MODEL SUSPENSION SYSTEM

THE suspension system for the Southern California Cooperative Wind Tunnel consists of two fundamental elements, having as their objective the supporting of the model and the measuring of the model forces and moments respectively. The first of these is the model suspension system proper and the second is known as the metrical system.

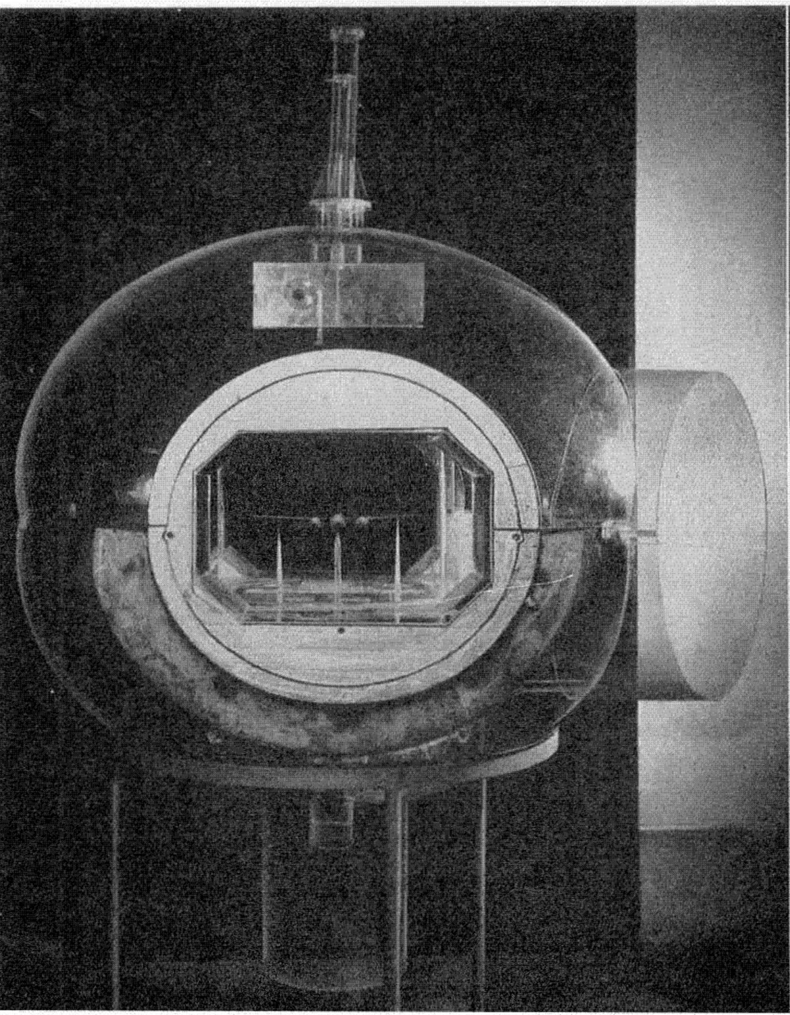
There are three ways in which the model may be supported in the tunnel working section. For determining the properties of wing sections, wing sections with flaps or other control devices, stub wing nacelle models, or other models which can be supported from wall to wall in the tunnel, a ring supporting system is used. This consists of a large ring completely around the tunnel working section, with two model supporting face plates on the horizontal centerline and two on the vertical centerline of the working section, shown in *Fig. 26*. Models can be supported on either of these pairs of face plates and can be rotated by remotely controlled motors in the ring frame. The ring frame does not touch the working section but is entirely supported from the metrical system; thus any forces applied to the model are transmitted directly through the ring frame to the force measuring system.

