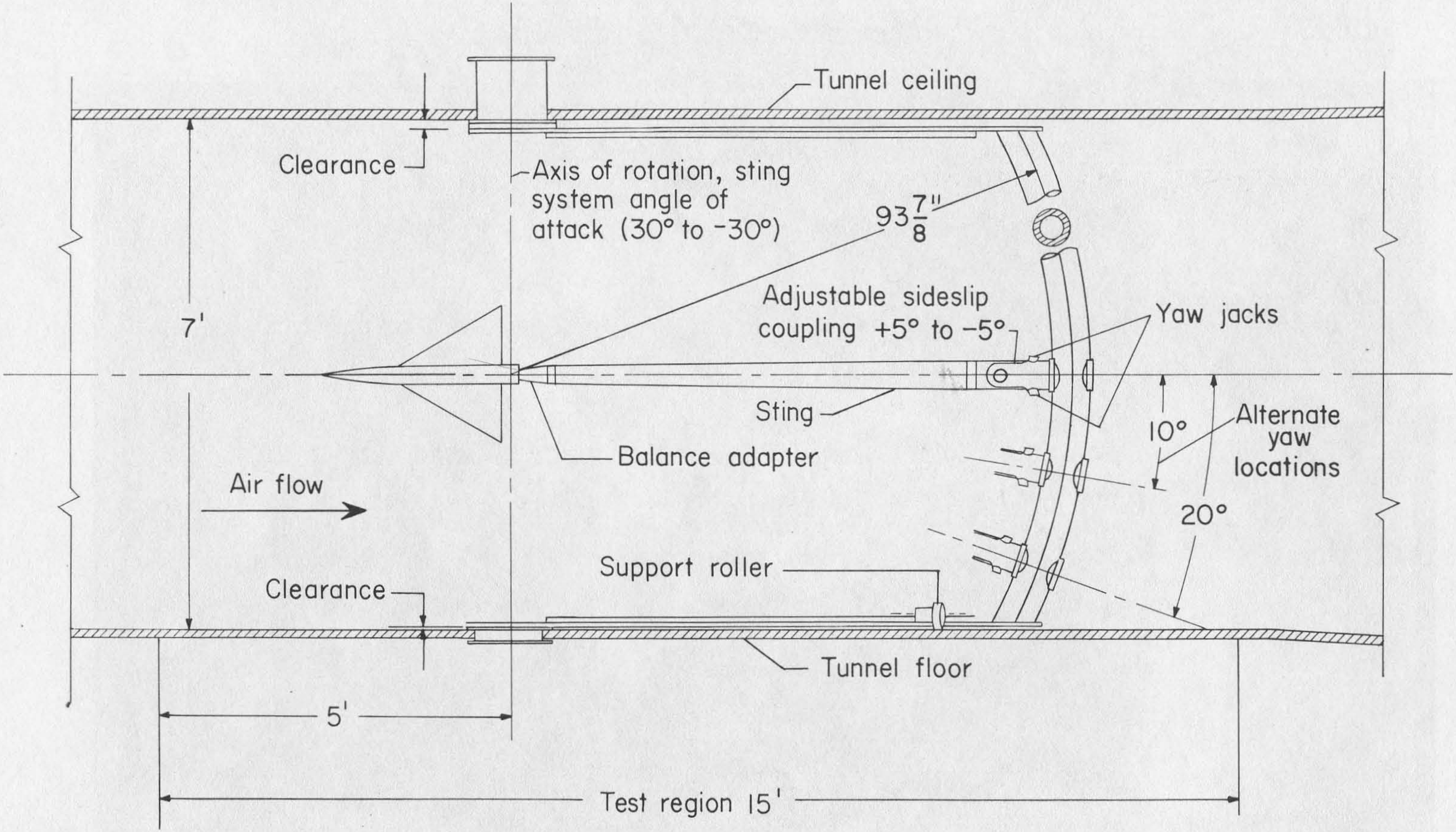
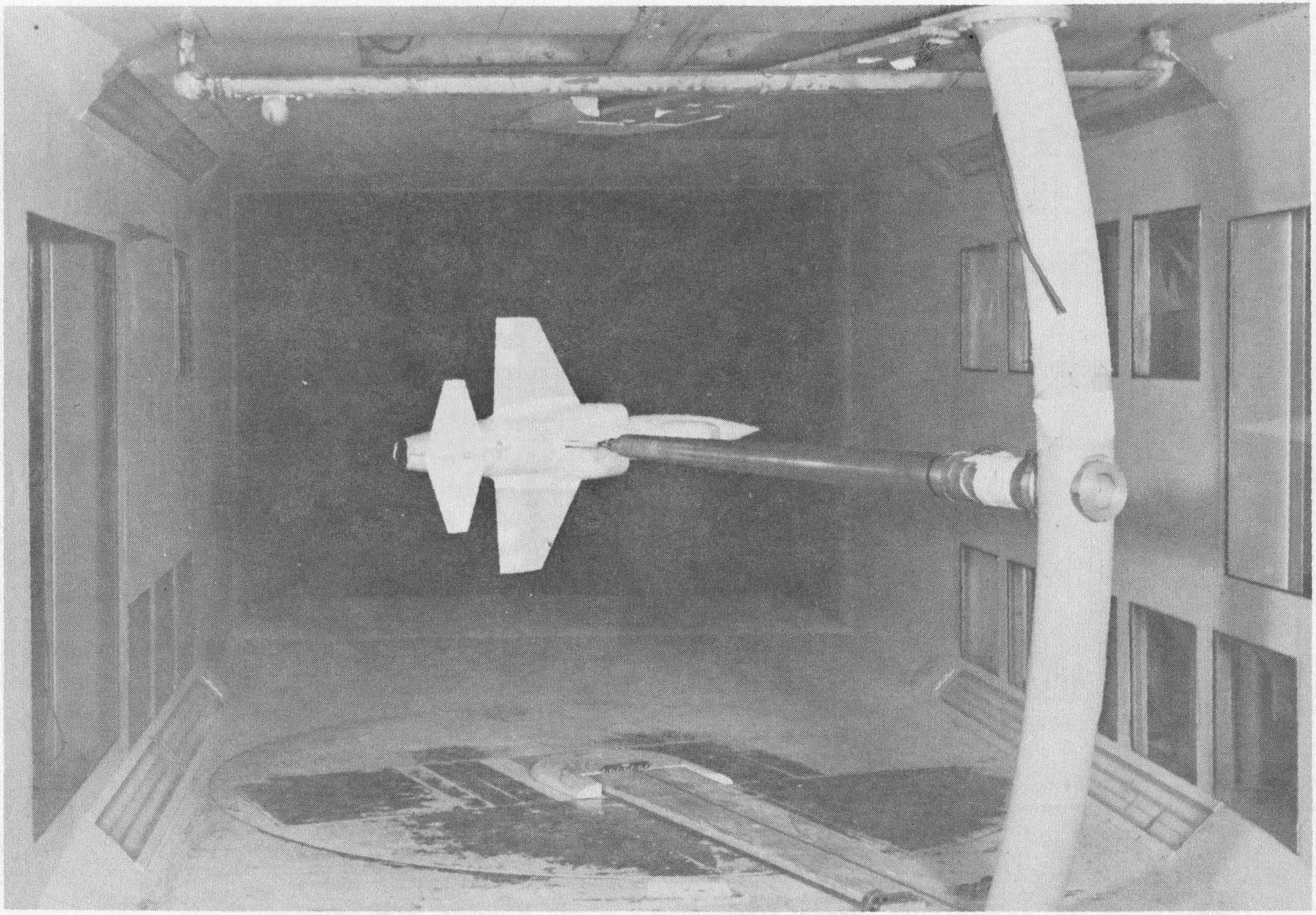
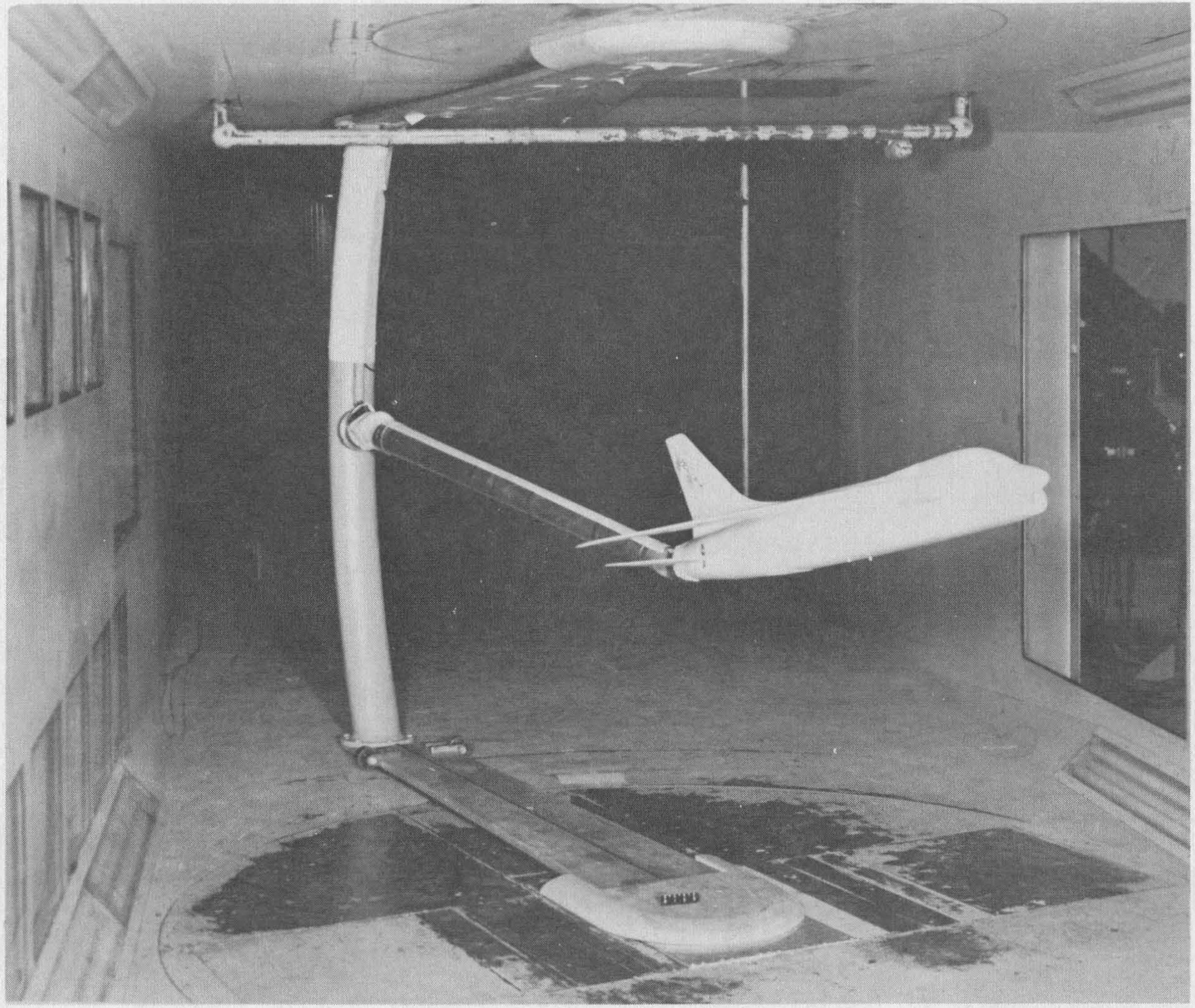


Figure 7.- Diagram of the sting-support system in the Langley 300-MPH 7- by 10-foot tunnel.



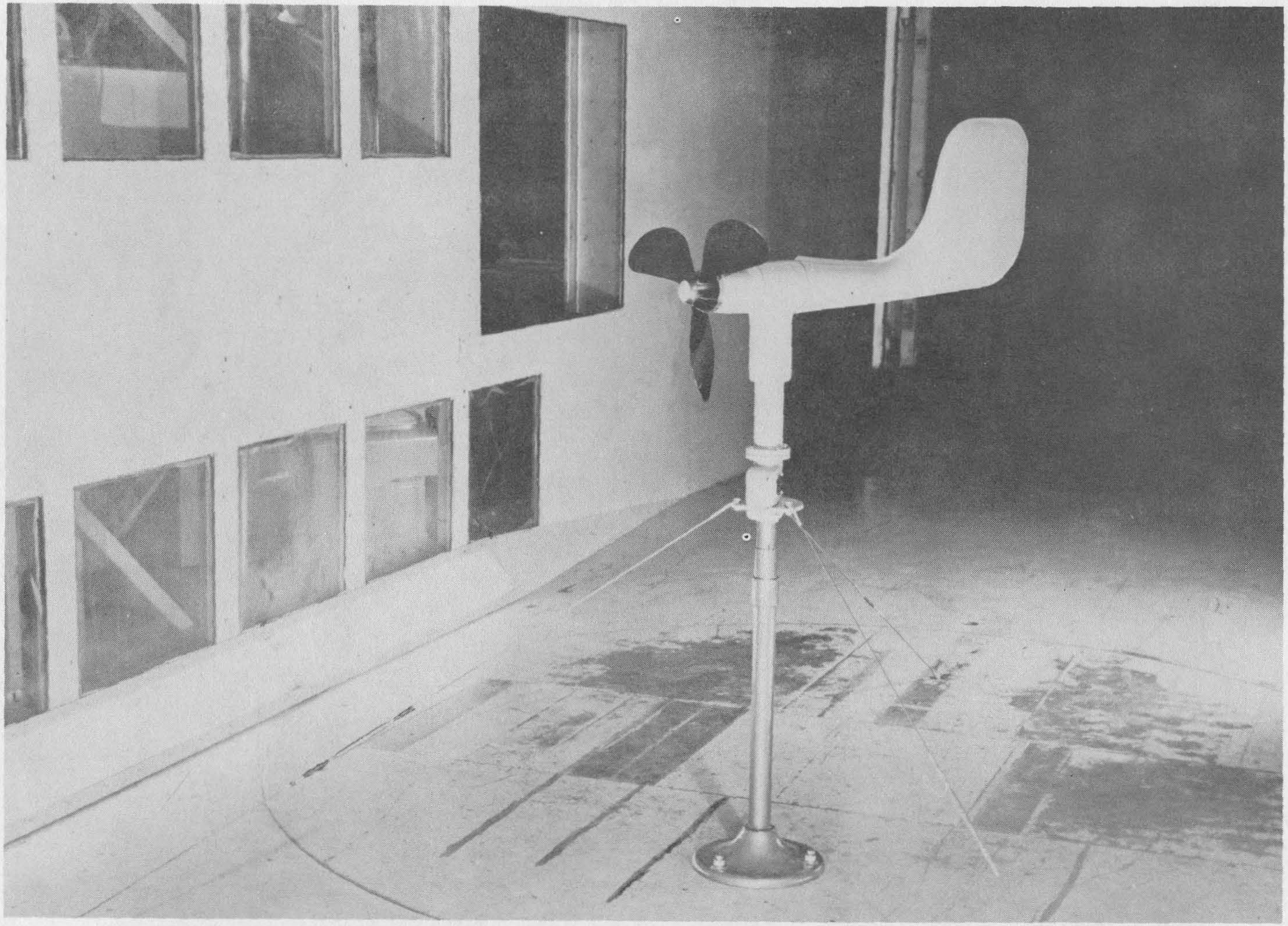
(a) Vertical model installation. L-90118

Figure 8.- Sting-supported-model installations in the Langley 300-MPH 7- by 10-foot tunnel.



