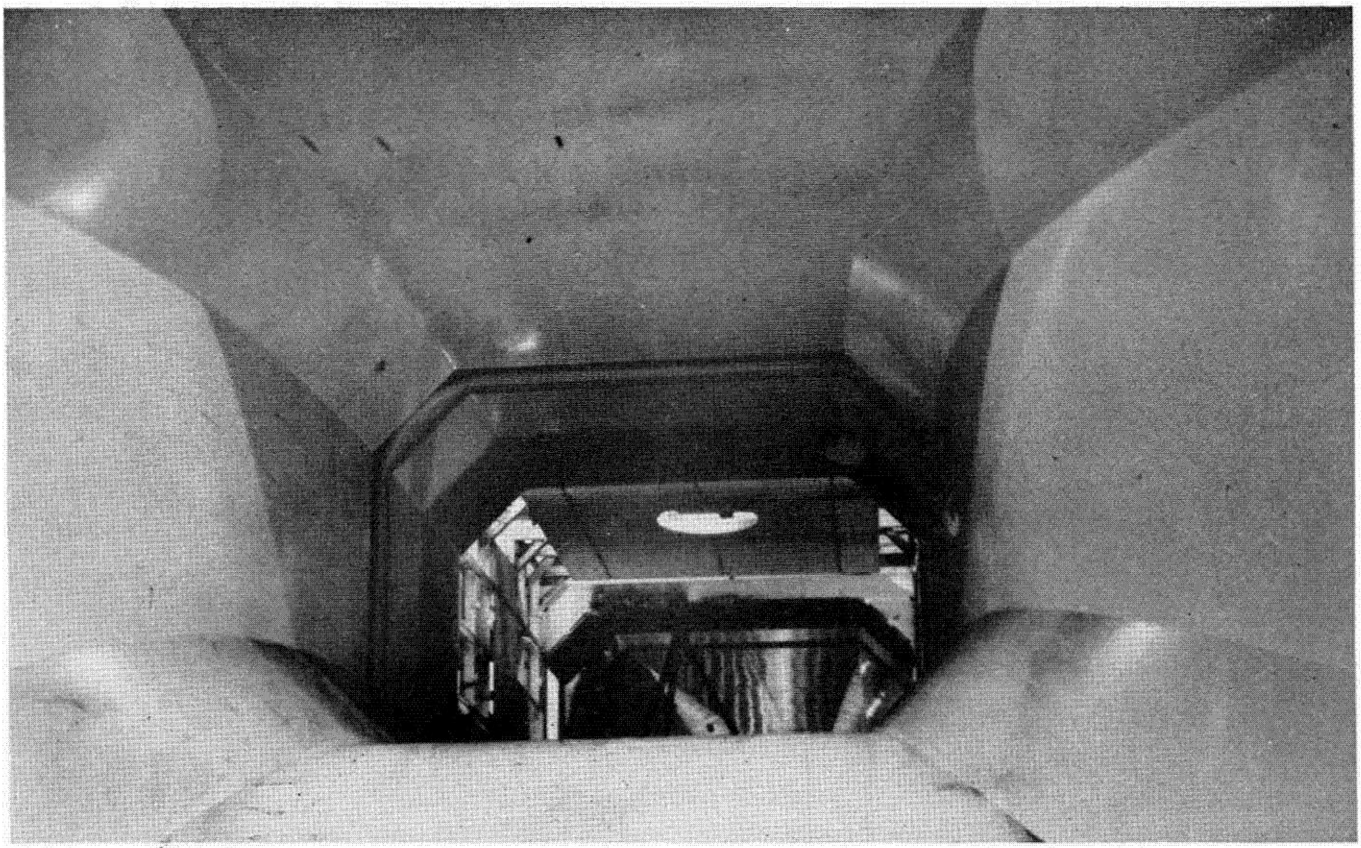


FIG. 21. View showing contraction entrance to working section.

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.