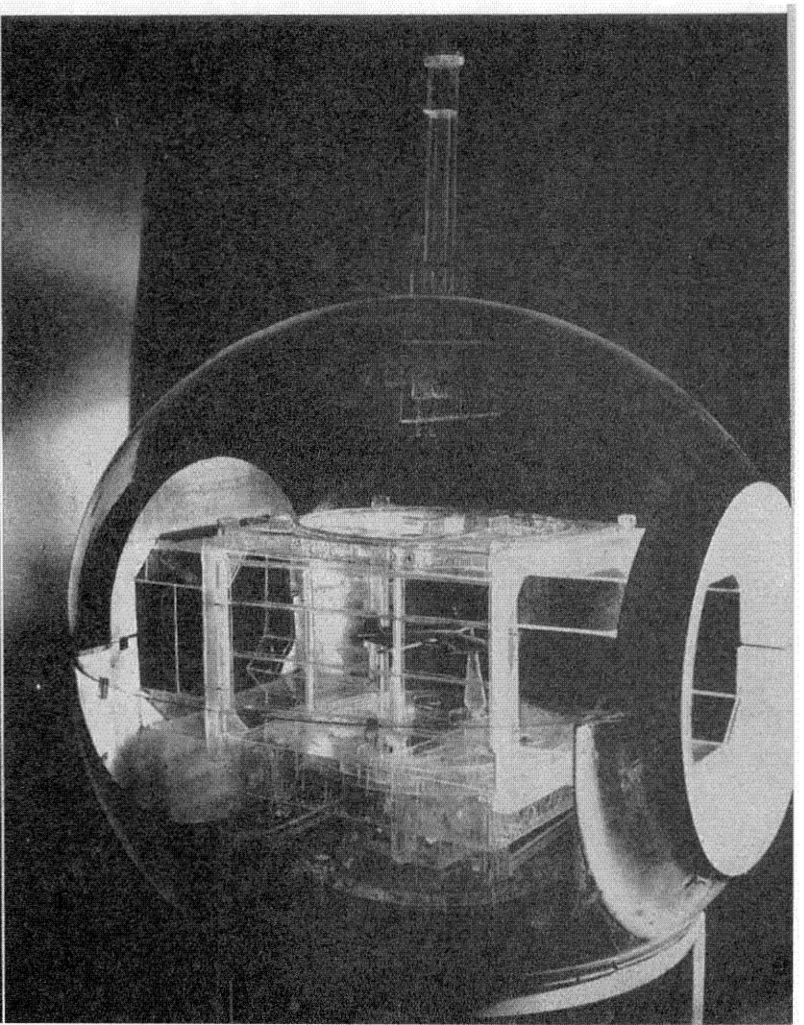
The second model supporting system is that most commonly associated with wind tunnels—the three-point system (see *Fig. 27*). In this, a scale-size model of a complete airplane is supported by means of two vertical model support arms (trunnion arms) attached to points on the wings, and a third strut which is attached near the tail of the model. These three struts are supported from the metrical system; thus any forces or moments applied to the model by the air stream are transmitted to the force measuring system. The attitude of the model in the tunnel is controlled by remotely operated motors attached to the three-point system. It is possible to change, over wide limits, both the pitch angle of the model (the rotation of the model about a horizontal axis through the ends of the two main trunnion arms) and the angle of yaw (the rotation of the model about a vertical axis, giving a cross-wind attitude). These model motions are controllable from the console in the control room, and the model position is indicated on the control console (see *Fig. 2*).

In order that the air forces on the trunnion arms and tail strut may be held to a minimum, all three units have windshields covering a large proportion of their length. The main trunnion arms are covered by a streamline windshield which is automatically kept lined up with the windstream, even when the model is operated at angles of yaw. This lining up is carried out by "follow-ups" working on an induction bridge principle, which keeps the windshields in the proper orientation with respect to the main trunnion arms and prevents any contact between the trunnion arms and the windshields. This is essential, since the trunnion arms are a part of the force measuring system, while the windshields are fastened to the tunnel shell. A similar device causes the tail strut windshield to move with the proper vertical and horizontal motion

FIG. 17 *(at left)*: View of plastic model of decompression sphere looking downstream through working section.

FIG. 18 *(at right)*: Showing details of working section, plastic model of decompression sphere.