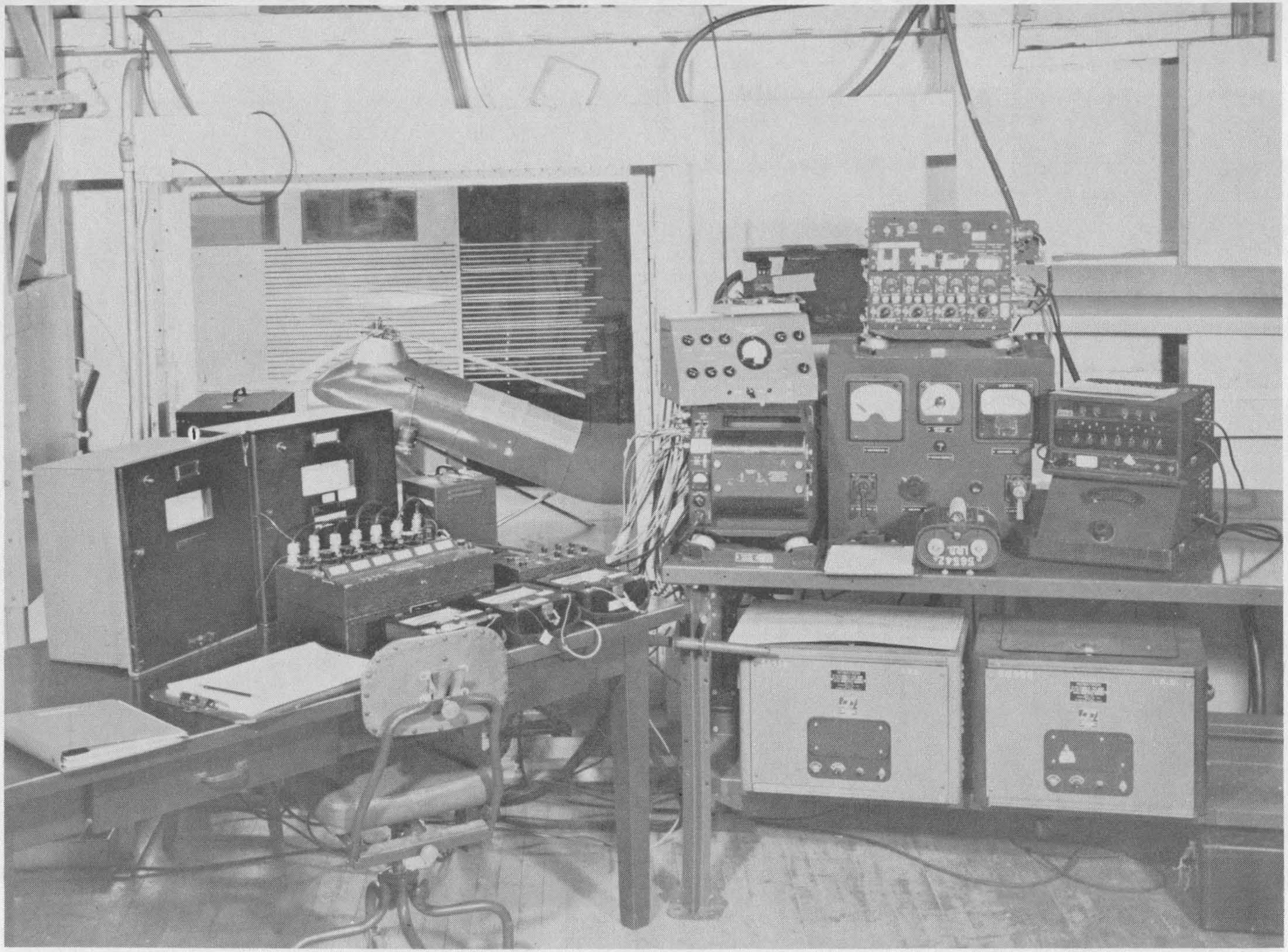
(b) Horizontal model installation. L-89999

Figure 8.- Concluded.



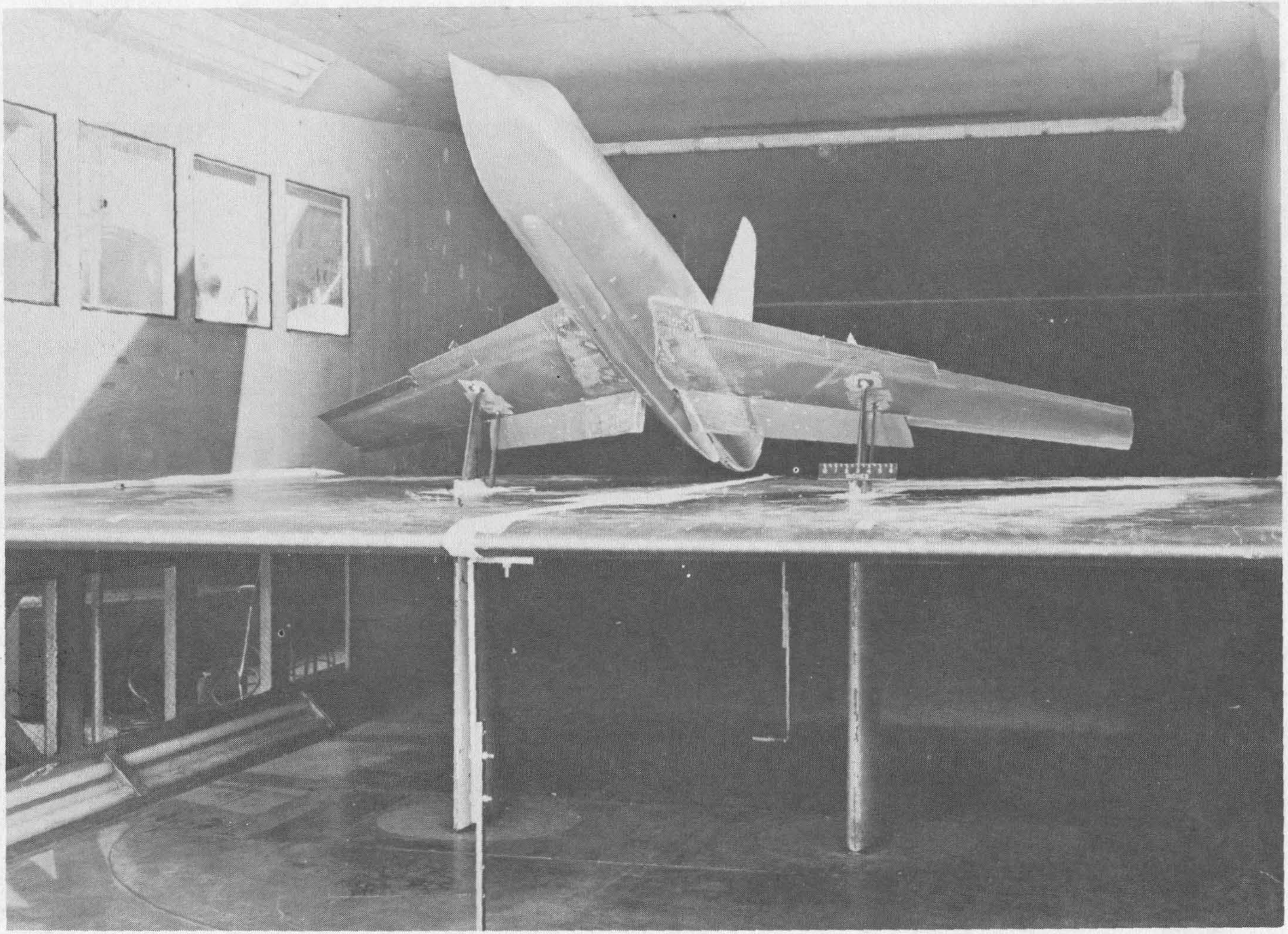
L-81375

Figure 9.- Wind-velocity and direction indicator investigated in the Langley 300-MPH 7- by 10-foot tunnel.



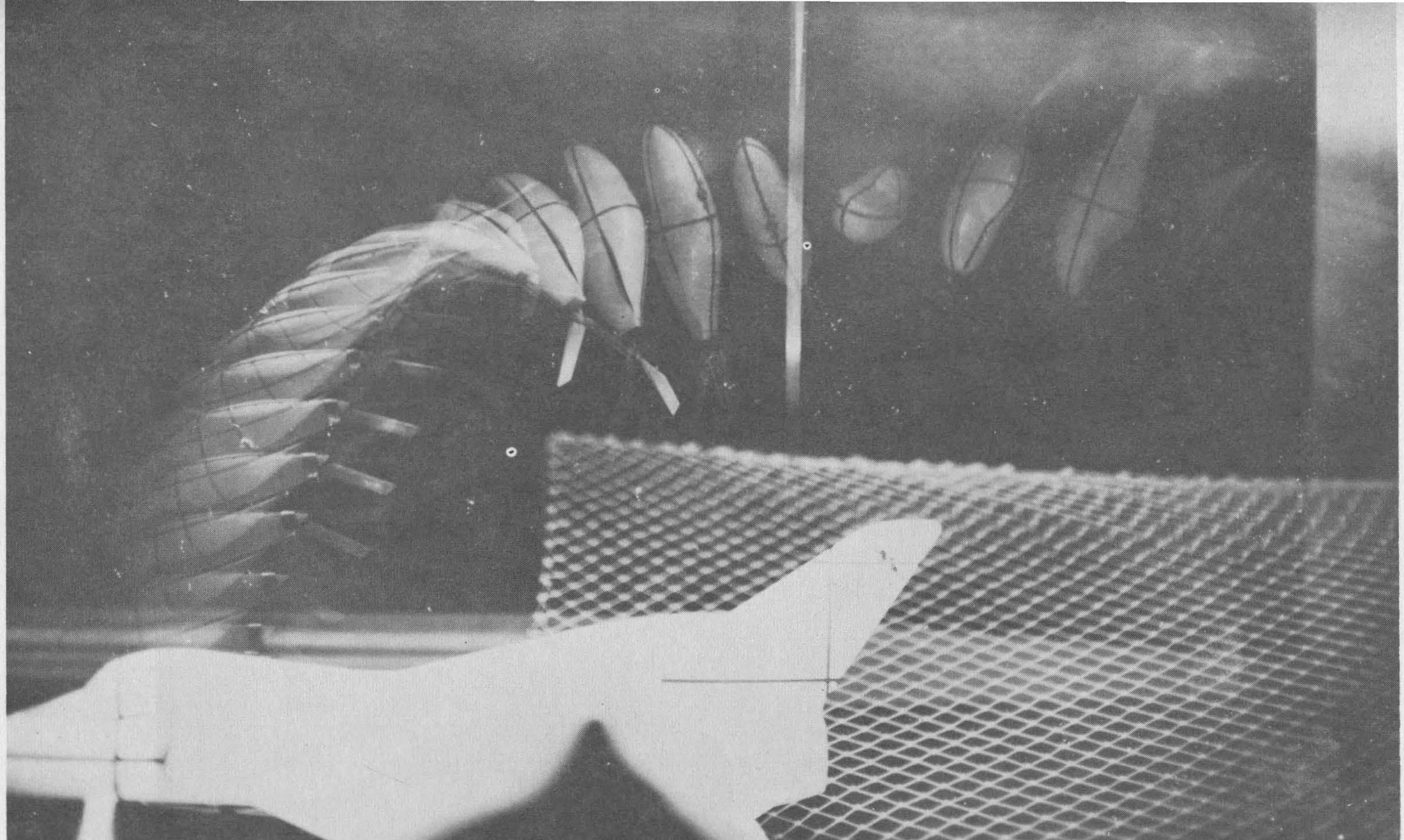
L-90676

Figure 10.- Dynamic model of a helicopter investigated in the Langley 300-MPH 7- by 10-foot tunnel.