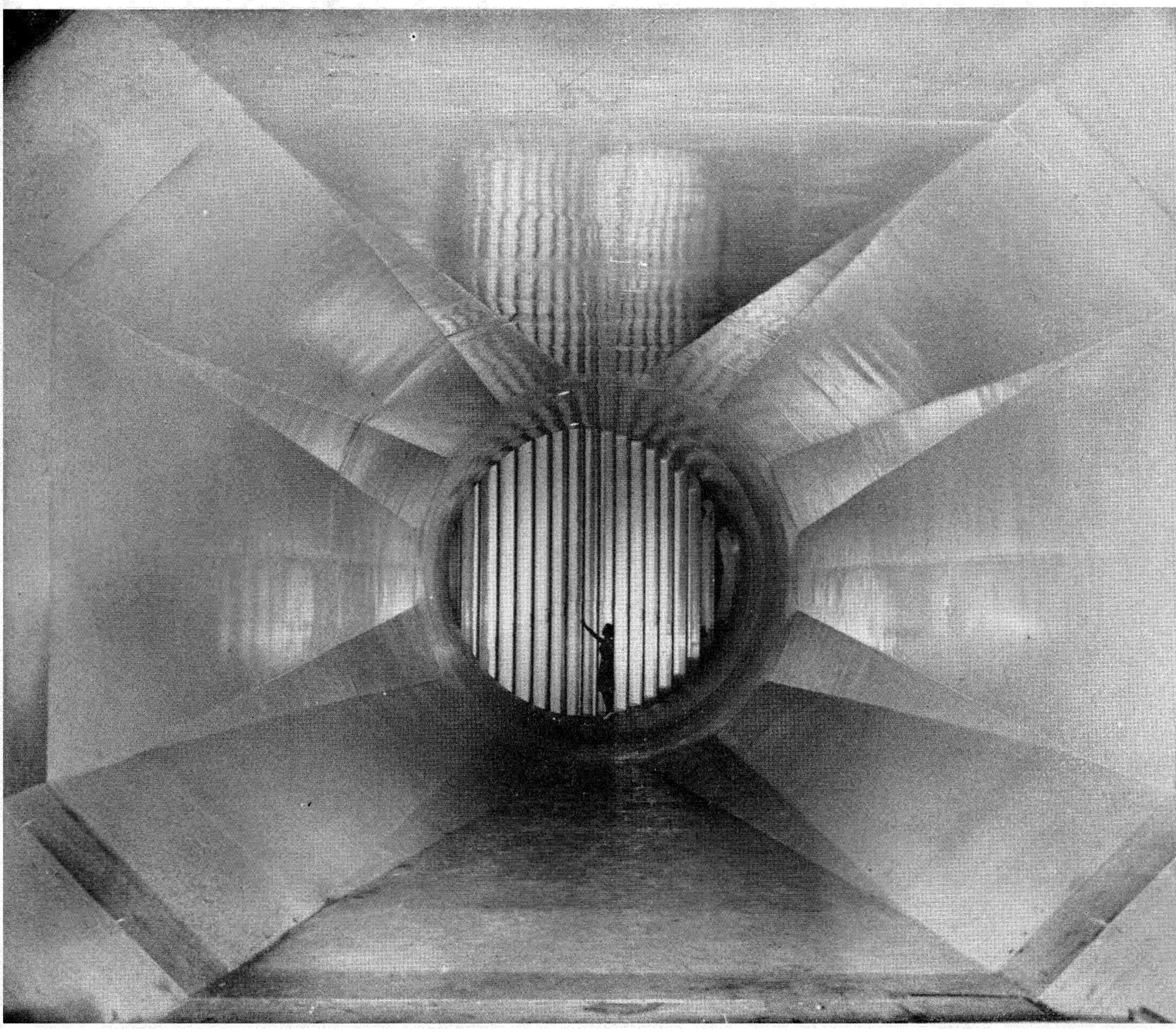
In order to rotate the model in yaw, a vertical axis is established on the large ring and the whole ring is rotated by means of a remotely controlled worm and gear drive, with the large ring rotating on the flat pads of the base frame. The worm-gear housing is actually connected to the base frame through, 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, through which all of the model forces and moments pass. The forces are transmitted through the spherical pads and are taken out in the manner described above. The moments, however, would tend to make the moment table rotate in the spherical oil pads unless it were restrained. This restraint is accomplished by means of links between the moment table and the large ring, each link being connected to a force-measuring capsule. Along the axis of the tunnel one link is used to measure the model pitching moment, and across the tunnel axis two links are used, spaced some distance apart. The sum of the forces in these two links is a measure of the rolling moment, while the difference gives the yawing moment on the model. The spherical oil pads are double acting and thus form a spherical cup which completely restrains the model.