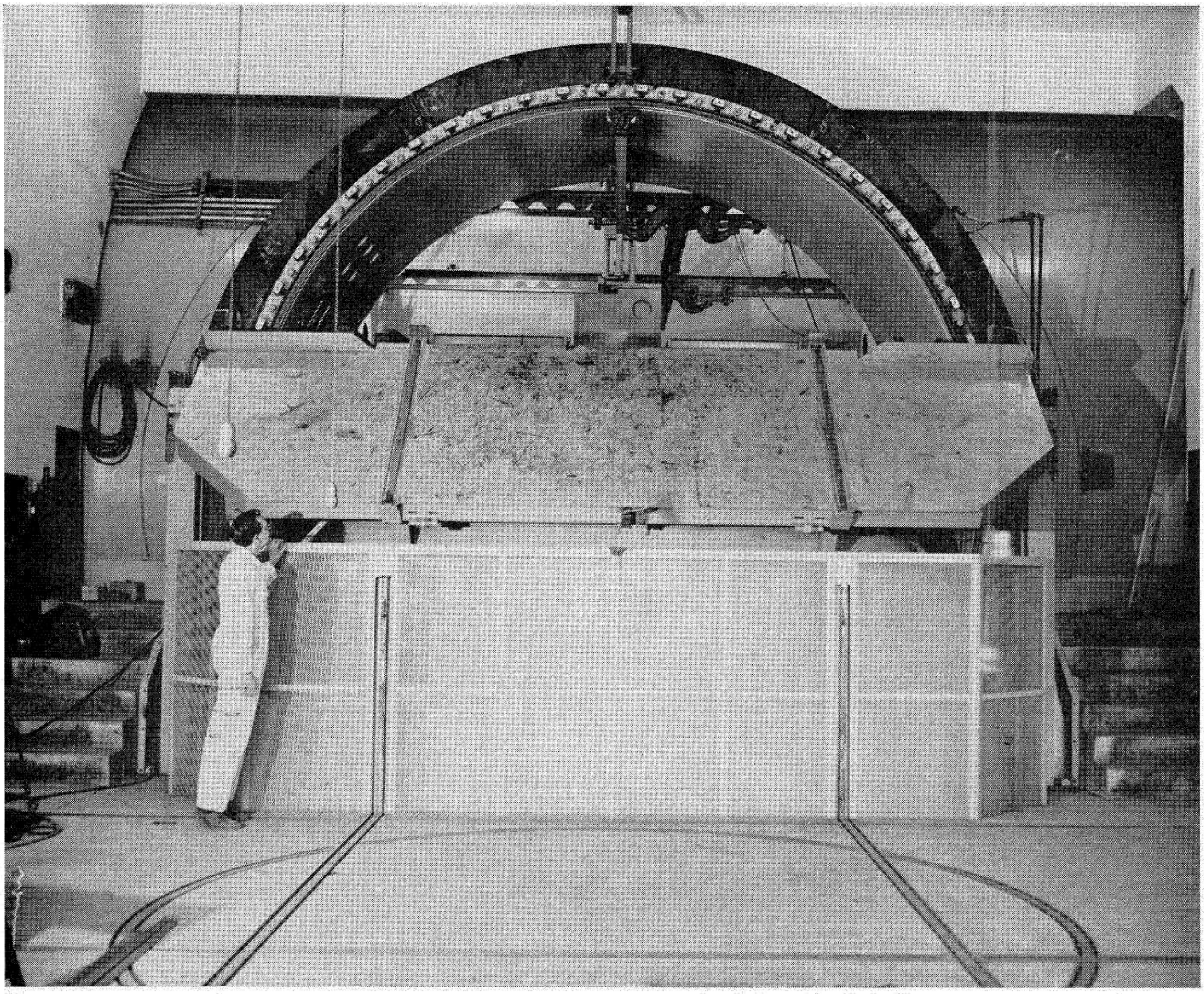


FIG. 19. Showing massive steel door of decompression sphere partially closed.

as the tail is moved up and down to change the angle of attack of the model.

If the model contains motors for running propellers, or power for the operation of various model functions, the power leads are led up through the tail strut and into the body of the model for distribution. Several sizes of main trunnion arms and tail struts may be used, depending upon the operating speeds of the tunnel and the forces expected on the model. Locations of both the tail strut and main trunnion arms are adjustable to accommodate various model sizes and configurations.

The third type of model support is known as the N.A.C.A. strut support system. In this, the tail strut is removed and the main trunnion arms are replaced by two other arms, each having a double strut at the top. The model is connected to these systems and, since the rear struts are remotely adjustable, the model may be adjusted in angle attack from the control room. In general, with this system in use, the model will not be rotated in yaw. For small or lightly loaded models, it is possible to put one N.A.C.A. trunnion at the center of the working section and support the model on a single tripod system. These arms are also attached to the metrical or force measuring system and are windshielded to reduce wind loads on the supporting arms.