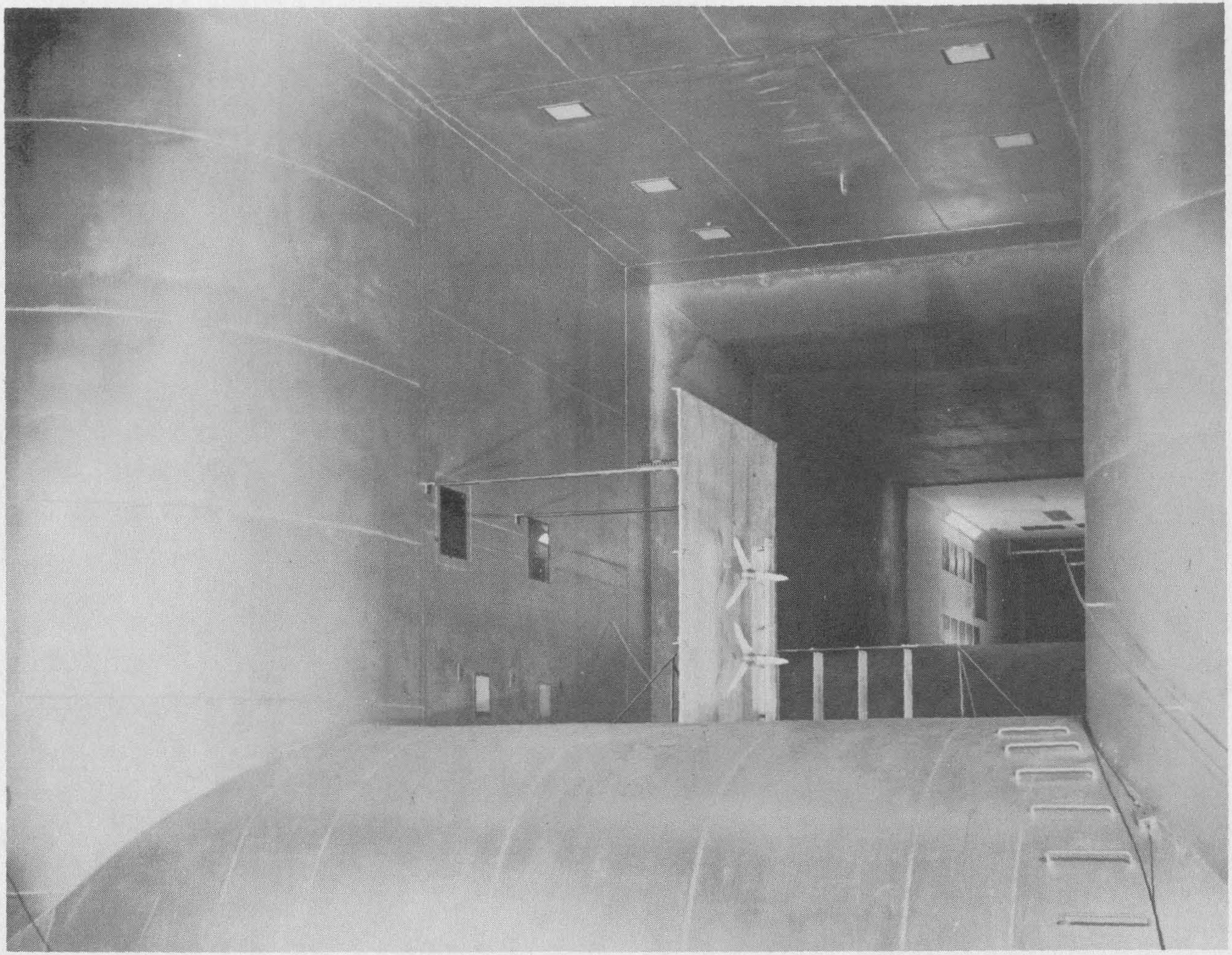
L-51274

Figure 11.- Installation used for determining effect of ground proximity on aerodynamic characteristics of an airplane configuration. Langley 300-MPH 7- by 10-foot tunnel.



L-74066

Figure 12.- Flight path of an airplane escape capsule as determined by means of a photographic technique. Langley 300 MPH 7- by 10-foot tunnel.



L-57-1191

Figure 13.- The 17-foot test section in the contraction cone of the Langley 300-MPH 7- by 10-foot tunnel. The 7- by 10-foot test section may be seen in the background.

THE LANGLEY 20-FOOT FREE-SPINNING TUNNEL

Langley Aeronautical Laboratory

Langley Field, Virginia

NACA

20-FT FREE-SPINNING

LANGLEY 20-FOOT FREE-SPINNING TUNNEL

GENERAL DESCRIPTION

The Langley 20-foot free-spinning tunnel has been in operation since 1941. An external view of the tunnel is shown in figure 1, and a sketch of the cross section is shown in figure 2. As can be seen, the tunnel is vertical with a propeller at the top, which draws air vertically upward, through turning vanes, into an annular return passage. The choice made of the return passage and the vanes, for the height and diameter selected for the tunnel, is such as to provide an energy ratio low enough to allow natural rapid deceleration of the air and yet rapid enough to permit acceleration of the air without excessive power requirements. The fan is driven by a direct-current motor, which generally supplies 400 horsepower and, for maximum tunnel speeds, supplies over 1,300 horsepower. Motion-picture cameras are mounted at the side and bottom of the tunnel.

TEST SECTION

Figure 3 shows an inside view of the tunnel, looking down through the test section. The test section has 12 sides, a distance across flats of 20 feet, and a vertical length of 25 feet. Use of vertical and horizontal screens in the entrance cone provides a slight saucer-shaped velocity gradient, which decreases toward the center of the tunnel, and thus keeps the free-spinning models from the tunnel walls. Use of a honeycomb above the horizontal screens smooths out the air flow and prevents swirling of the air. A slight divergence of the walls of the exit cone provides a stable vertical-velocity gradient.

TEST CONDITIONS

Mach number, continuously variable (0 to 66 mph)	0 to 0.09
Stagnation pressure	Atmospheric
Reynolds number per foot	0 to 0.62 million
Stagnation temperature (dependent upon seasonal atmospheric conditions), °F	From about 40 to 100

MODEL SUPPORT SYSTEM

For free-spinning model tests, the models are supported by the force of the upgoing air. For force and moment measurements on models, a gooseneck rotary arm (fig. 4) of welded tubular steel is moved into the tunnel to support the model. On this support, model angles of attack and of sideslip from 0° to 360° can be set.

MODELS

Dynamic models are used for free-spinning tunnel tests. A dynamic model is one for which geometric similarity between model and airplane is extended to obtain geometric similarity of the paths of motion of corresponding points by maintaining constant, in addition to the scale ratio of linear dimensions, three other ratios, that of force, mass, and time. In model testing, however, complete similarity can generally not be duplicated and some compromise is necessary. For free-spinning-model tests in the NACA 20-foot tunnel, the ratio of inertia to frictional or viscous forces (Reynolds number) is not maintained constant, but the ratio of inertia to gravity forces (Froude number) is maintained constant.

Models used in the spin tunnel until recently were made primarily of balsa and reinforced with hardwood. Now, plastic models are being used almost entirely, because they are more durable and when properly constructed are no heavier than balsa models. The models are constructed accurately to scale by pressing plastic material and glass cloth into a previously constructed mold. A typical model is shown in figure 5. The model is swung as a torsional pendulum and is ballasted to obtain dynamic similarity by placing lead weights in suitable locations within the model wings and fuselage. Corrections are made for the effect of ambient and entrapped air.

Provision for moving the model controls for recovery during free-spinning tests is made by means of a remote-control device mounted in the model. The device consists primarily of a permanent magnet which, in response to a magnetic field, trips a mechanism and permits control movement. The magnetic field is set up in the tunnel when the tunnel operator short-circuits a 24-volt storage battery by means of a foot pedal and 700 amperes are sent through five large coils of copper wire running around the periphery of the tunnel just below eye level. The model mechanism used is shown in figure 6.

INSTRUMENTATION

Balances

Although free-flight dynamic tests in the vertical spin tunnel afford valuable information as regards the resulting spin and recovery of a given design, it is desirable to know something about the factors that make up the spin and the mechanism of recovery therefrom. For this purpose, a six-component strain-gage rotary balance has been built and installed in the spin tunnel. Strains in the gages due to aerodynamic forces and moments are recorded electrically through use of slip rings and brushes. When ready for use, the balance can be moved into the center of the tunnel with the model support system previously described and held there for rotation tests of a given design (fig. 4). Spin radii up to 2 feet and rates of rotation up to 200 rpm can be obtained. With this balance, model sizes tested are approximately 1/10 of full scale. A new smaller balance is also available, on which 1/20-scale, free-spinning models will be tested. Load ranges of these two balances are shown in the following table:

	Large balance	Small balance
Normal force, lb	26	15
Longitudinal force, lb	15	4
Lateral force, lb	4	2
Yawing moment, ft-lb	8	3
Rolling moment, ft-lb	15	3
Pitching moment, ft-lb	12	6

Data Recording and Reduction

In free-spinning-tunnel investigations, details of spin and recovery motions are obtained by means of motion pictures, time and tunnel velocity records, and calculations based on spin-geometry relationships. Time histories of model attitudes and velocities during spins and recoveries are obtained when desired by using two cameras operating synchronously and more extensive calculations.

The force and moment data obtained from the rotary strain-gage balance are measured on six separate calibrated microammeters, read visually, and recorded manually. The data may then be reduced to coefficient form manually or by automatic computing machines, when necessary.

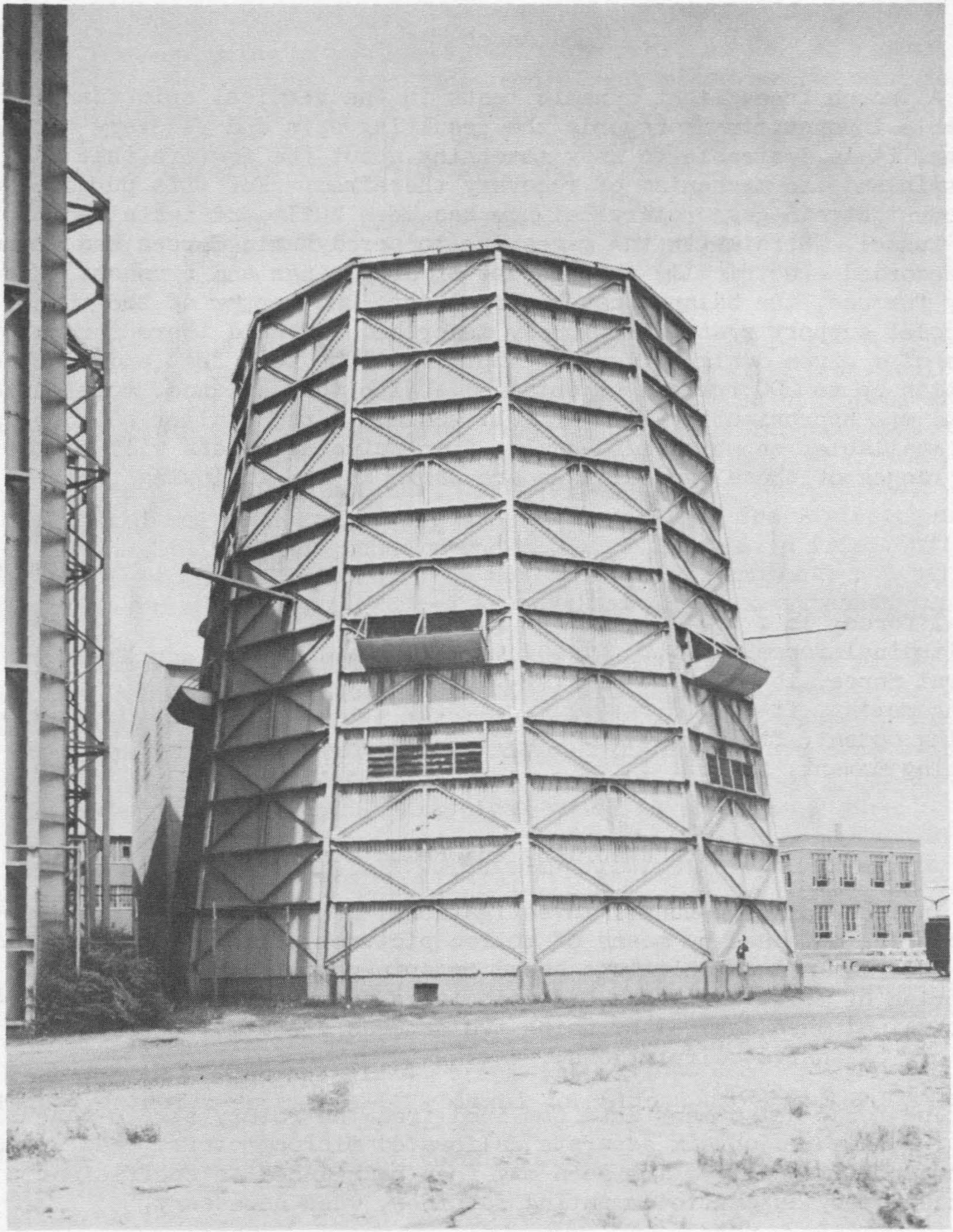
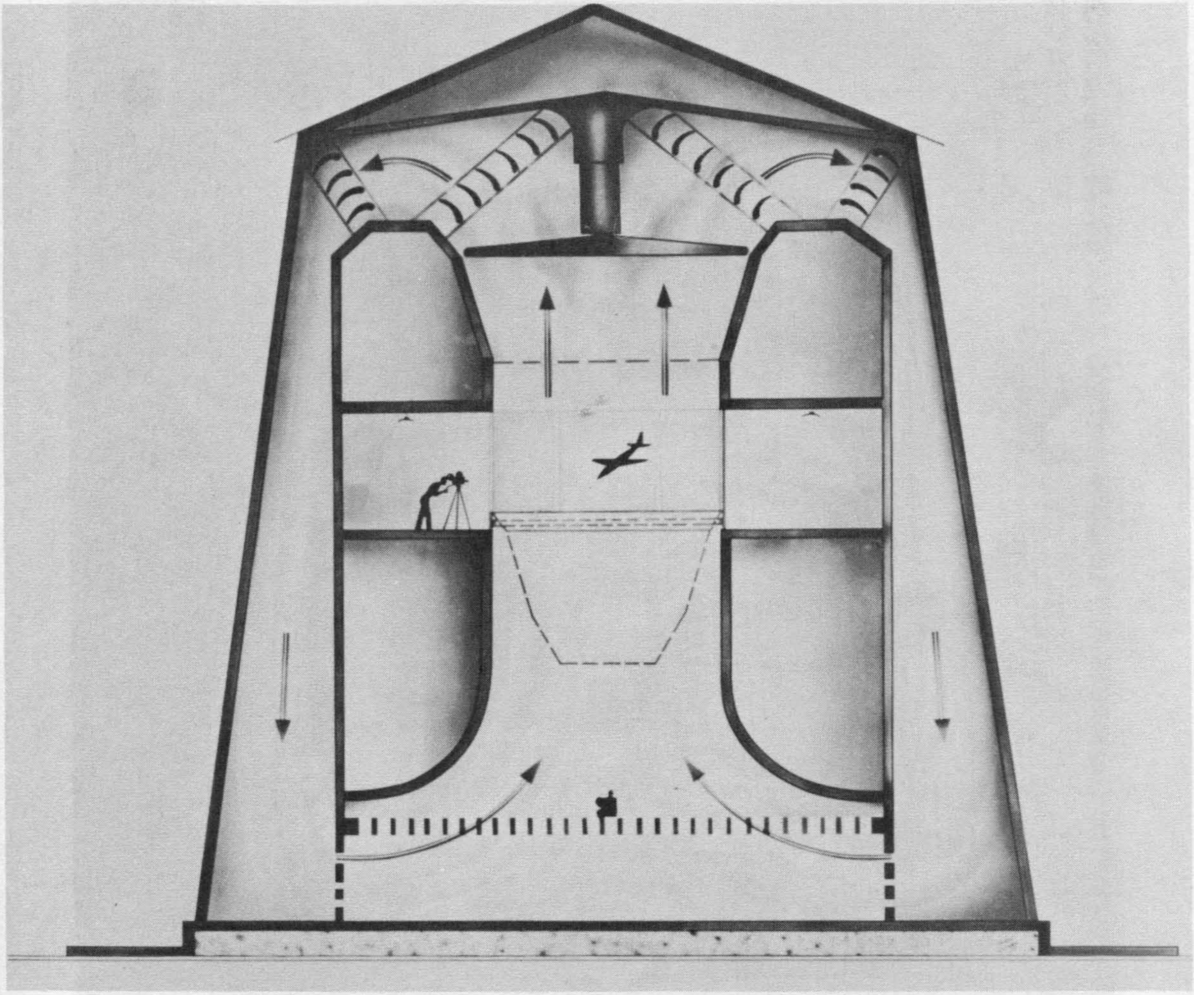
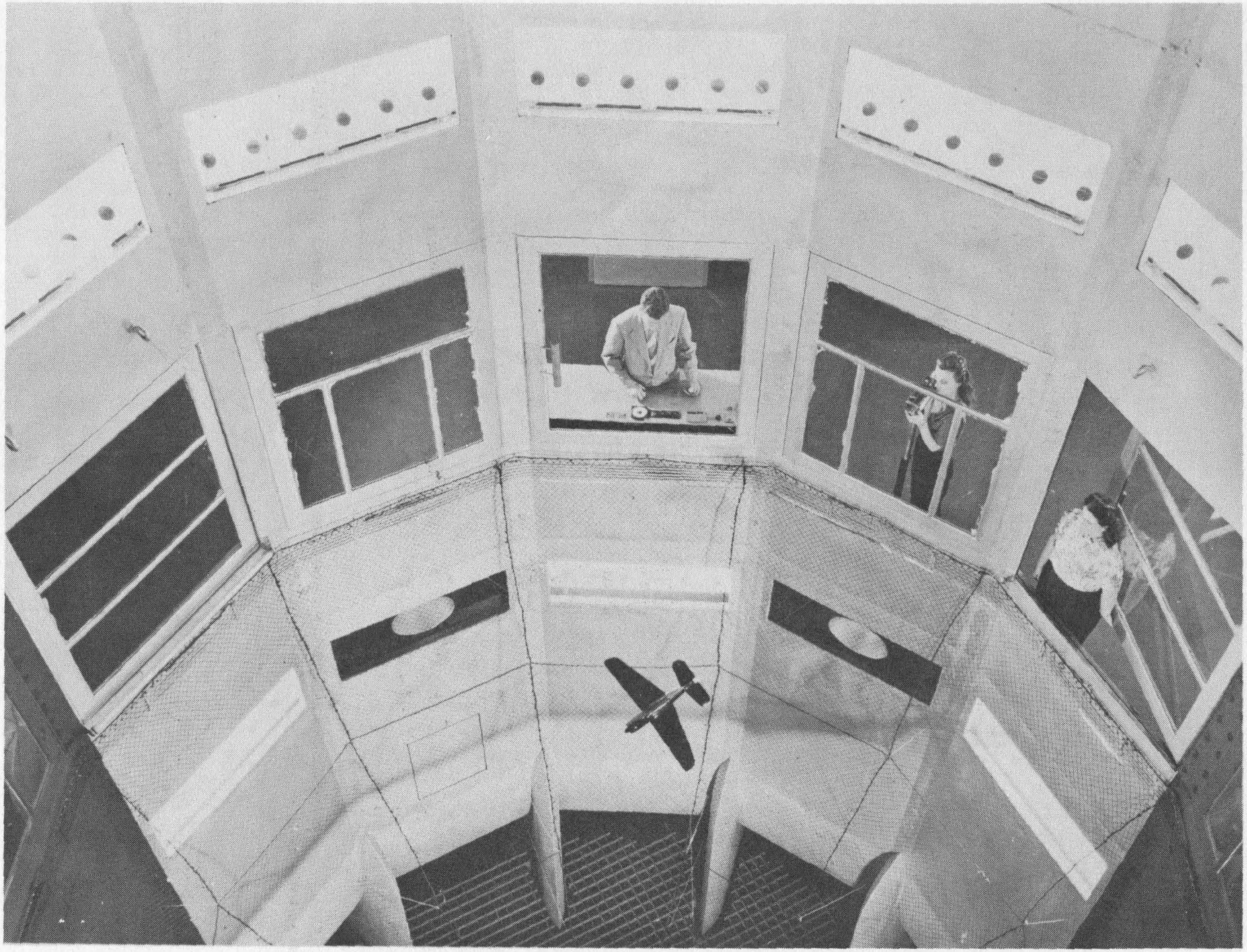