The top of the moment table is the line of separation between the metrical system and the model suspension system (see *Fig. 27*). For the three-point and the N.A.C.A. support systems there is attached at this point a cross beam which carries the main support arms and a device to support and move the tail strut. In addition this cross beam has in it weights which may be adjusted to compensate for any initial pitching moment of the model which may arise from the model weight's not acting on the pitching moment axis. For the ring frame system the bottom surface of the ring frame is attached to the top of the moment table and thereby transmits the model forces to the metrical system.

Having the system level is of extreme importance in view of the fact that everything above the base frame rests on the base frame flat oil pads. If these were not level, a component of all the weight above this point would contribute to the drag-force reading. In order to obtain the required drag accuracy these pads must be kept level to one part in two-hundred thousand (1/200,000), and this is accomplished by the use of two very sensitive tilt-measuring devices (tiltmeters) which can indicate an out of level in the system of one part in a million. Since the level of the system is also affected by the thickness of the oil film in the oil pads, the oil film thickness in all pads is continuously measured and indicated to the tunnel operator in the control room. By means of sensitive flow valves the operator may

FIG. 22. Exit downstream from working section, showing gate valve open.



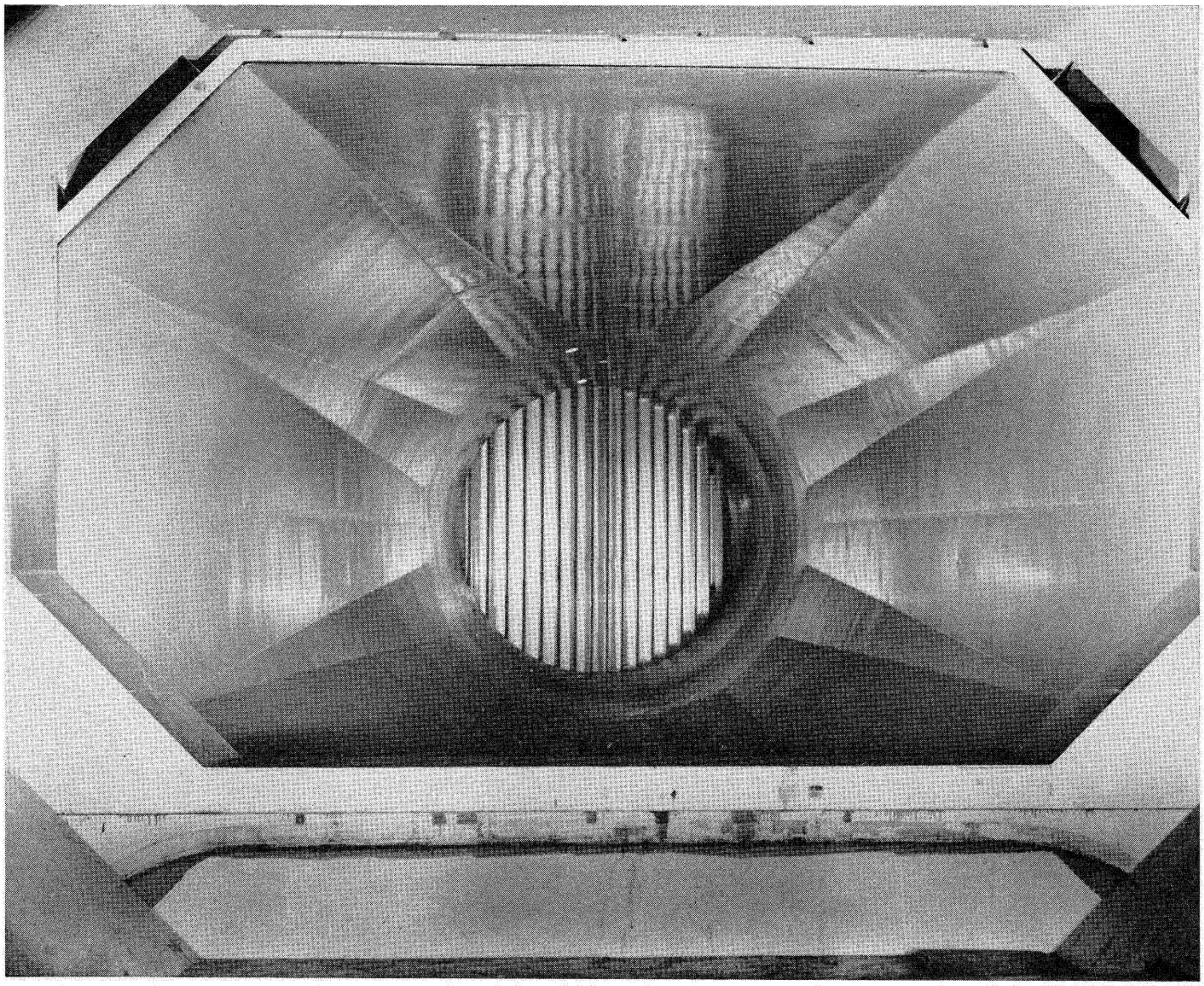


FIG. 23. Exit downstream from working section, showing gate valve beginning to close.

adjust the oil thickness from the control room whenever necessary. He also has a control on two of the base-frame supports, whereby he can adjust the level of the base frame.

TATE-EMERY SYSTEM

THE force-indicating system developed for use in the Cooperative Wind Tunnel is a new application of the principles used in the Southwark-Tate-Emery testing machines, which are manufactured by the Baldwin Locomotive Works in collaboration with the A. H. Emery Company. The Tate-Emery system is a method of hydraulic weighing of forces on the model in the tunnel and remote indication in the control room. This system is composed of two elements—the weighing system and the indicating system.