Any model supporting system may be easily separated from the force measuring system and removed from the working area (see *Fig. 25*). This is accomplished by a jacking system acting on a four-legged cart, the top of which comprises the floor of the tunnel working section. Normally this working section floor, on which is fastened any strut windshielding system, is supported by the main tunnel shell and is not connected to either the force measuring or model supporting system, the legs of the cart being shortened so that they hang freely in space. If a model, with its suspension system, is to be removed from the tunnel, the legs of this cart are jacked down on to a pair of tracks. As they contact the tracks, the floor of the working section rises, disconnects itself from the tunnel shell, and picks up the model suspension system, separating the suspension system from the metrical system. Electrical and hydraulic leads between the suspension and metrical systems must be broken (by the disconnection of multiple pin plugs). When this separation has been completed, the complete model suspension and windshielding system may be moved under its own power out of the tunnel on the tracks which extend from the sphere into the working area and over to one of the model shops. Then, assuming that one of the other available model suspension systems has been made up with a model completely installed, this second system can be rolled into the tunnel, lowered into place, the electrical and hydraulic lines plugged in, the tunnel doors closed, and the second system is then ready for testing. The jacking and traversing motors are built in as part of each cart and are connected to the power supply by a flexible cable which may be plugged in in various positions in the sphere and in the working room. Manual push buttons give smooth, controllable operation. All operations are interlocked so as to prevent starting the tunnel unless the working section floor is attached to the rest of the working section, the tunnel doors are closed, the windshield and trunnion arm systems are not touching, the proper electrical circuits are plugged in, and numerous other functions are correctly connected.

When a change is made from one three-point system to another or from a three-point to an N.A.C.A. system, the back wall, ceiling, and front doors of the working section remain in place in the tunnel. If the ring frame system is used, the back wall and ceiling of the working section are removed, since the cart carrying the ring frame system carries with it a special back wall and ceiling as well as the ring frame to support the model. This is all moved in as a unit, after which the tunnel working section part is attached to the tunnel shell and is separated from the ring frame, and the ring frame is fastened to the force measuring system.

This separation of the suspension system and the force measuring systems permits carrying out most of the model installations in the model shops rather than in the wind tunnel. Models are becoming very elaborate, some of them having hundreds of pressure and electrical leads. To install such complicated systems in the wind tunnel would mean seriously curtailing the number of hours it would be possible to use the tunnel for testing purposes. However, with more than one model suspension system available, the amount of installation necessary in the tunnel is greatly reduced and the tunnel may be used much more efficiently. It is even possible to attach to the cart carrying the suspension system a platform extension on which may be placed multiple manometers for taking large numbers of pressure readings and other data-taking devices. These also may be completely connected up in the model shops and rolled into the tunnel, ready for testing.

In order to determine the tare drag of the model supporting system and the effect of the supporting system on the airflow around the model, a so-called image system is used. This consists of an inverted frame hanging above the ceiling of the working section, upon which are attached main and tail strut windshields which are inverted duplicates of those for the three-point system. By the use of this image system, flow symmetry