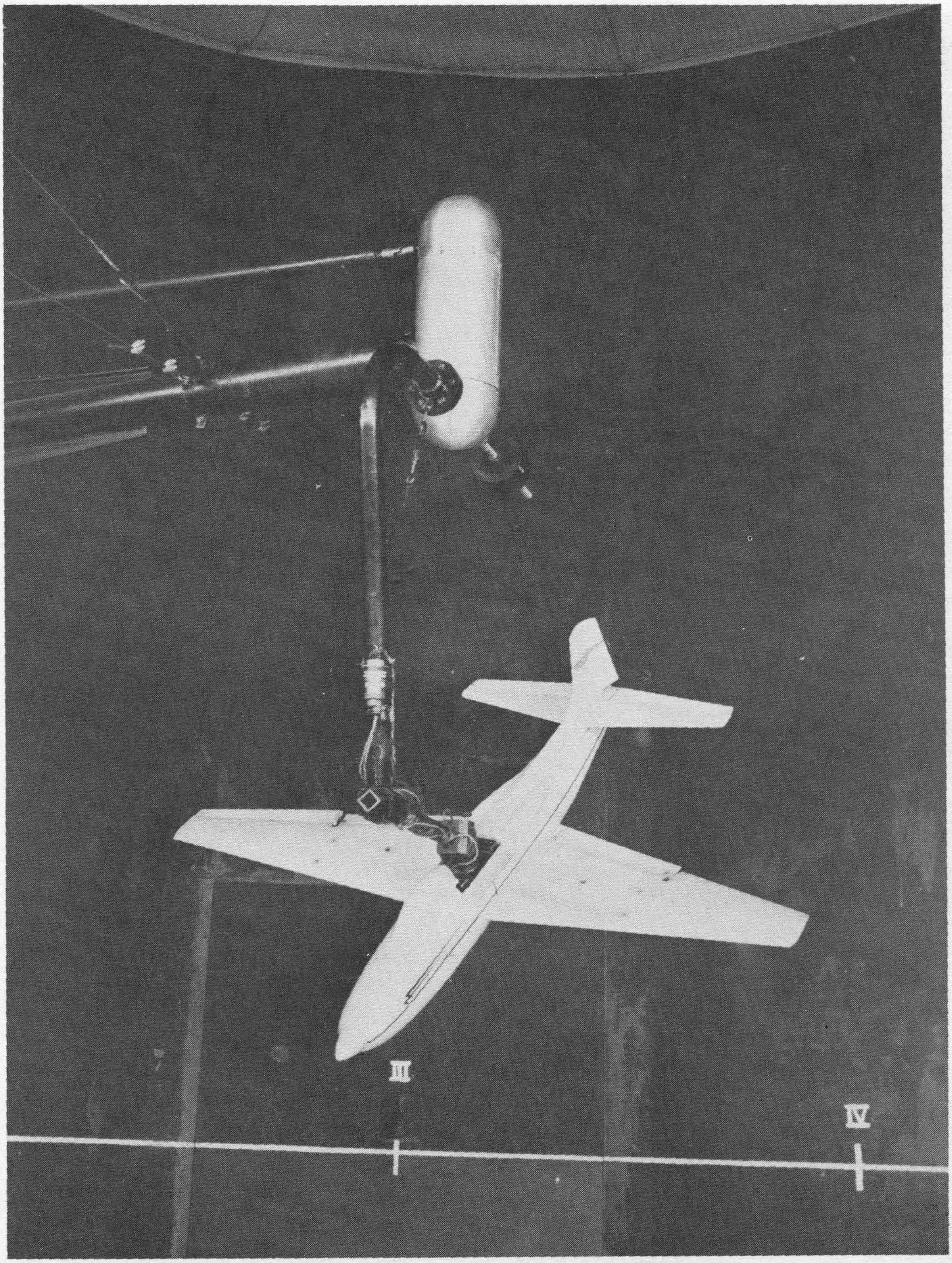
Figure 1.- Exterior of Langley 20-foot free-spinning tunnel. L-86257



L-86258
Figure 2.- Cross section of Langley 20-foot free-spinning tunnel.



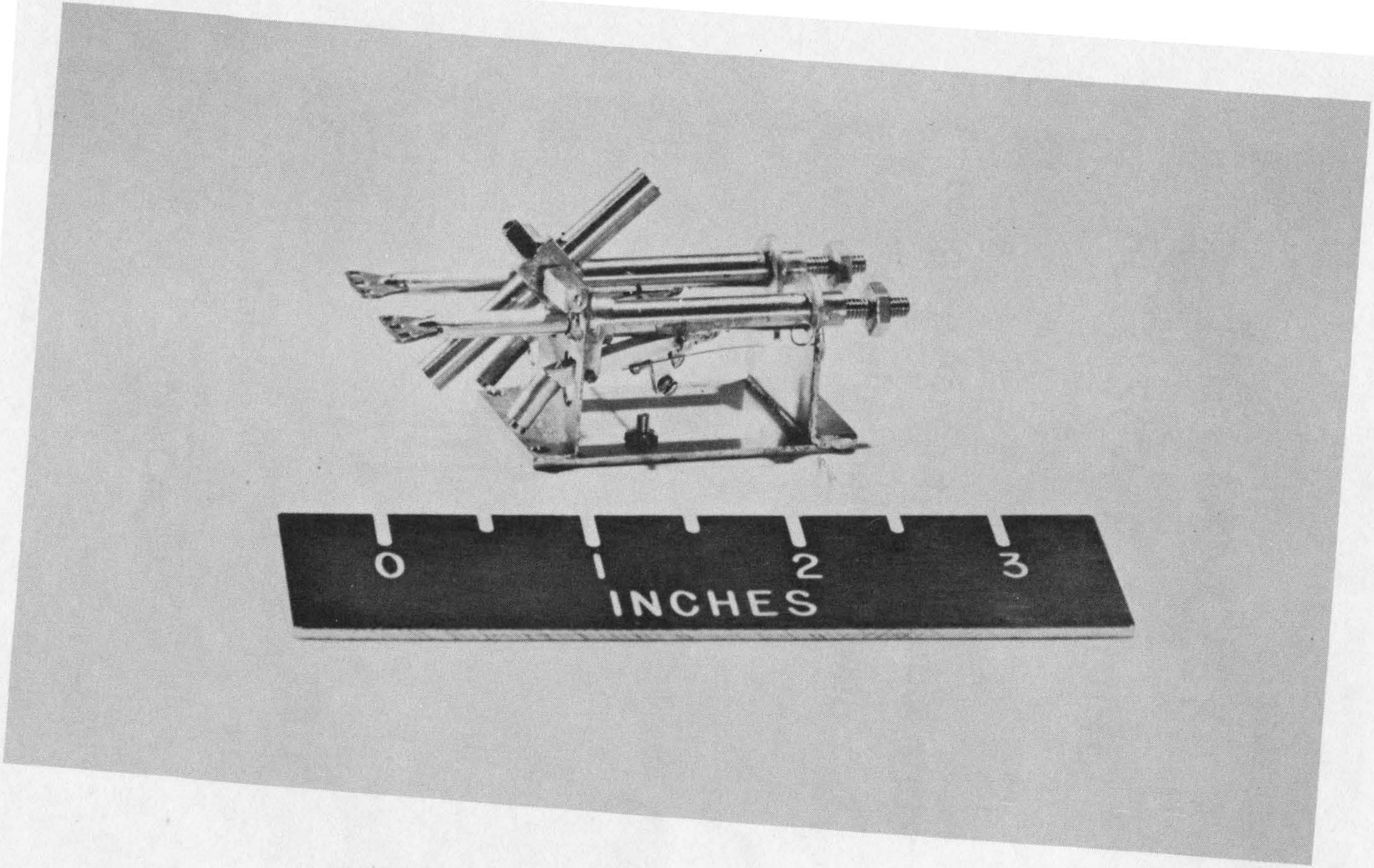
L-49000
Figure 3.- Interior view of Langley 20-foot free-spinning tunnel.



L-54511
Figure 4.- Gooseneck rotary arm support for models or, used in Langley 20-foot free-spinning tunnel.

L-86259

Figure 5.- Typical model used in Langley 20-foot free-spinning tunnel.



L-76471

Figure 6.- Remote-control mechanism used in spin models for Langley 20-foot free-spinning tunnel.

THE LANGLEY FULL-SCALE TUNNEL

Langley Aeronautical Laboratory
Langley Field, Virginia

FULL-SCALE

NACA

LANGLEY FULL-SCALE TUNNEL

GENERAL DESCRIPTION

The Langley full-scale tunnel is of the double-return type with an open throat as shown in figure 1. Figure 2 is a photograph of the exterior of the tunnel. The test airspeed range is from 25 to 110 miles per hour in 24 steps, and a separate speed control is available that permits a continuous airspeed variation from zero to approximately 40 mph. (At present this control cannot be used in conjunction with the step control.) The two side-by-side 35-foot-diameter fans rotate at a maximum rotational speed of 300 rpm and absorb 4,000 horsepower each. The powerplants are induction motors coupled directly to the fans. The facility can test large models, in some instances full-scale, and helicopter rotors with diameters up to 25 feet over the speed range adequately suited for the landing and take-off of the airplane and essentially the complete speed range of the helicopter. Power-on test conditions can be provided by means of available electric drive motors, and it is possible in some cases to operate the aircraft powerplant, although the air enchange system is not capable of long continuous operation.