WEIGHING SYSTEM

The weighing system consists essentially of nine new-type Emery capsules which are located in the suspension system. The Emery capsule is primarily a rigid cylinder and piston unit having a 0.10-inch clearance and less than 0.002-inch stroke. Forces exerted on the capsules are balanced by hydraulic pressures developed within the capsules. The resulting pressure changes within the capsules are transmitted to the indicating system.

The new-type Emery capsule has its piston stayed by two perforated, annular metal stay rings. Forces exerted on the capsule are conveyed to the piston through arms extending from the side of the piston. The piston is double faced and has two metal sheets (one on each end) spanning the gap between the piston and the cylinder, thereby preventing oil leakage. A constant hydraulic pressure is admitted to one end of the capsule from a constant pressure source outside the tunnel. The effect of the constant pressure (preload pressure) is to elevate the pressure on the opposite end of the piston (weighing side) to the same pressure as the constant pressure. This preloading of the capsule permits tensile or compressive forces to be exerted on the piston of the capsule. Such tensile or compressive forces cause the pressure in the weighing side to increase or decrease in proportion to the forces exerted. The pressure in the preload end remains constant because of its outside origin.

A hydraulic motion control (filling control), incorporated in the capsule, limits the capsule stroke, develops the weighing pressure, and compensates for volumetric changes due to temperature changes in the system. The capsules have natural frequencies well above the highest expected vibration frequency within the tunnel.

In the case of the lift capsules the entire weight of the suspension system (50,000 pounds) is supported on the new-type Emery capsules, yet a one-pound weight added