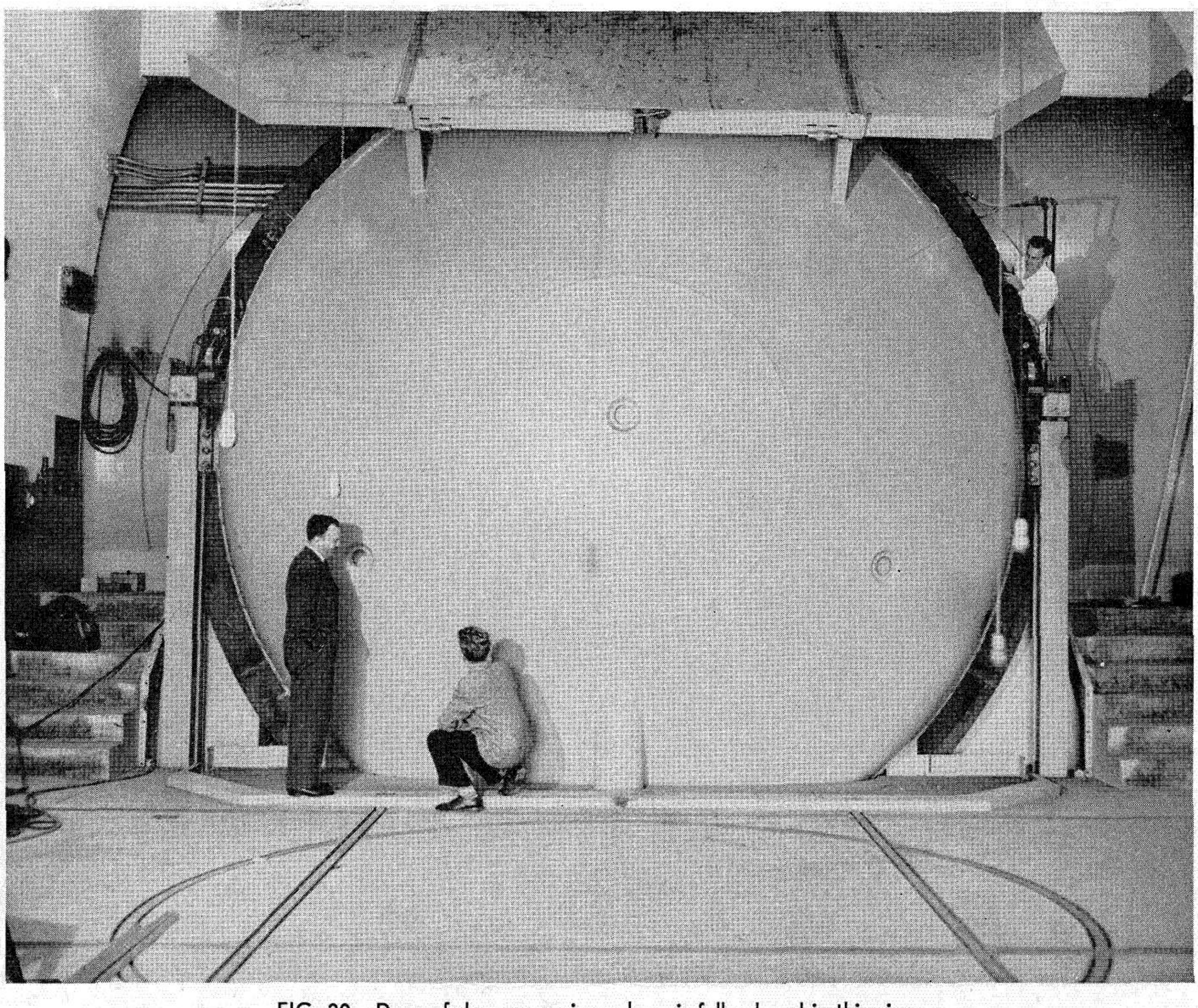


FIG. 20. Door of decompression sphere is fully closed in this view.