TEST SECTION

The test region of the full-scale tunnel is 30 feet high, 60 feet wide throat, and 56 feet long and thus allows considerable latitude in model parameters such as size, positioning, and attitude, as well as flexibility in the general arrangement of mounting test vehicles. The open-throat feature provides for quick manipulation of airplanes and models in the test region and for mounting on the support struts by use of a $7\frac{1}{2}$-ton overhead bridge crane.

TEST CONDITIONS

Mach number (0 to 110 mph)	0 to 0.14
Stagnation pressure	Atmospheric
Reynolds number per foot	0 to 1 million
Stagnation temperature (dependent upon seasonal atmospheric conditions), °F	From about 40 to 100

MODEL-SUPPORT SYSTEMS

The full-scale airplane configurations are mounted on a 3-point support system, as shown in figure 3. The two front struts support the major portion of the static load and are mounted off the wing spars or the landing gear supporting assembly. The rear strut functions as a support and as an angle-of-attack control. The range of lateral displacement for the two forward struts is 5 to 18 feet and the longitudinal displacement range between front and rear struts is 13 to 18 feet. The normal angle-of-attack range is from -5° to 25°, although special setups have extended the range to 35°. The airplane can be yawed $\pm 20^{\circ}$ by means of manual positioning of the screw jacks in each leg of the two forward struts. A diagram showing the relative positions of the struts and the ranges of travel is shown as figure 4. The helicopter rotor installations are varied. A single rotor is mounted on a pylon as shown in figure 5, whereas a twin-rotor system would utilize the two front support struts and rear strut, as shown in figure 6.

A reflection-plane floor 42 feet wide and 32 feet long can be installed for full-scale semispan-wing investigations. These semispan-wing models are mounted on a trunnion which permits wing sweep positions varying from 0° to nearly 60°, and a 14-foot-diameter turntable permits an unlimited range of angle of attack. A highly swept wing mounted on the reflection plane is shown in figure 7.

MODELS

The airplanes or models investigated in the full-scale tunnel are limited in wing area to 350 square feet, in span to 50 feet, and in gross weight to 15,000 pounds. Helicopter-rotor diameters are limited to 25 feet and body lengths are limited to 35 feet. The loads imposed on models are not severe because of the low test dynamic pressure (about 25 lb/sq ft), so that wood or composite metal and wood construction can often be used. However, consultation with the wind-tunnel staff is required before construction of a model is begun to insure adequacy of component flexibility, instrumentation, contour accuracy, and surface condition. Airplanes and models are instrumented to determine such factors as control-surface position and hinge moment, static pressures (internal and external), temperatures, fuel rate, engine or propeller rotational speed, and such. Helicopter rotors are instrumented to determine rotor forces and moments (by strain-gage balances), rotor blade motions, rotor coning angle, etc. Helicopter testing therefore requires much more elaborate preparation and a higher degree of precision of measurement than airplane testing. The overhead crane type of survey rake is frequently used for detailed measurement of dynamic pressure and flow angle at any point in the wake of an airplane or flow field about a helicopter rotor.

INSTRUMENTATION

Balances

The full-scale-tunnel balance system, used for all airplane and some rotor testing is a Toledo six-component beam balance with load ranges of 15,000 pounds of lift, 2,000 pounds of drag, ±2,000 pounds of side force, and ±20,000 foot-pounds of rolling, yawing, and pitching moments. The strain-gage balances used for rotor testing are specifically designed to suit the load range and frequency of the particular rotor under consideration.

Manometers

Steady pressures are measured by means of 60-tube manometers with a working height of five feet. Tetrabromoethane is normally used as the manometer fluid. A pinch-bar arrangement permits 300 to 600 steady pressures to be measured with the manometer equipment.

Data Recording and Reduction

Force data obtained from the six-component beam balance of the full-scale tunnel are generally converted to coefficient form by manual computations as a result of the particular method of data recording. The tests are usually short in duration and do not require automatic data reduction methods.

When a strain-gage balance is used in rotor testing, recording oscillographs are used to obtain the data. These data are then read manually, transcribed to punch cards, and processed by automatic computing machines.

Steady pressure data are recorded by photographing the 60-tube manometers, and the data are then transcribed from the film records to punch cards and processed in the same manner as that described for the 16-foot transonic tunnel.

Flow Visualization

The investigations in the full-scale tunnel can constantly be observed from strategic locations surrounding the test region. Various visual means such as ink flow, smoke flow, vanes, and tufts have been used for observing flow phenomena on model surfaces. Motion-picture and still photography may be used for recording the flow phenomena when necessary for subsequent detailed study.

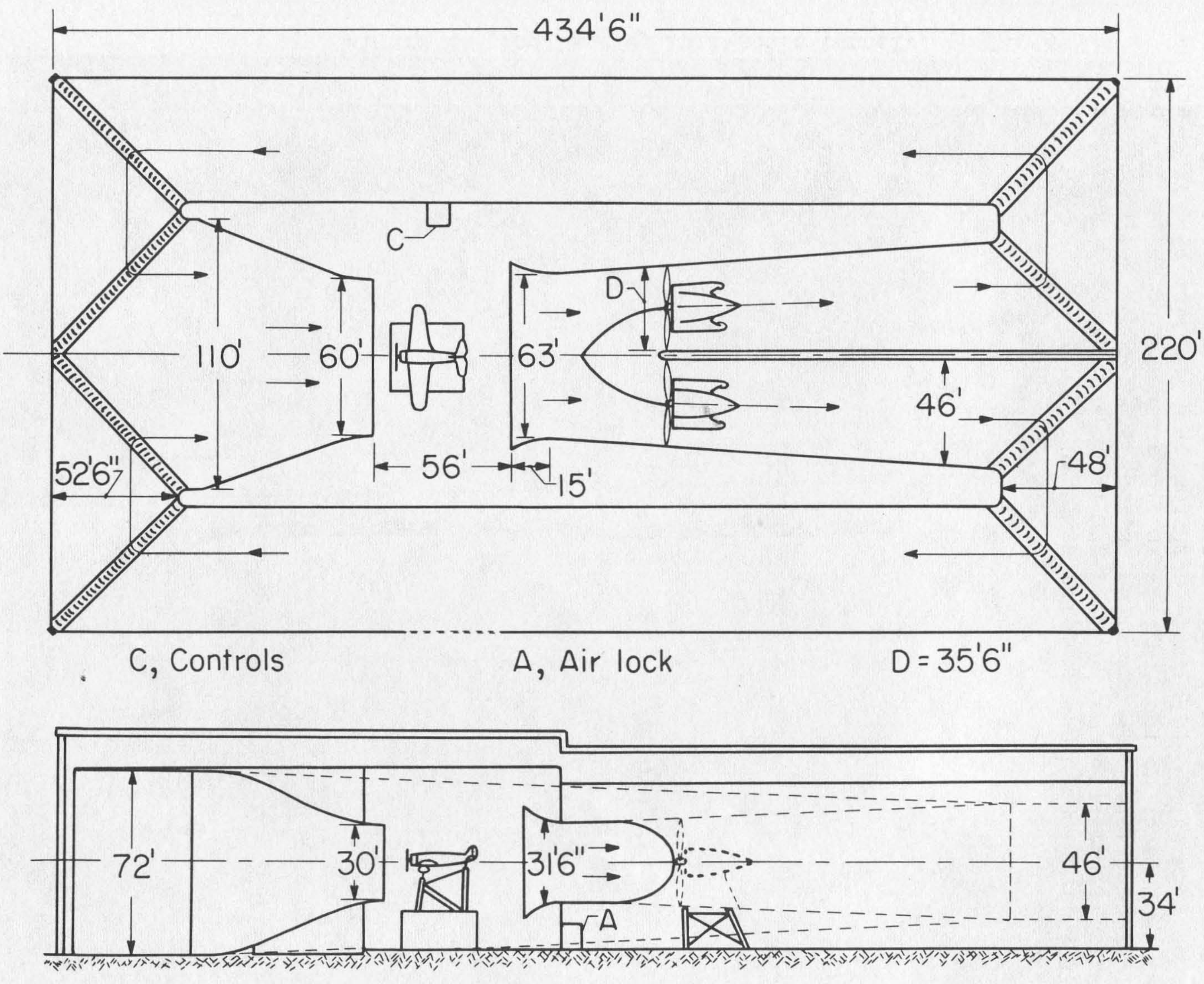


Figure 1.- Plan and elevation sketch of the Langley full-scale tunnel.

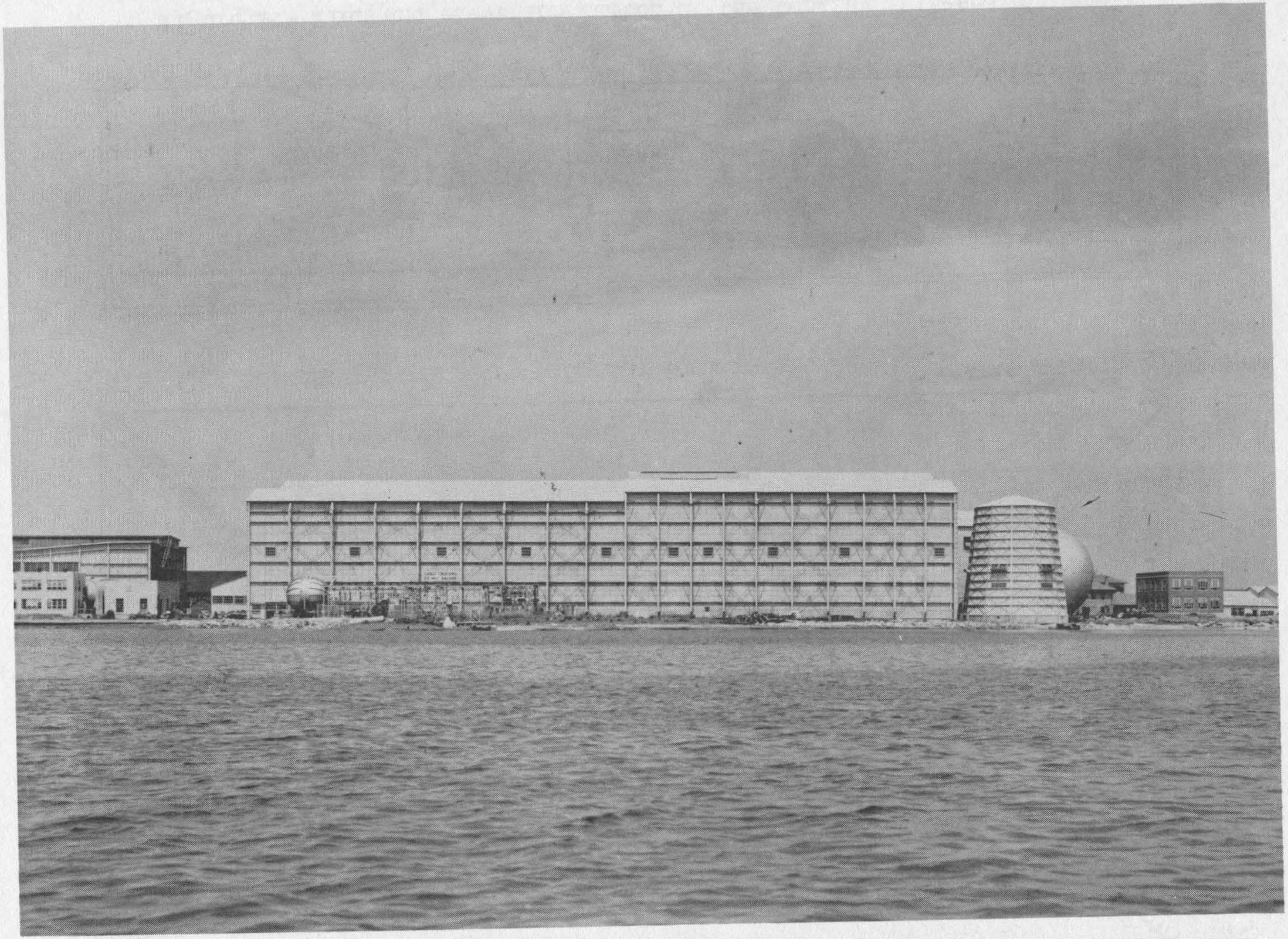
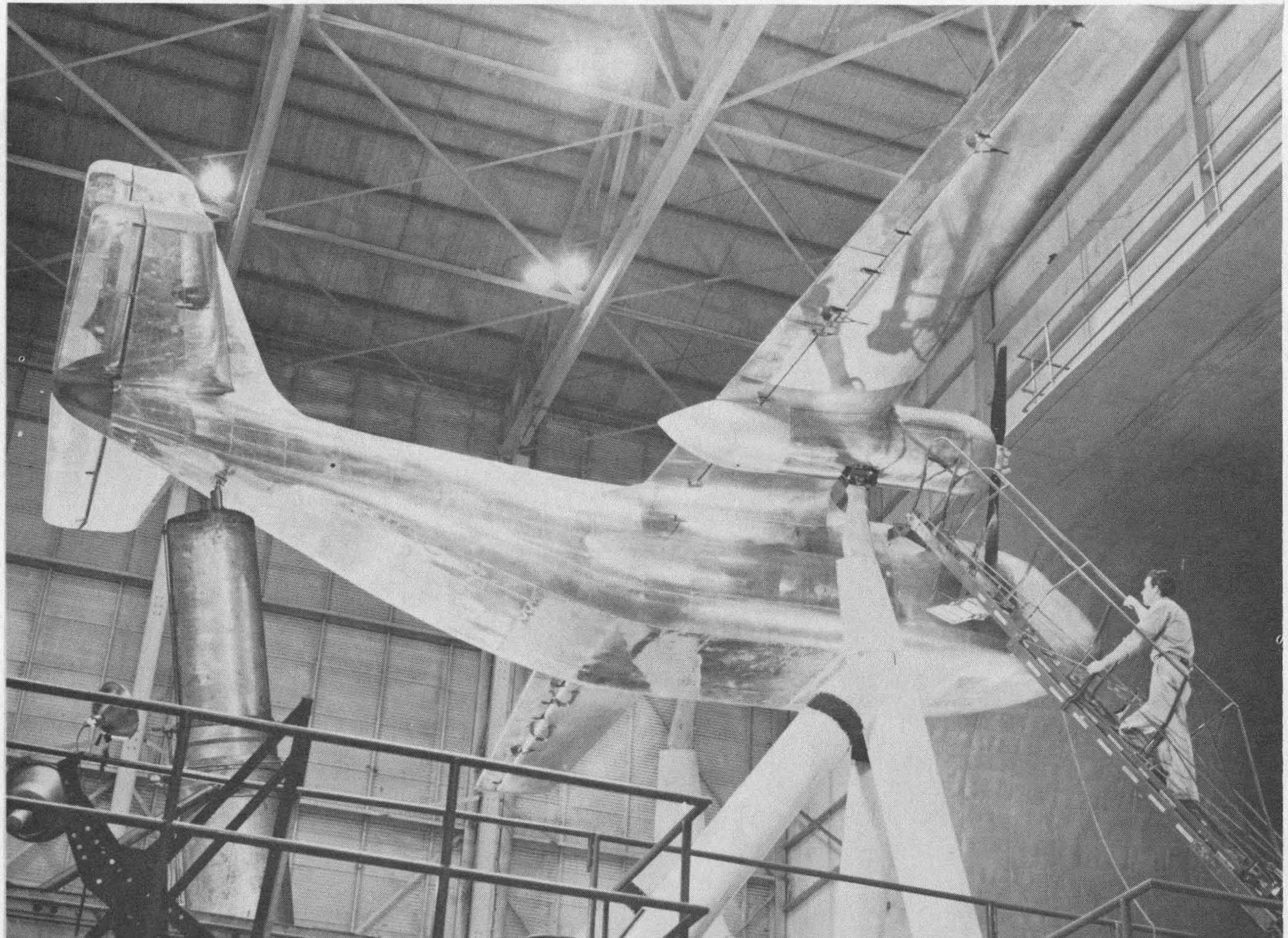
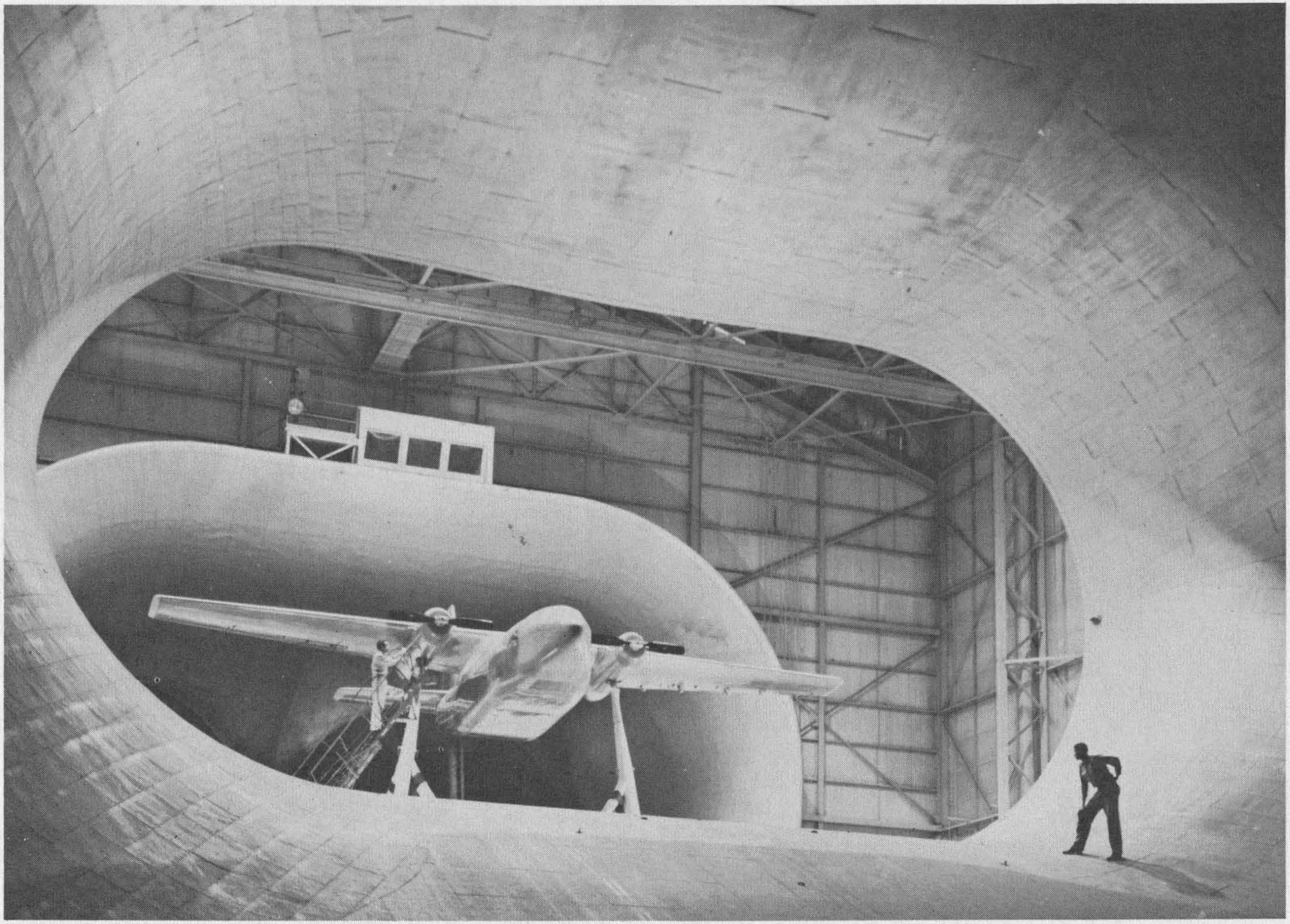


Figure 2.- The Langley full-scale tunnel. L-25358



(a) Side view. L-79948

Figure 3.- Typical model installation in the Langley full-scale tunnel.



(b) Front view. Langley full-scale tunnel. L-79944

Figure 3.- Concluded.

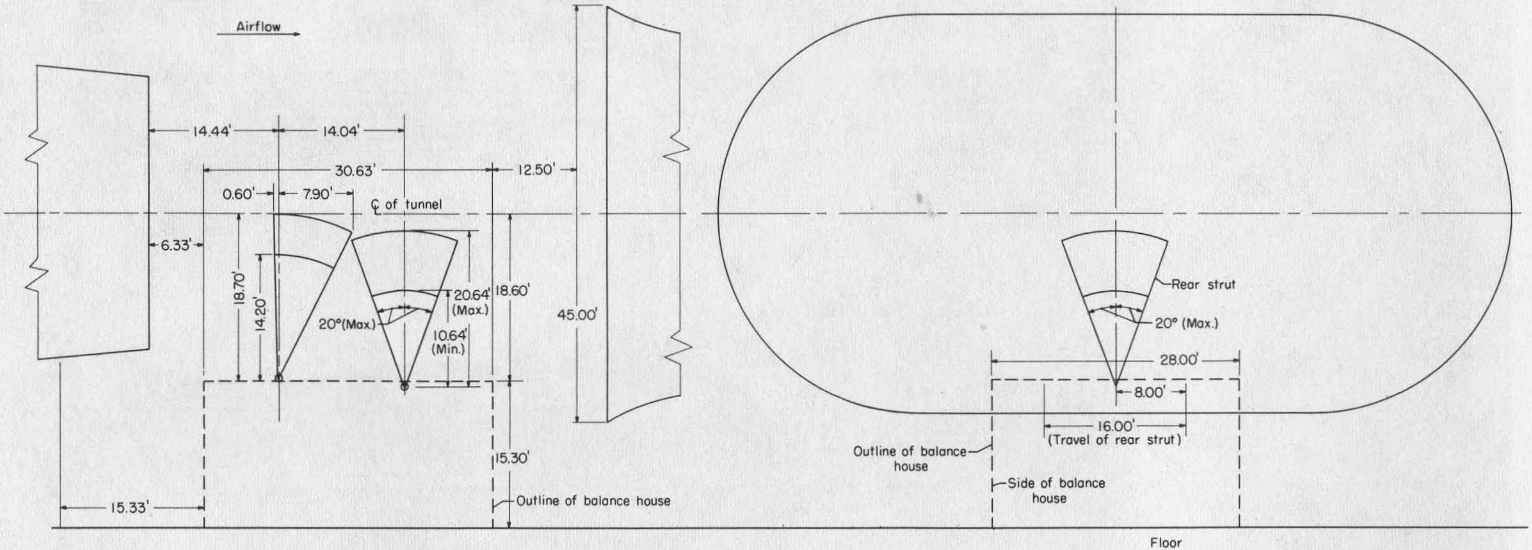
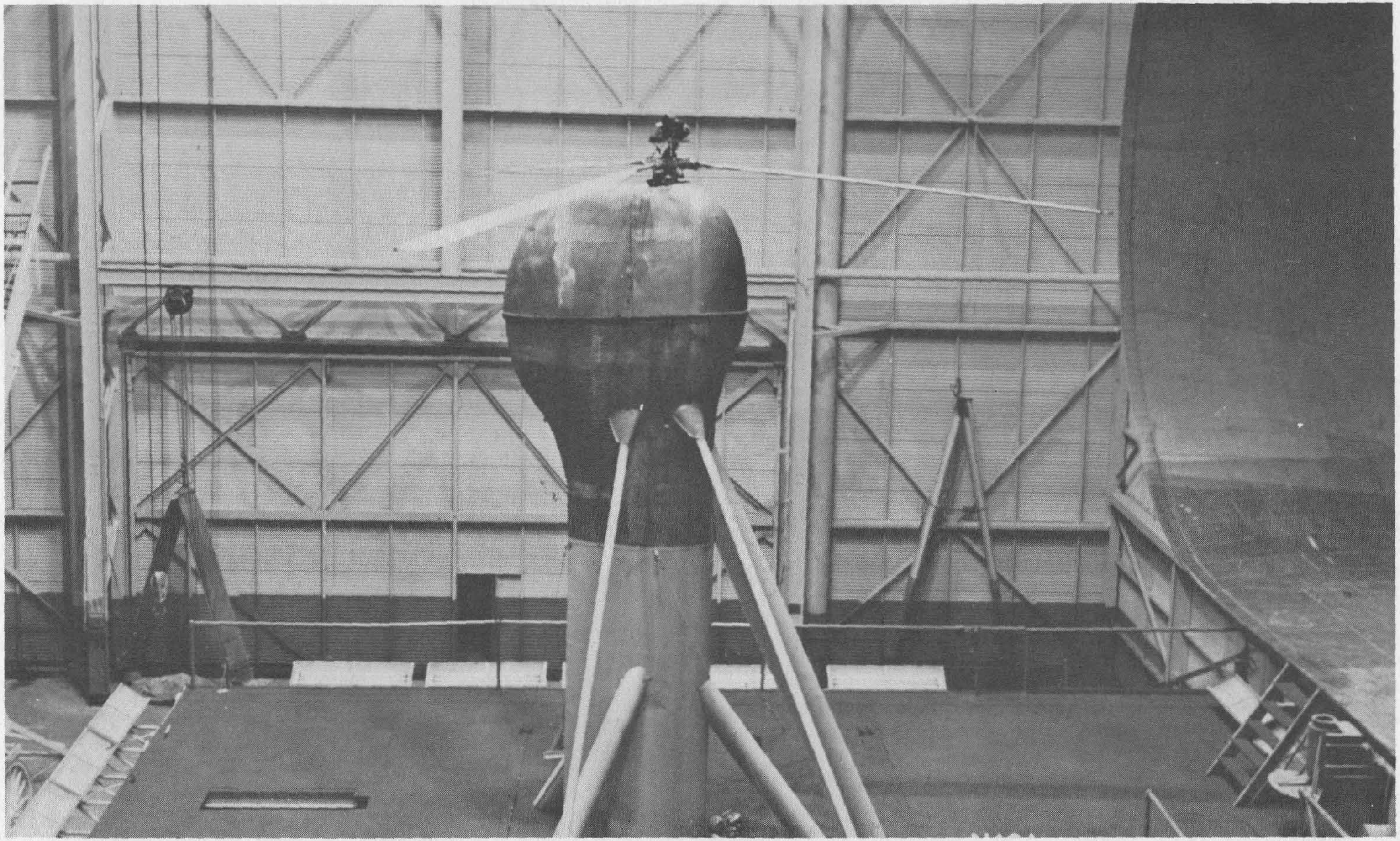


Figure 4.- Diagram of the relative positions of the support struts and their ranges of travel. Langley full-scale tunnel.



L-45746

Figure 5.- Helicopter-rotor installation in Langley full-scale tunnel.