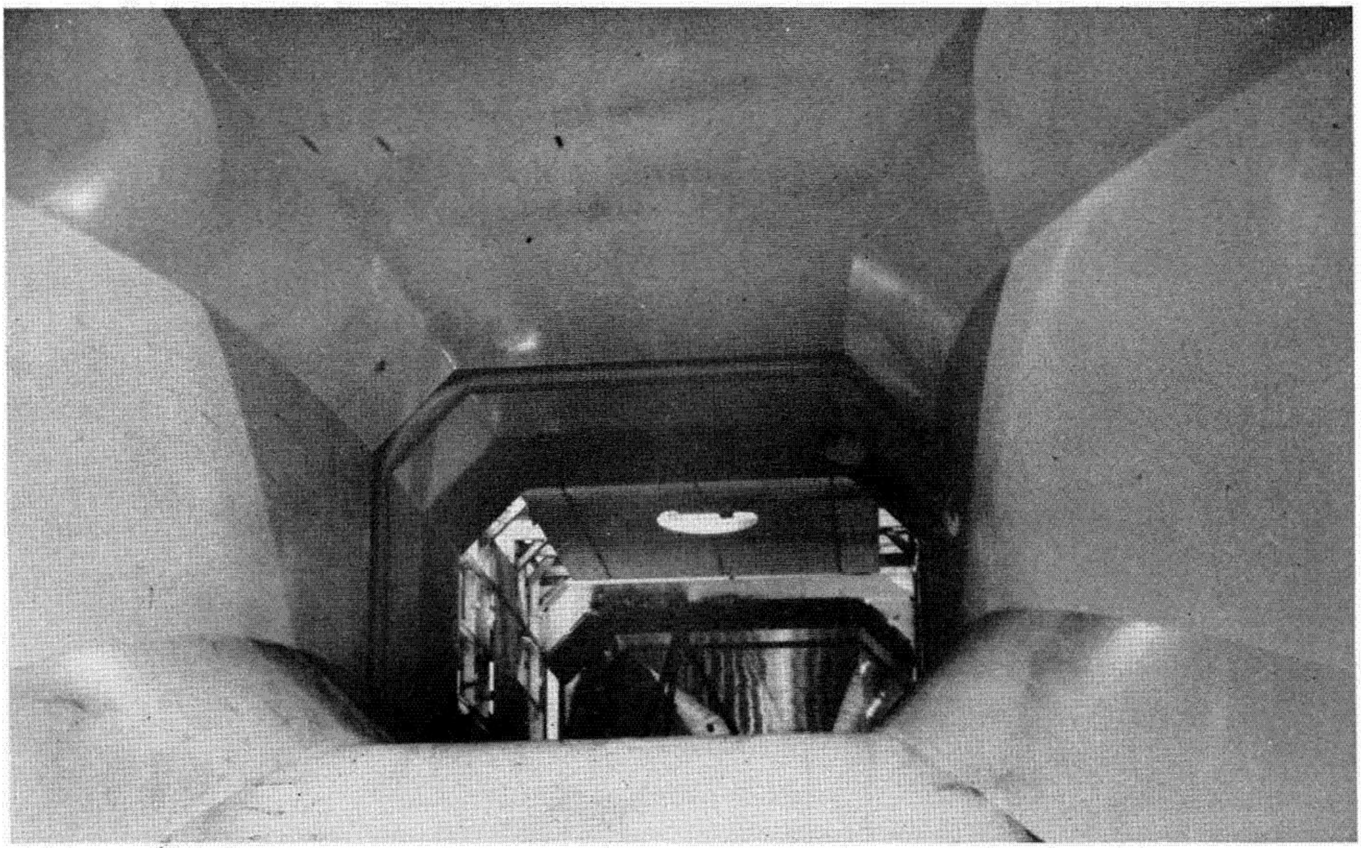


FIG. 21. View showing contraction entrance to working section.

about the model may be obtained and the effect of one asymmetrical set of supports can be determined. This image system is attached to a hydraulic ram passing through the top of the working region sphere and may be lowered into the working section as needed. The image system frame also may be used to support various flow measuring and calibrating devices, either instead of or in conjunction with one of the regular three-point systems.

METRICAL SYSTEM

THE metrical, or load- and moment-measuring system, used in the Cooperative Wind Tunnel, is unique in several ways. First, it is entirely contained within the structural shell of the tunnel and, therefore, must operate at pressures both above and below normal atmospheric pressure. Second, none of the forces or moments arising from the air loads on the model are connected to the force- and moment-measuring devices through ball or other normal types of bearings, and thus there are no bearing frictions entering the final data readings. Third, all forces and moments are separated so that the six components—lift, drag, cross-wind force, pitching moment, rolling moment, and yawing moment—are made available in the form of direct reading data without the necessity of additional computations.

The lowest member of the metrical system is a triangular frame (the base frame; see *Figs. 27 and 28*) which rests on three supports carried in the bottom of the spherical shell surrounding the tunnel working section. Between the base frame and these supports are three load-measuring capsules, to be described later. These capsules serve to measure any change in vertical load in the system. Since the model suspension system is attached to the metrical system during operation, and since vertical loads on the model correspond to lift forces, these capsules directly measure the lift forces on the model in the tunnel.

On the upper surface of the base frame are three circular flat pads. Resting on these flat pads is a large ring which is carefully machined flat on both top and bottom surfaces. During operation oil is pumped into the flat pads on the base frame, and the large ring is then entirely supported by a thin oil film. This dynamical form of oil support bearing is similar to that used on the 200-inch telescope on Mt. Palomar and was chosen as a metrical bearing because of its extremely low coefficient of friction. Any horizontal forces on the model (drag or cross-wind forces) are applied to the metrical system and are transmitted to this large ring, and, unless restrained, the large ring would slide on the oil pads. The large ring is, however, restrained by one drag link and two side force links, which in turn are connected to the base frame through force-measuring capsules. The drag link, running along the tunnel axis, measures drag directly. The two side force links lie perpendicular to the tunnel axis and are so arranged that the sum of the force increments on the two links gives the cross-wind force on the model.

In order to rotate the model in yaw, a vertical axis is established on the large ring and the whole ring is rotated by means of a remotely controlled worm and gear drive, with the large ring rotating on the flat pads of the base frame. The worm-gear housing is actually connected to the base frame through, and is stabilized by, the side force links.

Resting on top of the large ring are three more oil pads, one of which is shown in *Fig. 29*. These are spherical in shape and have as their center the center point of the tunnel. This center is the midpoint of the line connecting the tops of the two main model support arms. On these spherical pads rests a moment table,