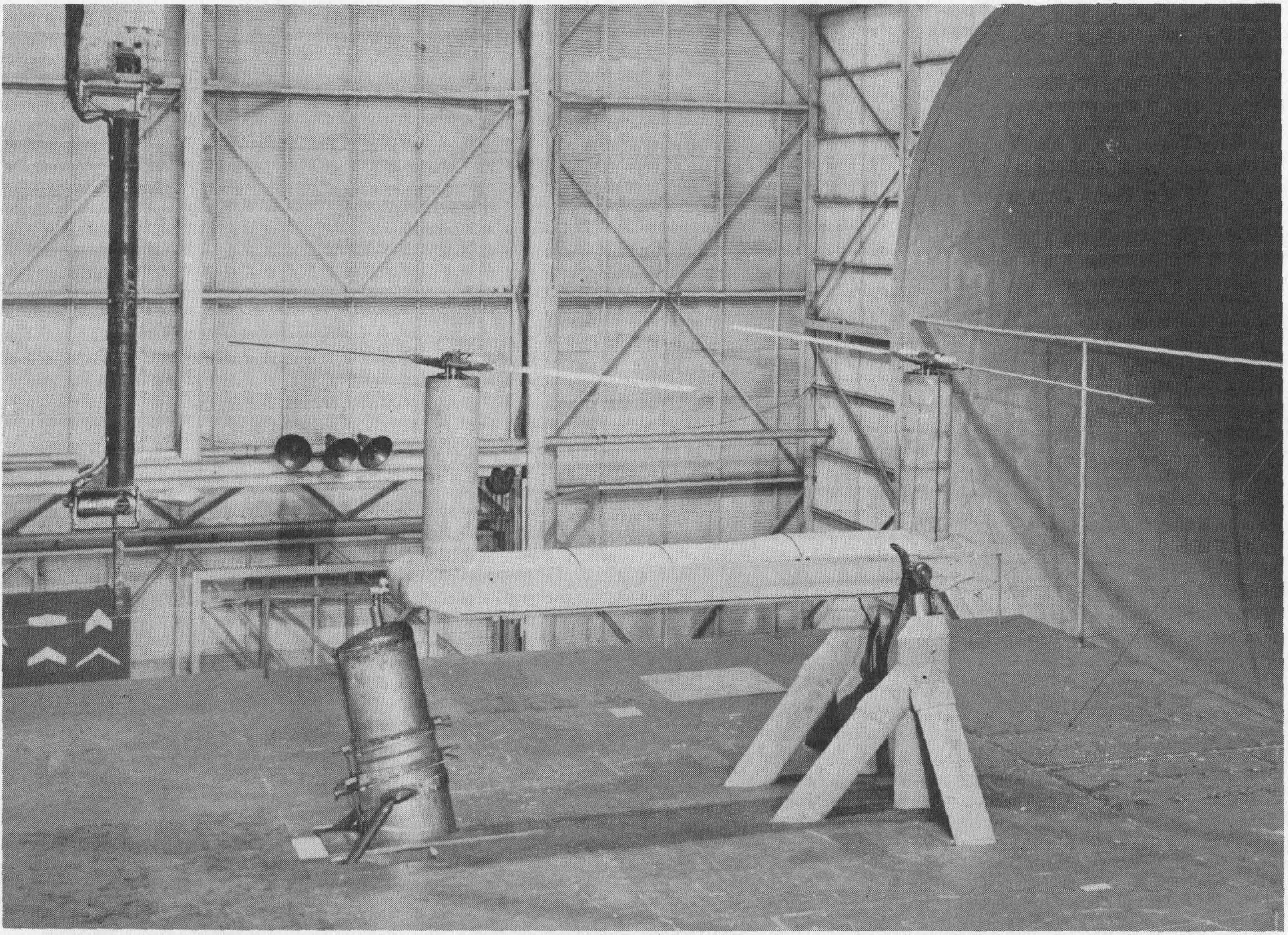


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Figure 6.- Twin-rotor installation in Langley full-scale tunnel.

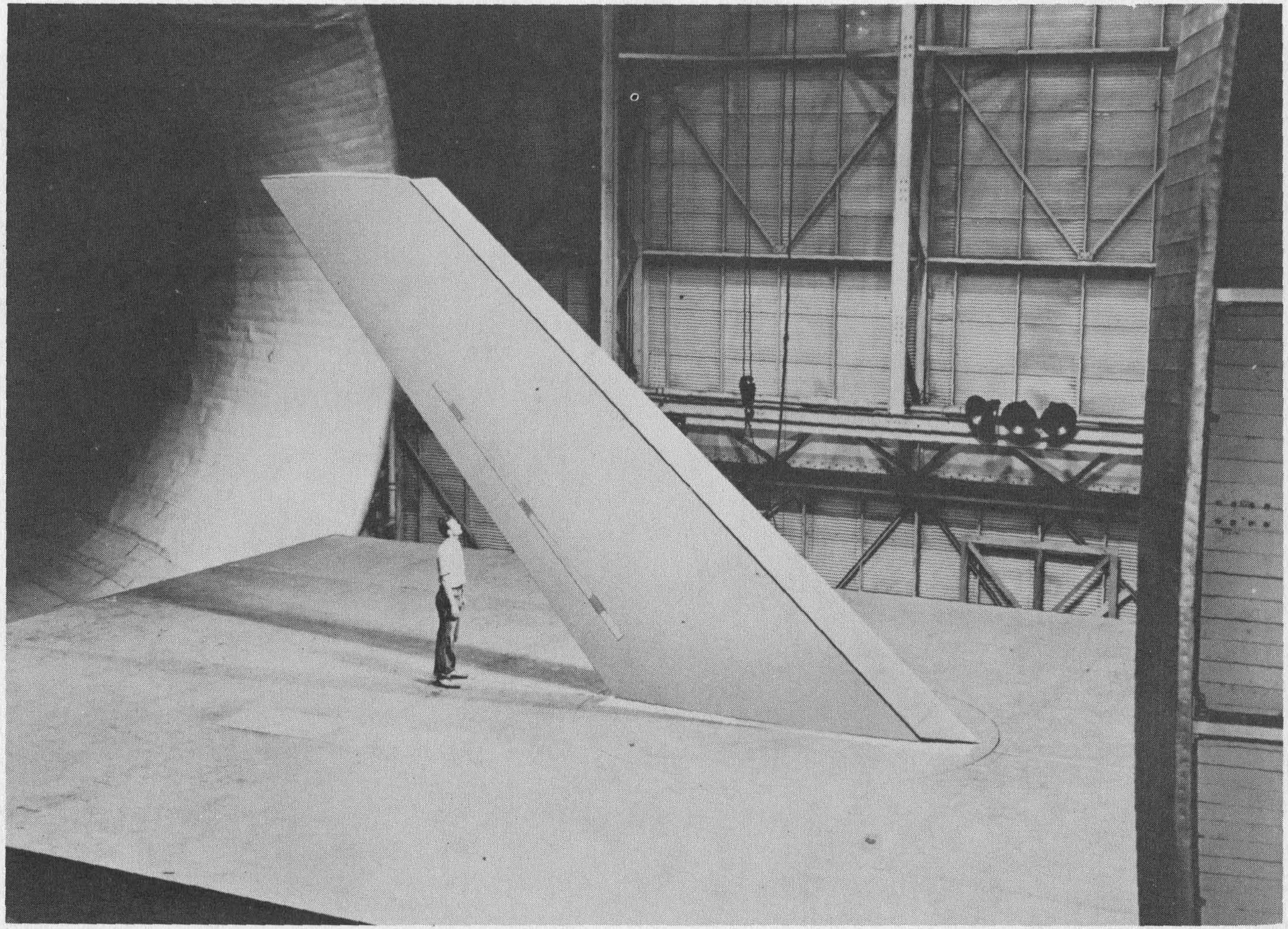

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Figure 7.- Semispan-wing installation in Langley full-scale tunnel.

THE LANGLEY TRANSONIC BLOWDOWN TUNNEL

Langley Aeronautical Laboratory
Langley Field, Virginia

NACA

LANGLEY TRANSONIC BLOWDOWN TUNNEL

GENERAL DESCRIPTION

The Langley transonic blowdown tunnel has been in operation since October 1950. The tunnel, which is of the intermittent, blowdown type, receives dry air from an 83,000-cubic-foot reservoir pumped to pressures as high as 10 atmospheres. The air, which is dried to a dew point of -60° F at 20 atmospheres, is supplied to the reservoir by compressors which have a capacity of 3600 cubic feet per minute. The time required to recharge the reservoir varies up to a maximum of about 1 hour. Three 24-inch-diameter Rotovalves, which connect the reservoir and tunnel settling chamber, can be position modulated with a single manually operated electronic control. The tunnel stagnation pressure can be held constant or varied for any range of pressure up to 5 atmospheres. The flow is exhausted to the atmosphere through a vertical stack containing sound baffles. A photograph and schematic drawing of the tunnel are shown as figures 1 and 2, respectively.

Test-section Mach number is controlled by the choking of a variable-area orifice plate located in the initial section of the tunnel diffuser. For low values of the tunnel stagnation pressure, the Mach number increases with the stagnation pressure until the flow at the plate becomes choked; thereafter, the test-section Mach number remains essentially constant as the stagnation pressure is further increased. The variable-area orifice plate, therefore, permits independent variation of Mach number and air density. The usual running time of the tunnel is of the order of 20 to 30 seconds. Longer running times are possible, depending upon the stagnation pressure and Mach number.

TEST SECTION

The test section, shown in figures 1(b) and 2, is octagonal in cross section and measures about 26 inches between flats. Longitudinal slots 7 feet long are located in each corner and comprise about 12 percent of the total periphery of the test section. Flow in the test section is sufficiently uniform that a testing length of more than two feet is available at subsonic speeds. At the highest test speed, uniform flow or test-section length is limited to about 10 inches.

A 6-foot-diameter cylindrical tank surrounds the test section. The space available for work or instrumentation within the tank shell is approximately annular in shape and measures about 20 inches by 9 feet long. Windows in six of the wall panels and in the tank make possible visual, photographic, and schlieren observations. Fixed equipment within the tank includes a 10-inch schlieren system, camera supports and lights for normal and high-speed motion-picture cameras, and pressure-tube panels for model pressure instrumentation.

TEST CONDITIONS

The tunnel may be operated at stagnation pressures from 1 to 5 atmospheres and at Mach numbers up to 1.45. The operating ranges of stagnation and dynamic pressure and Mach number are illustrated in figure 3. The relationship between dynamic pressure and Mach number is controlled by the stagnation pressure and the setting (as indicated by a counter) of the choking plate. The unbroken lines in figure 3 show the variation of dynamic pressure with Mach number as the stagnation pressure is increased for several plate settings; any plate setting below the maximum shown in figure 3 can be obtained. The maximum Mach number shown in figure 3 is about 1.33; however, Mach numbers as high as 1.45 can be obtained at stagnation pressures greater than 50 lb/sq in., absolute by bleeding air from the tank surrounding the test section. The density range extends from about 0.001 to 0.012 slug per cubic foot, which corresponds to a range of Reynolds numbers per foot of about 2 million to 27 million.

It should be pointed out that the test section velocity is not uniquely defined by the Mach number, since the stagnation temperature continually decreases during a run because of expansion of the air in the reservoir. The stagnation temperature depends upon the initial reservoir conditions and the amount and flow rate of air used during the run. For a representative run, the stagnation-temperature decrease is of the order of 40° F. A standard chart showing the variation of Reynolds number per unit length with Mach number for various total temperatures is presented as figure 25 of NACA Report 1135.

MODEL-SUPPORT SYSTEM

The model-support system as shown in figure 2 consists of a tapered sting attached to a motor-driven circular arc which extends vertically through the diffuser section of the tunnel into the tank. The system is so designed as to keep the center of gravity of the model on the center line of the tunnel through a range of angle of attack from -9° to 12°. By use of angular couplings, model angles of attack greater than 12° can be obtained. Sting adapters are available for models having sting diameters varying from 0.4 inch to 2.0 inches.

In flutter investigations, for which the tunnel has limited applications, the model is supported by longer sting which is located along the center line of the tunnel and extends upstream into the subsonic flow region of the entrance cone; thus, the formation of a bow shock wave which might reflect from the walls onto the model is avoided.

MODELS

In construction of models, plastics are employed wherever possible because of ease of fabrication. Because of the high dynamic pressures available (4,400 pounds per square foot, maximum), however, lifting surfaces are constructed of steel with high yield stresses. Construction is often of steel and plastic combinations. In order to minimize the range of supersonic Mach number in which model shocks reflect from the tunnel walls to the model surfaces, the size of models used for measurement of absolute external aerodynamic characteristics is limited. For example, characteristics obtained for a 10-inch-long wing-body combination having 7-inch-span wings are influenced by shock reflections only in the range of Mach number between 1.04 and 1.13. Models of this scale, however, are large enough to be instrumented with internal strain-gage balances and with pressure tubes for determination of internal air-flow rate and drag. For more complete evaluation of internal-flow systems, somewhat larger models can be investigated.

Flutter models are usually dynamically scaled so that the airplane altitude range of interest is simulated at values of dynamic pressure near the middle of the range available (fig. 3). Fifteen inches is probably a maximum span for wing flutter models.

INSTRUMENTATION

Balances

The internal strain-gage balances available for use in the Langley transonic blowdown tunnel range in size from 0.12 to 2 square inches in cross-sectional area and from 7.5 to 14 inches in length. A typical balance would have load limits of about 250 pounds of normal force, 50 pounds of axial force, and 200 inch-pounds of pitching moment. Details of the various balances available at the laboratory can be ascertained by consultation with the wind-tunnel staff.

Data Recording and Reduction

The short-duration tests of the tunnel require that automatic data recording equipment be used wherever possible. A central control panel is used to obtain simultaneously records of forces, pressures, temperatures, and visual flow.

Two methods are currently being employed to record force data: (1) single-channel self-balancing potentiometers are photographed, and (2) multichannel records are made through use of strip-chart recording potentiometers. Permanently installed strain-gage wiring will permit simultaneous measurements of up to twenty-one 4-wire gages.

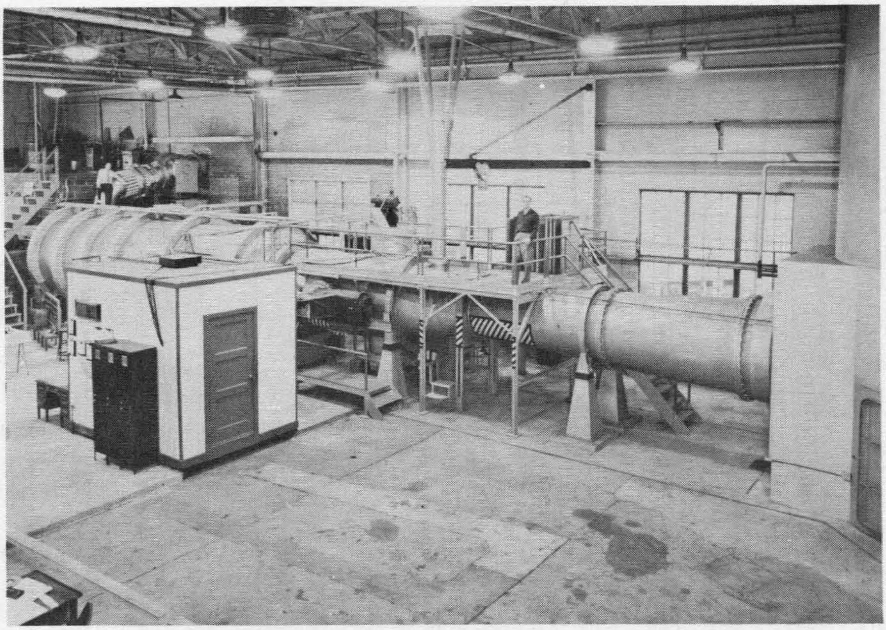
No manometers are used, and pressure measurements are made with diaphragm-type pressure cells which have a mechanical optical recording system. A beam of light projected on a moving strip of film gives continuous readings of all tunnel and model pressures. Space is provided for recording 108 pressures simultaneously, and there are available about 126 of the pressure cells with maximum pressure ranges from ±15 to ±60 psi.

For flutter tests, the outputs of the strain gages or accelerometers are fed into a bank of amplifiers which relay the signals to a recording oscillograph to yield a time history of the model motions. The test-section stagnation and static pressure and stagnation temperature are also recorded on the oscillograph record as well as indications of model fouling and of operation of the motion-picture camera.

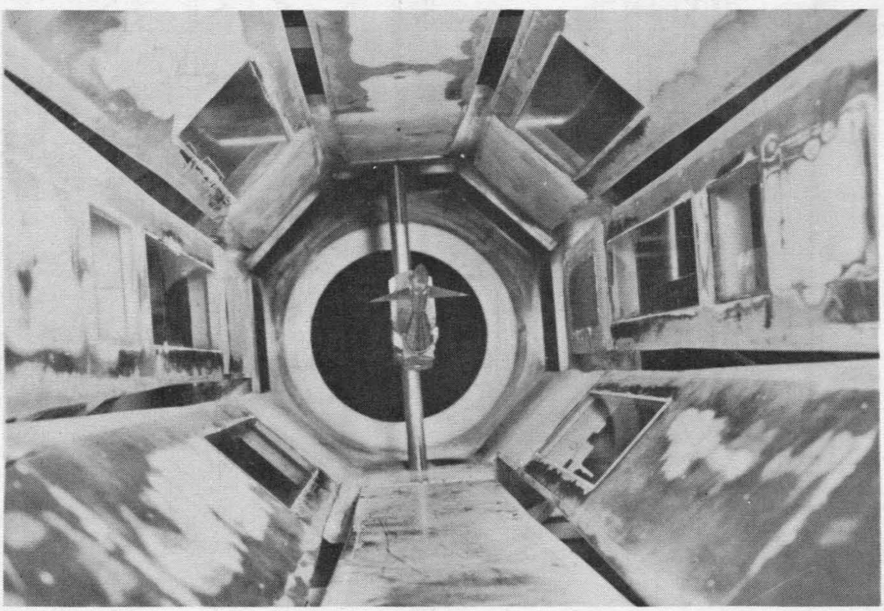
All the force or pressure and temperature data are transcribed manually from the film records or oscillograph traces to data sheets. Subsequent data reduction is performed on automatic computing equipment available at the Langley laboratory.

Flow Visualization

A schlieren system equipped with 10-inch-diameter F-8 parabolic mirrors is installed within the tunnel tank. With suitable arrangement of flat-faced mirrors, photographs of flow in any part of the test section can be made. Reflections from the knife-edge can also be projected on a screen within the tunnel control station for visual observations. High-speed motion-picture cameras are available for recording flutter and schlieren results. Typical schlieren photographs are presented in figure 4.



(a) Exterior view. L-73656



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(b) Test-section view showing typical model installed.

Figure 1.- The Langley transonic blowdown tunnel.

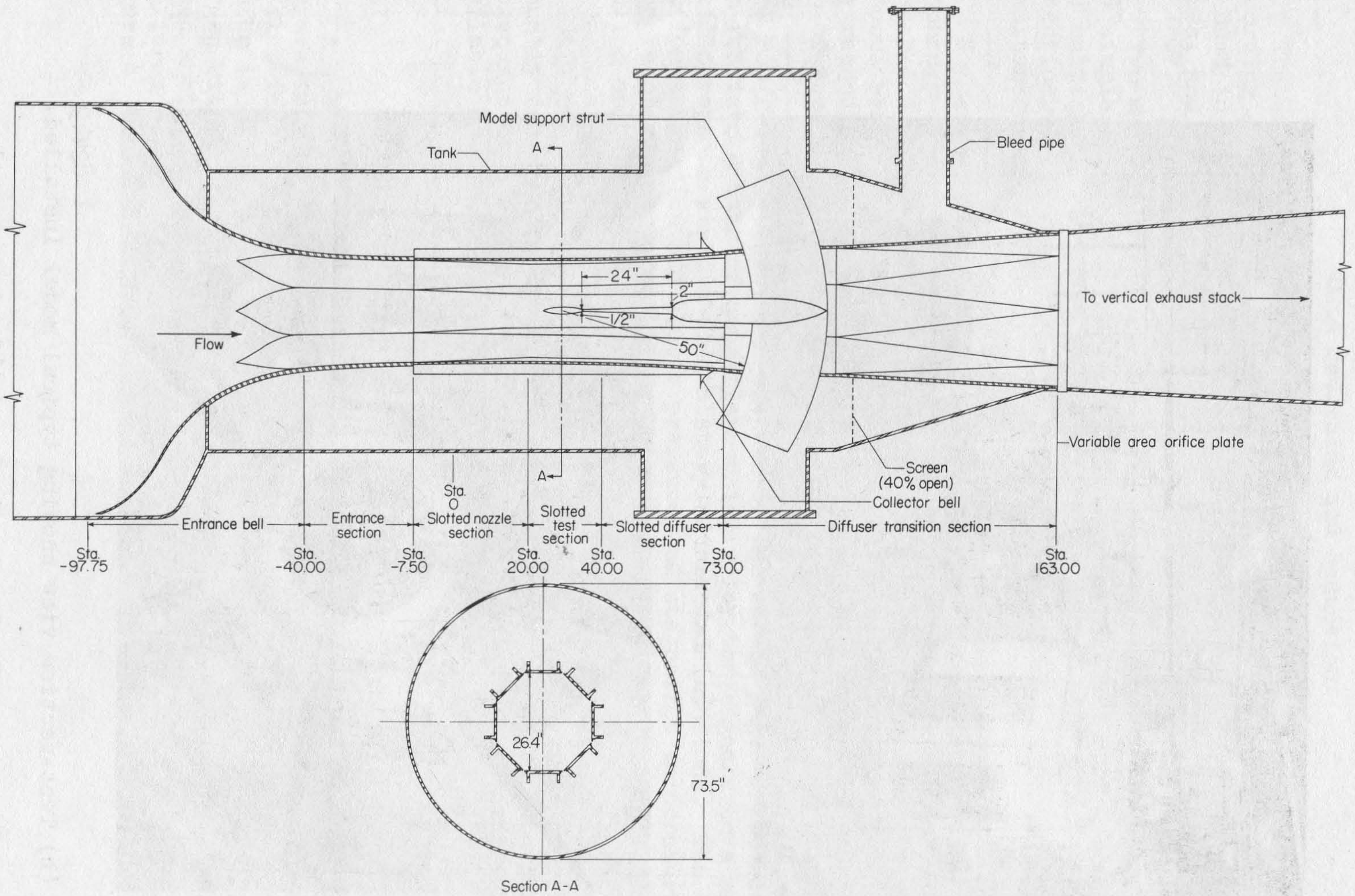

Figure 2.- Sketch of the test section in Langley transonic blowdown tunnel.

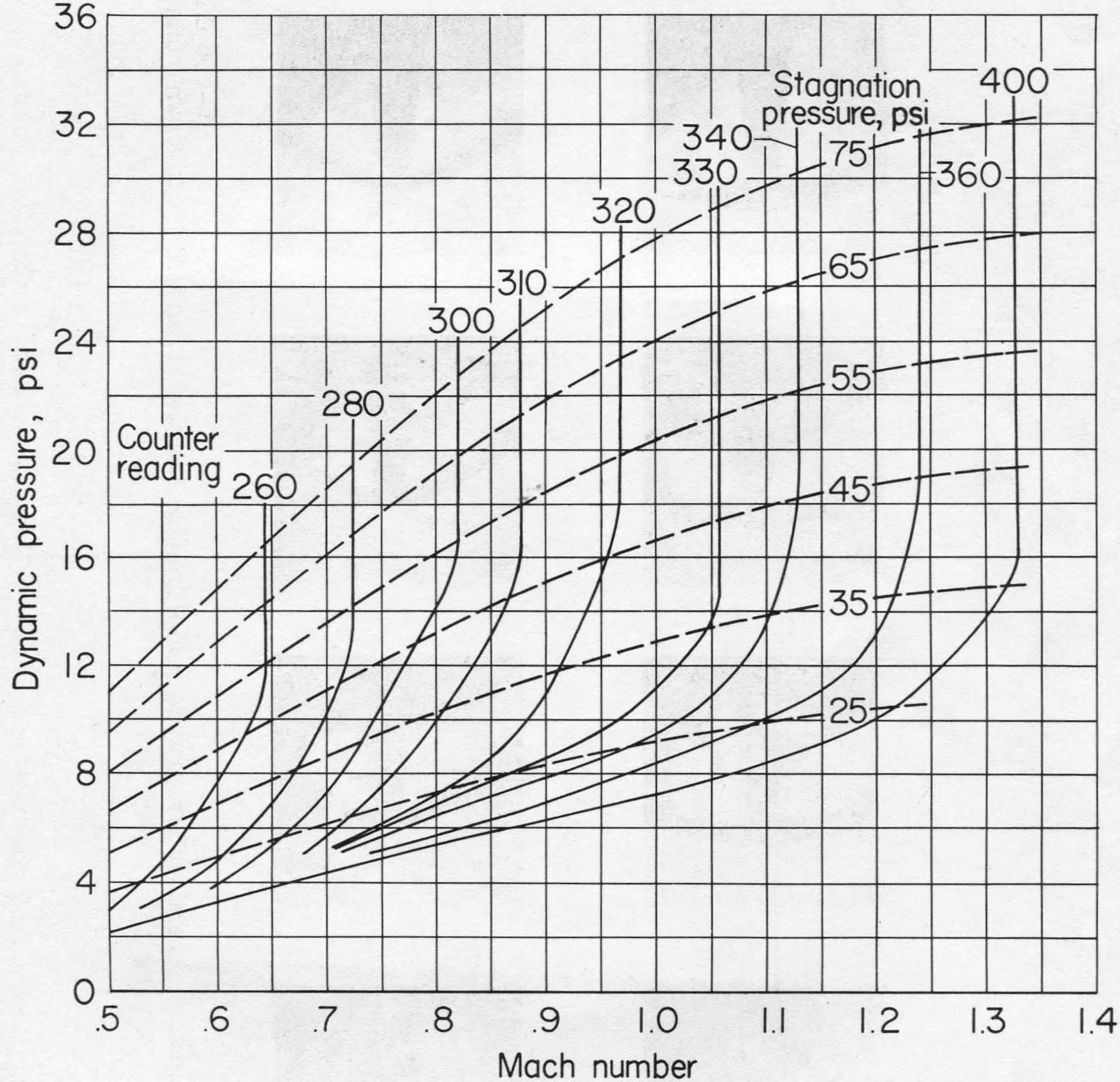

Figure 3.- Operating ranges of stagnation and dynamic pressures and Mach number with bleed duct closed. Langley transonic blowdown tunnel.

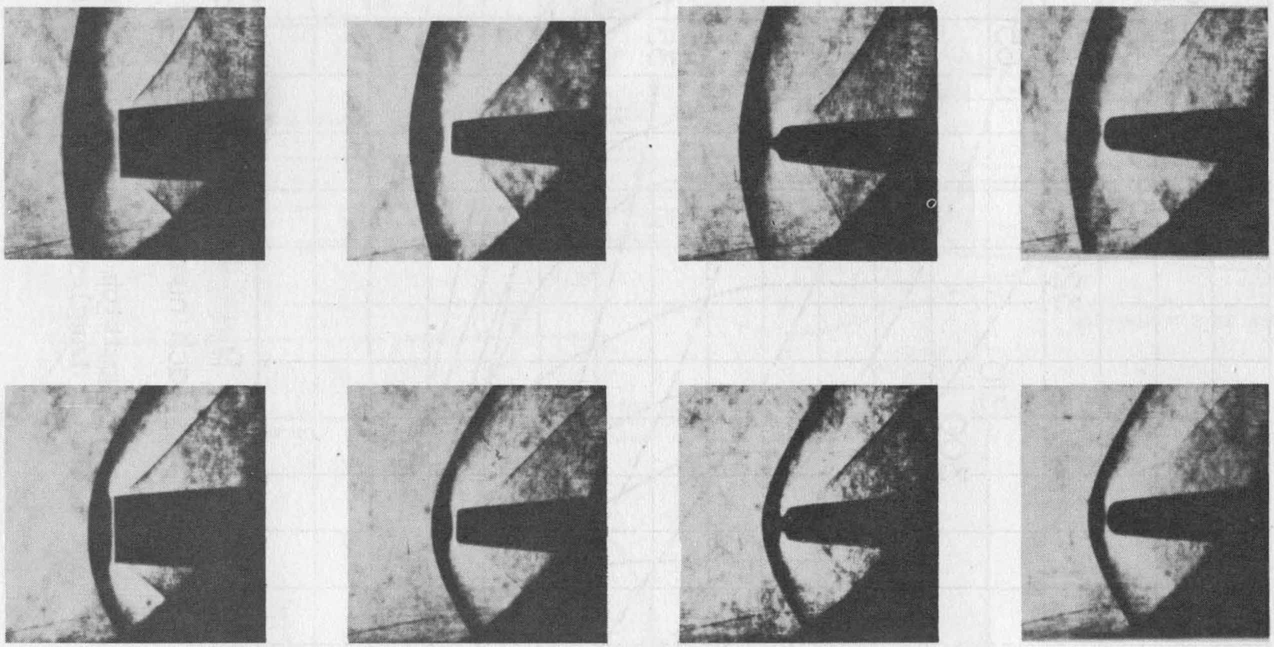

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Figure 4.- Sample schlieren photographs made in the Langley transonic blowdown tunnel.